Forage-Fed Beef

production and marketing alternatives in the south

BULLETIN 220
Southern Cooperative Series
June 1977

SOUTHERN COOPERATIVE SERIES

Bulletin 220

This is the 220th in the Cooperative Bulletin Series of the Southern Regional Association of State Agricultural Experiment Stations. Thus this Bulletin is in effect a publication of each of the Cooperating State Agricultural Experiment Stations and may be mailed under the penalty mail privilege of each. Requests for copies originating within the cooperating States should be made to the appropriate State Agricultural Experiment Station Director. Requests from other States should be made to the Director of the North Carolina Agricultural Experiment Station. Cooperating State Agricultural Experiment Stations and their Directors are:

R. Dennis Rouse, Director, Alabama Agricultural Experiment Station, Auburn, Alabama 36830

Lloyd O. Warren, Director, Arkansas Agricultural Experiment Station, Fayetteville, Arkansas 72701

K. R. Tefertiller, Director, Florida Agricultural Experiment Station, Gainesville, Florida 32611

William P. Flatt, Director, Georgia Agricultural Experiment Stations, Athens, Georgia 30602

Charles E. Barnhart, Director, Kentucky Agricultural Experiment Station, Lexington, Kentucky 40506

Doyle Chambers, Director, Louisiana Agricultural Experiment Station, Baton Rouge, Louisiana 70803

W. Lamar Harris, Director, Maryland Agricultural Experiment Station, College Park, Maryland 20742

James H. Anderson, Director, Mississippi Agricultural and Forestry Experiment Station, Mississippi State, Mississippi 39762

Kenneth R. Keller, Director, North Carolina Agricultural Experiment Station, Raleigh, N.C. 27607

Frank H. Baker, Director, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma 74074

W. C. Godley, Director, South Carolina Agricultural Experiment Station, Clemson, South Carolina 29631

D. M. Gossett, Director, Tennessee Agricultural Experiment Station, Knoxville, Tennessee 37901

Jarvis E. Miller, Director, Texas Agricultural Experiment Station, College Station, Texas 77843

Coyt T. Wilson, Director, Virginia Agricultural Experiment Station, Blacksburg, Virginia 24061

Dale W. Ginn, Director, West Virginia Agricultural and Forestry Experiment Station, Morgantown, West Virginia 26506

FORAGE-FED BEEF:
PRODUCTION AND MARKETING ALTERNATIVES IN THE SOUTH

Papers presented at the

Southern Regional Forage-Fed Beef Research Workshop
New Orleans, Louisiana, October 1975

Edited by

JOHN A. STUEDEMANN
(Editor-in-Chief)
Animal Scientist, Southern Piedmont Conservation Research Center
ARS, USDA, Watkinsville, Georgia

and

DALE L. HUFFMAN
Professor, Department of Animal and Dairy Sciences
Auburn University, Auburn, Alabama

J.C. PURCELL
Professor and Head, Department of Agricultural Economics
Georgia Agricultural Experiment Station
Experiment, Georgia

ODELL L. WALKER
Professor, Department of Agricultural Economics
Oklahoma State University, Stillwater, Oklahoma

PREFACE

This bulletin is the proceedings of the Southern Regional Forage-Fed Beef Research Workshop of October 20-22, 1975 in New Orleans, Louisiana. Its general theme was production and marketing alternatives in the South for beef finished with rations containing higher than typical amounts of forage. The workshop was the outgrowth of two different but highly interrelated needs. The first was the need by industry for guidance in the utilization of forage in beef finishing. The second was a need to identify priority research problem areas of the beef cattle industry in the Southern Region.

Industry Guidance

The ratio of feed concentrate prices to roughage costs has trended downward over the long run in the United States. In response to that trend, there has been a long-run tendency for the U. S. beef cattle industry to increase the percentage of feed nutrients from concentrates. This tendency has been particularly pronounced in the beef finishing segment of the industry. In recent years, many finishing operations have utilized rations approaching a biological minimum of roughage.

This tendency toward concentrate-intensive beef finishing also affected the U. S. market for block beef. The market became highly specialized in the handling of beef finished in this way. Market standards and practices, from live cattle markets through retail markets for beef, and consumer purchase and consumption patterns have evolved which are primarily designed to handle this dominant product. As a result, small quantities of beef finished on rations with larger proportions of forage tend to be discounted in the market. Yet, research results indicate that beef finished on such rations may be highly acceptable to consumers when handled properly.

Events from 1972 through 1975 indicated a continuing change in the historical U. S. price or cost relations between feed concentrate and forage. In 1972, there was a sharp increase in foreign demand for U.S.-produced feed concentrates and in U. S. feed concentrate prices. Aside from temporary adverse weather factors in foreign countries, exchange rate changes, and foreign economic growth were major forces contributing to this demand increase. In 1973, it became apparent that there was an international energy problem which would tend to raise feed concentrate production costs above historical levels for an indefinite period.

In the past, forage production costs in some locales of the South permitted forage to be utilized economically in limited-grain cattle finishing, despite the tendency of the market to discriminate against those cattle. In the early 1970s, when concentrate-intensive finishing operators were in a cost-price squeeze, important questions were: To what extent will higher grain prices encourage increased use of forage in finishing cattle and will an expanded volume of beef finished in

this way help to eliminate market discrimination? Those questions in industry were an important consideration influencing the Southern Regional Association of Agricultural Experiment Station Directors, the Agricultural Research Service and the Economic Research Service of the U. S. Department of Agriculture and the Tennessee Valley Authority to sponsor this workshop and to publish these proceedings.

Research Planning

In 1975, four major Southern Regional Research Technical Committees engaged in research on the beef cattle industry in the South were preparing to redirect their research. Each was completing a project on a problem of importance to the future of the forage-fed beef industry. The four committees and projects were:

Project & Committee Identification

Number	Title	Administrative Advisor
S-45	Relationship Between Properties for Southern Forages and Animal Response	C. O. Little
S-67	Evaluation of the Beef Production Industry in the South	R. Dennis Rouse
SM-41	Economic Evaluation of Alternative Forms of Vertical Coordination in the Livestock Meat Industry	J. C. Williamson, Jr.
SM-43	Factors Responsible for Tenderness Variations in Meat	Jarvis E. Miller

Thus, these four committees were in the process of identifying and selecting priority areas to be investigated over the next few years. It was expected that a workshop involving representatives from the four technical committees and others interested in physical, biological and economic questions in both production and marketing would enhance the research planning process of all four committees.

Contributed Papers

Authors of the papers presented at the workshop were selected to represent a broad spectrum of expertise relevant to an analysis of the potential for use of forage in finishing beef in the South. All papers were original and were presented by invitation. Authors were requested both to present what is known and to describe problem areas on which research is needed. Each paper was reviewed by two reviewers and by the editorial committee.

J. C. WILLIAMSON JR.

J. A. STUEDEMANN

D. L. HUFFMAN

J. C. PURCELL

O. L. WALKER

TABLE OF CONTENTS

Preface iii

Acknowledgments x

Program Planning Committee xi

Contributors xiii

Synopsis xvii

ECONOMIC ASPECTS

Moderator: *T. C. Cartwright*

A Systems View of the Beef Industry
Wayne D. Purcell 1

Energy, Fertilizer and Feed Grain Requirements and Prospects and Their Effect on the Beef Cattle Industry
James Vermeer 19

Discussion 38

Moderator: *Odell L. Walker*

Economics of Grain-Roughage Substitution in the Beef Sector
Ray F. Brokken 45

Economics of Alternative Beef Production Systems and Locations
Donald E. Farris and Raymond A. Dietrich 77

Discussion 100

STRUCTURE AND MARKETING

Moderator: *Richard J. Crom*

Structure and Performance of the Meat (Beef) Industry
Willard F. Williams 107

Market Potential for Block and Processed Beef
Robert Raunikar 127

Discussion 153

CARCASS CHARACTERISTICS, MEAT QUALITY AND CONSUMER ACCEPTANCE

Moderator: *Dale L. Huffman*

Growth and Development of Beef Cattle, With Reference to the Effect of Breed and Sex
J. J. Guenther 159

Qualitative Aspects: Tenderness, Flavor, Juiciness, Color of Lean and Fat
Robert F. Kelly 193

The New Beef: Review of Handling and Processing Techniques to Enhance Consumer Acceptance
H. Russell Cross and Gary C. Smith 217

Discussion 232

FUNDAMENTAL ASPECTS OF FORAGE AND BEEF PRODUCTION

Moderator: *R. R. Johnson*

Energy Requirements of Beef Cattle
W. C. Ellis 237

Meeting the Nutrient Requirements of Beef Cattle with Forage
Ethan C. Holt 261

Discussion 286

Breeding Better Forages
Wayne W. Hanna 291

Discussion 299

Increasing Digestibility and Intake Through Management of Grazing Systems
R. E. Blaser, W. C. Stringer, E. B. Rayburn, J. P. Fontenot, R. C. Hammes, Jr., and H. T. Bryant . . . 301

Discussion 346

The Role of Harvested or Processed Forage in Beef Feeding
M. E. McCullough 349

Discussion 361

CAPABILITIES OF VARIOUS PHYSIOGRAPHIC REGIONS

Moderator: *C. Oran Little*

Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain Rations in the Upper South
A. E. Spooner and Maurice L. Ray 363

Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain Rations in the Piedmont Region of the South
Carl S. Hoveland and W. B. Anthony 377

Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain in the Lower South
Warren G. Monson and Philip R. Utley 391

Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain Rations in the Semi-arid Southwest
F. P. Horn and C. M. Taliaferro 401

Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain Rations in the Tropical Region of the South
G. O. Mott and J. E. Moore 419

Discussion 444

USE OF MODELING SYSTEMS

Moderator: *John A. Stuedemann*

The Use of Modeling to Hasten and Enhance the Application of Research Information to Beef Production Systems and Feedback to Research
T. C. Cartwright 451

Discussion 458

REPORTS BY SOUTHERN REGIONAL TECHNICAL COMMITTEES

Moderator: *John A. Stuedemann*

SM-41--Economic Evaluation of Alternative Forms of Vertical Coordination in the Livestock-Meat Industry 463

SM-43--Factors Responsible for Tenderness Variations in Meat 465

S-45--Relationship Between Properties of Southern Forages and Animal Response 469

S-67--Evaluation of the Beef Production Industry in the South 470

Discussion 473

Closing Comments 475

ACKNOWLEDGMENTS

We appreciate support of the workshop by the administrators of the Southern State Agricultural Experiment Stations; the Agricultural Research Service, USDA; the Economic Research Service, USDA; the Cooperative State Research Service, USDA; and the Tennessee Valley Authority. Special appreciation is extended to D. Chambers, Director, Louisiana Agricultural Experiment Station; C. O. Little, Associate Director, Kentucky Agricultural Experiment Station; R. D. Rouse, Director, Alabama Agricultural Experiment Station; and A. W. Cooper, Deputy Administrator, Southern Region, Agricultural Research Service, USDA. Funds for publication of the proceedings were provided by the Agricultural Research Service, the Cooperative State Research Service, the Economics Research Service, the North Carolina Agricultural Experiment Station and the Tennessee Valley Authority.

We acknowledge the excellent cooperation of all authors. Special thanks are extended to those who assisted the editorial committee in reviewing manuscripts and to those who aided in conduct of the workshop. The following served as recording secretaries of discussion sessions: J. G. Dillard, Agricultural Economist, Division of Agricultural Development, TVA; H. Lippke, Associate Professor of Animal Nutrition, Texas Agricultural Experiment Station; W. G. Moody, Professor of Meats, University of Kentucky; J. A. Stuedemann, Animal Scientist, ARS,USDA; J. E. Via, Associate Professor of Marketing, University of Maryland. The following were sessions moderators: T. C. Cartwright, Professor of Animal Breeding, Texas A&M University; R. J. Crom, Leader, Meat Animals Program Area, Commodity Economics Division, ERS, USDA: D. L. Huffman, Professor of Meats, Auburn University; R. R. Johnson, Head, Department of Animal Science, University of Tennessee; C. O. Little, Associate Director, Kentucky Agricultural Experiment Station; J. A. Stuedemann, Animal Scientist, ARS, USDA: and O. L. Walker, Professor of Agricultural Economics, Oklahoma State University.

Thanks are due Mrs. Betty Thomas, ARS, USDA, Watkinsville, Georgia, whose secretarial efforts contributed to the success of the meeting and subsequent publication of the proceedings. Special recognition goes to Ms. Ann Cooke, North Carolina Agricultural Experiment Station, who patiently provided final editing and typing of the publication.

WORKSHOP PLANNING COMMITTEE

J. C. Williamson, Jr., General Chairman

J. A. Stuedemann, Coordination Chairman

D. L. Huffman J. C. Purcell O. L. Walker

PROGRAM PLANNING COMMITTEE

General Chairman: J. C. Williamson, Jr., Former Director*
North Carolina Agricultural Experiment Station
North Carolina State University
Raleigh, N. C. 27607

Coordination Chairman: J. A. Stuedemann, Animal Scientist
Southern Piedmont Conservation Research Center
ARS, USDA
Watkinsville, Georgia 30677

Economics and Marketing

Co-chairman: J. C. Purcell, Professor and Head
Department of Agricultural Economics
Georgia Agricultural Experiment Station
Experiment, Georgia 30212

Co-chairman: O. L. Walker, Professor
Department of Agricultural Economics
Oklahoma State University
Stillwater, Oklahoma 74074

T. C. Cartwright, Professor
Department of Animal Science
Texas A&M University
College Station, Texas 77843

R. J. Crom, Leader
Meat Animals Program Area
Commodity Economics Division
ERS, USDA
Washington, D. C. 20250

*Now Professor of Economics and Business, North Carolina State University, Raleigh, N. C. 27607

Carcass Characteristics, Meat Quality and Consumer Acceptance

Chairman: D. L. Huffman, Professor
Department of Animal and Dairy Sciences
Auburn University
Auburn, Alabama 36830

Fundamental Aspects of Forage and Beef Production: Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain Rations: Use of Modeling Systems

Chairman: J. A. Stuedemann, Animal Scientist
Southern Peidmont Conservation Research Center
ARS, USDA
Watkinsville, Georgia 30677

J. G. Dillard, Agricultural Economist
Agricultural Development Division
Tennessee Valley Authority
Muscle Shoals, Alabama 35660

C. S. Hoveland, Professor
Department of Agronomy and Soils
Auburn University
Auburn, Alabama 35830

H. Lippke, Associate Professor
Texas Agricultural Experiment Station
Angleton, Texas 77515

Other Members of the Planning Committee: J. R. Janssen, Assistant Director*
Economic Development Division
ERS, USDA
Washington, D. C. 30350

*At the time of the workshop, Dr. Janssen was serving temporarily as Principal Agricultural Economist with the Cooperative State Research Service, USDA.

CONTRIBUTORS TO THIS VOLUME

JOHN R. ALLISON

Associate Professor, Department of Agricultural Economics, University of Georgia, Experiment, Georgia

W. B. ANTHONY

Professor, Department of Animal and Dairy Science, Auburn University, Auburn, Alabama

R. E. BLASER

University Distinguished Professor, Department of Agronomy, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

RAY F. BROKKEN

Agricultural Economist, Commodity Economics Division, Economic Research Service, U. S. Department of Agriculture, Corvallis, Oregon

H. T. BRYANT

Associate Professor, Department of Agronomy, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

H. RUSSELL CROSS

Research Food Technologist, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Maryland

T. C. CARTWRIGHT

Professor, Department of Animal Science, Texas A&M University, College Station, Texas

G. L. M. Chappell

Associate Extension Professor, Department of Animal Sciences, University of Kentucky, Lexington, Kentucky

RAYMOND A. DIETRICH

Associate Professor, Department of Agricultural Economics, Texas A&M University, College Station, Texas

W. C. ELLIS

Professor, Department of Animal Science, Texas A&M University, College Station, Texas

DONALD E. FARRIS

Professor, Department of Agricultural Economics, Texas A&M University, College Station, Texas

J. P. FONTENOT

Professor, Department of Animal Science, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

J. J. GUENTHER

Professor, Department of Animal Science and Industry, Oklahoma State University, Stillwater, Oklahoma

R. C. HAMMES, JR.

Assistant Professor, Department of Animal Science, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

WAYNE W. HANNA

Geneticist, Agricultural Research Service, U. S. Department of Agriculture, Tifton, Georgia

ETHAN C. HOLT

Professor, Department of Soil and Crop Sciences, Texas A&M University, College Station, Texas

F. P. HORN

Research Animal Husbandman, Agricultural Research Service, U. S. Department of Agriculture, El Reno, Oklahoma

CARL S. HOVELAND

Professor, Department of Agronomy and Soils, Auburn University, Auburn, Alabama

ROBERT F. KELLY

Professor, Department of Food Science, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

M. E. McCULLOUGH

Professor, Department of Animal Science, University of Georgia, Experiment, Georgia

WARREN G. MONSON

Agronomist, Agricultural Research Service, U. S. Department of Agriculture, Tifton, Georgia

WILLIAM G. MOODY

Professor, Department of Animal Sciences, University of Kentucky, Lexington, Kentucky

J. E. MOORE

Professor, Department of Animal Science, University of Florida, Gainesville, Florida

G. O. MOTT

Professor, Department of Agronomy, University of Florida, Gainesville, Florida

WAYNE D. PURCELL

Professor, Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma

ROBERT RAUNIKAR

Associate Professor, Department of Agricultural Economics, University of Georgia, Experiment, Georgia

MAURICE L. RAY

Professor, Department of Animal Science, University of Arkansas, Fayetteville, Arkansas

E. B. RAYBURN

Graduate Student, Department of Agronomy, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

GARY C. SMITH

Professor, Department of Animal Science, Texas A&M University, College Station, Texas

A. E. SPOONER

Professor, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas

W. C. STRINGER

Graduate Student, Department of Agronomy, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

C. M. TALIAFERRO

Associate Professor, Department of Agronomy, Oklahoma State University, Stillwater, Oklahoma

PHILIP R. UTLEY

Associate Professor, Department of Animal Science, University of Gerogia, Tifton, Georgia

JAMES VERMEER

Assistant Director, Commodity Economics Division, Economic Research Service, U. S. Department of Agriculture, Washington, D. C.

WILLARD F. WILLIAMS

Horn Professor, Department of Agricultural Economics, Texas Tech University, Lubbock, Texas

SYNOPSIS

The general margin for finishing beef has been sharply limited in recent years by aggressive expansion of the specialized concentrate-intensive beef finishing industry. Stimuli for that expansion have been low prices of concentrate feeds and advances in technology and management in these specialized enterprises. Low concentrate prices have in turn reflected low energy and fertilizer prices and advances in technology and management of feed grain production. Beef produced in such operations has dominated the market and has become the standard in market channels from the meat packer to the final consumer. Cattle and beef finished with rations containing appreciable amounts of forage have differed from that standard and have been discounted in the market. This discounting has further reduced the margin for finishing cattle on such rations.

Despite these narrow finishing margins, producers in some locales in the Southern Region have been able to develop profitable forage and/or limited grain finishing operations. But forage-fed beef accounts for only a small percentage of regional and national consumption of beef. Research results indicate that there are opportunities for other producers to utilize forage in profitable beef feeding operations. These opportunities would be enhanced if forage-fed beef were not discounted in the market or if concentrate prices were higher, thereby raising the general margin for finishing beef and particularly the margin for finishing beef with predominantly forage.

This workshop was addressed primarily to those factors which determine the margin for finishing beef in the Southern Region on rations containing appreciable amounts of forage. Those factors are diverse. They range through nutritional requirements for cattle and the use of forage in meeting those requirements, alternative forage-finishing systems in different physiographic areas of the region, the substitution of roughage for concentrates in finishing rations, structure and performance of the market for feeder cattle, fed cattle and beef, physical and biological characteristics of beef finished on rations containing forage, consumer acceptance of forage-fed beef, and interrelationships among energy and fertilizer costs, feed grain prices and the beef cattle industry.

The workshop did not produce clearly definable answers about the future of forage finishing of beef in the Southern Region. However, the workshop did suggest the following generalizations.

1. There are numerous localized opportunities in the Southern Region for expanded use of forage in finishing beef at historical finishing margins and forage production costs.

2. Discounting of forage-fed cattle and beef reflects costs imposed upon marketing firms and consumers by low volume, uncertainty and variability in the supply of forage-fed beef rather than inherently inferior characteristics of such beef relative to grain-finished beef.

3. Energy, fertilizer and feed concentrate price increases may widen the general margin for finishing cattle. However, the effectiveness of this increase in improving the profitability of finishing beef on rations containing forage may be limited by (a) associated increases in costs of producing forage, (b) increased demand for forage in other segments of the beef industry.

4. Additional research and education is needed on the market for cattle and beef to improve the efficiency with which forage-fed beef moves from feeder to consumer. This research and education should treat both the economic problems of structure and performance and the biological and physical problems of technology and performance.

5. Additional research is needed to reduce costs of finishing beef on forages, to identify those locales and resource situations where such enterprises may be profitable, to stabilize the production of forage-fed beef and to reduce variability in characteristics of forage-fed beef from area to area, season to season and year to year. Physical science, biological science and economic research are needed and there should be close coordination of research in different disciplines.

6. There are great variations in soil, climate and economic conditions in the Region. Consequently, the potential for and problems of forage-finishing of beef and the production systems which are appropriate will vary widely among locales. As a result, researchable problems are numerous and diverse. These circumstances provide a special incentive for close regional research and coordination among industry, extension and research groups. Such coordination will improve research priority identification and problem selection and enhance the process of screening, adaptation and adoption of research results.

J. C. WILLIAMSON, JR.

J. A. STEUDEMANN

D. L. HUFFMAN

J. C. PURCELL

O. L. WALKER

ECONOMIC ASPECTS

A SYSTEMS VIEW OF THE BEEF INDUSTRY

Wayne D. Purcell*

A pause is in order to reflect on the title of my assignment. My charge is to paint a picture of the beef industry as a production-marketing system. I accepted this charge with mixed emotions. Because of a long-standing conviction that much of the research in the beef industry is too narrow in scope and fails to come to grips with the truly important issues, I gladly accept the opportunity to share my thoughts with other members of the research community.

But the reality of the situation brings on a feeling of apprehension and perhaps frustration. I am not the first researcher to develop the conviction that we must turn our attention to the total system. It has been 20 years since leading agricultural economists began calling for increased attention to the entire system and for systems-oriented research (3, 10). Change has been slow in coming, however, and the need persists to encourage critical self examination of our efforts.

A Systems Orientation

The need is for a systems orientation in our approach to research dealing with beef production, processing and distribution. Basically, I agree with one of our persistent critics of the 1960s when he described what is needed as follows:

> But I would argue for a systems orientation. By this I do not mean formal mathematical systems modeling and formal simulation. Such modeling may be a useful tool and should be used along with other tools where appropriate. By a systems orientation I simply mean the analysis of problems in the context of the broader system, an analysis which takes into account feedback, sequences, and externalities (10).

Shaffer, then, suggests the need for a research orientation which stresses feedback, identifies the sequence and flows of incentives within different types of organizational structures, and deals with

*Professor, Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma 74074.

the externalities (to the individual firm) due to change within the system.

But we must walk before we can run. And though it is a bitter pill for us to swallow after all these years, I would argue that we must identify the qualitative interrelationships which comprise the beef production-marketing system before we rush in to quantify that which we do not understand. Against this perspective, the related objectives of this paper are as follows:

1. to describe the conceptual framework inherent to our beef production-marketing system;
2. to isolate and examine the impact of systems dimensions which influence the relative efficiency of the beef production-marketing system;
3. to identify developing changes in the environment within which the beef system operates and discuss implications of these changes to system organization and performance; and
4. to provide brief empirical evidence of the relative performance of the system for selected organizational structures.

The Beef System: A Conceptual Framework

A systems orientation requires a view of beef production, processing, distribution and consumption as an ongoing and continuous process. There is no single starting point, no single point at which the process ends. Adopting a systems orientation also requires a shift in emphasis from the activity at any one of the stages to emphasis on interstage activity.

Figure 1 provides a simple schematic view of the beef system. Each stage constitutes a "building block" and contributes to the activities of the system as a whole. The output of one stage becomes input to the next highest stage in the vertical continuum of activities. The manner in which these technical input-output interrelationships are handled becomes a primary determinant of system performance and provides the actions which are visible to the external observer.

Viewed in this context, it is the interstage linkages which should become the focal point of our attention. The interstage linkages tie the several identifiable but surely not independent stages into a system. And if we are concerned with performance of the system as a whole, it is to this set of linkages that we as researchers must look to find the determinants of system performance. If we do not like what we see, if performance does not measure up to broadly accepted norms, it is to the interstage activity--the linkages--that we must look for a research focus and for an entry point through which to exert influence.

The linkages are more complex than I have implied. Interstage product flows obviously are involved. But of critical importance to the performance of the system are the interstage informational flows.

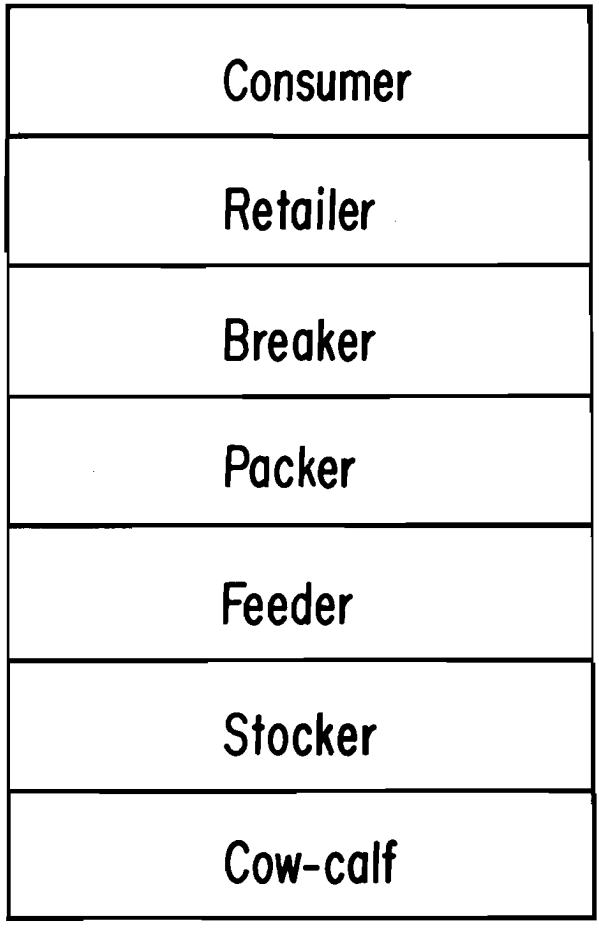


Figure 1. A schematic view of the beef system

The degree of interstage coordination achieved depends to a large extent on the content, accuracy and timeliness of the information upon which decisions must be made.

Interstage coordination is of key importance if the system is to function in an effective and efficient manner. The basic charge to the system is to coordinate what is produced with needs and/or demands at the consumer level. And we could, of course, add the related charges--accomplish this producer-consumer coordination efficiently (at minimum cost) given available technology and with a minimum of delay.

The need for interstage coordination is present regardless of the organizational structure of the system. The coordinating mechanism differs, however, across systems which are structured differently with regard to ownership and control. To complete even a simplified view of the conceptual framework inherent to the beef system requires examination of how interstage coordination is achieved within existing or emerging organizational structures.

The Open Market Exchange System

The exchange system is the traditional system and is characterized by separate control of the stages of activity. Buyer-seller interaction is featured at each interstage point of product transfer. From the buyer-seller interaction emerges a price. Prices therefore are determined at each major point of exchange as the product flows through the system.

Price thus becomes the primary coordinating mechanism. The much-discussed concept of "pricing efficiency" refers to the relative ability of the system to effect interstage coordination through the workings of the price mechanism.

Coordination is achieved through price signals which transmit information. Consumers make a yes-no decision on the product-price bundle they see at the retail level. Retailers read the message which emerges as consumers make their decisions. If the particular product--or quality or grade--finds favor with the consuming public, the price of this particular product will be "bid up" relative to competing products or competing grades of the same product. A "price premium" is established and passed down to the stage which is supplying the retail segment. Competitive buying pressure evolves as the breaker or processor attempts to buy more of the product or grade which is moving well at retail. The price premiums are passed step by step through the stages and through the system.

The final receiver of the message contained in the price premium is the original producer of the product--the cow-calf man in the beef industry. Theoretically, the price premium provides the necessary incentive for the producer to reallocate his resources to produce more of the product or grade for which the consumer is expressing a

preference. For a product or grade which is not finding favor with the consumer, a price discount emerges at the retail level and the ultimate message to the producer is to consider decreasing production of the particular product or grade.

Exchange System with Forward Contracting

In this system contractual arrangements are used as a supplement to exchange processes. As with the exchange system, each stage of activity is controlled by different management entities. Provisions of any contractual arrangement usually deal with some combination of the following facets of the exchange process:

1. price or indication of how price will be established;
2. quality of the product, often with a corollary set of price premiums or discounts for quality differentials;
3. time of delivery; and
4. related terms of trade such as when title transfer occurs, weighing conditions, etc.

Contracts typically exist between two or more stages of the system which have direct technical or input-output ties. For example, the cow-calf operator may enter into a contractual arrangement with the cattle feeder calling for sale and delivery of feeder or stocker cattle. Moving up through the system we may find contractual arrangements between the cattle feeder and the meat packer or between the meat packer and the breaker.

Conceptually, the price mechanism remains the coordinating device. Product flows follow the same general path through the system as with the traditional exchange system. Any differences generally take the form of bypassing intermediate steps. Contractual arrangements between the cow-calf man and the cattle feeder may mean cattle do not flow through an organized market. To the extent this occurs, the number of points at which price is negotiated or determined may be decreased.

The use of contractual arrangements can exert significant influence on the accuracy and content of informational flows. If the contract specifies quality, the message received by the seller via price premiums and discounts may be more obvious. For example, contractual arrangements between the cattle feeder and the packer may include a schedule of prices for quality grade, dressing percentage, yield grade or some combination of the three. When compared to exchange procedures which price slaughter cattle based on estimates of dressing percentage and final carcass merit, the messages from the price signals may be much easier to identify and interpret. Incentives to change feeding practices (length of feeding period, rations fed, etc.) and to worry more about the inherent carcass potential of purchased feeder cattle (breed, performance data, etc.) exert pressures for change which might not appear from the more traditional liveweight exchange

processes. Similar examples of the possible impact of contractual arrangements could be cited at other points of interstage transfer in the system.

The Vertically Integrated System

Vertical integration involves bringing control (through ownership, lease arrangements, etc.) of two or more stages of activity under a common management center. To the extent that integration occurs, coordination by management directive replaces coordination through price.

Moves to vertically integrated structures effect dramatic changes in the conceptual framework of the system. In any form of exchange system characterized by separate ownership of the various stages of activity, management at each stage pursues a profit goal. Decisions which influence the level and nature of interstage coordination are in turn influenced by the profit goal. The emphasis changes when the stages of activity are integrated. Profit to the integrated system (or subsystem), not to any particular stage, becomes the goal. Interstage coordination is handled accordingly and decisions on types of cattle to produce or buy, how they should be fed, when they are to be slaughtered, etc. are made so as to contribute to the profit position of the combined set of activities. Pricing points and price determination procedures are eliminated. At the extreme, for a totally integrated system, the only observable price would be at the point the final product is bought by the consumer.

Selected Dimensions of the System: Implications to Performance

In developing a conceptual picture of the beef system, emphasis was placed on description of the coordinating mechanism and how it functions in each of the organizational structures. In practice, the level of interstage coordination achieved falls short of the conceptual or theoretical optimum. Consequently, performance of the system fails to measure up to conceptual norms. Isolation of the barriers to more effective interstage coordination facilitates understanding of the workings of the system and provides a possible focus for research efforts.

Research conducted in Oklahoma has begun the task of isolating important behavioral facets of interstage activity. Decisionmakers whose actions constitute the interstage linkages were interviewed using "mirror image" questionnaires (5). Questionnaires which probed the goals, decision criteria, operational procedures, etc. of the seller were developed and administered. Mirror-image questionnaires, which probed along the same dimensions, were developed and administered to the buyers in the particular subsystem being investigated. Analysis of the cow calf-cattle feeder and the cattle feeder-packer subsystems have been completed (7, 9).

Goal Conflicts

Conflicts in basic operating goals influence interstage activity. In the cow calf-cattle feeder subsystem, marked differences emerged with regard to what managers feel constitutes the "best" feeder animal. What the cow-calf operator generally tried to produce in terms of frame, weight and degree of finish was largely contrary to what the cattle feeders said they try to buy. A series of pictures was shown to both groups and supplemented by questions which probed production and buying goals for the two respective groups and the conflict was verified. In a related question, however, most producers said they attempt to produce the type of animal which matches the needs of the feedlot operator. We must conclude the price mechanism has not provided incentives to effect the adjustments necessary to achieve input-output coordination in this particular subsystem.

A related development deserves mention. The producers who also conduct stocker operations and who therefore sell directly to feeders more frequently tended to select as best the same type of animal the feeders selected. The direct contact and understanding of the input needs of the feeding operation apparently conveys a message the price mechanism has not been able to transmit.

In the feeder-packer subsystem a conflict emerged along the time dimension of operating goals. Most feeders indicated they try to maximize returns to each pen of cattle. The packers indicated they try to realize satisfactory or maximum returns over some time period, usually one year. Perhaps related to these differences were significant differences in the relative importance attached to short-run price variability. Feeders were not overly concerned about short-run (weekly and monthly) price variability. A significant number of the feeders selected a pattern of net returns which showed maximum price variability even though the interviewers were careful to point out that the net returns per head were constant for all patterns used in the question.

Conversely, the packers demonstrated concern over price variability and the fluctuating flows of cattle which are usually the underlying causal factor. Many said they would be willing to pay a premium--sometimes up to $2 per cwt.--to be able to schedule the majority of their kill into the plant. Again, there exists an apparent inability of the price mechanism to effect changes along a dimension which appears to offer considerable potential for improved interstage coordination.

Other examples of conflicting goals or operating norms could be cited. As long as the existing behavioral interrelationships include conflicts which extend beyond the legitimate buyer-seller conflict, the level of interstage coordination will be below what could be achieved.

Operating Inconsistencies

Numerous inconsistencies in daily operating procedures were isolated. By "inconsistencies" I mean types of interstage activities and/or operational strategies which appear to be inconsistent with the conceptual rules for effective interstage coordination.

A vivid example emerged from the analysis of the feeder-packer subsystem. A set of questions which probed attitudes and procedures concerning the supplying of information during price negotiations was developed and administered. A majority of the cattle feeders polled selected an approach which could be paraphrased as follows:

> Make the cattle available for the buyer's inspection but "hold back" any information on grade distribution, dressing percentage and/or carcass merit for previously fed cattle.

The packers, in responding to the mirror image question, lined up solidly behind an alternative which stressed the importance of such information. Most indicated that in the absence of objective information, price offers are discounted to reflect the uncertainty and the need to estimate the true value of the cattle.

In this case, and for the many other types of inconsistencies we managed to isolate, decisionmakers at the various levels appear to operate from a perspective which views their activities and their role as largely independent of the rest of the system. We have to conclude the price mechanism has not provided the incentives necessary to facilitate moves toward coordinated activity.

Inadequacies in Grades

Adequate grades and related descriptive terminology are essential to price signals as mediums of communication. Since price premiums and discounts reflect value differences, there must be a grade or a symbol which identifies these value differentials and brings them into the pricing process.

The existence of value differentials due to differences in carcass cutability[1] has long been recognized. The USDA's "dual grading" proposal of 1962 was an attempt to establish standards which would identify these value differences. The dual grading scheme did not receive widespread acceptance. In 1965 the USDA introduced yield grades as a means of identifying value differentials, due to cutability, within quality grades.

Theoretically, the adoption of a set of standards such as yield grades is essential to effective communication via the price mechanism.

---

[1]Cutability is defined as the ratio of lean boneless retail cuts to cold carcass weight.

For example, it is difficult to see how the exchange system can promote the production of high-cutability cattle unless cutability differences are identified and brought into the pricing process.

In practice there appears to be some important unknowns with regard to the application of yield grades under industry operating conditions. The USDA's official position is that the difference in production of lean semi-boneless retail cuts will change 4.6 percent of carcass weight per yield grade. With composite retail beef prices around $1.50 per pound, this suggests value differences between a yield grade 1 carcass and a yield grade 5 carcass of as much as $200 for the heavier carcasses. Only in extraordinary short-run supply-demand imbalances have we seen market prices come close to such differentials.

Recent work on carcass cutability at Oklahoma State raises some interesting questions (6, 8). We completed cut-out tests on 168 fed beef carcasses in a commercial breaking plant. The only change in operating procedure was to give us control of the pace of activity to insure complete and accurate recording of all data.

Estimated cutability equations, using the USDA's specification, gave somewhat surprising results. The statistical properties were not impressive (R^2 less than 0.5 for all estimated equations). Regressing several alternative series estimating cutability (lean cuts as percent of carcass weight; lean cuts plus lean trim as percent of carcass weight, etc.) on yield grade gave estimated coefficients on the yield grade variable which ranged from 0.7 to 1.3. These estimates are well below the 4.6 reported by the USDA.

There are several possible reasons for the differences but the more significant appear to be the following.

1. The classes of cattle which comprise the data set are a factor. The original USDA formulation was based on cut-out tests on carcasses ranging from canner and cutter cows to prime steers. All the 168 carcasses analyzed in the Oklahoma research were fed steers or heifers grading good or better. A subset involving 118 head was all steers and came from the same pen of cattle in the feedlot. A functional relationship which "fits" all classes of cattle would not necessarily "fit" a more homogeneous class or subset.

2. Trimming procedures on the final retail cuts is apparently a very important factor. The USDA data allowed a fat cover of no more than 0.5 inches at any one point on the retail cuts. Most related analyses which have been reported have employed similar or more restrictive fat cover tolerances. Some have gone to what was described as "fat free lean." In the Oklahoma study, a fat cover of up to 0.75 inches at any one point (and related, an average cover of no more than 0.5 inches) was the normal procedure for the breaking plant. Further analysis and study suggests both the explanatory power (R^2) of any estimated

cutability function and the slope of any regression of cutability on yield grade will be materially affected by the trimming procedures (6, 8).

This is a complex area which apparently needs more work. Yield grades can make a contribution to pricing processes and interstage coordination only if they are applicable under normal industry operating conditions and are accurate reflectors of value differences in beef carcasses.

The Micro-Macro Paradox

Many of the obstacles to interstage coordination are rooted in what we might call the micro-macro paradox. The entrepreneur at any one level, and this appears to be especially true in the production sector, is preoccupied with the daily running of his operation. There is little or no recognition of, or concern for, how his operation "fits" in the total system. Consequently, goals and operating strategies are firm oriented, not system oriented.

From this perspective emerges an attitude toward interstage coordination which fits what economists call a zero-sum game. The individual decisionmaker feels he can benefit from coordination only if the other party loses and vice versa. Consequently, he sees no reason why he should try to coordinate his activities with the next stage in the system.

But this appears to be a most limited perspective. In many instances there would appear to be potential cost savings via coordination. For example, variable flows of live cattle into a slaughtering facility are costly to the packer. Flows which vary markedly move daily or weekly kill levels above or below the optimal (least-cost) level for which the plant was designed. Scheduled flows could keep per-head killing costs down and these cost savings constitute a pool of dollars which could be shared with the cattle feeder who works with the packer to coordinate activities.

Overall Implications

An exhaustive listing of all the obstacles to coordination we have been able to isolate is not needed here. What we have seen lays the base for inferences and/or hypotheses which should make us, as researchers, a bit uncomfortable:

1. The exchange system does not achieve optimal levels of interstage coordination. There are too many obstacles to effective communication when total reliance is placed on the price mechanism. Our research programs have allowed these obstacles to stand.
2. In integrated structures interstage coordination is achieved via management control. Given a continued inability of the exchange system to achieve interstage coordination and

thereby eliminate some of the risks and uncertainties facing the decisionmakers who must provide the interstage linkages, we will see more pressures toward integrated structures.

3. Without reaching a decision as to what type of system is "best," we as researchers must move toward in-depth exploration of the obstacles to interstage coordination and make the implications of such obstacles known to all system participants. Failure to do so may well mean the continued and possibly accelerated demise of the exchange system as we now know it in favor of integrated structures.

Current and Pending Changes

If the spectrum of activities in the beef industry from production to consumption comprises a system, then changes or "shocks" in the operating environment will be felt throughout the system. It follows, therefore, that any policy change which is being contemplated will require change or adjustment throughout the system.

Proposed Changes in Beef Grades

Opposition came from several points but it was the active opposition by the packers which brought the court injunction. Under the new standards the packers would be required to make significant changes in procedure. They could see no reason why they should do so. The micro-macro issue cropped up here. It is apparent the packers, or any other group at other stages in the system, will be motivated to accept change designed to increase system efficiency only if they can see benefits from the change. With a micro versus system orientation and with a tendency to focus on the more clearly defined short-run implications, acceptance of such proposed changes will not be easy to achieve. And conspicuous in their absence are the research results to (1) demonstrate the implications of the proposed change at the firm and system level, (2) estimate the magnitude and distribution of any costs or benefits, and (3) effectively relate the firm (or stage) to the system and analyze the need for change.

Changing Forage-Concentrate Price Relationships

Developments in the 1973-75 period have prompted many observers to project continued increases in the ratio of forage fed to grain fed beef production. Whether this occurs will depend on the producer-level incentives provided by the system and the adjustments required within the system.

Non-Fed Beef Prices

Prices for live cattle are basically derived prices. The retailer interprets consumers' decisions on the final product and tries to buy beef subject to a gross operating margin. The breaker looks at retail offers, considers his operating margin needs, and formulates a bid for

dressed carcasses. Packers examine price levels in the carcass market and send their buyers into the market with buying objectives which, if met, yield at least a pre-established gross margin per head. The live price is thus derived from the retail price and the composite operating margins.

Derived prices at the live animal level for the non-feds will be lower than bids on the heavier grain-fed steers for several reasons:

1. A price discount for quality since choice beef commands a premium at retail.
2. Lower dressing percents on the non-fed cattle meaning lighter carcass weights as a percent of live weight.
3. A higher per-unit cost of breaking the carcass. Costs of breaking tend to be constant on a carcass basis. Therefore, the costs per-pound on the smaller non-fed carcass will be higher and the breaker's operating margin will be higher.
4. Higher per-pound costs of slaughtering. Again, costs tend to be constant on a per-head basis rather than on a per-pound basis. Operating margins are accordingly higher on a per-pound basis.

The packer would be expected to buy the non-fed when it shows profit potential equal to or greater than that from the fed steer or heifer. It was in the second half of 1974 that the mix of slaughter changed and the non-fed slaughter moved to a higher level of importance. And since that time, the differential between 900-1100 pound choice fed steers and 600-700 pound steers has stayed near the $10-12 per cwt range. The only exceptions were in the May-July period of this year. It would appear packers find the lighter cattle equally profitable as the feds when the non-feds are discounted more than $10 per cwt.

Given the derived nature of price, non-fed or any beef which will not grade choice will start with a price discount at retail. The cost implications of handling a smaller animal or carcass will be "added on" down through the system. At the live animal level, the discount will be significant and will definitely be a factor in the incentive to produce or not produce such beef.

Changing Production Patterns

Significant increases in forage-fed beef production are considered to be inevitable by many analysts. Examination of the changes in the system which would be required should help in projecting the magnitude and permanency of any moves to increased use of forages.

Changes in consumption patterns would be required. Years of promotional effort to establish the term "Choice" have left their mark. More research on consumer behavior with emphasis on the factors which affect consumer decisions and how they might be influenced is needed. We know too little of what goes on in the consumer's mind as he or she

moves along the meat counter. If a smaller percentage of beef will make the choice grade, consumption habits must adjust to the new mix of qualities. Facilitating those adjustments would enhance the economic merit of increased use of forages.

Significant disinvestment and subsequent relocation of investment funds would be required in feeding, slaughtering, processing or breaking and retail distribution. The geographical trends in recent years have been pronounced and, except in the long run, largely irreversible. Several analysts have documented the shift in feeding and processing into the Texas-Oklahoma-Kansas-Colorado area (1, 2). Forage production, on the other hand, is important in the Corn Belt and the Southeast. The $2 million initial investment in the 40,000-head feedlot in the Texas Panhandle is not easily moved. The same is true of the investment in the relatively new packing plants which have been built in the concentrated feeding areas in the Southwest. These investment funds will move to the forage producing areas only after the management of such funds are convinced the move to increased use of forages is permanent and are also convinced the "writing off" of fixed facilities to permit geographical moves is profitable. This will take time.

Perhaps most important in determining whether the system will change to forage-fed beef are the basic economic forces at work. High feed grain prices and low fed cattle prices, seasoned with a large pinch of uncertainty, are the forces which leave feedlots standing empty. But high grain prices and low slaughter cattle prices come in pairs only under rather unique circumstances--during periods of cyclical herd liquidation. Under more normal circumstances, forces within the system are "self correcting." High grain prices restrict feedlot placements which (1) decreases fed marketings in the following months bringing on higher fed cattle prices, and (2) forces prices of feeder cattle down. Given time for these adjustments to occur, the profit picture changes and cattle move into the feedlot again. In late 1974 and early 1975, these "self correcting" forces have been slow to work because of the liquidation phase of the current beef cycle. Cow slaughter has been heavy and non-fed and calf slaughter are running well above the levels of 1972, 1973 and early 1974. But return to the more normal pattern is coming--placements of cattle into feedlots are running very heavy in the fall of 1975.

In short, I think the rigidities in the system and the basic economic facts of life will preclude any dramatic increase in forage-fed beef--at least over the next four to five years. The system will go the way profit motives take the decisionmakers at each stage. The yearling steer off grass or wheat pasture will again be worth more into the feedlot than as a slaughter animal. Strong demand for beef and the heavy slaughter levels of 1975 will permit, by 1977 at the latest, a supply-demand balance which will move fed cattle prices to a level which makes feeding corn at or above $3 per bushel profitable.

System Possibilities and Comparisons of Alternative Structures

Over the next decade we will see two basic developments in the beef system:

1. Some improvement in those parts of the system which continue to rely on exchange processes and the price mechanism as a coordinating device.
2. Moves to vertically integrated structures, especially in the feeding-slaughtering-breaking (processing) subsystem, because improvements in the exchange system will not occur at a pace rapid enough to offset the pressures for integration.

The exchange system could and probably will improve as a coordinating mechanism. Even though developments have been slow in coming, the current state of knowledge would support more effective procedures (4, 5).

Many of the obstacles to move effective interstage coordination could be overcome. Such changes as the following would be required:

1. The introduction of such information as feedlot performance, carcass merit, etc. by herds or by genetic background into exchange processes in the cow calf-stocker-feeder subsystem.
2. The extended application of current knowledge on the replacement decision as the cattle feeder decides when to sell.
3. Trade in slaughter cattle based on objective measures of carcass characteristics.
4. An enlightened and broadened perspective by decisionmakers at each stage in the system with regard to systems operation and firm-systems interrelationships.

The above changes will gradually occur. Systems-oriented research to clarify the issues and to demonstrate possible benefits of change, etc. would facilitate orderly change and adjustment.

Unless stopped by non-economic forces such as government regulation, moves toward integrated structures will continue. And most of the pressure will come from the need to exert control over decisions at the interstage level which influence quality, access to information, product flows, timing of product flows, etc.

Table 1 gives a brief glimpse at the magnitude of the incentives to move to integrated structures. The table provides a comparison of costs, returns, rate of return on investment, etc. for two alternative simulation runs in research we are now completing. When the objective of maximizing returns to the feeding sector is employed, we note the following:

Table 1. Comparison of alternative organizational structures of selected performance measures

Performance measures	Maximize returns to cattle feeding stage	Maximize returns to the total system
Cattle fed	Hereford-Angus 170 days	Charolais-Angus 160 days
Rate of return to total investment in the system	.148	.189
Cost per lb. of retail cuts	$.804	$.726
Profit per head to:[a]		
Cow-calf	$10.79	$ 7.85
Feeder	22.33	44.10
Packer	1.49	2.14
Breaker	57.37	79.61

[a]Profits to the stages under the objective of maximize returns to the total system are based on accounting procedures within the model since no actual price is determined at these stages which are internal to the system. Consequently, the distribution of these profits between stages is not of particular interest.

1. A Hereford-Angus cross is fed for 170 days;
2. Final cost per pound of retail lean (choice grade) is $.804 per pound;
3. The rate of return to the total investment in the system is .148; and
4. Profits range from $1.59 per head for the packer to $57.37 per head for the breaker.

The "system solution" differs primarily as follows:

1. Charolais-Angus cross cattle are fed for 160 days;
2. The cost per pound of retail lean (choice grade) falls from $.804 per pound to $.726 per pound;
3. The rate of return to the total investment in the system increases from .148 to .189; and
4. Some redistribution of "profits" between the stages occurs.

The research I refer to is complex and not amenable to reporting here. In general, we are finding the following:

1. The adoption and full use of current knowledge on growth relationships, genetic background, carcass merit, replacement decisions, yield grades, etc. can influence the open exchange system by (a) increasing the summation of profits accruing to all stages, and (b) reducing the cost of producing lean beef. The improvements come primarily through selection of the right type of cattle for particular sets of circumstances, through the making of replacement decisions designed to maximize profit over time (handled by simulation in the model), through the use of objective measures of carcass merit in carcass pricing, etc.
2. The use of team or system objective functions results in a redistribution of profits between stages, a lower cost of the final product at retail, and a profit to the system which usually exceeds the summation of all profits when profit is maximized to each stage via separate applications of the model.

Summary

The beef industry is a total economic system. The several stages of activity are tightly bound in a technical or input-output context. How effective the system is in bridging the gap between producer and consumer will be determined largely by how these technical interrelationships are handled. Interstage coordination is of vital importance if the system is to maintain alignment between what is produced and the needs or demand of consumers.

Research efforts which focus on the activity at any one level of the system will be less productive as time passes. Emphasis on the interstage linkages, on the action of decisionmakers at the respective stages as they carry on their day-to-day activities and long-range planning, is what is needed. There exist many obstacles to more effective coordination in the exchange system and unless these obstacles are offset by better informed procedures the exchange system is likely to be invaded by integrated structures.

The exchange system could function more effectively if existing knowledge and technology were adopted. But the incentives are not always obvious to system participants and research to demonstrate application, implications, incentives, etc. is conspicuous in its absence.

Adopting a view of the beef industry as a system also brings a new perception of the likelihood of change. Given the stages of economic activity are bound together into a total system, change in any one stage will precipitate "shocks" which reach to varying degrees throughout the system. Acceptance of new policy, such as the proposed change in beef grades, constitutes one example. Moves to forage-fed beef constitute another example. The change is not simple and would

require change and/or adjustment at many junctions in the system. There are too many fixities and the adjustments required are too complex to expect any rapid change to occur. If, over time, the economic incentives for increased use of forages versus grains prevails, the necessary adjustments will evolve.

Adopting a "systems view" of the beef industry makes research and analysis tougher. But such a view can also bring a potential and real-world relevancy our research results have not always enjoyed.

LITERATURE CITED

1. Goodwin, J. W. and J. R. Crow. 1973. The interregional structure of the American beef industry in 1975 and 1980. Okla. Agric. Exp. Sta. Bul. B-708. 55 pp.

2. Goodwin, J. W. and J. R. Crow. 1973. Optimal regional locations of beef production and processing enterprises. Okla. Agric. Exp. Sta. Bul. B-707. 64 pp.

3. Kohls, R. L. 1957. A critical evaluation of agricultural marketing research. J. Farm. Econ. 39:1600-1609.

4. Nelson, K. E. and W. D. Purcell. 1972. A quantitative approach to the feedlot replacement decision. Southern J. of Agric. Econ. 4:143-149.

5. Purcell, W. D. 1973. An approach to research on vertical coordination: The beef system in Oklahoma. American J. of Agric. Econ. 55:65-69.

6. Purcell, W. D. 1974. Needs in beef grades: The cutability dilemma. Okla. Current Farm Econ. 47:3-10.

7. Purcell, W. D. and T. L. Dunn. 1972. Economic implications of conflict and inconsistency in the beef marketing system: The feeder-packer subsector. Okla. Agri. Exp. Sta. Bul. B-700. 26 pp.

8. Purcell, W. D. and K. E. Nelson. 1975. Current needs and issues in beef grades. Okla. Agri. Exp. Sta. J. Article 3007. 24 pp.

9. Rathwell, P. J. and W. D. Purcell. 1972. Economic implications of conflict and inconsistency in the beef marketing system: The producer-feeder subsector. Okla. Agri. Exp. Sta. Bul. B-704. 28 pp.

10. Shaffer, J. D. 1968. Changing orientations of marketing research. J. Agri. Econ. 50:1437-1449.

SOUTHERN COOPERATIVE SERIES

Bulletin 220

This is the 220th in the Cooperative Bulletin Series of the Southern Regional Association of State Agricultural Experiment Stations. Thus this Bulletin is in effect a publication of each of the Cooperating State Agricultural Experiment Stations and may be mailed under the penalty mail privilege of each. Requests for copies originating within the cooperating States should be made to the appropriate State Agricultural Experiment Station Director. Requests from other States should be made to the Director of the North Carolina Agricultural Experiment Station. Cooperating State Agricultural Experiment Stations and their Directors are:

R. Dennis Rouse, Director, Alabama Agricultural Experiment Station, Auburn, Alabama 36830

Lloyd O. Warren, Director, Arkansas Agricultural Experiment Station, Fayetteville, Arkansas 72701

K. R. Tefertiller, Director, Florida Agricultural Experiment Station, Gainesville, Florida 32611

William P. Flatt, Director, Georgia Agricultural Experiment Stations, Athens, Georgia 30602

Charles E. Barnhart, Director, Kentucky Agricultural Experiment Station, Lexington, Kentucky 40506

Doyle Chambers, Director, Louisiana Agricultural Experiment Station, Baton Rouge, Louisiana 70803

W. Lamar Harris, Director, Maryland Agricultural Experiment Station, College Park, Maryland 20742

James H. Anderson, Director, Mississippi Agricultural and Forestry Experiment Station, Mississippi State, Mississippi 39762

Kenneth R. Keller, Director, North Carolina Agricultural Experiment Station, Raleigh, N.C. 27607

Frank H. Baker, Director, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma 74074

W. C. Godley, Director, South Carolina Agricultural Experiment Station, Clemson, South Carolina 29631

D. M. Gossett, Director, Tennessee Agricultural Experiment Station, Knoxville, Tennessee 37901

Jarvis E. Miller, Director, Texas Agricultural Experiment Station, College Station, Texas 77843

Coyt T. Wilson, Director, Virginia Agricultural Experiment Station, Blacksburg, Virginia 24061

Dale W. Ginn, Director, West Virginia Agricultural and Forestry Experiment Station, Morgantown, West Virginia 26506

FORAGE-FED BEEF:
PRODUCTION AND MARKETING ALTERNATIVES IN THE SOUTH

Papers presented at the

Southern Regional Forage-Fed Beef Research Workshop

New Orleans, Louisiana, October 1975

Edited by

JOHN A. STUEDEMANN
(Editor-in-Chief)

Animal Scientist, Southern Piedmont Conservation Research Center
ARS, USDA, Watkinsville, Georgia

and

DALE L. HUFFMAN

Professor, Department of Animal and Dairy Sciences
Auburn University, Auburn, Alabama

J.C. PURCELL

Professor and Head, Department of Agricultural Economics
Georgia Agricultural Experiment Station
Experiment, Georgia

ODELL L. WALKER

Professor, Department of Agricultural Economics
Oklahoma State University, Stillwater, Oklahoma

PREFACE

This bulletin is the proceedings of the Southern Regional Forage-Fed Beef Research Workshop of October 20-22, 1975 in New Orleans, Louisiana. Its general theme was production and marketing alternatives in the South for beef finished with rations containing higher than typical amounts of forage. The workshop was the outgrowth of two different but highly interrelated needs. The first was the need by industry for guidance in the utilization of forage in beef finishing. The second was a need to identify priority research problem areas of the beef cattle industry in the Southern Region.

Industry Guidance

The ratio of feed concentrate prices to roughage costs has trended downward over the long run in the United States. In response to that trend, there has been a long-run tendency for the U. S. beef cattle industry to increase the percentage of feed nutrients from concentrates. This tendency has been particularly pronounced in the beef finishing segment of the industry. In recent years, many finishing operations have utilized rations approaching a biological minimum of roughage.

This tendency toward concentrate-intensive beef finishing also affected the U. S. market for block beef. The market became highly specialized in the handling of beef finished in this way. Market standards and practices, from live cattle markets through retail markets for beef, and consumer purchase and consumption patterns have evolved which are primarily designed to handle this dominant product. As a result, small quantities of beef finished on rations with larger proportions of forage tend to be discounted in the market. Yet, research results indicate that beef finished on such rations may be highly acceptable to consumers when handled properly.

Events from 1972 through 1975 indicated a continuing change in the historical U. S. price or cost relations between feed concentrate and forage. In 1972, there was a sharp increase in foreign demand for U.S.-produced feed concentrates and in U. S. feed concentrate prices. Aside from temporary adverse weather factors in foreign countries, exchange rate changes, and foreign economic growth were major forces contributing to this demand increase. In 1973, it became apparent that there was an international energy problem which would tend to raise feed concentrate production costs above historical levels for an indefinite period.

In the past, forage production costs in some locales of the South permitted forage to be utilized economically in limited-grain cattle finishing, despite the tendency of the market to discriminate against those cattle. In the early 1970s, when concentrate-intensive finishing operators were in a cost-price squeeze, important questions were: To what extent will higher grain prices encourage increased use of forage in finishing cattle and will an expanded volume of beef finished in

this way help to eliminate market discrimination? Those questions in industry were an important consideration influencing the Southern Regional Association of Agricultural Experiment Station Directors, the Agricultural Research Service and the Economic Research Service of the U. S. Department of Agriculture and the Tennessee Valley Authority to sponsor this workshop and to publish these proceedings.

Research Planning

In 1975, four major Southern Regional Research Technical Committees engaged in research on the beef cattle industry in the South were preparing to redirect their research. Each was completing a project on a problem of importance to the future of the forage-fed beef industry. The four committees and projects were:

Project & Committee Identification

Number	Title	Administrative Advisor
S-45	Relationship Between Properties for Southern Forages and Animal Response	C. O. Little
S-67	Evaluation of the Beef Production Industry in the South	R. Dennis Rouse
SM-41	Economic Evaluation of Alternative Forms of Vertical Coordination in the Livestock Meat Industry	J. C. Williamson, Jr.
SM-43	Factors Responsible for Tenderness Variations in Meat	Jarvis E. Miller

Thus, these four committees were in the process of identifying and selecting priority areas to be investigated over the next few years. It was expected that a workshop involving representatives from the four technical committees and others interested in physical, biological and economic questions in both production and marketing would enhance the research planning process of all four committees.

Contributed Papers

Authors of the papers presented at the workshop were selected to represent a broad spectrum of expertise relevant to an analysis of the potential for use of forage in finishing beef in the South. All papers were original and were presented by invitation. Authors were requested both to present what is known and to describe problem areas on which research is needed. Each paper was reviewed by two reviewers and by the editorial committee.

J. C. WILLIAMSON JR.

J. A. STUEDEMANN

D. L. HUFFMAN

J. C. PURCELL

O. L. WALKER

TABLE OF CONTENTS

Preface iii

Acknowledgments x

Program Planning Committee xi

Contributors xiii

Synopsis xvii

ECONOMIC ASPECTS

Moderator: *T. C. Carturight*

A Systems View of the Beef Industry
Wayne D. Purcell 1

Energy, Fertilizer and Feed Grain Requirements and Prospects and Their Effect on the Beef Cattle Industry
James Vermeer 19

Discussion 38

Moderator: *Odell L. Walker*

Economics of Grain-Roughage Substitution in the Beef Sector
Ray F. Brokken 45

Economics of Alternative Beef Production Systems and Locations
Donald E. Farris and Raymond A. Dietrich 77

Discussion 100

STRUCTURE AND MARKETING

Moderator: *Richard J. Crom*

Structure and Performance of the Meat (Beef) Industry
Willard F. Williams 107

Market Potential for Block and Processed Beef
Robert Raunikar 127

Discussion 153

CARCASS CHARACTERISTICS, MEAT QUALITY AND CONSUMER ACCEPTANCE

Moderator: *Dale L. Huffman*

Growth and Development of Beef Cattle, With Reference to the Effect of Breed and Sex
J. J. Guenther 159

Qualitative Aspects: Tenderness, Flavor, Juiciness, Color of Lean and Fat
Robert F. Kelly 193

The New Beef: Review of Handling and Processing Techniques to Enhance Consumer Acceptance
H. Russell Cross and Gary C. Smith 217

Discussion 232

FUNDAMENTAL ASPECTS OF FORAGE AND BEEF PRODUCTION

Moderator: *R. R. Johnson*

Energy Requirements of Beef Cattle
W. C. Ellis 237

Meeting the Nutrient Requirements of Beef Cattle with Forage
Ethan C. Holt 261

Discussion 286

Breeding Better Forages
Wayne W. Hanna 291

Discussion 299

Increasing Digestibility and Intake Through Management of Grazing Systems
R. E. Blaser, W. C. Stringer, E. B. Rayburn, J. P. Fontenot, R. C. Hammes, Jr., and H. T. Bryant . . . 301

Discussion 346

The Role of Harvested or Processed Forage in Beef Feeding
M. E. McCullough 349

Discussion 361

CAPABILITIES OF VARIOUS PHYSIOGRAPHIC REGIONS

Moderator: *C. Oran Little*

Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain Rations in the Upper South
A. E. Spooner and Maurice L. Ray 363

Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain Rations in the Piedmont Region of the South
Carl S. Hoveland and W. B. Anthony 377

Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain in the Lower South
Warren G. Monson and Philip R. Utley 391

Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain Rations in the Semi-arid Southwest
F. P. Horn and C. M. Taliaferro 401

Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain Rations in the Tropical Region of the South
G. O. Mott and J. E. Moore 419

Discussion 444

USE OF MODELING SYSTEMS

Moderator: *John A. Stuedemann*

The Use of Modeling to Hasten and Enhance the Application of Research Information to Beef Production Systems and Feedback to Research
T. C. Carturight 451

Discussion 458

REPORTS BY SOUTHERN REGIONAL TECHNICAL COMMITTEES

Moderator: *John A. Stuedemann*

SM-41--Economic Evaluation of Alternative Forms of Vertical Coordination in the Livestock-Meat Industry 463

SM-43--Factors Responsible for Tenderness Variations in Meat 465

S-45--Relationship Between Properties of Southern Forages and Animal Response 469

S-67--Evaluation of the Beef Production Industry in the South 470

Discussion 473

Closing Comments 475

ACKNOWLEDGMENTS

We appreciate support of the workshop by the administrators of the Southern State Agricultural Experiment Stations; the Agricultural Research Service, USDA; the Economic Research Service, USDA; the Cooperative State Research Service, USDA; and the Tennessee Valley Authority. Special appreciation is extended to D. Chambers, Director, Louisiana Agricultural Experiment Station; C. O. Little, Associate Director, Kentucky Agricultural Experiment Station; R. D. Rouse, Director, Alabama Agricultural Experiment Station; and A. W. Cooper, Deputy Administrator, Southern Region, Agricultural Research Service, USDA. Funds for publication of the proceedings were provided by the Agricultural Research Service, the Cooperative State Research Service, the Economics Research Service, the North Carolina Agricultural Experiment Station and the Tennessee Valley Authority.

We acknowledge the excellent cooperation of all authors. Special thanks are extended to those who assisted the editorial committee in reviewing manuscripts and to those who aided in conduct of the workshop. The following served as recording secretaries of discussion sessions: J. G. Dillard, Agricultural Economist, Division of Agricultural Development, TVA; H. Lippke, Associate Professor of Animal Nutrition, Texas Agricultural Experiment Station; W. G. Moody, Professor of Meats, University of Kentucky; J. A. Stuedemann, Animal Scientist, ARS,USDA; J. E. Via, Associate Professor of Marketing, University of Maryland. The following were sessions moderators: T. C. Cartwright, Professor of Animal Breeding, Texas A&M University; R. J. Crom, Leader, Meat Animals Program Area, Commodity Economics Division, ERS, USDA: D. L. Huffman, Professor of Meats, Auburn University; R. R. Johnson, Head, Department of Animal Science, University of Tennessee; C. O. Little, Associate Director, Kentucky Agricultural Experiment Station; J. A. Stuedemann, Animal Scientist, ARS, USDA: and O. L. Walker, Professor of Agricultural Economics, Oklahoma State University.

Thanks are due Mrs. Betty Thomas, ARS, USDA, Watkinsville, Georgia, whose secretarial efforts contributed to the success of the meeting and subsequent publication of the proceedings. Special recognition goes to Ms. Ann Cooke, North Carolina Agricultural Experiment Station, who patiently provided final editing and typing of the publication.

WORKSHOP PLANNING COMMITTEE

J. C. Williamson, Jr., General Chairman

J. A. Stuedemann, Coordination Chairman

D. L. Huffman J. C. Purcell O. L. Walker

PROGRAM PLANNING COMMITTEE

General Chairman: J. C. Williamson, Jr., Former Director*
North Carolina Agricultural Experiment Station
North Carolina State University
Raleigh, N. C. 27607

Coordination Chairman: J. A. Stuedemann, Animal Scientist
Southern Piedmont Conservation Research Center
ARS, USDA
Watkinsville, Georgia 30677

Economics and Marketing

Co-chairman: J. C. Purcell, Professor and Head
Department of Agricultural Economics
Georgia Agricultural Experiment Station
Experiment, Georgia 30212

Co-chairman: O. L. Walker, Professor
Department of Agricultural Economics
Oklahoma State University
Stillwater, Oklahoma 74074

T. C. Cartwright, Professor
Department of Animal Science
Texas A&M University
College Station, Texas 77843

R. J. Crom, Leader
Meat Animals Program Area
Commodity Economics Division
ERS, USDA
Washington, D. C. 20250

*Now Professor of Economics and Business, North Carolina State University, Raleigh, N. C. 27607

Carcass Characteristics, Meat Quality and Consumer Acceptance

Chairman: D. L. Huffman, Professor
Department of Animal and Dairy Sciences
Auburn University
Auburn, Alabama 36830

Fundamental Aspects of Forage and Beef Production: Existing and Potential Systems of Finishing Cattle on Forages or Limited Grain Rations: Use of Modeling Systems

Chairman: J. A. Stuedemann, Animal Scientist
Southern Piedmont Conservation Research Center
ARS, USDA
Watkinsville, Georgia 30677

J. G. Dillard, Agricultural Economist
Agricultural Development Division
Tennessee Valley Authority
Muscle Shoals, Alabama 35660

C. S. Hoveland, Professor
Department of Agronomy and Soils
Auburn University
Auburn, Alabama 35830

H. Lippke, Associate Professor
Texas Agricultural Experiment Station
Angleton, Texas 77515

Other Members of the Planning Committee: J. R. Janssen, Assistant Director*
Economic Development Division
ERS, USDA
Washington, D. C. 30350

*At the time of the workshop, Dr. Janssen was serving temporarily as Principal Agricultural Economist with the Cooperative State Research Service, USDA.

CONTRIBUTORS TO THIS VOLUME

JOHN R. ALLISON

Associate Professor, Department of Agricultural Economics, University of Georgia, Experiment, Georgia

W. B. ANTHONY

Professor, Department of Animal and Dairy Science, Auburn University, Auburn, Alabama

R. E. BLASER

University Distinguished Professor, Department of Agronomy, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

RAY F. BROKKEN

Agricultural Economist, Commodity Economics Division, Economic Research Service, U. S. Department of Agriculture, Corvallis, Oregon

H. T. BRYANT

Associate Professor, Department of Agronomy, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

H. RUSSELL CROSS

Research Food Technologist, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Maryland

T. C. CARTWRIGHT

Professor, Department of Animal Science, Texas A&M University, College Station, Texas

G. L. M. Chappell

Associate Extension Professor, Department of Animal Sciences, University of Kentucky, Lexington, Kentucky

RAYMOND A. DIETRICH

Associate Professor, Department of Agricultural Economics, Texas A&M University, College Station, Texas

W. C. ELLIS

Professor, Department of Animal Science, Texas A&M University, College Station, Texas

DONALD E. FARRIS

Professor, Department of Agricultural Economics, Texas A&M University, College Station, Texas

J. P. FONTENOT

Professor, Department of Animal Science, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

J. J. GUENTHER

Professor, Department of Animal Science and Industry, Oklahoma State University, Stillwater, Oklahoma

R. C. HAMMES, JR.

Assistant Professor, Department of Animal Science, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

WAYNE W. HANNA

Geneticist, Agricultural Research Service, U. S. Department of Agriculture, Tifton, Georgia

ETHAN C. HOLT

Professor, Department of Soil and Crop Sciences, Texas A&M University, College Station, Texas

F. P. HORN

Research Animal Husbandman, Agricultural Research Service, U. S. Department of Agriculture, El Reno, Oklahoma

CARL S. HOVELAND

Professor, Department of Agronomy and Soils, Auburn University, Auburn, Alabama

ROBERT F. KELLY

Professor, Department of Food Science, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

M. E. McCULLOUGH

Professor, Department of Animal Science, University of Georgia, Experiment, Georgia

WARREN G. MONSON

Agronomist, Agricultural Research Service, U. S. Department of Agriculture, Tifton, Georgia

WILLIAM G. MOODY

Professor, Department of Animal Sciences, University of Kentucky, Lexington, Kentucky

J. E. MOORE

Professor, Department of Animal Science, University of Florida, Gainesville, Florida

G. O. MOTT

Professor, Department of Agronomy, University of Florida, Gainesville Florida

WAYNE D. PURCELL

Professor, Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma

ROBERT RAUNIKAR

Associate Professor, Department of Agricultural Economics, University of Georgia, Experiment, Georgia

MAURICE L. RAY

Professor, Department of Animal Science, University of Arkansas, Fayetteville, Arkansas

E. B. RAYBURN

Graduate Student, Department of Agronomy, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

GARY C. SMITH

Professor, Department of Animal Science, Texas A&M University, College Station, Texas

A. E. SPOONER

Professor, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas

W. C. STRINGER

Graduate Student, Department of Agronomy, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

C. M. TALIAFERRO

Associate Professor, Department of Agronomy, Oklahoma State University, Stillwater, Oklahoma

PHILIP R. UTLEY

Associate Professor, Department of Animal Science, University of Gerogia, Tifton, Georgia

JAMES VERMEER

Assistant Director, Commodity Economics Division, Economic Research Service, U. S. Department of Agriculture, Washington, D. C.

WILLARD F. WILLIAMS

Horn Professor, Department of Agricultural Economics, Texas Tech University, Lubbock, Texas

SYNOPSIS

The general margin for finishing beef has been sharply limited in recent years by aggressive expansion of the specialized concentrate-intensive beef finishing industry. Stimuli for that expansion have been low prices of concentrate feeds and advances in technology and management in these specialized enterprises. Low concentrate prices have in turn reflected low energy and fertilizer prices and advances in technology and management of feed grain production. Beef produced in such operations has dominated the market and has become the standard in market channels from the meat packer to the final consumer. Cattle and beef finished with rations containing appreciable amounts of forage have differed from that standard and have been discounted in the market. This discounting has further reduced the margin for finishing cattle on such rations.

Despite these narrow finishing margins, producers in some locales in the Southern Region have been able to develop profitable forage and/or limited grain finishing operations. But forage-fed beef accounts for only a small percentage of regional and national consumption of beef. Research results indicate that there are opportunities for other producers to utilize forage in profitable beef feeding operations. These opportunities would be enhanced if forage-fed beef were not discounted in the market or if concentrate prices were higher, thereby raising the general margin for finishing beef and particularly the margin for finishing beef with predominantly forage.

This workshop was addressed primarily to those factors which determine the margin for finishing beef in the Southern Region on rations containing appreciable amounts of forage. Those factors are diverse. They range through nutritional requirements for cattle and the use of forage in meeting those requirements, alternative forage-finishing systems in different physiographic areas of the region, the substitution of roughage for concentrates in finishing rations, structure and performance of the market for feeder cattle, fed cattle and beef, physical and biological characteristics of beef finished on rations containing forage, consumer acceptance of forage-fed beef, and interrelationships among energy and fertilizer costs, feed grain prices and the beef cattle industry.

The workshop did not produce clearly definable answers about the future of forage finishing of beef in the Southern Region. However, the workshop did suggest the following generalizations.

1. There are numerous localized opportunities in the Southern Region for expanded use of forage in finishing beef at historical finishing margins and forage production costs.

2. Discounting of forage-fed cattle and beef reflects costs imposed upon marketing firms and consumers by low volume, uncertainty and variability in the supply of forage-fed beef rather than inherently inferior characteristics of such beef relative to grain-finished beef.

3. Energy, fertilizer and feed concentrate price increases may widen the general margin for finishing cattle. However, the effectiveness of this increase in improving the profitability of finishing beef on rations containing forage may be limited by (a) associated increases in costs of producing forage, (b) increased demand for forage in other segments of the beef industry.

4. Additional research and education is needed on the market for cattle and beef to improve the efficiency with which forage-fed beef moves from feeder to consumer. This research and education should treat both the economic problems of structure and performance and the biological and physical problems of technology and performance.

5. Additional research is needed to reduce costs of finishing beef on forages, to identify those locales and resource situations where such enterprises may be profitable, to stabilize the production of forage-fed beef and to reduce variability in characteristics of forage-fed beef from area to area, season to season and year to year. Physical science, biological science and economic research are needed and there should be close coordination of research in different disciplines.

6. There are great variations in soil, climate and economic conditions in the Region. Consequently, the potential for and problems of forage-finishing of beef and the production systems which are appropriate will vary widely among locales. As a result, researchable problems are numerous and diverse. These circumstances provide a special incentive for close regional research and coordination among industry, extension and research groups. Such coordination will improve research priority identification and problem selection and enhance the process of screening, adaptation and adoption of research results.

J. C. WILLIAMSON, JR.

J. A. STEUDEMANN

D. L. HUFFMAN

J. C. PURCELL

O. L. WALKER

ENERGY, FERTILIZER, AND FEED GRAIN REQUIREMENTS AND PROSPECTS AND THEIR EFFECT ON THE BEEF CATTLE INDUSTRY

James Vermeer*

In a report on "Cattle Feeding in the United States," in 1970, Gustafson and Van Arsdall said "Beef now accounts for about two-thirds of all red meat consumed in the United States. Continuation of present per capita trends coupled with increasing population will call for a third more beef by 1980. However, the supply of feeder cattle may become the limiting factor" (5). Five years ago, these authors were not alone in that concern. Cattlemen obviously agreed with them because in addition to expanding beef production by 8 percent from 1969 to 1974, they expanded the total cattle herd by 18 percent, from 112 million head January 1, 1970 to 132 million head January 1, 1975. However, many cattlemen today probably would say that concern, if not misplaced, was at least premature.

The increasing demand for food and feed grains, the small feed grain crops in 1970 and 1974, and the sharp increase in the prices of petroleum and related products, which could not be foreseen in 1970, have sharply altered price-cost relationships in the cattle industry.

In this paper, I plan to review some past relationships of beef production, prices and costs; to provide some measure of the changes that have occurred in supplies, prices and costs of energy; and to speculate on the effects that these changes may have on future beef production systems.

Liveweight production of cattle increased nearly 60 percent from 1952-53 to 1973-74 (year beginning October 1)[1] (1). Two factors were chiefly responsible for this increase. These were the increasing demand for beef and the generally favorable beef-feed price relationships. Beef consumption per capita rose from 62 pounds (carcass weight equivalent) in 1952 to 117 pounds in 1974. The retail price of beef

---

*Assistant Director, Commodity Economics Division, Economic Research Service, U. S. Department of Agriculture 20250. Paper presented at the Southern Regional Forage-Fed Beef Research Workshop, New Orleans, Louisiana, October 20-22, 1975.

[1]Liveweight production includes beef and veal slaughtered plus the increase in pounds of beef on the hoof on farms and ranches and in feedlots.

rose slightly more than 50 percent during the same period, but in relation to the retail prices paid for all food, the price of choice beef declined 16 percent. The proportion of consumer income spent for beef has fluctuated from about 2.3 percent to 2.7 percent but with no apparent trend during the 25 years since 1950.

Measures of Production

Until recently, fed beef as a proportion of total beef production has increased steadily, at least since the 1950s. In 1960, the number of fed cattle slaughtered was 53 percent of the total slaughter. This proportion rose to 77 percent in 1972 and 1973; however, by the spring of 1975 it had dropped back to 54 percent of the total, or nearly back to the 1960 level.

The changing proportion of fed beef to total beef can also be expressed in terms of carcass weights. In 1960, fed beef accounted for 58 percent of total commercial beef production. By 1973 this proportion had risen to 80 percent of the total; it dropped back to 68 percent in 1974, and by the second quarter of 1975, it was down to about 57 percent.

Part of the increase in the proportion of cattle slaughtered as fed cattle occurred because for most of the time since the 1950s, the total cattle herd was expanding and those increasing numbers were forage-fed and not going to slaughter.

There is a difference, however, in the proportion of cattle slaughtered as grain-fed cattle, or the proportion of beef that is grain-fed, and the proportion of total beef produced from grain. The term grain-fed applies only to those animals finished on grain, but more than half of the growth of grain-finished cattle was produced on forage before the animals entered the feedlot.

Total beef produced on forage can be obtained by subtracting gains in the feedlot from total liveweight of beef produced. If we start with total liveweight of beef produced as reported by the Statistical Reporting Service and subtract liveweight gain of cattle in feedlots as estimated by the Economic Research Service, the remainder is the liveweight of beef produced on forage. Even this estimate may understate slightly the volume of beef produced on forage because cattle in feedlots also obtain part of their growth from forage. But beef cattle and calves on pasture also consume some protein supplements and grain; thus, the estimate may be a fair measure of the quantity of beef produced on forage.

Total liveweight of beef produced rose from nearly 27 billion pounds in 1952-53 (year beginning October 1) to more than 42 billion pounds in 1973-74 (Figure 1). During that period, the quantity of beef grown on forage increased from 23.3 billion pounds in 1952-53 to 31.3 billion pounds in 1973-74. However, because the amount of beef produced on grain and concentrates was rising at a more rapid rate than

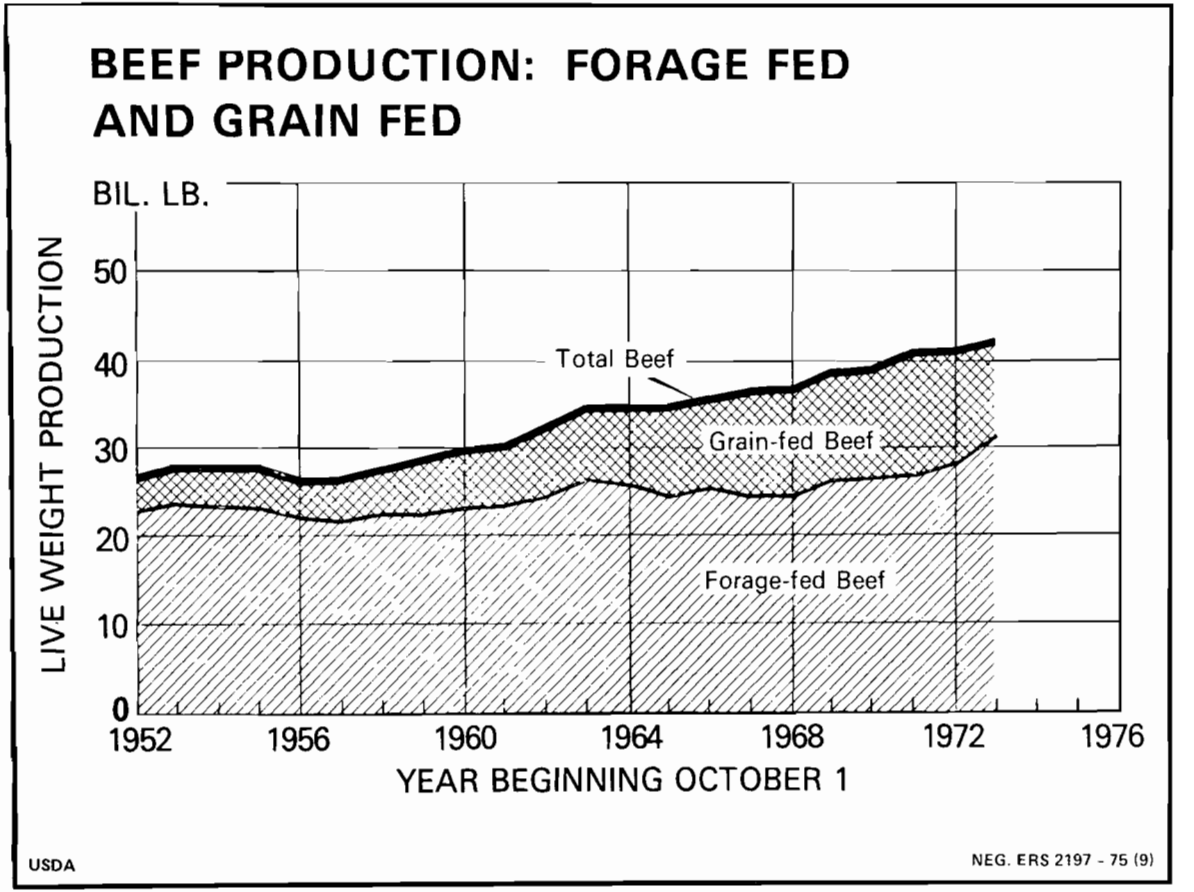

BEEF PRODUCTION: FORAGE FED AND GRAIN FED
BIL. LB.
LIVE WEIGHT PRODUCTION
50
40
30
20
10
0
Total Beef
Grain-fed Beef
Forage-fed Beef
1952
1956
1960
1964
1968
1972
1976
YEAR BEGINNING OCTOBER 1
USDA
NEG. ERS 2197 - 75 (9)

Figure 1

the increase in total beef produced, the proportion of beef produced on forage declined from 87 percent of the total in 1952-53 to 66 percent in 1971-72. Since then it has risen to 74 percent in 1973-74.

Demand for Forage-Fed Cattle

The long-term demand for forage-fed cattle has been expanding as indicated by increases in both the supply of feeder cattle and prices from at least 1960 to date (Figure 2). A measure of the supply of feeder cattle is obtained from the sum of all steers, heifers, and calves in inventory on January 1, less heifers kept for breeding and cattle on feed January 1. Although the observations in Figure 2 are too few to permit construction of supply curves, the coordinates by years indicate that the demand curve has been shifting upward and to the right.

Cattle-Feed Price Relationships

Because such a large proportion of the supply of range and grass fed cattle go through the feedlot before being slaughtered, the price of these cattle is inversely related to the price of feed. The relationship can be clarified by comparing the ratios of fed cattle to feed prices and feeder cattle to fed cattle prices (Figure 3). As the price of fed cattle rises relative to the price of feed, the price of feeder cattle also rises relative to the price of fed cattle. These values are higherly correlated with an r value of 0.86 based on annual data.

Figure 3 shows these annual data, but the adjustment is not instantaneous. Figure 4 shows the relationship of 10-month moving averages for corn, fed cattle, and feeder cattle from January 1973 through June 1975. From late 1972 to August 1973 (the 10-month moving average continued to climb until October) these prices moved up together. While fed cattle prices leveled off in the fall of 1973 and early 1974, corn prices continued to rise, and feeder cattle prices started their long descent from about $50 per hundredweight as of October 1973 (10-(10-month average) to below $30 per hundredweight in the spring of 1975. Despite the plunge, prices of feeders remained above prices of fed cattle for nearly a year after they began their descent. But as prices of corn continued to climb, feeder cattle prices fell further until the relationship between prices of feed, feeder cattle, and fed cattle were such as to allow feedlot operators to turn a profit. In recent months these prices appear to have stabilized again, but the margin of fed cattle prices over those of feeder cattle is about $10 per hundredweight compared with a negative margin at least as large a year earlier. A major reason for this reversal was the sharp rise in the price of feed.

Although the fed cattle-corn and feeder cattle-fed cattle price ratios shown in Figure 3 are highly correlated on a calendar year

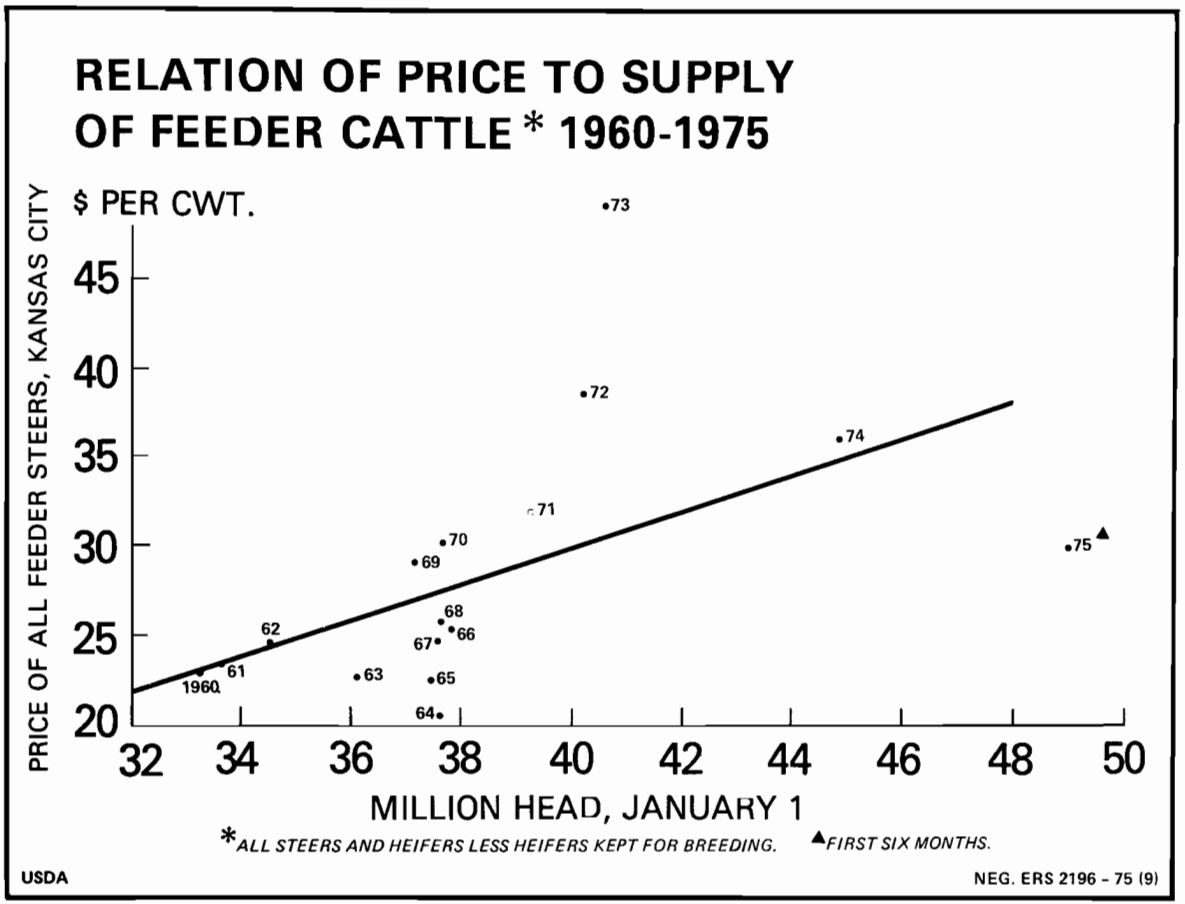

RELATION OF PRICE TO SUPPLY
OF FEEDER CATTLE * 1960-1975
$ PER CWT.
PRICE OF ALL FEEDER STEERS, KANSAS CITY
45
40
35
30
25
20
32
34
36
38
40
42
44
46
48
50
MILLION HEAD, JANUARY 1
1960
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
*ALL STEERS AND HEIFERS LESS HEIFERS KEPT FOR BREEDING.
▲FIRST SIX MONTHS.
USDA
NEG. ERS 2196 - 75 (9)

Figure 2

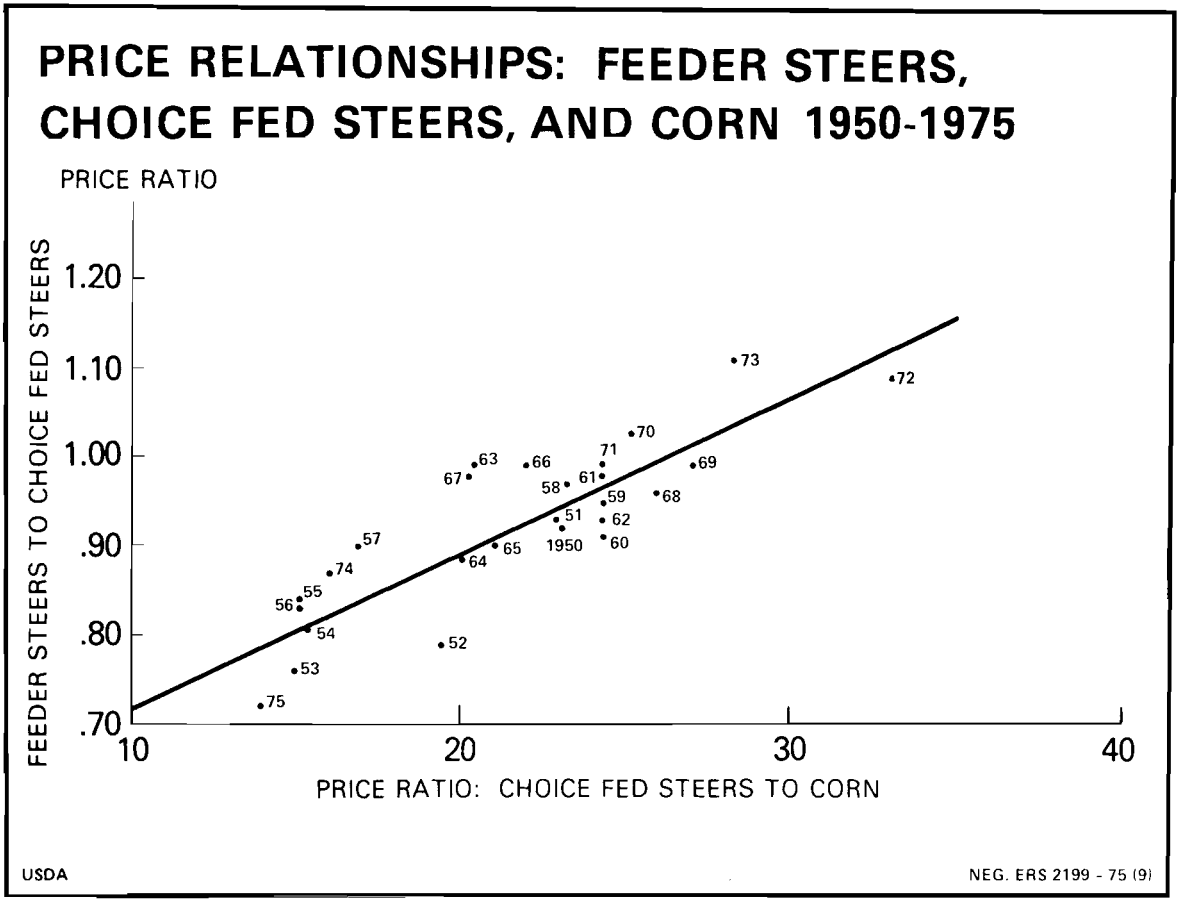

PRICE RELATIONSHIPS: FEEDER STEERS, CHOICE FED STEERS, AND CORN 1950-1975
PRICE RATIO
FEEDER STEERS TO CHOICE FED STEERS
1.20
1.10
1.00
.90
.80
.70
10
20
30
40
PRICE RATIO: CHOICE FED STEERS TO CORN
73
72
70
71
63
66
69
67
61
58
59
68
51
62
57
65
1950
60
64
74
55
56
54
52
53
75
USDA
NEG. ERS 2199 - 75 (9)

Figure 3

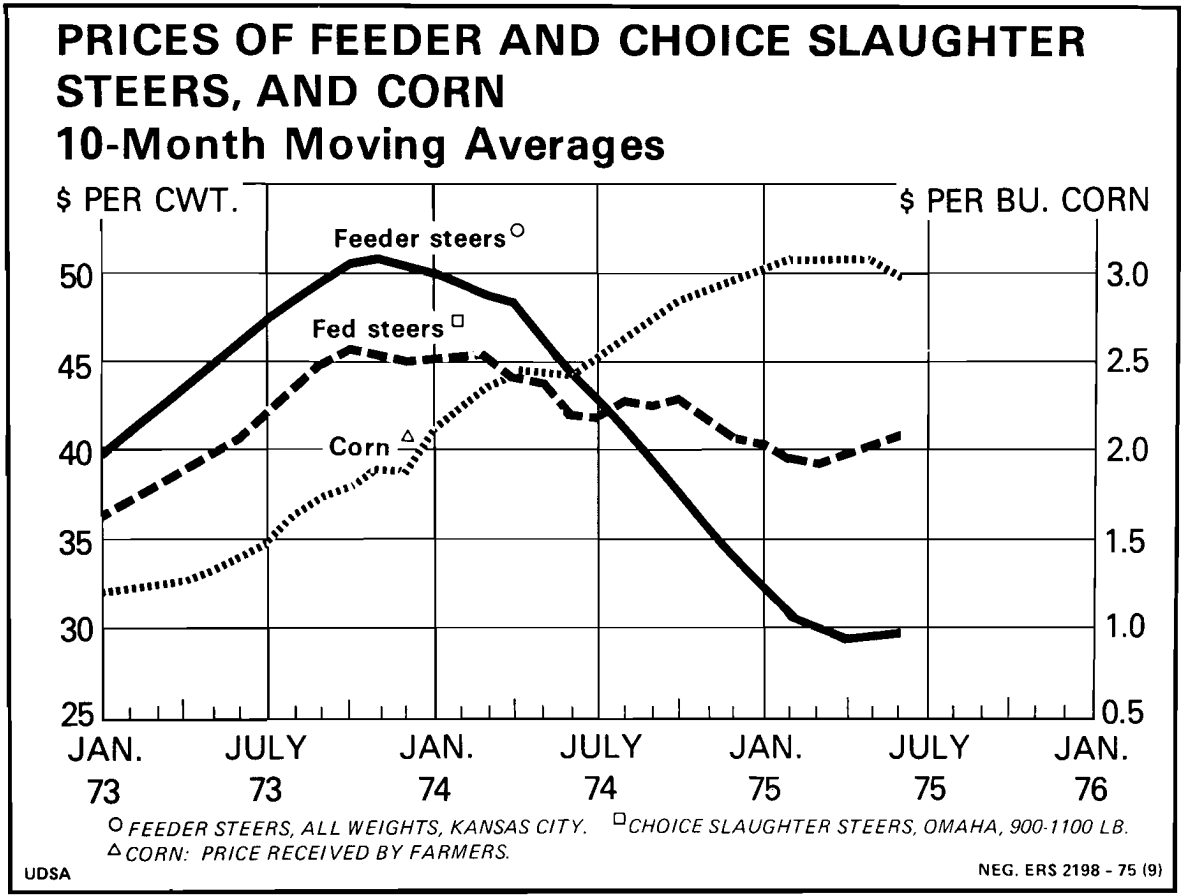

PRICES OF FEEDER AND CHOICE SLAUGHTER STEERS, AND CORN
10-Month Moving Averages
$ PER CWT.
$ PER BU. CORN
Feeder steers ○
Fed steers □
Corn △
50
45
40
35
30
25
3.0
2.5
2.0
1.5
1.0
0.5
JAN. 73
JULY 73
JAN. 74
JULY 74
JAN. 75
JULY 75
JAN. 76
○ FEEDER STEERS, ALL WEIGHTS, KANSAS CITY. □ CHOICE SLAUGHTER STEERS, OMAHA, 900-1100 LB.
△ CORN: PRICE RECEIVED BY FARMERS.
UDSA
NEG. ERS 2198 - 75 (9)

Figure 4

basis, the coefficient of correlation probably would be even higher if the time periods selected for comparison more nearly corresponded with the turning points in the fed cattle-feed price ratios.

The decline since 1973 in the proportion of beef marketed as fed beef has been sharp, but not entirely unexpected. With relatively cheap feed during the 1960s and early 1970s, feedlot operators could operate profitably even with negative feeder-fed cattle margins. But as the price of feed rose sharply, profit margins were eroded, feeder cattle prices plummeted and slaughter of grass fed cattle rose markedly.

Beef Production in Transition

With the worldwide shortage of grain crops in 1972 and again in 1974, much of the public has become concerned about the use of grain for livestock feed. Critics of beef feeding argue that the practice is morally unjustified in a time of world food shortages because cattle yield only 1 pound of protein for every 20 pounds they consume in grain (6). Although cattle are among the least efficient animals for converting concentrate feeds into meat for human consumption, they are among the most efficient in using materials that would otherwise go to waste. Thus, the question of feed conversion in beef production should not be viewed in isolation from the issue of the quality of feed used. This point will be developed more fully a little later in this paper.

With the threat of an interruption in the supply of fuel and the sharp rise in prices of fuel, fertilizer, and other inputs associated with the use of energy, a different kind of concern has surfaced. That is, with sharply higher prices of energy related inputs, what will be the effect on cost of food production? This task force is concerned with one part of that problem, namely the effect on beef production.

The Energy Situation

Until 1965, the United States produced more oil and natural gas than it needed. But with the ever rising demand, this country became increasingly dependent on foreign sources until today about 35 percent of our crude oil is imported. Environmental pollution controls accelerated the shift from coal to oil, and from coal and oil to natural gas. Nearly two years after the embargo on oil shipments from some of the Organization of Petroleum Exporting Countries (OPEC) to the United States and the subsequent sharp rise in prices of petroleum products, our policies with respect to the use of energy remain relatively unchanged. However, projections of energy production and consumption suggest that energy will continue to be less available and more expensive as far as we can see into the future.

The policy to hold down prices of natural gas during the last 20 years has reduced the number of exploratory wells (some estimate by as much as one-half) since it has not been profitable to drill for gas or

to sell that which has been discovered. At the same time, the artificially low prices have encouraged uses of natural gas particularly in industrial processes that could have used more plentiful coal. At prices paid for energy in 1972, the cost of a million BTU of energy from natural gas was 60 cents compared with $1.24 from anthracite coals, the next cheapest source (3).

The composition of energy sources has changed dramatically over the years and will continue to change. At present the energy mix in the United States consists of 46 percent crude oil, 31 percent natural gas, 18 percent coal, 4 percent hydroelectric power, and 1 percent nuclear power (4). By the year 2000, the Bureau of Mines estimates that crude oil will still be the most important source of energy, but nuclear power will provide a fourth of the total. Large amounts of capital, successful explorations, and improve technological processes will be necessary to bring about such changes in the sources of energy.

Composition of energy sources

Kind	Current	Bur. of Mines projection, 2000
	(percent)	(percent)
Crude oil	46	37
Natural gas	31	18
Coal	18	16
Hydroelectric power	4	3
Nuclear power	1	26

The United States has an estimated 300-year supply of coal at projected consumption rates. But to obtain much of the coal in the western states involves serious environmental adjustments with enormous problems of waste disposal and water usage. Capital needs and economic costs are formidable, and time is required for development. Oil from shale involves processing and technological problems that have not yet been solved. Costs have been high and sufficient water is questionable. Little expansion is expected in hydroelectric power, and nuclear power development has been hindered by legal and environmental problems. These problems will need to be overcome if nuclear power is to supply a substantially larger part of the supply of total energy.

Laboratory techniques have been developed for manufacturing methane gas from wood, manure, human wastes, and other products. But the system for gathering these materials in the quantities needed and the disposition of the waste products from these processes have not been developed. Thus, over the next 10 to 15 years, petroleum is the only environmentally acceptable and technologically proven source of energy. Hopefully that will provide sufficient time to develop alternative sources.

The U. S. Geological Survey estimates that up to 130 billion barrels of crude oil and 800 trillion cubic feet of natural gas are recoverable with current technology and economics under the outer continental shelf (from the seacoast to the 600-foot water depth). Available offshore resources are equal to about one-half the crude oil and two-thirds of the natural gas available on shore.

The United States is the highest per-capita user of energy in the world, and U. S. agriculture is among the most energy dependent. Inexpensive food has been related directly to the use of inexpensive fossil fuel stored up eons ago. Energy input per unit of energy output has been high relative to more primitive kinds of agricultural production.

The food and fiber sector accounted for about 13 percent of the total energy consumption of the nation in 1974. Of this total, about 50 percent was liquid petroleum fuel, 30 percent natural gas, and 14 percent electricity.

Farm production requires about 8 billion gallons of petroleum fuel, about 3 percent of the U. S. total. Since U. S. policy is to give agriculture a high priority in the allocation of available fuel, the lack of availability of fuel is not expected to be a serious deterent to food production. However, fuel shortages may limit production of fertilizer and other petrochemicals used in agricultural production, and may restrict the transportation industry and other industries which agriculture depends on for its inputs.

The embargo on oil from the Arab countries to the United States in the fall and winter of 1973-74 brought home to most Americans the vulnerability of our source of oil. As a result of monopoly pricing by the Organization of Petroleum Exporting Countries (OPEC), the price of crude oil increased more than fourfold in a matter of a few months. Imports of crude oil dropped sharply in late 1973 and early 1974 as a result of the embargo, and rose abruptly with the lifting of the embargo. After remaining about level from May 1974 to February 1975, imports declined at least until May 1975 (**Figure** 5).

Refinery inputs from domestic and imported crude oil followed a pattern similar to imports. The amount of crude from domestic sources was lower in 1974 than in 1973. In recent months, however, refinery inputs have increased while imports continued to decline (Figure 6).

Domestic production of natural gas has been declining steadily (Figure 7). Production in each of the last two years was below that in the corresponding month of the previous year. Our known reserves of natural gas will last only 11 or 12 years at current usage rates.

Consumption of coal varies somewhat throughout the season, but there is no indication of any appreciable change in the rate in recent years (Figure 8). Patterns of consumption in 1973 and 1974, and to date in 1975 are similar. Concerns about damage to the environment from strip mining, air pollution from burning coal by the electric

Imports of Crude Oil

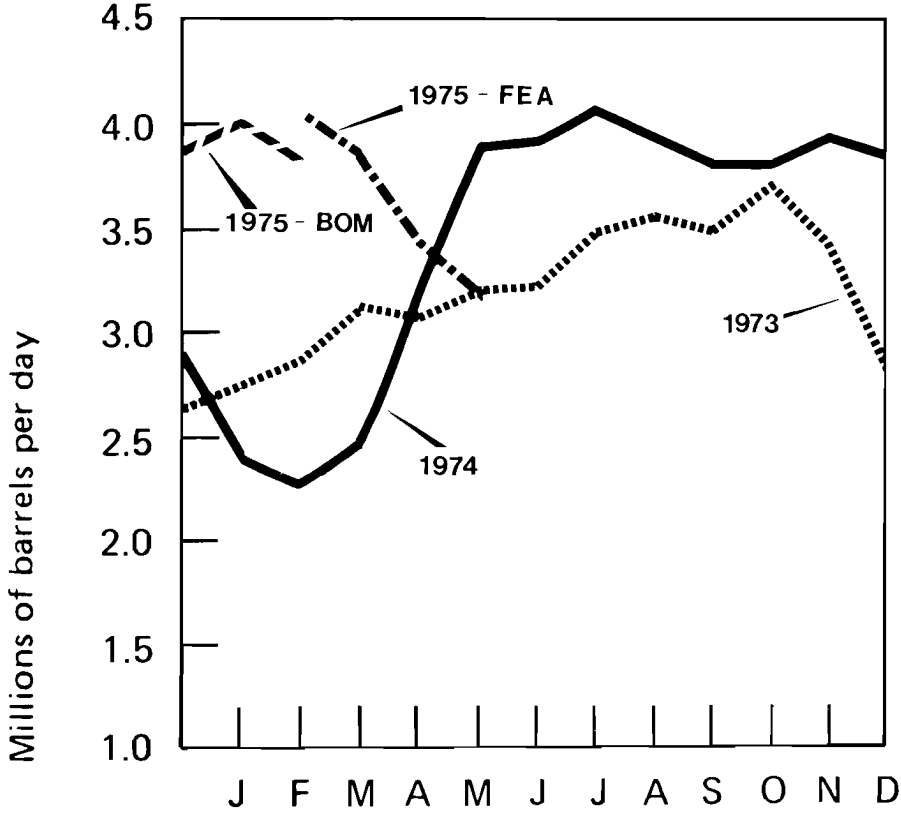


Figure 5

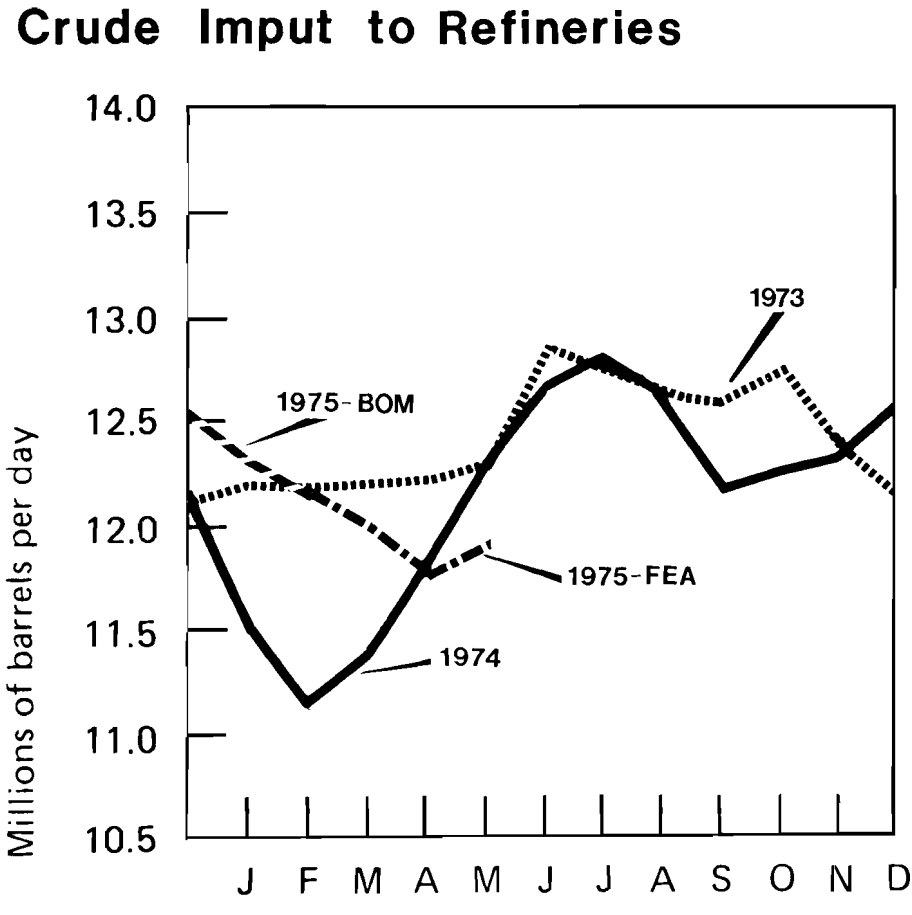

Crude Imput to Refineries
14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5
Millions of barrels per day
1973
1975-BOM
1975-FEA
1974
J F M A M J J A S O N D

Figure 6

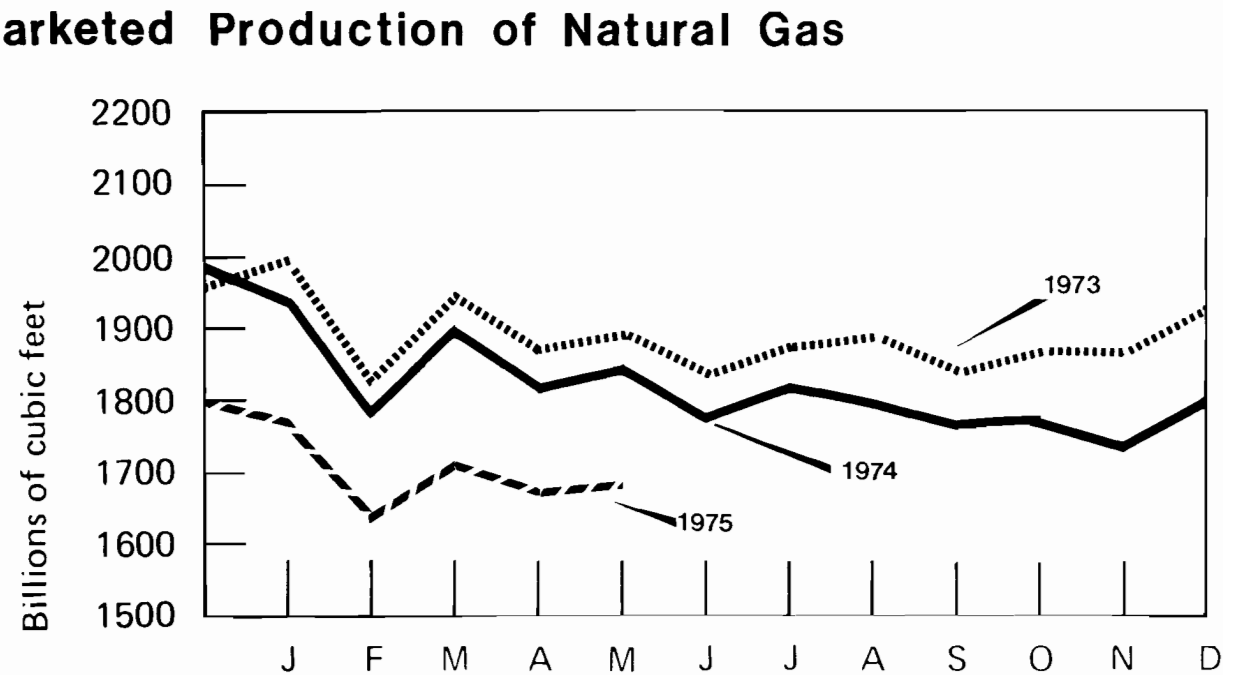

Marketed Production of Natural Gas
Billions of cubic feet
2200
2100
2000
1900
1800
1700
1600
1500
J
F
M
A
M
J
J
A
S
O
N
D
1973
1974
1975

Figure 7

Domestic Consumption of Coal

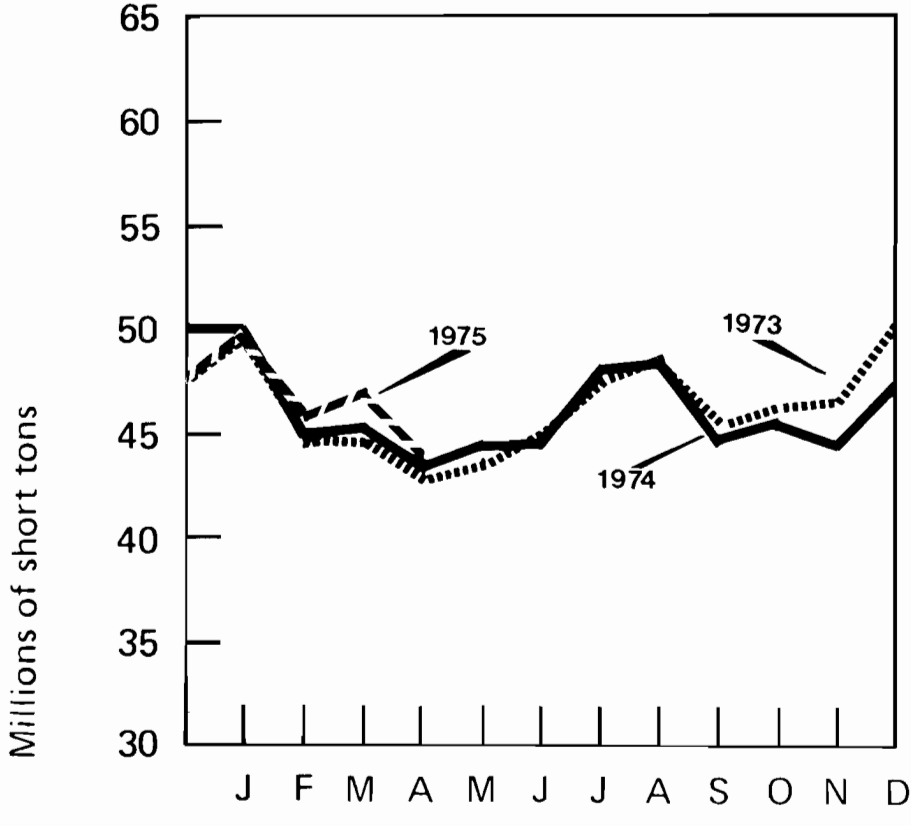


Figure 8

utilities, and the still relatively low price of natural gas have retarded the shift to this more abundant source of fuel.

Because of the higher price of crude oil, prices of other fuels moved up too. Higher prices for natural gas, an important ingredient in nitrogen fertilizer, and many pesticides, have been cited as part of the cause of a threefold increase in the price of anhydrous ammonia from the spring of 1973 to the spring of 1975, and fertilizer prices as a whole more than doubled. However, the cost of natural gas is only a small part of the cost of producing anhydrous ammonia. If the price of natural gas were increased fivefold--from 10 cents to 50 cents per million cu. ft.--the total cost of a ton of anhydrous ammonia would rise only 25 percent--from $62.15 to $77.60 per ton. In making these estimates, it was assumed that prices of other inputs also were higher because of inflation, but some savings were obtained by greater efficiency in some operations (2).

The cost of energy is a relatively small part of the cost of feed production. Commoner, et al., have estimated that in 1970, energy input costs for some selected crops ranged from 6 percent of variable costs of producing grain sorghum to 26 percent for irrigated alfalfa. By 1974, energy costs were a slightly higher proportion of variable costs for some crops, but slightly lower for others (Table 1). Energy costs as a percentage of prices received ranged from 3 to 4 percent for grain sorghum and soybeans to 14 percent for irrigated alfalfa, or less than half of the energy costs as a percentage of variable costs.

In a fully competitive economy, the effect of higher prices for fuel would have caused prices of other products to decline and the price level (or index of inflation) would have remained unchanged. But because of the rigidities in our pricing mechanisms and adjustments in the money supply to avert the adverse effects of higher fuel prices on the rest of the economy, higher fuel prices added to the inflationary pressures.

With higher fuel prices, we could have expected some reduction in the consumption of major fuels. Figure 6 shows the amount of crude oil flowing to refineries, by months, since January 1973. For 1974 as a whole, crude input was 2 percent lower than in 1973, but in early 1975 it ran above the comparable months in 1973 and 1974.

Until September 1, 1975 crude oil was allocated under a complicated system of quotas, entitlements and price controls. Whether this system will be allowed to expire, continue, or be modified remains to be decided. It is possible that by the time of the workshop, crude oil may be distributed free of government controls and restrictions. What would be the effect on cost under a free market system with supplies allocated by the pricing mechanism? Under the system in effect until September 1, we had two levels of prices, one level ($5.25 per barrel) for "old" domestic crude oil and another price, the "market" price for "new" and imported crude. These prices apply to refiners. Final prices to consumers are relatively free from government control and more nearly reflect an equilibrium of supply and demand. Without

Table 1. Energy input costs as a proportion of total variable costs and of prices received, selected crops, 1970 and 1974

Crop	Region	Energy cost as a percentage of variable costs		Energy cost as a percentage of prices received	
		1970	1974	1970	1974
		(percent)		(percent)	
Alfalfa, dryland	E. Kans. Nebr.	7.4	7.9	2.2	3.5
Alfalfa, irrigated	Kans.	26.5	24.7	11.0	14.0
Corn, grain	C. Iowa N. Ill.	11.6	12.2	3.9	3.7
Corn, silage	C. Iowa N. Ill.	8.3	8.1	NA	NA
Hay	C. Iowa N. Ill.	9.0	9.6	4.0	5.6
Sorghum, grain	Texas Blacklands	6.3	8.4	3.5	3.3
Soybeans	Ark., La., Miss.	9.8	11.2	3.2	2.6

Source: Commoner, Barry, Michael Gertler, Robert Klepper, and William Lockeretz, December 1974, The Effect of Recent Energy Price Increases on Field Crop Production Costs, Center for the Biology of Natural Systems, Washington University, St. Louis, Missouri, 108 pp.

restrictions on prices of "old" crude oil it is quite possible that more "old" oil would find its way into the marketplace. The increased supply would restrict if not eliminate any rise in the average price to consumers, although all consumers would not be affected uniformly.

If the international picture deteriorates and supplies of crude oil become scarce in the United States, pressures will develop for rationing domestic petroleum products to consumers. If rationing were adopted, allocation would be controlled by political forces rather than by economic forces. And without the argument that agricultural production is needed for exports to pay for imported crude, agriculture might not continue to enjoy the high priorities accorded to it under the present system.

Although higher prices for fuel and fertilizer contributed to the increased costs of feed production, the worldwide demand for grain was the major cause of the sharp increases in grain prices since early 1972. This strong demand for grain in turn strengthened the demand for fertilizer and fuel, thus removing much of the resistance to higher prices which otherwise might have limited price rises for these inputs. As a result of substantial increases in feed production costs and prices, the cattle industry also has been making some large adjustments.

Adjustments in the Cattle Industry

The United States has 600 million acres of grassland pasture and range excluding forestland used for grazing. Much of this land is in low rainfall areas where response to application of fertilizer would be low. Whether application of fertilizer would be profitable depends on the prices of land, fertilizer, and beef. With the rise in the price of fertilizer, beef production on unfertilized pastures may have become relatively more profitable than growing beef on the more productive, fertilized pastures. Thus, the drier western ranges may have gained an advantage over the rest of the country in the production of beef as a result of the higher fertilizer and grain prices.

Until recently, a pound of beef could be produced at lower cost in the feedlot than on grass. Because of the longer feeding period required to produce a pound of beef on forage only, both the interest charges and the total feed requirements are higher for forage-fed beef. In physical terms, more feed is required to produce beef on forage alone than cattle which are fattened on grain and forage. ERS data on livestock feed relationships indicate that from 1960 to 1973, total feed consumption per pound of liveweight production for all beef production other than cattle on feed, averaged 11.78 pounds; for cattle on feed it averaged 8.44. In other words, forage-fed cattle required about 40 percent more feed per pound of gain. Howevever, that ratio was narrower in recent years than in the earlier years of the period. When feeders were holding back cattle in 1973-74 and feeding to much heavier weights, they fed more than 10 pounds of feed per pound of gain. At the same time, producers of range cattle were feeding more

carefully and reduced feed requirements to about 11.7 pounds per pound of gain, or a ratio of only 1.16 to 1.

But with the changed fertilizer and grain prices, it is not clear whether beef can be produced at lower cost in the feedlot or on fertilized, highly productive pasture. The data which I have been able to find are not precise enough to answer the question.

In the humid areas, rates of fertilization on feed grains probably are more nearly at optimum levels than for pasture and hayland. Thus, the marginal returns from use of fertilizer on hay and pasture may be higher than on feed grains. If beef could be produced more cheaply on well managed pastures than on grain before fuel and fertilizer prices rose, forage-produced beef probably still has a relative advantage.

The advantages of producing beef on forage or grain depends in part on the amount of feed harvested per acre and the alternative markets for that feed. Experimental data indicate that in many areas feed produced per acre of forage is as high or higher than per acre of grain. But even if feed production from forage is greater, two problems remain. These are: large quantities of forage can only be utilized by ruminant animals whereas grain can be fed to hogs or poultry and to some extent used directly as human food. Secondly, forage is more bulky per feed unit and therefore must be used near the source of production. Thus, cost per unit of feed utilized is highly dependent on the management of the livestock enterprise.

For the producer with a good balance between forage production and cattle numbers, and the facilities to harvest and store surplus forage during periods of lush growth, the changed relationship of fertilizer, feed and cattle prices, probably hasn't reduced his relative advantage in beef production. And unless consumers develop a preference for leaner beef over choice fed beef, a large proportion of our beef cattle will spend some time in the feedlots before slaughter. However, there may be some shift in the location where these cattle are fed. But that is the subject of another paper.

LITERATURE CITED

1. Allen, George C., and Margaret Devers. 1975. Livestock-feed relationships, national and state, supplement for 1974 to Statis. Bul. 530. Econ. Res. Serv., U. S. Dept. of Agr. 125 pp.

2. Buividas, L. J., J. A. Finneran and O. J. Quartulli. October 1974. Alternate Ammonia Feedstocks, Chemical Engineering Progress.

3. Committee Print, 93rd Congress, 2nd Session. September 20, 1974. The U. S. food and fiber sector: Energy use and outlook.

4. Foreign Agricultural Service/Economic Research Service, U. S. Dept. of Agr., June 1975. Energy developments. Digest of World Agriculture.

5. Gustafson, Ronald A., and Roy N. Van Arsdall. 1970. Cattle feeding in the United States. Econ. Res. Serv., U. S. Dept. of Agr., Ag. Econ. Rpt. 186. 93 pp.

6. Lockeretz, William. 1975. Agricultural resources consumed in beef production. Center for Biology of Natural Systems, Washington University, St. Louis, Missouri.

DISCUSSION

ECONOMIC ASPECTS

Discussion of the papers by:
Wayne D. Purcell and James Vermeer

MODERATOR: T. C. Cartwright, Texas A&M University

COMMENT: Russell Cross, ARS, USDA, Beltsville, Maryland. I would like to make a comment to Dr. Prucell concerning the yield-breed research. The USDA (Agricultural Marketing Service and Agricultural Research Service) in conjunction with Texas A&M University and Safeway Food Stores recently completed a composition or cutability study this year. I would like to outline briefly what we did and just partially what we found.

We looked at 280 carcasses of steers, heifers and cows. We looked at variations of muscling, weight and fatness in our selection design. We used industry meat cutters for fabricating the carcasses, using industry practices as much as possible. We trimmed the cuts to various stages of trim, finally getting down to fat, meat and bone.

The results of this study surprised some of us a little bit in that the regression equations for the steers, heifers and cows were almost identical to the present yield grade. The estimated yield for steer versus the actual yield differed by less than 1 percent for steers and, surprisingly, for cows it differed by less than .5 percent. We hoped from these data to be able to discern if heifers and cows deposit their fat somewhat differently from steers. This is why we think perhaps the present grade might be missing heifers and cows in comparison to steers because of fat depsotion, not because of the muscle.

COMMENT: Wayne Purcell, Oklahoma State University. That's good to hear. That is what we hoped would happen. We knew that part of our data set was without an answer. What we're concerned about are the differences we found. We would hope that when it is done again this fat-trim factor could be in the control department. I would detect from what you said that it was controlled to some extent. I also would have liked to have seen it done at different income levels.

COMMENT: Milton Wise, Virginia Polytechnic Institute and State University. I would like to direct a request to Dr. Vermeer. Let me paraphrase something you said. I believe you said that a major

part in the rise of fertilizer prices, i.e., the recent price, is not due to increased production costs, but to something else. I wonder if you would like to enlarge on that statement.

ANSWER: James Vermeer, ERS, USDA, Washington, D. C. Fertilizer prices were controlled until October of 1973. One condition of specified control was that the manufacturers would sell more of their fertilizer in the United States until the next June 30. Up until that time, they moved all exports. Foreign buyers were paying $30 to $50 more a ton than domestic users, so we had reduced our stocks of fertilizer here. By the time price controls were off, those stocks were seriously depleted. We also had a strong demand for fertilizer in this country as we put more land into production. In 1972 we had some 60 million acres of land out of production. All of this land was released by 1974, thus increasing the demand for fertilizer in this country. This made it possible to get a higher price for fertilizer. And that's what really triggered the higher prices, not the increased cost of fertilizer production.

QUESTION: Philip Utley, Coastal Plain Experiment Station, Tifton, Georgia. I'd like to direct a question to Dr. Vermeer. You made the statement that all forage-finishing systems required 40 percent more feed input, and you defined feed as a feed unit. What is your definition of a feed unit?

ANSWER: James Vermeer, ERS. I used someone else's definition so I'm not sure that I can define it. It was all feed required, in physical terms, to produce a pound of gain. It included forage from pasture and harvested forage. It also included grains. However, I'm not quite sure how they defined it.

QUESTION: Philip Utley, Georgia. I'm not sure whether this is appropriate for you to cover, but I don't know that it will be covered anywhere else. What, if any, data are available on energy cost per unit of edible feeds in the Purdue study, forage or grain or a combination of the two? Are there data on this?

ANSWER: James Vermeer, ERS. Yes. I have a reference from a paper on some work done by Barry Commoner and his associates at St. Louis University. They do have some data on the total energy requirements per pound of feed produced. I can't cite this for you right now but they are in that reference.

QUESTION: Philip Utley, Georgia. You have indicated all these dramatic changes. How have they changed, for example, in the past year? This is what we're looking for.

ANSWER: James Vermeer, ERS. Well, this is, I think, avoided in the data. I'm not sure they had a good measure of the change. They do have the data at one point in time and how much it has changed.

QUESTION: Robert Kelley, Virginia Polytechnic Institute and State University. Dr. Purcell, you indicated that there is a flow of information up and down the chain from the cow-calf man up to the consumer. I am wondering, though, if that's a valid thing to do. I am wondering how you measure that flow of information down, especially to the cow-calf man. Isn't it lost somewhere in the chain of events? Along with that, is there a flow of information from the bottom up? Is there a flow from the cow-calf man saying that "I can't make it under a particular pricing system that we have now?" Maybe we need to devise some kind of a mechanism to get that information from the bottom up as well as getting it from the top down.

ANSWER: Wayne Purcell, Oklahoma. That's a good point. I left you cold on two points, obviously. One, I did not mean to suggest that these flows of information trickle one way. Not at all. And certainly I didn't mean to give you the impression that this message always comes from the top down to the cow-calf man. That's what all the obstacles to effective flows in the exchange system are all about. I think there is no question that it is distorted and garbled. For example, you can just go back and look at the time lags in making some adjustments that appear to be needed. When you look at this communication system, there have to be feedback loops. In other words, it is a continuous process. A lot of people argue that this message does not need to be brought to the consuming public. I wouldn't argue against this. I think that they are probably right. However, I would argue against the notion that we necessarily have to have a higher price because our costs are up.

COMMENT: Robert Kelly, Virginia. I would like to make another observation. I know that this conference is mainly for people involved in research at universities in one area or another. But, I would also like to raise the point that we have no representatives of retailers, breakers or packers or people from those segments of the industry present. This might be a deficiency at this conference.

ANSWER: Doyle Chambers, Louisiana Agricultural Experiment Station. No, I don't think that at all. We must get our leading scientists, including economists, agronomists, animal scientists and others, communicating in-house. This is a main goal of this conference--to see what our voids are so that we can get our job done better. I think we are reviewing research projects and this is the purpose of the conference. I think we need some in-house communications on these subjects right now. I think it would detract from our own purpose to bring other people in at this point. If you folks will design a program we are ready to communicate to the industry, then I think we've got to bring in the entire industry. But that's a different step and these are the research steps. However, I think it's a vital step if we are to give credibility to our research.

QUESTION: Doyle Chambers, Louisiana. May I ask a question? This concerns the lack of communication and integrated approach mentioned by Dr. Purcell for cattle. This has happened in the poultry industry.

If the cattle industry is to be integrated, who's going to own it? The feed companies owned the poultry industry for a period of time. Who is going to own the cattle industry? Will it be the feedlots, the packers, the producers or who?

ANSWER: Wayne Purcell, Oklahoma. I wasn't suggesting such a change. I was just suggesting that if the exchange system didn't do a better job, we might move in that direction. The most likely candidates to do some integrating are the feeder and packer subsections without any question, and it's going both ways. We've had packers who have been involved in feeding for a long time. Now they can't own feedlots but they could be kept.

I am not sure the cow-calf man will be left out. You know we argued a few years ago that one of the things that was stopping integration from coming back down all the way to the cow-calf man was the tremendous capital investment that would be required. We now have cases where feeders and all the way up to the packers are leasing tremendous acreages and are gaining control of cow herds. However, I don't think it is necessarily going to be like that. The same old problem seems to be involved in this part of the system. The feeder doesn't like to put up with the horrible and unthinkable supply and flow, quality and quantity of feeder cattle, and the packer receives trouble from variability of cattle in his facilities, and has problems with labor and all the other costs.

QUESTION: Maurice Ray, University of Arkansas. I have a question for Dr. Purcell along the same point. One of your slides indicated that the price the consumer pays is the retail margin deducted, the breaker margin deducted, the packer margin deducted and then it stopped. And you said nothing about the margin of the feeder, nothing about the margin of the stocker, nothing about the margin of the cow-calf man. Going back to this same question over here, do you think then that the economic impetus moves towards integration?

ANSWER: Wayne Purcell, Oklahoma. The fact is, you could start at retail level, back all the way down, deduct operating margins, and the cow-calf man gets what's left and he gets it last. Those are the facts of life. Now the Communists in the group would know that when we talk about this we talk about an economic structure that approaches what we call pure competition. This means that the producer is a price-taker in the short run within the production areas of pricing. He takes whatever the industry-wide price determines for him. It's not a cost-plus situation.

QUESTION: Maurice Ray, Arkansas. We have got to look at the long run, don't we?

ANSWER: Wayne Prucell, Oklahoma. Why, I think so, without any question. If you want to gaze a little bit, I'd say the long run looks good. But that may be a new ball game.

COMMENT: Richard Crom, ERS, USDA, Washington, D. C. When the Cost of Living Council was intact in 1973, they asked us to analyze for them who shared in the gains in the meat business in 1973. We chose one point in time, April 1973 versus April 1972. With the gain in the value of beef you knew the prices were going up. Two-thirds of that went to the cow-calf man, the residual, after taking out the other margins, the feeder got a little bit, the retailer got about one-fourth, and the packers essentially made it in the green with by-products. At that time, as you remember, people were out buying equipment and enjoying life as they never had before. Two years later, they could hardly stand the operating costs. And I think that's one of the big problems we have to address here. Remember, we have this extreme price variability.

COMMENT: Willard Williams, Texas Tech University. Dr. Purcell, there is a wide gap between information and communication. I don't know a packer or many of our feeders out there that aren't better informed about what is going on today than any man here today. They know what is going on at the retail level and the producer level. He is informed. The commercial man of today has to be informed. What he needs to know from all of us is, what does that information mean? What does the nutritional information mean to his operation, to his industry, and to his sector of the industry? What do the data mean and how do we interpret this material so we can communicate it to him? He has to have it in a form so he can absorb it. What do we do to close the gap between data generated and that absorbed by the people in the industry?

ANSWER: Wayne Purcell, Oklahoma. This is a good point. It is one of the points that I would have pursued here if we had time. One of the reasons we get into arguments about systems efficiency is that many can't perceive a need for any adjustment at their level to help out anything in the broad context. It's mainly because they are pre-occupied with running a business. And you're right, it's not a tree versus the forest situation. They do sometimes feel as if they're inundated with data, but it's a daily sort of data. One of the points I would like to make here is that they have not been shown anything that gives them a better idea of how the stage of which they are a part fits into the system. They don't seem to be concerned about making the system better, and I think we have reached the point recently where the industry doesn't see these sorts of things, and things get out of perspective, mainly because they are inundated with data from daily operations. I am inclined to suggest that's where we need to play a role. We ought to be able to paint this picture for them better than we have done. We haven't done it, by and large, because we haven't been concerned about it. It's a tough ball game to work in when you start getting at possible levels and are trying to keep this thing as a system as opposed to working at one interview level.

COMMENT: Willard Williams, Texas. The only point on which I would tend to disagree with you is that a great many of them are involved with the data today. The modern farmer is a businessman, and he's asking questions to which he is not getting answers.

ANSWER: Wayne Purcell, Oklahoma. Well, I'm overstating the case. For example, I would make the point here that generally we found feeders were not concerned with price variability--they couldn't see the reasons why they should be concerned about it. Yet there are exceptions to this and I've observed many cases as you have. Some of the forward-looking people get in there and say, "Okay, would you give me something extra if I work with you to coordinate" and the packer says, "yes," and they share this responsibility. They're out there, but unfortunately there is not a majority of them yet. I think you will agree with me on that.

COMMENT: E. H. McIlvain, ARS, USDA, Woodward, Oklahoma. Recalling the seven entities in the beef production system mentioned by Dr. Purcell, I would like to suggest that each of these entities may have further divisions or entities. Each entity must make a profit in order to stay in business. In addition, we have stresses on the animals at each transition point, at least until the animal is slaughtered. There's continual stress and inefficiency in the system. The small producer who owns less than 50 cows needs a system whereby he can integrate and take animals all the way to the breaking point. And if we, in this room, can get together to give these producers an alternative of taking an animal, either grain- or forage-fed to market, we will have circumvented many links in this beef production chain. I think we need to work hard on this and set our goals rather than worrying too much about the ineptness of the past marketing system. The beef cattle business is probably one of the few industries where a product costs more per pound the farther away it is from being marketed for slaughter. For example, you could spend $1 a pound for a calf and sell him at 40 cents a pound to the packer. This seems to be the opposite of a product like sugar which costs the least when it's a pound of sugar in the form of a beet rather than when it is ready to be marketed. I think this whole thing is backwards. I think that part of it is the extremely poor market position the producer has been in because there is only one segment of the chain he can govern.

ANSWER: Wayne Purcell, Oklahoma. I don't argue the point. You could also add trucking, storage, credit agency and a number of other functions that occur here. I don't disagree with your point about providing producers with integrated systems they can use; however, it does involve a major decision as to what the goals ought to be. I guess my position has always been that I hate to see the exchange system go by fault. If it's going to go, let's get some information out so that these people can function rather effectively. Let the transition be made in an orderly and positive fashion. I guess I'm not willing to jump yet and say that the answer is moving toward an integrated structure for all these parts. It could be. The incentive is there, and I think we could move that way over time.

QUESTION: Luther Keller, University of Tennessee. I want to ask a question along the same lines, relative to how you build a model or a system. You build it with beef going from the producer all the way up to the consumer. But I noticed that you did not include, for

example, grain price systems, which seem to me to be a very important factor in the unhealthy expansions and contractions of the beef industry in the last year or two. In other words, would you define your system as you have or would it be better also to outline parts of the feed system?

ANSWER: Wayne Purcell, Oklahoma. I will make a very brief reference to where we compare the effectiveness of all kinds of structures. In other words, you could do this parametrically and rerun the model and check changes, types of data, who feeds and how often, etc. That's not a complete answer because I think the grain system needs to be built in the model. You're right! The grain system has importance, no question about it.

COMMENT: T. C. Cartwright, Moderator, Texas. I think some of the negative comments we have heard relate to size and scale. We haven't heard much about scale except apparently by the implication to vertically integrate when fairly large sizes are required. I don't know that we shouldn't try to think of alternatives along those lines. There are such things as cooperatives which could serve some of the same purposes.

COMMENT: Doyle Chambers, Louisiana. I'm sure that only a few people with direct interest in extension work are present because this is a research conference. Maybe we should talk to extension people in order to help us see what can possibly be done in the way of getting people to make changes along these very difficult series of stages that Dr. Purcell has presented to us.

ECONOMICS OF GRAIN-ROUGHAGE SUBSTITUTION IN THE BEEF SECTOR

Ray F. Brokken*

The efficiency of the fed-cattle sector and grain feeding has been falsely maligned in the past two years. This is not to say that our present thrust of looking into ways of producing beef with less grain or no grain at all is improvident. No one knows how high grain prices might go in the next several decades. We may also be facing an era of wide year-to-year fluctuations in grain and roughage prices. Then again, prices may stabilize and not go much higher for several years. However, present prices (October 1975) are two and a quarter times the prices of the last decade. Even if prices remain stable, regional patterns of production which emerged in the 60s may now undergo change. The best technology for growing and fattening cattle may vary among regions and firms more in the future than in our recent past.

It now appears more important than ever to develop useful technical theories and systems for predicting animal requirements and performance over a wide range of diets, types of animals, and production conditions. Such decision tools could enable decisionmakers to choose optimally among their many technical, organizational and market options. The need for industry-wide, macroeconomic models is also critical. False diagnoses of optimal production adjustments can easily be made in the context of the economics of a single region, a single firm, a single enterprise or a single animal. For example, under aggregate market analysis, the adjustments in the inventories of breeding and replacement stock required to maintain a given output of beef as average slaughter weight changes are quite evident. In our recent past, weight added in the feedlot was inexpensive relative to cost per pound for weaner calves or yearling feeders. Therefore the heavy animals produced lower market-wide equilibrium prices than lighter animals. Under those conditions, the lighter animal had less invested per animal, but more per pound of slaughtered weight than if it were fed to heavier weights. In spite of what current market prices may suggest, it is still expensive to produce weaner calves and yearlings on pasture or range.

Grain-roughage tradeoffs are examined in this paper at two levels of production. The first part of the paper deals with grain-roughage

*Agricultural Economist, Commodity Economics Division, Economic Research Service, U. S. Department of Agriculture, Stantioned at Oregon State University, Corvallis, Oregon 97331.

substitution by changing proportions of roughage in the finishing diet and the second part deals with grain-roughage substitution between range and the feedlot that occurs when proportions of calves, yearlings and two-year-olds going from range to the feedlot are changed. The second part is divided into three sections dealing with average cost curves, marginal cost curves and the effect of slaughter price and feed price on the price of feeder cattle. Professor Jacobs pointed out in his review that this last section is probably the most important to the understanding of the nature of needed inventory adjustment in the beef sector. No macro-analysis is offered, but the relative merits of the tradeoffs are examined in the context of several different sets of feed and slaughter prices for the different production situations.

The analysis is based on technical models and theory presented in the appendix. All data are also presented for the various examples calculated. The precise numerical conclusions are secondary in importance to the development of general behavior of cost curves and general implications for adjustments in organization of beef production as relative prices change. However, the functions and values of the variables used are intended to portray realistic approximations in some time setting, be it historical, current or future. For the reader who finds the mathematics difficult, the nature and purpose of each mathematical function is described verbally and nearly all of the equations are diagrammed in one or more ways.

Grain versus Roughage in Feedlot Rations

This analysis employs the system outlined in the appendix in Figure A.1 and Equations A.1 through A.5 and the profit and cost functions of Equations A.9 through A.12. For those who wish to verify the following, analysis data used in this system are presented in the footnotes and tables. The example presented is drawn from another paper where this issue and technical research needs relative to it is dealt with in more detail (Brokken, et al., 1976). The example, one of three presented in the foregoing reference, is a hybrid of sorts. The daily voluntary dry matter (DM) intake (the appetite function) corresponds to that of the highest gaining animals in each of the five diets in the experiment on which the relation is based (Brokken and Dinius, 1976). However, the intake is matched with the NRC requirements function for calculating the implied gain from this intake as in Equation A.1 or Chart A of Figure A.1. The NRC function overestimated the gains at lowest energy concentrations and underestimated gains obtained at the highest concentration. Therefore, compared with the original data, the hybrid example used here is biased in that it overstates the efficiency of the high roughage diet relative to the high concentrate diet. The experimental results must be considered tentative, however, and may be modified after further experimentation. Many possible variations must also be checked. For example, how do the relationships differ between calves and yearlings; between English breeds and Exotic breeds; between heifers and steers; between summer and winter; for different physical forms of the rations; for particular ingredient combinations; and for variations in nutrient energy ratios? Perhaps a well

defined system must eventually include a basic relationship between voluntary feed intake and ration nutrient concentration for each of the several types of cattle with different sets of operating rules to modify these relationships appropriately as various other factors are introduced.

Expected gains and programmed ration costs are shown in Table 1 for each level of ration energy concentration.[1] Feed prices were those that prevailed in Eastern Nebraska in November 1974 and March 1975 and are shown in Table 2.[2] The calculated payweight to payweight rate of gain, profit per head, number of days on feed, cost of gain (COG), breakeven purchase price (BEPP), and breakeven slaughter price (BEP) are shown in Table 3 for November 1974 and March 1975 feed prices.

A difference of $12 in profit per head between the high energy ration and the low energy ration is shown for the March 1975 feed prices, but no difference for the November 1974 feed prices. Notice that for the 1974 feed prices the profit level is lower for ration energy levels in between the ration with highest proportion of roughage (lowest energy concentration) and the one with the lowest proportion of roughage (highest energy concentration). A set of results such as this implies that the roughage-grain isoquants are concave to the origin. An isoquant is a curve describing the potential tradeoffs between two inputs in the production of given level of output (weight added). It is quite accidental that the roughage/grain price ratio of November 1974 in Eastern Nebraska along with the parameters in the appetite function A.3 and the energy requirements function A.1 combine to give exactly the same profit for both the high and low energy rations (i.e., the same profit at both ends of a grain-roughage isoquant). Before pursuing this issue further, consider another set of appetite and requirement functions. In another example (Brokken, et al., 1976), a daily energy requirements function which was derived from data of the experiment was used instead of the NRC requirements function. These alternative functions still underestimated the actual difference in treatment mean gains between the high and low energy diets. Even so, the per-head profit difference was $29 for corn at $.108/Kg and $25 for corn at $.134/Kg in favor of the high energy diet. Hence, the high roughage ration would be a poor choice at either set of prices in the latter example. The grain-roughage isoquant for this case is also concave but much steeper. Brokken, et al. (1976) show that the system

[1]Gains were calculated from Equation A.5 where A = .0625 and B = .05766.

[2]Professor Jacobs pointed out that in systems where the animals are born, raised and finished on the same farm, the price of roughage relative to the price of corn could be much lower than is recorded in Table 2. Other costs used in the profit function include: feed preparation, C_p = .0033/Kg ($3/ton); yardage, C_n = $.04/day; acquisition and start-up costs, K_1 = $8.55; fixed costs, K_2 = $14.80; annual interest rate, 8 percent; purchase price, P_p = $.679/Kg; slaughter price, P_s = $.80/Kg for Choice.

Table 1. Ration cost and expected average gain by ration energy concentration

Item	Ration energy concentration (Mcal NE_g/Kg)				
	.9	1.0	1.1	1.2	1.3
	$/Kg & (Percent roughage)				
Ration cost (100% dry basis)					
November 1974	.0889 (53)	.0997 (42)	.1120 (33)	.1243 (23)	.1367 (16)
March 1975	.0740 (53)	.0825 (42)	.0917 (32)	.1010 (23)	.1102 (14)
Average gain Kg/day	1.116	1.170	1.234	1.306	1.383

Table 2. Two sets of ingredient prices used in analysis

Item	November 1974	March 1975
	($/Kg)	
Corn	.1338	.1097
Corn silage	.0258	.0472
Alfalfa	.0612	.0540
Mixed hay	.0507	.0496
Soybean meal	.2315	.1600
Urea	.2200	.2200
Salt and mineral mix	.1190	.1190

as outlined in the appendix implies a concave (to the origin) grain-roughage isoquant over the range energy concentration where dry matter intake is declining as ration energy concentration increases. At one end of the isoquant is the ration with the minimum safe level of roughage and at the other end is a ration at the point where gut fill becomes the regulatory mechanism in daily dry matter intake. The practical and research implications of concave isoquants are very important. It means that one extreme or the other is always superior to any point in between. It does not mean that both extremes are always simultaneously superior to the rations in between, however. When grain prices are low relative to roughage prices, a very high concentrate diet is most economical. This diet remains most economical until the price of grain relative to the price of roughage rises sufficiently to require a change in the proportions of grain and roughage in the ration. With concave grain-roughage isoquants, the change in grain-roughage proportions required would be a large one.

As pointed out earlier the response of animals to changes in dietary energy concentration may vary with type of animals, physical form of the diet, climate and nutrient energy ratios. These variations imply variations in the grain-roughage tradeoff relationships. Since both the physical relationships as well as the grain/roughage price ratios can vary widely among firms, even within a region, only very limited generalizations can be made with the presently available information.

The marginal cost curves, MC_1 for the high energy diet and MC_2 for the low energy diet, are shown in Figure 1. Though the difference in marginal cost appears small, there is a difference of $12 profit per

Table 3. Profit per head, rate of gain, number of days on feed and breakeven prices by ration energy concentration with March 1975 and November 1974 feed prices[a]

Feed price level	Item[b]	Ration energy concentration NE_g Mcal/Kg				
		.9	.1	1.1	1.2	1.3
	g' (Kg/day)	.898	.943	.993	1.052	1.116
	n (day)	178	170	161	152	144
March 1975	π ($/head)	-32	-29	-28	-27	-24
	COG ($/Kg)	1.241	1.224	1.220	1.209	1.193
	BEPP ($/Kg)	.583	.591	.593	.598	.606
	BEP ($/Kg)	.870	.864	.862	.859	.853
November 1974	π ($/head)	-60	-61	-62	-62	-60
	COG ($/Kg)	1.420	1.421	1.430	1.430	1.418
	BEPP ($/Kg)	.496	.495	.490	.491	.496
	BEP ($/Kg)	.929	.930	.933	.932	.929

[a]Animal is purchased at 320 Kg, fed from 300.8 Kg to 495 Kg, and marketed at 475.2 Kg.

[b]π is profit in $/head; COG (cost of gain) is total cost exclusive of animal cost ($P_p W_p$) divided by net weight added (total gain from payweight to payweight), g_1' is payweight to payweight gain per day; n is number of days on feed; BEPP, breakeven purchase price given the market price; BEP, breakeven market price given the purchase price.

$$MC = \frac{1}{g}\left[r(1+d)P_pW_p + (C_x + C_p)W^{.75} + C_n + rK_1\right]$$

$$TR = A+B+C+D+F+G+H$$

$$TC = B+C+C+D+E+F+K;\ \pi = A+G+H-(C+E+K)$$

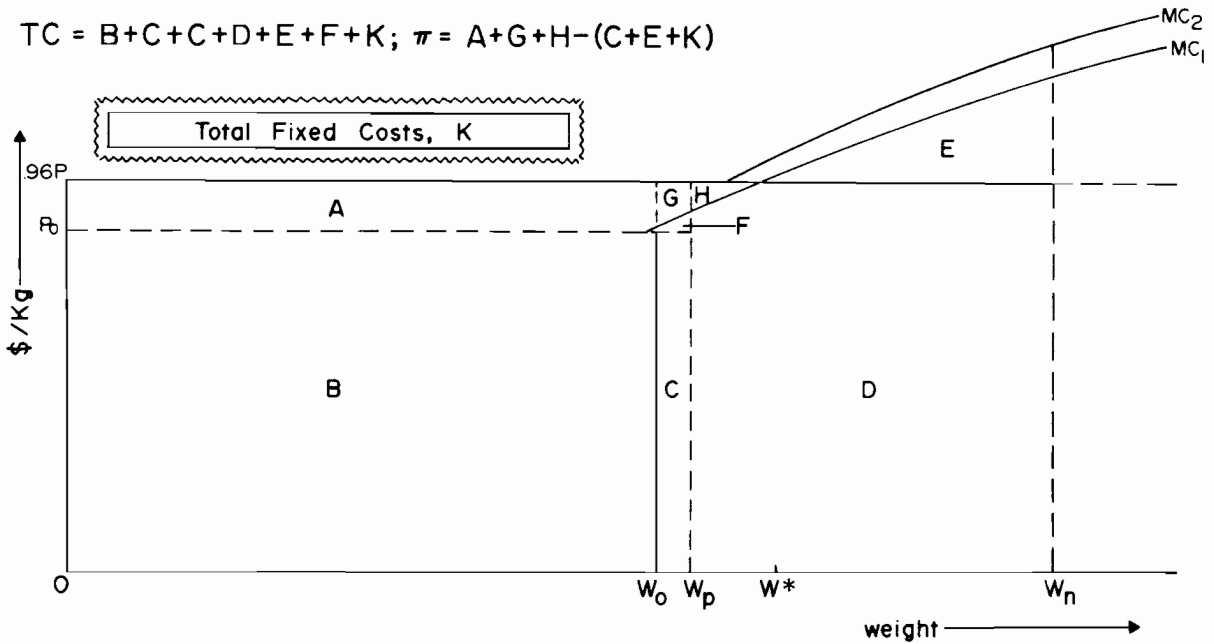


Figure 1. Feedlot costs and returns diagrammed for one animal in relation to weight

head (the loss from the high energy diet being $12 less than the loss from the low energy diet).

Since the dimensions of this diagram are dollars per unit weight on vertical scale and units of weight on the horizontal scale, total cost and total revenue are represented by areas under the appropriate marginal curves. Equation A.12 is evaluated and diagrammed as MC_1 for the high energy ration and MC_2 for the low energy ration. Total fixed costs, $K_2 + K_3$, from Equation A.11 do not appear in Equation A.12 and are not a function of body weight but are drawn to scale in the inset as area K to permit graphic comparison and analysis. Total revenue is represented by areas A+G+H+B+C+D+F, total variable cost by areas C+D+E+F. The animal cost is B+C. Total cost to regain initial shrink is C+F (net cost to regain shrink is -G). Acquisition and start-up costs are K (see inset). Total cost is B+C+C+D+E+F+K. Notice that area C is counted twice: once as part of the cost of the animal and again as part of the cost to regain shrink. Hence, total profit is A+G+H-E-C-K, a loss of $24. Of course, in an ex-post analysis, the animal would: (a) not be purchased; or (b) be purchased at a lower price (the breakeven purchase price is $.606/Kg, a drop of $.073/Kg compared to the one charted). Notice W^*, the weight at which discounted expected slaughter price equals MC_1. (See Equation A.13 and Footnote 8 in the appendix.)

The reader can analyze the effect on the profit area through various adjustments in the variables on the diagram. One way to increase profit when large positive price spreads can be obtained through changing grades, is to increase the purchase weight W_p (and the on-feed weight, $W_0 = (1 - s')W_p$). The larger animal would tend to have a higher rate of gain and so a lower MC curve. It has been argued that if consumers accepted a lower grade, this would allow a cheaper ration consisting of more roughage to be used in the feedlot ration. The diagram does not lead us to this conclusion. A shift of the market weight leftward does not call for changing diets; that is shifting to a higher marginal cost curve.

Grain Roughage Substitution in Feedlot vs. Range Production (Calves vs. Yearlings vs. Two-Year-Olds)

In this section, the relative economic merits of producing and feeding calves, yearlings, and two-year-olds is analyzed. The animals used in this section are described in Table 4. They are intended to match the examples used by the NRC in their nutrient requirements for beef cattle. Several additional simplifying assumptions are made. However, it is easy to deduce the nature of bias introduced by them. Only one diet is assumed, a high energy diet consisting mostly of corn. It is assumed that ration cost per Kg is $C_{1.3} = 1.021P_c$, where P_c is price of number 2 corn per Kg and $C_{1.3}$ is the ration cost per Kg for a ration of 1.3 Mcal NE_g/Kg (100% dry basis).[4]

[4]Other costs include: interest at 10 percent per annum; feed preparation, yardage, acquisition and start-up costs, and fixed cost on

Table 4. Description of animals

	Weaner Calves	Yearlings	Two-Year-Olds
Purchase weight, Kg	200	320	388.5
Initial shrink, %	10	6	4
Beginning weight, Kg	180	300.8	373
Death loss, %	3	1	1
Average gain in lot Kg/day	1.048	1.258	1.398
Final weight, Kg	475	495	540
Slaughter weight, Kg	456	475.2	518.4
Days in lot	281	154	119
Days to regain payweight	19	15	11
Payweight to payweight gain, Kg/day	.991	1.008	1.09
Profit per animal @ 8¢/day	22.48	12.32	9.52
DM intake Kg/day/$W^{.75}$	.08778	.09884	.10647

Average Cost Curves

Average cost, AC, is calculated by dividing total cost by body weight as in Equation A.14.

The general relationship between average cost and marginal cost is well known by economists, but worth reviewing in the case of a growing calf. The average cost (total cost divided by weight) is quite high at birth. Marginal cost (the cost of an additional pound of growth) is very low. Marginal cost continues to be very low during the early period of growth but is increasing. Average cost is very high but decreasing rapidly in the early period of life, and will decrease as weight increases as long as marginal cost is less than average cost. Average cost reaches a minimum at the point where the declining average cost meets the rising marginal cost. Beyond this point of intersection, MC is greater than AC and both are increasing. At points in the production process where sale and/or movement of

equipment and facilities at the same values as in Footnote 3; cost of inputs in animals that die per head sold, K_3: calves, $4; yearlings and two-year-olds, $1.00; profit per head sold, π, is $.08/day (calves at 281 days is $12.32, and two-year-olds at 119 days is $9.52).

the animals takes place, the cost curves are disjointed. The following analysis focuses on the behavior of the average cost curve as weight is added in the feedlot stage of production.

The weight at which AC is a minimum is designated W** and is calculated as in Equation A.14. However, as noted in the appendix, exclusion of slaughter and processing cost which tend to be fixed per carcass, will bias the value of W** downward.

Four AC curves are plotted in Figures 2, 3 and 4 for finishing weaner calves, yearlings and two-year-olds, respectively. The four curves in each figure represent different combinations of feeder cattle production costs and corn prices. Other costs are taken from Table 4. These are not empirical examples but represent somewhat arbitrary combinations of feeder cattle production costs and corn prices to illustrate the behavior of average cost in cattle production. Cost of a weaner calf is set at levels 10 percent higher than the cost of a yearling feeder calf to make the curves somewhat comparable. This is the approximate relationship between the cost of calves and yearlings developed by Jacobs (1975).

Notice in Figures 2, 3 and 4 that the AC curves are declining throughout for all three animals when feeder cattle prices are high relative to corn prices.

In the intermediate set of prices (the middle curves) W**, the minimum of the AC function, occurs at 461, 515 and 553 Kg, respectively, for finishing calves, yearlings and two-year-olds. The values of the AC functions at these weights are 1.05, 1.08 and 1.10 dollars per Kg, respectively. The respective weights at which the animals are assumed to grade Choice are 475, 495 and 540 Kg.

With relative prices of this approximate magnitude (and acknowledging some variance about each estimate), all three programs would give meat of essentially the same quality at nearly the same cost per pound. It is also interesting that under such a set of relative prices the preferred grade (Choice) might be produced from yearlings and two-year-olds at a competitive equilibrium price lower than that which would occur with predominantly lower grades.

The curves designated AC_3 represent a case with low production costs of feeder cattle and high grain prices. The price in this example for yearling feeder cattle is similar to current market prices but well below their cost of production.[5] The fourth set of curves, AC_4 represents approximate feeder cattle prices (cost of production?) and feed prices for the late 1950s and 1960s. The curves are declining throughout the finishing stage for all three types of feeder cattle and do so even at much higher corn prices. In this case, corn is set at \$0.0453/Kg (\$1.15/bu). The weights at which the curves AC_4 are

[5]The present market price is lower for calves than for yearlings even though their production cost per pound is higher.

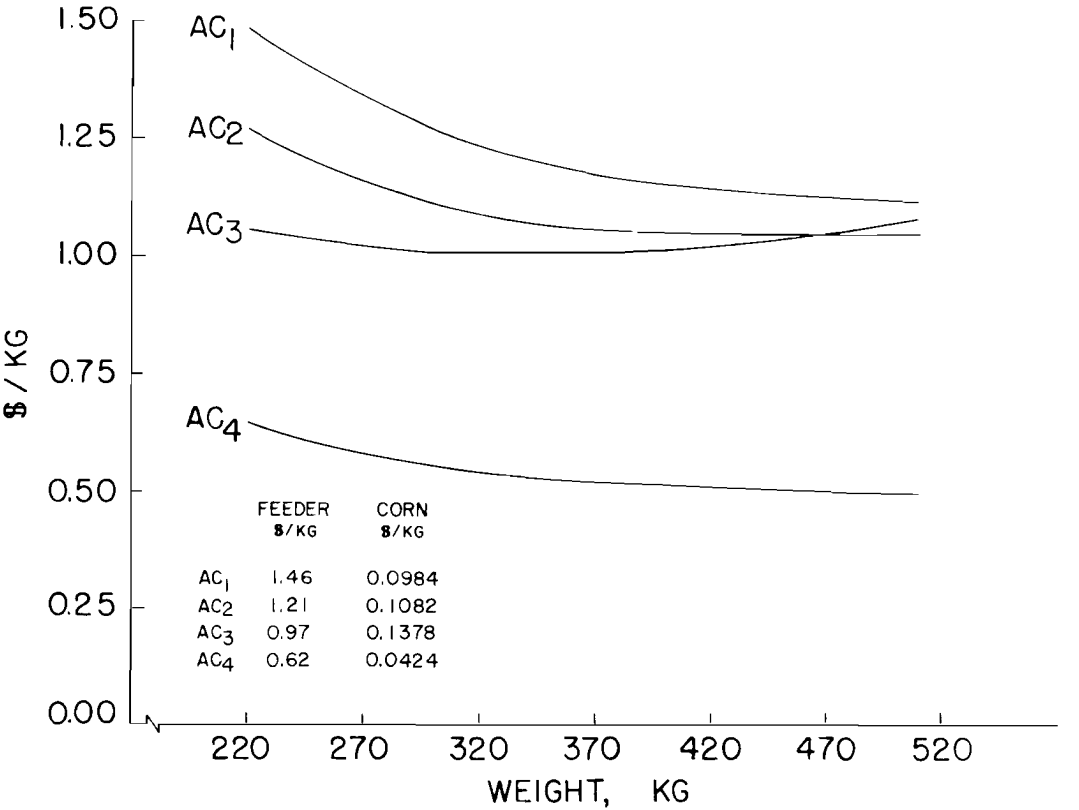


Figure 2. Average cost curves for a calf finishing program under alternative sets of purchase prices and corn prices

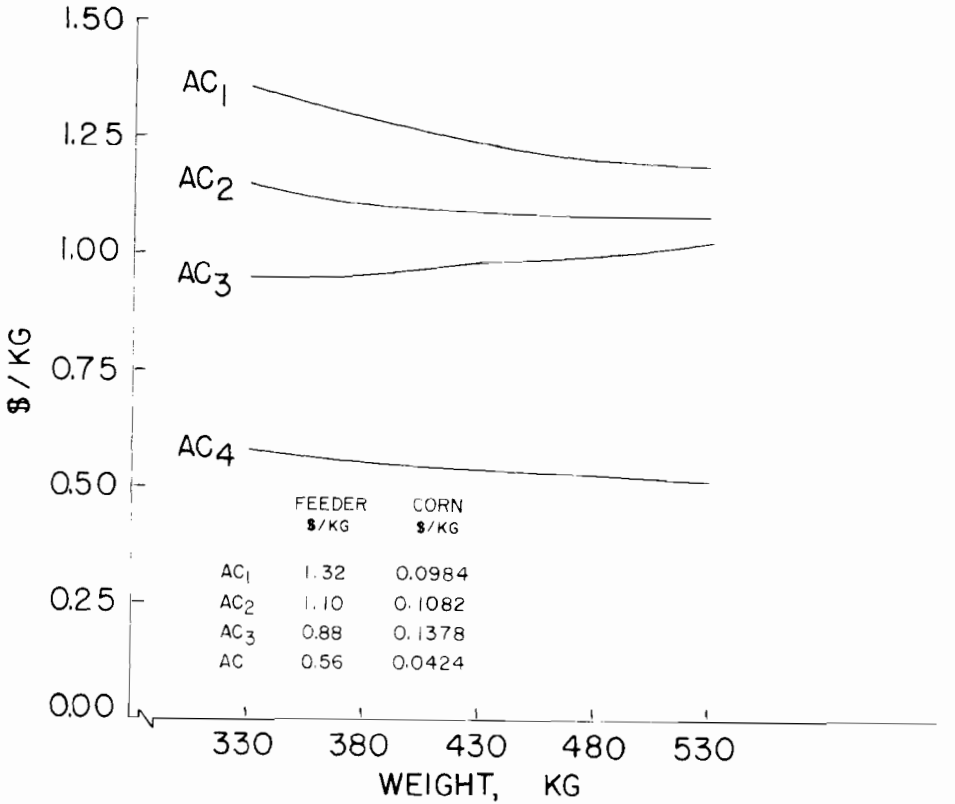


Figure 3. Average cost curves for a yearling finishing program under alternative sets of purchase prices and corn prices

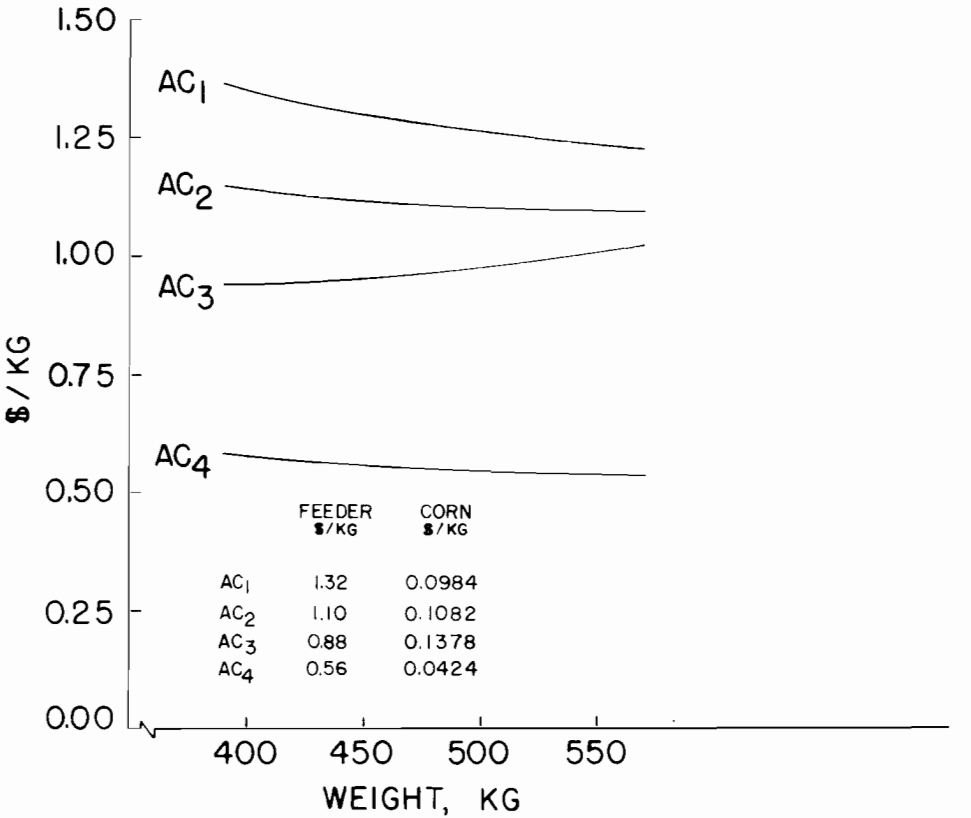


Figure 4. Average cost curves for a two-year-olds finishing program under alternative sets of purchase prices and corn prices

minimized are 553, 604 and 658 Kg, respectively, for calves, yearlings and two-year-olds.

It is safe to say that over most of the decades of the 1950s and 1960s the Choice animal had lower cost per pound than it would have had if marketed at a lower grade. Thus, a preponderance of Choice animals resulted in lower consumer prices than would have occurred with a preponderance of Good or lower grade animals.

One can only speculate about the shape of the average cost curve that will emerge in the coming years. It is by no means clear that the W**, the weight at which AC is minimized, will occur at weights below Choice. Nor can one rule out such a possibility. Even so, optimum market weights or slaughter grades of cattle is very much a matter of product differentiation and consumer preferences. The economics of optimum market weights (and grades) must incorporate market prices which involve simultaneous interaction of supply and demand.

Marginal Cost Curves

Once the costs, except the price of corn, are established, the marginal cost with respect to body weight of Equation A.12 can be rewritten as follows:

$$MC = \frac{A}{g} + \frac{Y}{g}(b_1 + b_2 P_c)W^{.75} \quad . \qquad (1)$$

Though Y increases as g increases, Y/g declines as gain increases (see Figure 5). Therefore, animals with the higher rate of gain have the lower marginal cost, other things being equal. Also, as the price of corn, P_c, increases, the MC curve becomes steeper.

Assuming present purchase prices: calves, \$.66/Kg; yearlings, \$.84/Kg; two-year-olds, \$.88/Kg, the MC functions become: [6]

$$\text{Calves, } MC = .0713 + .0838\ (.0033 + 1.021P_c)W^{.75} \qquad (2)$$

$$\text{Yearlings, } MC = .0928 + .0786\ (.0033 + 1.21P_c)W^{.75} \qquad (3)$$

$$\text{Two-year-olds, } MC = .0979 + .0762\ (.0033 + 1.021P_c)W^{.75} \qquad (4)$$

These functions are plotted in Figure 6. It is interesting that the cost per unit gain at any particular body weight is lower for two-year-olds than for yearlings and lower for yearlings than for weaner calves. However, since the range of weight over which the animals are fed is different, the average cost per pound of gain is less for calves than yearlings which is less than for two-year-olds.

[6] The steepness is further aggravated as the first term of Equation 1 declines. Since A contains the purchase price of the animal which drops as corn prices increase, the marginal cost curve would become quite steep as corn prices increase without offsetting increases in slaughter prices.

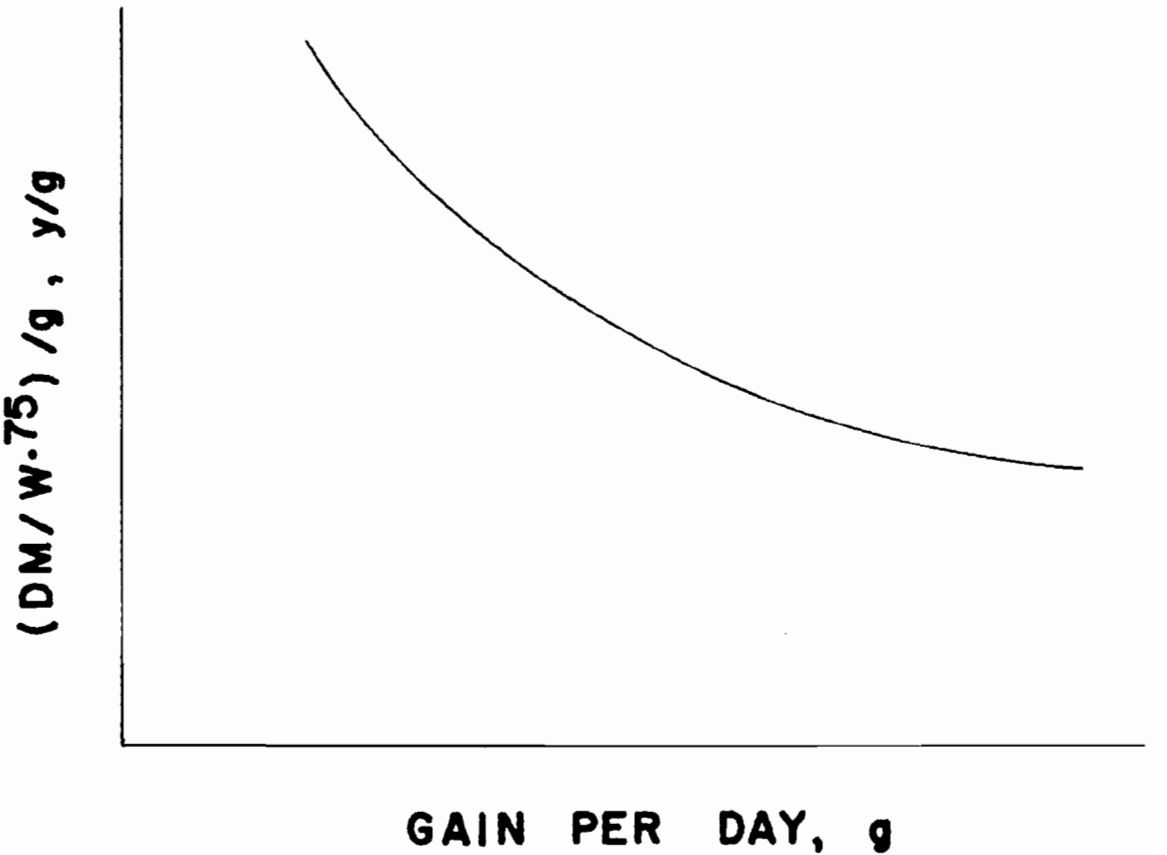


Figure 5. Relationship between daily feed per unit gain and rate of gain

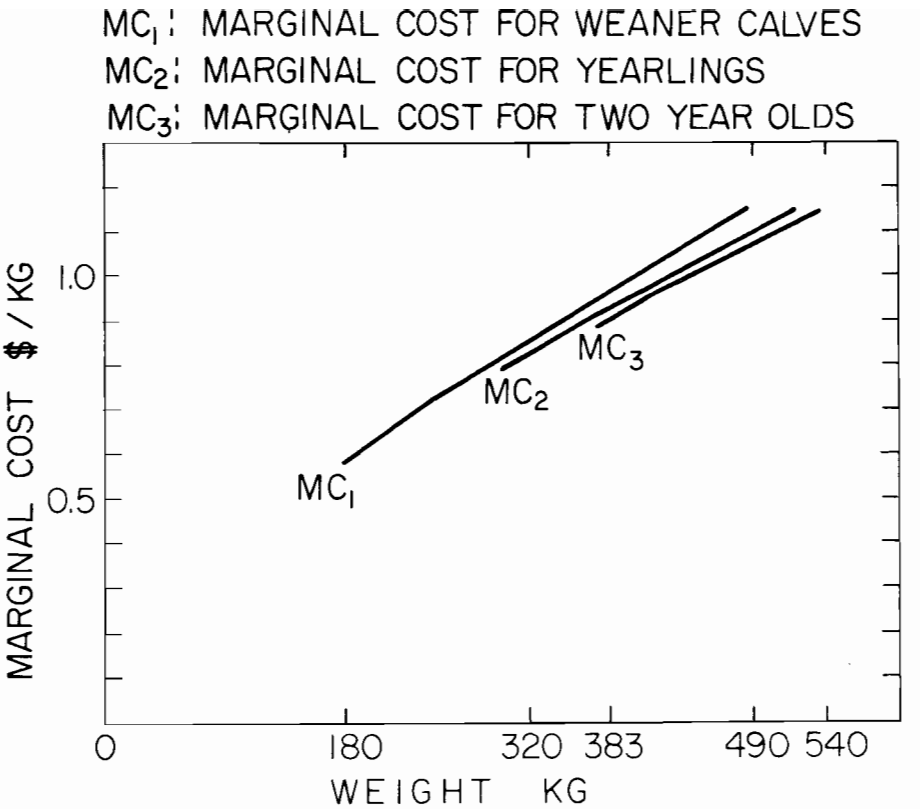


Figure 6. Feedlot marginal cost and revenue curves with total cost and total return represented by areas under corresponding marginal curves (inset shows fixed costs in comparable scale).

Effect of Slaughter Price and Corn Price on Feeder Cattle Prices

It is quite clear that present prices being bid for feeder cattle do not cover cost of their production. Obviously, their supply and demand are out of equilibrium and change is underway. There is little information to be obtained from analysis with present prices about the relative merits of calves, yearlings, and two-year-old feeder cattle in the context of where we are heading. Because of the large losses at the ranch level, we are headed toward a smaller breeding inventory. This will lead to a lower supply of slaughter animals which will lead to higher slaughter prices and in turn higher prices for calves, yearlings, and two-year-old feeders. In a world where everything depends on everything else and nothing is fixed, the equilibrium points are not easy to establish. However, there is an economic incentive to adjust output downward as long as prices bid for feeder cattle fail to cover their cost of production.

Under conditions of certainty, a feedlot operator could bid a set of prices for the various classes of feeder cattle that would leave him indifferent with regard to which class he fed. The class that emerged as predominate in numbers would then be the one which, under the given prices, yielded the greatest return to the ranch sector. In this analysis, a set of prices is imputed to calves, yearlings, and two-year-olds which covers total costs and a certain profit level per head for various feed and slaughter prices.

To simplify the analysis, only a single feeding program for each type of feeder animal will be considered. The following formulas are derived using data from the previous section in Equation A.14.

$$\text{Calves, } P_p = -.2050 - 8.713P_c - 2.050P_s - .0045\pi \quad (5)$$

$$\text{Yearlings, } P_p = -.1049 - 4.143P_c + 1.41P_s - .0033\pi \quad (6)$$

$$\text{Two-year-olds, } P_p = -.1074 - 3.165P_c + 1.28P_s - .0025\pi \quad (7)$$

The profit level is set so as to equalize profit per unit time among the three classes of cattle fed. It is evident from the coefficients in these equations that changes in the price of corn, P_c, the expected slaughter price, P_s, and profit per head, π, affect prices of feeder calves much more than yearlings or two-year-olds and yearlings more than two-year-olds. The fundamental reasons for this are easily deduced from the definition of the coefficients which are defined in Equations A.16 through A.19. A change in the price of corn affects the price of weaner calves nearly three times as much as it affects the price of two-year-old feeders and more than twice as much as the price of yearlings.

A change in slaughter prices also affects the purchase price of feeder calves more than yearlings and two-year-olds. A permanent increase in the price of corn sets in motion a reduced supply of fed cattle (also hogs and poultry) which, in turn, increases slaughter

prices. Therefore, the final adjustments in purchase prices of calves and yearlings resulting from an increase in corn prices is not clear unless both the supply and demand are simultaneously considered. There is also important interaction with other food sectors especially in the swine and poultry sectors.

The calculated or imputed purchase prices which cover costs and profits for given slaughter prices and corn prices are shown in Tables 5 and 6. Purchase prices are plotted against the price of corn for a slaughter price of $1.058/Kg ($48/100 lbs.) in Figure 7. The functions plotted are linear under the assumptions of this exercise. However, since all ingredient prices would not be strictly proportional to corn prices and shifts in diets to include less corn might take place, the functions might become non-linear, decreasing at a decreasing rate as corn prices increased.

Estimated production costs of feeder cattle cover a wide range. Suppose weaner calves of the type described herein cost $1.10/Kg ($50/100 lbs.) and corn prices are $.118/Kg ($3.00/bu.). A slaughter price of $54 would be required to bring about this price. Corresponding prices for yearlings would be $1.047/Kg ($47.50/100 lbs.). This relationship between calf prices and yearling prices would stimulate more yearling production. As corn prices increase, yearlings rise in price relative to calves and as slaughter prices rise, calf prices rise relative to yearling prices. Calf prices are more responsive than yearling prices to change in either grain or slaughter prices. This has implications for managing income variability under unstable grain and slaughter prices.

The uncertainty aspect is highlighted in Figures 8 and 9. In these figures, the downward sloping lines define loci of corn prices and slaughter prices that yield a constant imputed value per unit weight; i.e., an iso-price line. The lines are drawn in intervals of $.22/Kg ($10/100 lbs.), but interpolations can be made between the lines. Notice that the lines are much flatter for calves than for yearlings and the distance between the iso-price lines is much greater for yearlings in Figure 9 than for calves in Figure 8. The large shaded area represents the price range of the past two years. We have certainly moved into a boom or bust world for the rancher. The shaded area in Figure 8 covers a feeder calf price range from more than $1.32/Kg ($60/100 lbs.) to less than $.22/Kg ($10/100 lbs.). The same range in corn prices and slaughter prices covers a yearling price range of $1.18/Kg ($53.50/100 lbs.) to $.453/Kg ($20.60/100 lbs.).

Summary and Conclusions

The economics of grain-roughage substitution has been examined first within the feedlot sector and second between the pasture or range sector and the feedlot sector. It was shown that, within the feedlot, high concentrate rations remain economical on a profit per head basis even with relatively high grain prices. Moreover, the example calculated was biased in favor of roughages in many important

Table 5. Purchase prices calculated to cover cost plus profit for calves, yearlings, and two-year-old feeder cattle at specified corn and slaughter prices

Corn price	Slaughter prices, $/Kg								
	1.058			1.146			1.190		
	Calves	Yearlings	Two-year olds	Calves	Yearlings	Two-year olds	Calves	Yearlings	Two-year olds
	($/Kg)								
.069	1.263	1.065	1.002	1.444	1.190	1.112	1.625	1.370	1.226
.079	1.177	1.024	.971	1.358	1.149	1.081	1.539	1.329	1.195
.088	1.091	.983	.940	1.272	1.108	1.051	1.453	1.288	1.164
.098	1.005	.942	.909	1.186	1.067	1.020	1.367	1.247	1.133
.108	.919	.901	.878	1.100	1.026	.989	1.281	1.206	1.102
.118	.833	.860	.847	1.014	.985	.958	1.195	1.165	1.071
.128	.747	.819	.816	.928	.944	.927	1.109	1.124	1.040
.138	.661	.778	.785	.842	.903	.896	1.023	1.083	1.009
.148	.575	.737	.754	.756	.862	.865	.937	1.042	.947
.157	.489	.696	.723	.670	.821	.834	.851	1.001	.916

Table 6. Purchase prices calculated to cover cost plus profit for calves, yearlings, and two-year-old feeder cattle at specified corn and slaughter prices

Slaughter prices	Corn prices, $/Kg								
	.108			.118			.128		
	Calves	Yearlings	Two-year olds	Calves	Yearlings	Two-year olds	Calves	Yearlings	Two-year olds
	($/Kg)								
.8	.3900	.5378	.5505	.3050	.4971	.5194	.2190	.4600	.4883
.85	.4930	.6083	.6145	.4075	.5676	.5834	.3215	.5305	.5523
.9	.5950	.6788	.6785	.5100	.6381	.6474	.4240	.6010	.6163
1.0	.6975	.7493	.7425	.6125	.7086	.7114	.5265	.6715	.6803
1.1	.8000	.8198	.8065	.7150	.7791	.7754	.6290	.7420	.7443
1.2	.9025	.8903	.8705	.8175	.8496	.8394	.7315	.8125	.8083
1.3	1.0050	.9608	.9345	.9200	.9201	.9034	.8340	.8830	.8723
1.4	1.1075	1.0313	.9985	1.0225	.9906	.9674	.9365	.9535	.9363

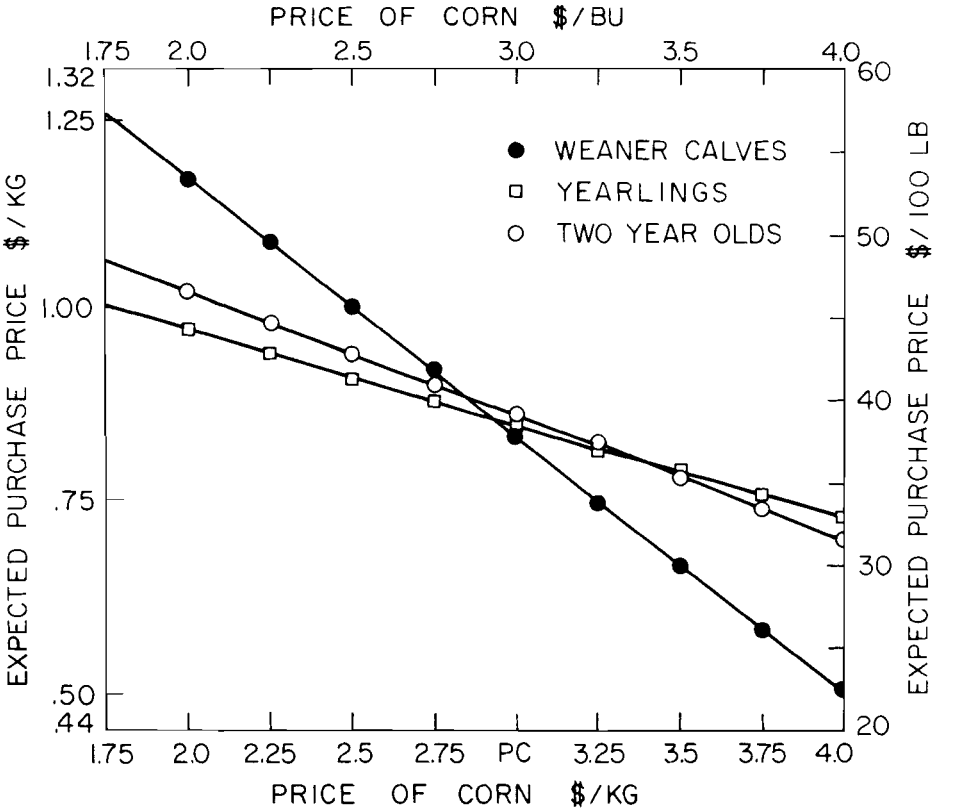


Figure 7. Imputed purchase prices for calves, yearling, and two-year-old feeder cattle in relation to price of corn with slaughter price fixed at $1.058/Kg

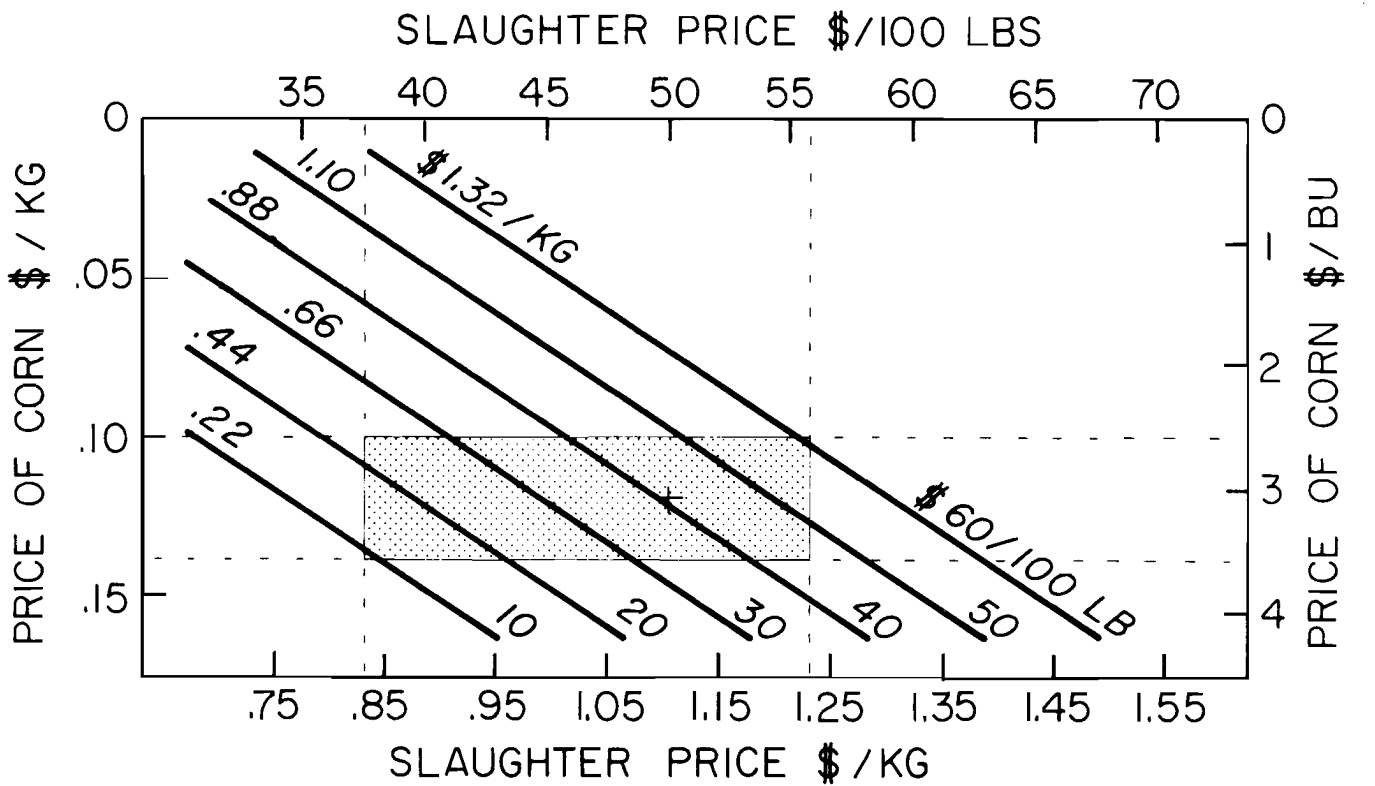


Figure 8. Imputed purchase price lines for feeder calves in relation to price of corn and slaughter prices

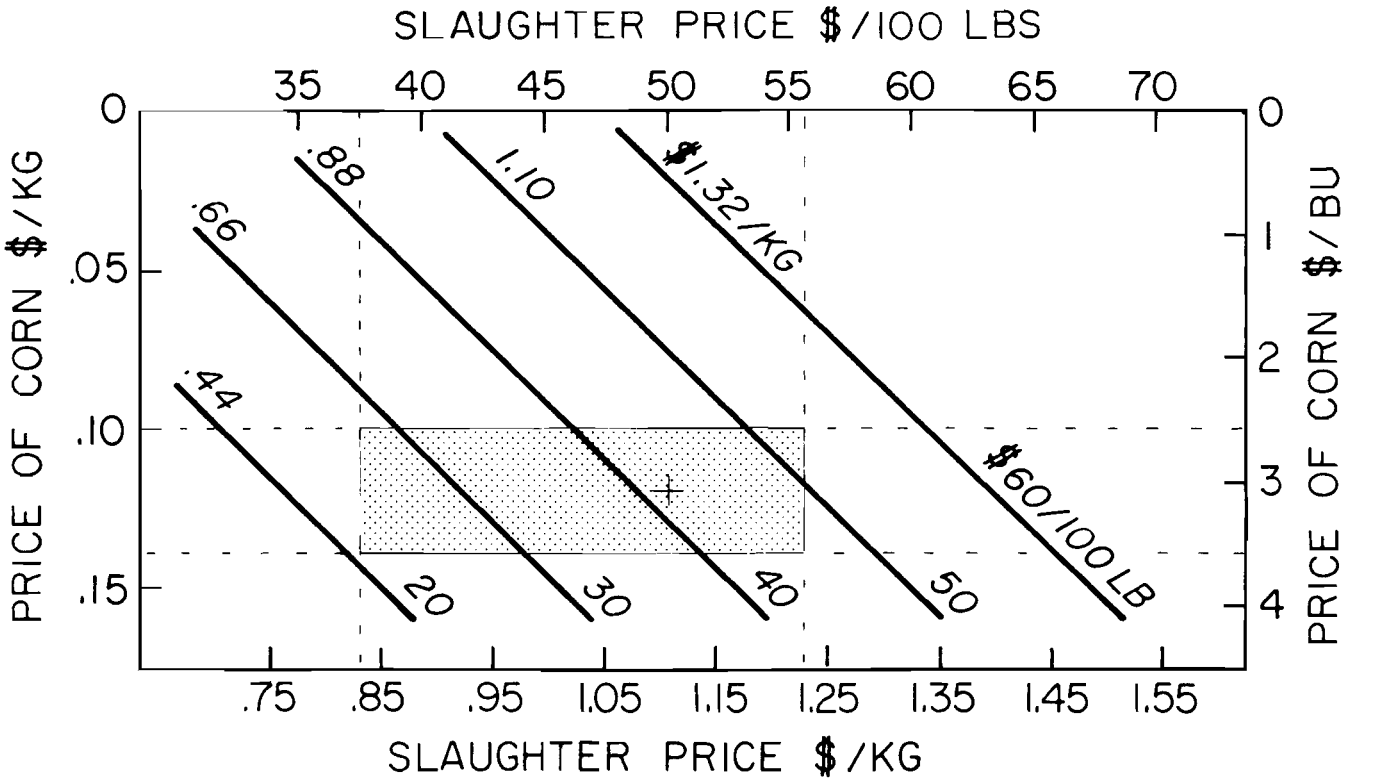


Figure 9. Imputed purchase price lines for yearling feeder cattle in relation to price of corn and slaughter prices

respects. The lowering of ration energy concentration is even less economical when the criterion of optimization is to maximize feedlot profits per unit of time. The criterion is appropriate for custom feeding clients and for single enterprise firms with full utilization of feedlot capacity. In some cases, maximizing profits per head per unit time is consistent with overall objectives of maximizing per-head profits (e.g., when maximum per-head profit is zero or when the maximum per-head profit is also achieved with least time). However, there are cases where optimum feeding programs would diverge for the two optimizing criteria. Given the diversity of the physical and economic circumstances among firms in the beef-producing sector, one would also expect a wide array of optimum programs. The analytical framework on which this analysis rests appears quite sound for the limited cases considered. However, information required to determine optimization over the full range of physical and economic circumstances in cattle production is inadequate.

There are many possible logical variations within the theoretical framework. For example, how do the relationships differ between sexes, between yearlings and calves, between English breeds and exotics of the same age and sex, between summer and winter, among physical forms of the ration and among diets having variations in nutrient/energy ratios? While information is available on each of these variations, it is not yet developed in a systematic coherent set. It is suggested that the theoretical framework proposed will be useful in this regard.

Historically, growth in the feedlot has been efficient. Average cost curves, calculated for production costs per unit live weight gain, were shown to decline throughout the feedlot production stage. Consumers' preferences for Choice beef have not been inconsistent with production of beef at lowest cost irrespective of grade. If slaughter costs and dressing yield were brought into the calculations, the case for the heavier animals would be even further strengthened. If prices bid for feeder cattle covered their costs of production, this would still be the case. Since it is not clear whether grain prices will rise more than costs at the grazing phase of cattle production, it cannot be stated that lighter weights and lower market grades will result in more efficient, less costly beef in the future.

Roughage can also substitute for grain between the range or pasture and the feedlot by increasing the proportions of yearlings and two-year-old feeder cattle relative to calves being placed in feedlots. In the examples calculated, calves were marketed at 20 Kg less weight, but required 39 percent more grain than yearlings. Yearlings were marketed at 45 Kg less weight, but required 8 percent more grain than two-year-old feeder cattle. Because of their greater grain requirements and lighter purchase weights, the price of feeder calves is more responsive to change in grain prices and slaughter prices than is the price of yearlings or two-year-olds. Yearlings are more responsive in this regard than two-year-olds.

Higher grain prices suggest a movement away from calf production to yearling production. On the other hand, higher slaughter prices

suggest a movement toward more calf production and less yearling production. Unstable grain and slaughter prices suggest a movement to yearling production to reduce ranch income variability.

The analysis presented does not permit precise statements to be made about optimum adjustments in proportions of calf and yearling production.

The author's judgment is that adjustments will be in the direction of a larger proportion of yearling and older feeder cattle. The feedlot sector is expected to remain a very strong link in the economics of beef production. High energy rations are expected to remain economical in a large part of the feedlot sector. However, good judgment requires us to be prepared for the contingency of very high grain prices. It is prudent to invest in research on grass finishing beef for slaughter, even if it does not now seem economical.

Just as important is the need to invest in further development of the technical information for assessing the efficiency of feedlot production over a wide range of diets, types of animals, and production circumstances.

APPENDIX

Analytical Models and Theory

First, a system for predicting the effect of dietary energy concentration on feed intake and performance is presented. A dynamic profit function which incorporates these relationships is then developed. This profit function can be used to analyze the effects of dietary energy levels on expected feedlot profits for animals of different gain potential. With modification, it can be used directly with the California Net Energy (CNE) system in the case where rate of gain and dietary energy concentration is given. This permits analysis of the profit potential and breakeven values of calves, yearlings and two-year-old cattle under a wide range of slaughter prices and feed prices. The system and its many possible variations, some of which have been subjected to empirical testing, are presented in more detail elsewhere (Brokken and Dinius, 1974; 1976; Dinius, et al., 1976; Brokken, et al., 1976). These references suggest a great deal of experimentation which will be required to bring the system to a more complete operational level.

Effect of Ration Energy Concentration on Feed Intake and Gain

Two expressions are used for daily dry matter (DM) intake. The first is the NRC requirements function (N.A.S., 1970) and the second is a function describing daily voluntary DM intake as a function of dietary energy concentration.

By equating these two expressions, the relationship between dietary energy concentration and gain per day is derived. To simplify, concentration of net energy for maintenance (NE_m/Kg) is expressed as a function of the concentration of net energy for gain (NE_g/Kg). This is possible since both are shown to be a function of concentration of metabolizable energy (ME/Kg) (Lofgreen and Garrett, 1968; N.A.S., 1970; Brokken and Dinius, 1976).

Let Y_i denote daily DM intake per unit metabolic weight (MW) of the ith animal; let X be dietary energy concentration measured in NE_g/Kg (then XY denotes daily intake of energy per unit metabolic weight with all intake evaluated in NE_g concentration only) and g_i, the gain per day of the ith animal.

Then, from the NRC requirements, daily energy requirements per unit MW for maintenance and gain are:

$$XY_i = .08089X - .03184X^2 + .05272g_i + .00684g_i^2 . \qquad (A.1)$$

Daily requirements of DM per unit MW for maintenance and gain are:

$$Y_i = .08089 - .03184X + \frac{.05272g_i}{X} + \frac{.00684g_i^2}{X} . \qquad (A.2)$$

It is well established that ruminant dry matter intake is negatively related to dietary energy concentration at concentrations above a certain level (Montgomery and Baumgardt, 1965a; 1965b; Dinius and Baumgardt, 1970). Different classes of animals consuming the same diet, consume different daily amounts per unit MW and grow at different rates. Therefore, the function describing daily voluntary dry matter intake (the appetite function) features a different set of parameters for each animal (or each class of animals). The function used here is hyperbolic in dietary NE_g concentration with only a general designation of its parameters as A_i and B_i:

$$Y_i = A_i/X + B_i . \qquad (A.3)$$

The voluntary DM intake function is changed into a voluntary energy intake function by multiplying DM intake, Equation 3, by X. Notice that a hyperbolic DM intake function requires that energy intake be linear:

$$XY_i = A_i + B_iX . \qquad (A.4)$$

By equating Equation 4 with Equation 1 (or 2 with 3) we derive the relationship between rate of gain and dietary energy concentration:

$$g_i = -3.8584 + \left[14.85178 + \frac{A_i + B_iX + .03184X^2 - .08089X}{.00684}\right]^{\frac{1}{2}} \qquad (A.5)$$

This system is diagrammed for two animals and traced through at two levels of energy concentration in Figure A.1. Notice in Chart C of Figure A.1 that the curves for the two animals are parallel. This implies that voluntary energy intake curves, Chart D of Figure A.1, are divergent which implies that performance of the animal with the higher potential for voluntary intake per unit MW is affected by changes in dietary energy concentration more than animals of lower growth potential.[7]

Total Feed Intake

Daily feed intake of the ith animal on day t is (F_{it}):

$$F_{it} = Y_i W_{it}^{.75} \quad . \tag{A.6}$$

The following equation is used to estimate total feed requirements of the ith animal (TF_i) to gain from the induction weight W_{io} of final weight W_{hi} at an average rate of gain g_i.

$$TF_i = \frac{Y_i}{1.75 g_i} \left[W_{in}^{1.75} - W_{io}^{1.75} \right] , \tag{A.7}$$

where Y_i is calculated from Equation A.3 and g_i from Equation A.5, alternatively, if g_i is also known, Y_i is calculated from Equation A.2. This function is very useful analytically as it expresses total feed requirements in terms of beginning and ending weights and rate of gain.

Equation A.7 is derived by a continuous summation of daily feed requirements over the duration (n days) of the feeding period. Let weight on day t of the feeding program be weight at time zero plus the rate of gain times the number of days of feed, $W_{it} = W_{io} + g_i t$. Then,

$$TF_i = Y_i \int_0^n (W_o + g_i t)^{.75} \, dt$$

$$= \frac{Y_i}{1.75 g_i} \left[(W_{io} + g_i n)^{1.75} - W_{io}^{1.75} \right] \quad . \tag{A.8}$$

The weight on the nth and final day of the feeding period, $W_{io} + g_i n$, is written as W_{in}, obtaining the expression shown in Equation A.7.

---

[7] This system, alternative formulations of it, and implications for performance are presented in more detail elsewhere (Brokken and Dinius, 1976; Brokken, et al., 1976).

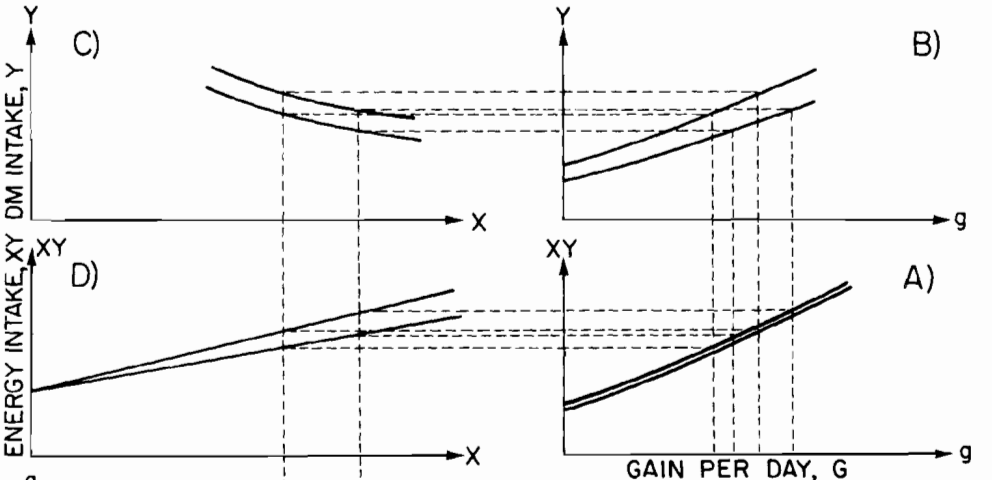


Figure A.1. System of daily voluntary feed and energy intake and daily requirements for maintenance and gain in relation to dietary energy concentration

Profit Equation

Profit per head (π) is total revenue (TR) minus total cost (TC) or

$$\pi = TR - TC \tag{A.9}$$

$$TR = .96\ P_s W_n \tag{A.10}$$

$$TC = (1 + d)(1 + rn)P_p W_p + (C_x + C_p)\frac{Y}{1.75g}(W_n^{1.75} - W_o^{1.75})$$

$$+ nC_n + (1 + rn)K_1 + K_2 + K_3\ , \tag{A.11}$$

where .96 = (1 - s), where s is a shrinkage factor of 4 percent, P_s is the slaughter price; d is death rate; r is daily interest rate; n is days on feed; P_p is purchase price; W_p is purchase weight; C_x is the minimum cost per Kg of dry feed for a given energy concentration with appropriate concentrations of other nutrients; C_p is feed preparation cost per Kg; C_n is yardage cost per day; K_1 is acquisition costs including commissions, trucking, vaccination, dipping, etc.; K_2 is fixed cost on equipment and facilities; and K_3 is a charge to cover input costs on animals that die. $W_o = (1 - s')W_p$, where s' is the initial shrinkage factor from point of purchase to the feedlot. Marfinal cost with respect to body weight (MC), (setting $n = (W - W_o)/g$), is $\partial(TC)/\partial W$.

$$MC = \frac{1}{g}\left[r(1 + d)P_p W_p + (C_x + C_p)YW^{.75} + C_n + rK_1\right]. \tag{A.12}$$

Designate the weight at which marginal cost equals slaughter price, W*,[8]

$$W^* = \left[\frac{.96P_g - rP_p W_p - C_n - rK_1}{(C_x + C_p)Y}\right]^{\frac{1}{.75}} \tag{A.13}$$

[8]It should be understood that optimum market weight may not occur at the point where marginal cost equals expected slaughter price. The reason for this is that expected slaughter price is not marginal revenue when part of the returns from feeding obtains from changing the product form (Grade), hence from producing a change in price per pound. This positive increment in price applies to all previous growth. Optimum weights are discussed more fully elsewhere (Brokken, et al., 1976).

Average cost, AC, is total cost divided by weight, W,

$$AC = TC/W \ , \qquad \text{(A.}$$

where TC is taken from Equation A.11. W** is the weight at which AC is a minimum.

$$W^{**} = \Big[[1.75g\ K_1 + K_2 + K_3 + (1 + d)P_p W_p) - 1.75\ r(1 + d)P_p W_p W_o C_n + rK_1] - (C_x + C_p)YW_o^{1.75} \quad .75(C_x + C_p)Y \Big]^{\frac{1}{1.75}} \qquad \text{(A.1}$$

where the notation is the same as for Equation A.11. It can be seen from Equation A.15 that W** depends on the magnitude of the fixed components of costs and the cost of the feeder animal at induction into the feedlot relative to the variable costs in the feedlot.[9] One important missing component of cost is slaughter and processing cost which also tends to be fixed per head cost and not a function of weight. Exclusion of this cost biases W** downward.

Imputed Values for Feeder Cattle

The profit equation is also used to focus on the effects of the level of expected profit per head (or per unit time), slaughter price and grain prices on the imputed value or purchase price of the animal. An imputed or purchase price which covers profit and costs of production is derived from the profit equation and rewritten for analytical convenience as:

$$P_p = B_0 + B_1 P_s - B_2 P_c - B_3 \pi \qquad \text{(A.16}$$

where P_c is the price of corn.[10] The coefficients B_0, B_1, and B_3 are derived from Equations A.17 through A.20.

---

[9] The TC curve represents an approximation which is valid only over a certain span of weight. Values of W** from Equation A.15 that fall outside of this range would properly be interpreted as equivalent to the upper or lower limit of the relevant range of weights, depending on whether W** was above or below the relevant range.

[10] C_x from Equation A.11 is written as a function of the price of corn; $C_x = a + bP_c$. For the high energy ration (X = 1.3) using Eastern Nebraska ingredients, the relationship obtained was $C_{1.3} = 0 + .0402P_c$ where P_c is \$/bu.of corn, as fed moisture basis; $C_{1.3} = 0 + 1.0211P_c$ when price of corn is \$/Kg, as fed moisture basis. With a pocket calculator $W^{.75} = \sqrt{W\sqrt{W}}$, then $W^{1.75} = W(W^{.75})$.

$$B_0 = \frac{1}{(1+d)(1+rn)W_p} \left[- \frac{C_p Y}{1.75g} (W_n^{1.75} - W_0^{1.75}) - nC_n \right.$$

$$\left. - (1+r)K_1 - K_2 - K_3 \right] . \qquad (A.17)$$

$$B_1 = .96W_n/(1+d)(1+rn)W_p . \qquad (A.18)$$

$$B_2 = \frac{1}{(1+d)(1+rn)W_p} \left[\frac{Y}{1.75g} (W_n^{1.75} - W_0^{1.75}) \right] . \qquad (A.19)$$

$$B_3 = \frac{1}{(1+d)(1+rn)W_p} . \qquad (A.20)$$

Acknowledgments

The author is indebted to Professor Victor E. Jacobs and Kenneth E. Nelson for reviews and helpful critique of an earlier draft of this paper.

LITERATURE CITED

1. Brokken, Ray F. and D. A. Dinius. 1976. Effect of dietary energy concentration on feed intake of beef steers and implications for performance and heat production. CED Working Paper, Economic Research Service, U. S. Department of Agriculture.

2. Brokken, Ray F. and D. A. Dinius. 1974. Effect of ration energy density on cattle performance. 1974 Proceedings Western Agricultural Economics Association 47:110-113.

3. Brokken, Ray F., T. H. Hammonds, D. A. Dinius and J. Valpey. 1976. Framework for economic analysis of grain versus harvested roughage for feedlot cattle. Amer. Jour. Agr. Econ. 58.

5. Dinius, D. A., R. F. Brokken, K. P. Bovard and T. S. Rumsey. 1976. Feed intake and carcass composition of Angus and Santa Gertrudis steers fed diets of varying energy concentration. J. Anim. Sci. 42.

6. Jacobs, V. E. 1975. Feed grain prices and the economics of backgrounding: A revolution in the making? Speech at NCR-88 annual meeting, Purdue University, May 15, 1975.

7. Lofgreen, G. P. and W. N. Garrett. 1968. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. J. Anim. Sci. 27:793.

8. Montgomery, J. J. and B. R. Baumgardt. 1965. Regulation of food intake in ruminants. 1. Pelleted rations varying in energy concentration and physical form. J. Dairy Sci. 48:1623.

9. National Academy of Sciences. 1970. Nutrient requirements of beef cattle (4th Rev. Ed.). National Research Council, Washington, D.C.

ECONOMICS OF ALTERNATIVE BEEF PRODUCTION SYSTEMS AND LOCATIONS*

Donald E. Farris and Raymond A. Dietrich**

One of the main reasons for this conference is to analyze the future role of the South's beef industry and to develop a program of beef research for the near future. It is our understanding that behind the planning of this conference is the hypothesis that the increased cost of energy and feed would at the very least alter the competitive position of beef in the South and likely would increase the competitive position of the South in cattle production, including increasing the length of ownership of cattle and finishing cattle on a high forage ration.

Unfortunately, while this conference was being planned, the competitive position of beef production relative to crops or almost any agricultural enterprise in the South has become very unfavorable. The cow-calf industry at this time is in a depression. It is our purpose to look beyond the current crisis because we are involved here in trying to formulate new research programs. Prices and costs have been most unstable in the past few years; under these circumstances an operator can hardly evaluate the competitive position of his cattle operation relative to other geographic areas, other cattle systems, or even relative to cash crop production.

In cases where feasible alternatives are limited, there might not be much of a decision problem, but when the industry is viewed in the aggregate, there are enough operators that have feasible alternatives that the market will force adjustments. Perhaps this conference can assist the industry in anticipating these adjustments and thereby reduce the shocks to the system. However, the primary objective of this conference is to develop research that can provide new information and refine the available information for decisions.

The beef industry is badly out of adjustment at this time (1975) in the United States and in much of the rest of the world. Bringing

* Paper presented at "Forage-Fed Beef Research Workshop," October 20, 1975, New Orleans, Louisiana. It was reviewed by Gordon Kearl and Odell Walker. The authors appreciate their helpful comments.

** Professor and Associate Professor, respectively, Texas Agricultural Experiment Station, Texas A&M University, College Station, 77843 TAES Technical Article TA 12246.

the industry back near equilibrium is a complex matter and it has always taken considerable time. Considering the anticipated volatility of the industry, cow-calf operators may want to consider adjustments in their business to increase their alternatives. One way of increasing alternatives is to add a stocker operation. Finishing in a custom lot or an owned lot are other alternatives.

Since this paper is early in the schedule it would appear appropriate to examine some of the broad aspects of the economics of forage feeding versus the traditional systems of grain feeding. This involves a review of the available literature and development of some hypotheses that this group may want to examine. The cattle industry is very diverse and operates under many resource and management conditions. It is difficult if not impossible for research to develop generalizations to cover all areas and systems. The available research results provide a basis for substantial insight but the reason this conference was organized is that we obviously need more answers.

It would be useful in analyzing future developments to consider th hypothesis mentioned earlier in more detail. That is, whether the higher cost of energy, feed, fertilizer, transportation, etc., experienced since 1972 has changed the competitive position of beef cattle systems within an area and among geographic areas.

An efficient economic system tends to economize on the resource or input that is relatively scarce or more expensive. We have seen a complete turnaround in cattle feeding as a result of this principle. By 1973 cattle slaughter consisted of about 75 percent grain fed cattl whereas in 1975 it is about 50 percent--back where it was in 1960. Apparently there has also been a sharp cutback on application of fertilizer to pasture which will reduce the beef output per unit of land.

By 1975 most of the effects of higher feeding costs had been passed back to the cow-calf stage in the form of lower prices. A brie review of the shock to the industry of price and cost movements will help put recent developments in perspective. These can be summarized in the beef/corn price ratio. A careful examination of Figure 1 will show that inventory peaks and valleys in number of cattle on farms in the U. S. has roughly lagged peaks and valleys in the price ratio. Favorable beef prices produced record high price ratios in 1971 and 1972, then high grain prices and the recession produced the deepest valley in the price ratio during 1974-75 since the decade of the 1940's. It would appear that during the 1975-80 period we could expec the cost of feed grains, hay, fertilizer and transportation to be roughly double that prevailing during 1965-70. If that is true, whole sale beef prices will need to nearly double that period to cover costs

Hypotheses

Hypotheses concerning future adjustment in the cattle-beef industry should aid the development of this paper and the development of testable hypotheses for future research.

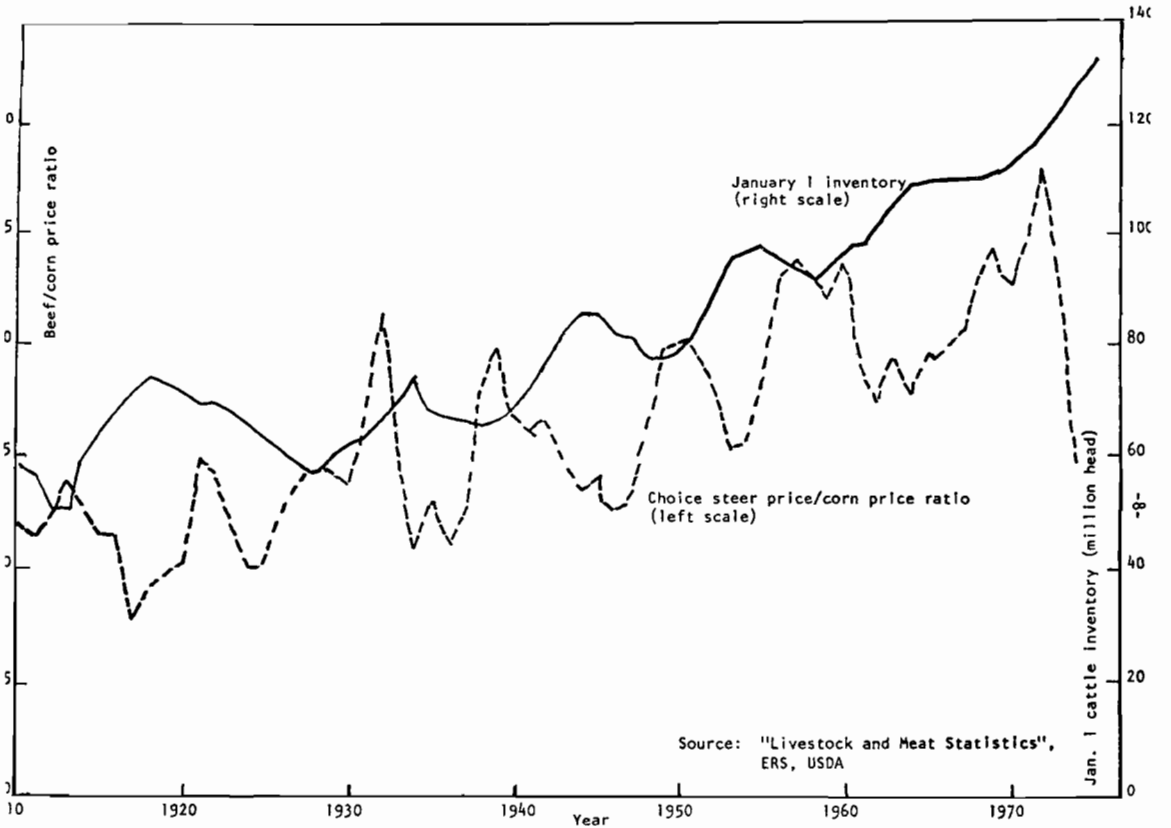


Figure 1. Beef-corn price ratio and January 1 inventory of cattle on farms, U. S., 1910-1974
Source: (4).

Starting with the premise that there has been a fundamental change in the basic cost structure of beef production as a result of higher energy and higher feed grain costs, the following adjustments appear likely for 1980 relative to the pre-1973 period.

1. Relatively higher cost beef production will result in a slower growth in per capita supplies (and consumption).

2. More specifically, beef production cost increases and the lag in price adjustment to cover total costs will result in a reduction in per capita output near 1980 relative to 1975.

3. The higher cost of feed grain will result in fewer cattle being fed in feedlots and in cattle being fed to lighter weights. These two factors will result in no need to increase the aggregate feedlot capacity prior to 1980.

4. The change in relative advantage in feeding will result in little increase in feedlot capacity outside of the existing feeding areas since most of the existing feeding areas are also efficient producers of high quality forage.

5. Lack of slaughter capacity outside of the grain feeding areas will discourage growth of forage feedlots in the South. However, it would not limit this alternative, because cattle still can be moved long distances, but at a cost.

6. Some cow-calf operators in the South will find it profitable to carry calves to heavier weights for sale as feeders at 500 to 600 pounds (227 to 272 kilograms) or as slaughter calves to local packers.

7. More slaughter capacity is needed in the non-grain feeding areas, and especially in the South to handle an increased percentage of non-fed beef, but it is not clear if this is a sufficiently long-run problem to justify the investment.

Economics of Forage vs. Grain Feeding Systems

The relative prices of inputs and outputs determine the profitability of a feeding system. For a specialized commercial feedlot in the Southern Plains, profits turn on the markets for grain, feeder cattle, credit and fed cattle. In a positive feeding margin situation (fed price exceeds feeder price per unit of weight) feedlots are able to absorb relatively higher priced feed grain costs and still make a profit. In contrast, when grain is relatively cheap, feeders tend to bid up the prices for feeder calves. With increased cost of feed, other things equal, the first adjustment a feedlot operator can make is to bid less for feeder cattle.

Some cow-calf producers have a variety of options depending on their resources, their banker and their future expectations regarding price relationships. For example, Gee and Pursley (1972) estimated that Eastern Colorado ranchers would have made the greatest return on their investment only once out of 15 years during 1955-1969 by selling weaner calves. Returns were higher from fattening 11 out of 15 times and 3 out of 15 from selling yearlings (5, p. 10).

Pasture vs. Feedlot for Growing Phase

Gain on pasture forage has generally been more economical for the growing or stocker phase than gain in the feedlot on either forage or grain. This has never been seriously challenged even when grain prices were their lowest in the past two decades and fertilizer was cheap, although there were some cases where feedlot forage feeding was practiced; especially when good quality pasture forage was not available. Studies made over the last two decades and under many conditions have documented the fact that growing cattle on pasture forage is more profitable even prior to the period when grain feeding became more expensive. Southern Plains feedlot operators have been quick to use lower cost of gain alternatives thereby bidding up the price of silage and stocker pastures. The important question for most producers then becomes: when to operate the pasture growing phase, for what type of cattle and for how long?

The high risk experienced in the growing phase of the business attests to this being a very complex question. Normally, wheat pasture in the Southern Plains from November through February is clearly one of the answers to the "when and where" part of the question. When available, winter wheat is one of the most economical sources of gain. Properly managed wheat fields can provide some grazing without any noticeable sacrifice in grain yields. However, Whitson, Lacewell and Shipley found that when the wheat price exceeded $3.50 per bushel ($.13 per kilo) and there was a negative price margin on stockers, it was more profitable to produce the wheat for grain only and not graze cattle. When the wheat prices are relatively low compared to feed grain or when there is a positive stocker price margin, there are times when wheat can be profitably grazed from November to June sacrificing the grain crop entirely (2, p. 21).

Whether a cow-calf operator in the South can generally expect to profit from a stocker operation based on temporary pasture depends on whether that operation can compete with crop production and the cow-calf operations for the land. Clearly, if the cattle are also to be finished and/or slaughtered in the area, it would be expected to be profitable, otherwise it depends on so many variables, it is hard to generalize.

Feedlot Forage vs. Grain

Feeding forage in the feedlot for the growing phase certainly has its possibilities and its place in beef systems, particularly when high quality forage is not available from grazing, and at the beginning of a finishing phase to be conducted at the same feedlot.

Feedlot forage feeding versus temporary winter pasture in the South for light stocker cattle is a possibility but its profitability is not clear when alternatives are considered. Brodnax, Couvillion and Tyner (1975) estimated a winter pasture gain cost of 28 to 29 cents per pound ($.63 per kilo) on 300/600 pound (136/272 kgs.) calves in Mississippi in 1975 (1, p. 2). It would have been interesting if they had compared this with feeding silage for the same period.

Generally feedlot full forage feeding would not be more profitable for finishing, unless there were a serious imbalance in grain prices relative to forage cost; some grain mixed with the forage will generally improve the feedlot results and improve the slaughter price.

Heady, et al. (1963), reports that in experiments conducted in Iowa during 1957-1959 the greatest profits were obtained by feeding a high concentrate ratio (two parts green chop and one part corn). However, when the silage (green chopped forage) price is low relative to the price of corn, the most profitable ration includes less corn and more silage. Using a wide range of silage and corn prices, they did not find that an all silage ration was more profitable than some combination of silage and corn. They also found that the high silage ration was more profitable for short feeding periods than for long feeding periods (6, p. 883).

Research conducted in Texas by Williams and Farris (1972) and using cost and price relationships for the 1966-1968 period, provided estimates of relative cost of net gain for fifteen cattle systems in four different geographic areas (13, p. 13). Ranking the cost of gain from lowest to highest for all four areas provides more evidence to support the previous comments (Table 1).

Calves were backgrounded on irrigated wheat pasture in the Panhandle, on native range pasture in North Texas and in South Texas and on wheat-ryegrass pasture in East Texas. Pasture was clearly the lowest cost gain in all four areas even when grain prices were relatively low ($2 to 2.25/cwt.--$0.04 to 0.05 kg. for milo). Backgrounding in the feedlot was more expensive per pound of gain than for the warm-up ration with twice as much grain; however, a changed relationship in the grain and silage price could easily change this ranking. See Table 2 for the cost details.

Poenisch, Kay and Rouquette (1975) reported that for prices for the 1968-1972 period stockers and grass fat cattle could not compete with a straight cow-calf herd in East Texas (Table 3). However, breakeven prices were estimated that would provide the same return to the operator from the three systems.

Table 1. Total cost of gain, 1966-68

Cost rank from lowest to highest	Beef system
1	Backgrounding calves on pasture (350/600)
2	Warm-up calves in feedlot. The ration was corn silage/milo ≃ 2:1. (350/600)
3	Finishing slaughter calves in feedlot on grain (350/550)
4	Finishing light steers and heifers to USDA Good grade on grain (400/900 and 400/700)
5	Backgrounding steer calves in feedlot. The ration was corn silage/milo ≃ 4:1. (350/600)
6	Finishing Choice steers and heifers on grain in feedlot (starting weights were 600 lbs.)
7	Feeding thin cull cows to Utility grade. Mainly a corn silage ration. (800/950)

Source: (13).

These were:

(1) Spring calves weaned at 500 lbs. @ $0.35/lb., or 227 kgs. @ $0.77/kg.

(2) Stocker cattle sold at 740 lbs. @ $0.34/lb., or 336 kgs. @ $0.75/kg.

(3) Grass fat slaughter cattle sold at 1010 lbs. @ $0.30/lb., or 458 kgs. @ $0.66/kg.

These levels were $1.68/cwt. ($0.04/kg) above the average price for slaughter cattle of comparable quality during the period and $1.73/cwt. ($0.04/kg.) above the average price for stockers during the period. Adding the stocker operations reduced cow numbers from 225 on 100 acres to 159. Adding the grass fat slaughter cattle reduced cow numbers to 129 per 100 acres (9, p. 17).

A review of work by Saunders, et al. (1966), in Georgia can provide some perspective on the economics of different systems for costs and prices that prevailed during the 1960-1964 period. They varied cattle prices and corn prices from the average of the period and concluded "Changes of only one cent per pound in the price of cattle, particularly on the selling side, have by far the greater effect on net returns than a change of ten cents per bushel in the price of corn."

Table 2. Total cost per pound of net gain for 15 systems of feeding cattle in a 20,000 head capacity in four areas of Texas[a]

System	Area			
	Panhandle	North	South	East
	(dollars)			
Finishing				
Choice steer 600/1050	.2461	.2650	.2712	.2725
Good steer 600/1100	.2421	.2639	.2711	.2715
Good steer 400/900	.2021	.2225	.2284	.2289
Choice heifer 600/850	.2731	.2947	.3024	.3029
Good heifer 400/700	.2158	.2291	.2349	.2340
Slaughter calf				
Good steer 300/550	.1837	.1980	.2024	.2034
Good heifer 300/550	.1951	.2107	.2158	.2168
Thin cow				
Cow 800/950	.2813	.2957	.2999	.2937
Backgrounding-feedlot				
Choice steer 350/600	.2303	.2427	.2444	.2466
Good steer 350/600	.2273	.2388	.2405	.2416
Backgrounding-pasture				
Choice steer 350/600	.1685	.1934	.1946	.1931
Good steer 350/600	.1656	.1890	.1903	.1889
Choice heifer 350/600	.1759	.2071	.2092	.2019
Warmup-feedlot				
Choice steer 350/600	.1966	.2107	.2137	.2161
Good steer 350/600	.1939	.2071	.2102	.2113

[a]Net gain is the finish weight with 4 percent shrink minus the starting weight. The 1966-68 average price of milo in the Panhandle, North, South and East Texas Area was $1.93, $2.21 and $2.31 and $2.31 per cwt., respectively.

Source: (13).

A summary of net returns to management shows that some grain feeding in dry lot during the 1960-1964 period yielded the highest return (Table 4). Two grazing systems, however, were among the most profitable systems (10, pp. 37-38).

Walker and Phillips (1966) found that finishing steers during 1960-1964 on high-energy corn silage was the most profitable in Mississippi. Second in profitability was a silage feeding period of three months followed by a concentrate feeding period of two months, and lowest in profitability was the concentrate feeding for the entire period. These estimates were for finishing 715 (324 kgs.) pound

Table 3. Costs and returns at break-even prices for alternative calf ownership on 100 acres (spring calving)

	Weaned calves	Stockers	Grass fat
Price per cwt.	$ 34.98	34.19	29.67
Gross receipts	35,388.51	36,285.94	34,655.55
Production costs			
Livestock			
Cows	14,262.39	10,107.90	8,153.12
Bulls	846.50	599.80	483.98
Stockers	-	3,775.72	3,045.46
Grass fat	-	-	3,085.94
Forage			
Coastal-Ryegrass	1,105.44	1,853.67	994.05
Coastal-Crimson Clover	2,161.70	947.05	1,945.89
Coastal-Bermudagrass	689.03	795.81	860.99
Fertilizer	9,283.73	9,172.81	9,104.99
Hay	4,798.25	6,788.45	4,737.41
Total costs	33,147.04	34,041.21	32,411.83
Net returns	2,241.47	2,244.73	2,243.72

Source: (9).

Table 4. Net returns to management from different cattle feeding systems in a 500-head feedlot in Georgia, 1960-1964[a]

Beef system	Dollars per head
Feeder steer calves:	
A. 75 days limited feeding 120 days winter grazing 90 days dry lot	2.13
B. 120 days winter grazing 120 days in dry lot	11.85
C. 150 days winter grazing 90 days summer grazing	9.41
D. 180 days in dry lot	-1.68
E. 120 days winter grazing 75 days summer grazing 60 days dry lot	5.19
Stocker calves:	
A. 150 days winter grazing 150 days on Coastal Bermuda pasture	11.11
B. Same as A plus 90 days dry lot	19.70
Yearling steers:	
A. 90 days dry lot	-3.53
B. 120 days dry lot	-3.30
C. 150 days dry lot	-7.04

[a]Dry lot ration was about 50 percent corn by weight.

Source: (10).

feeders to 1040 pound Choice and Good slaughter steers. High-energy corn silage was produced by cutting the corn stalk just below the ear (11, pp. 17-18).

High Concentrate Ration vs. Low Concentrate

Production functions developed by Heady, et al., referred to earlier are not only useful to examine grain versus forage but they help to illustrate the role of feed ingredient price in specifying the optimum level of concentrates and forage in a ration. Holding cattle prices constant at a ten-year average, they varied corn prices from .75 to 1.75 per bushel ($0.13 to $0.07 per kilo) and silage from $1 to $8 per ton ($0.98 to $7.87 per metric ton). For only 100 pounds (45.36 kgs.) of gain it was not feasible to feed corn when the corn price/silage price ratio exceeded 8.0; but for higher levels of gain some grain was fed to achieve the least cost gain even up to the relatively high corn price/silage price ratio of 10.0 and above. This means even where a pound of corn would buy 10 pounds of silage or more, some corn would need to be fed to achieve the least cost (6, p. 883). When grade was considered, even more corn in the ration was justified. Hence, it has been documented and can be documented again that for a given level of cattle prices, when grain becomes expensive relative to forage prices some forage can be substituted for grain, but it would take an extreme imbalance in the relative prices to justify all forage. This extreme difference has existed for many years in Argentina, and this explains why they have generally found that it is not profitable to feed grain to cattle. During the 1960-1969 period, the steer/corn price ratio was more than two and a half times higher in the United States than in Argentina with a steer/corn price ratio of 4.53 compared to the USDA Good steer/corn price ratio of 11.53 in the United States (7, p. 37). The USDA Choice steer/corn price during the period was even higher.

Economics of Feeding Systems at Different Cattle Prices

We discovered in 1974 just how responsive the beef industry throughout the world had been in 1972-73 to favorable beef prices relative to feed prices. Operators and professionals knew there would be some response but most everyone was surprised with the speed of the recent response. A couple of studies that provided estimates of these responses might be worth reviewing. A recent study by Nix and Hubbard (1974) estimated that as price increased from $24/cwt. to $44/cwt., or $0.53 to $0.97/kg. (almost a doubling of price) there would be a proportionate increase in beef production in the South (60 to 130 million cwt., 2.72 to 5.9 million metric tons). See Figure 2.

McGrann and Farris estimated a similar response in the Central Pampean area of Argentina (Figure 3). The rate of increase appeared to be a little slower than for the Southern United States, however.

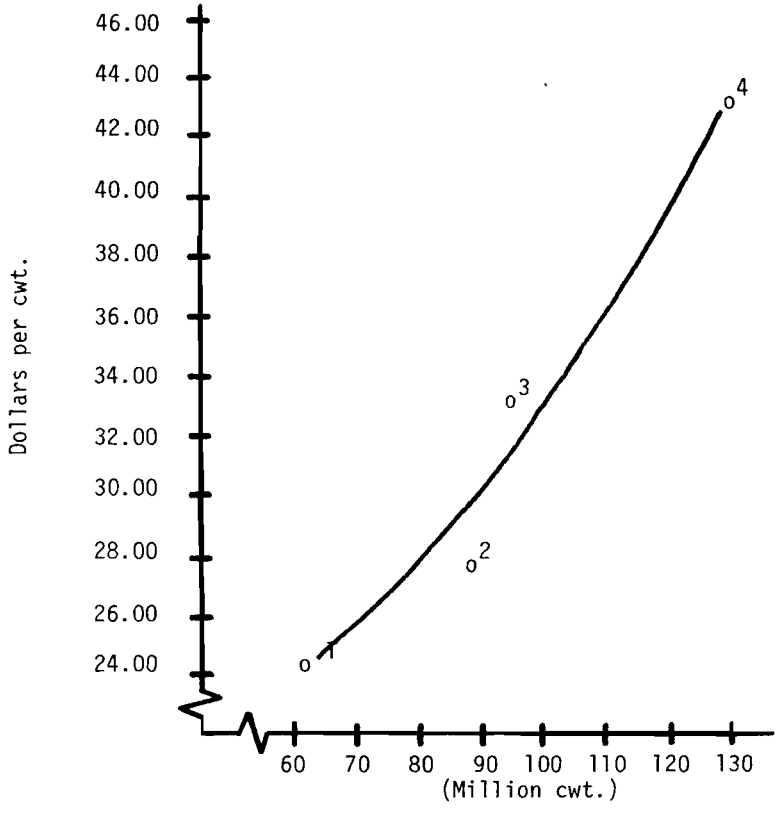


Figure 2. Total quantity of beef produced at each of the four beef price levels in the intermediate-run application of the model.

Source: (8).

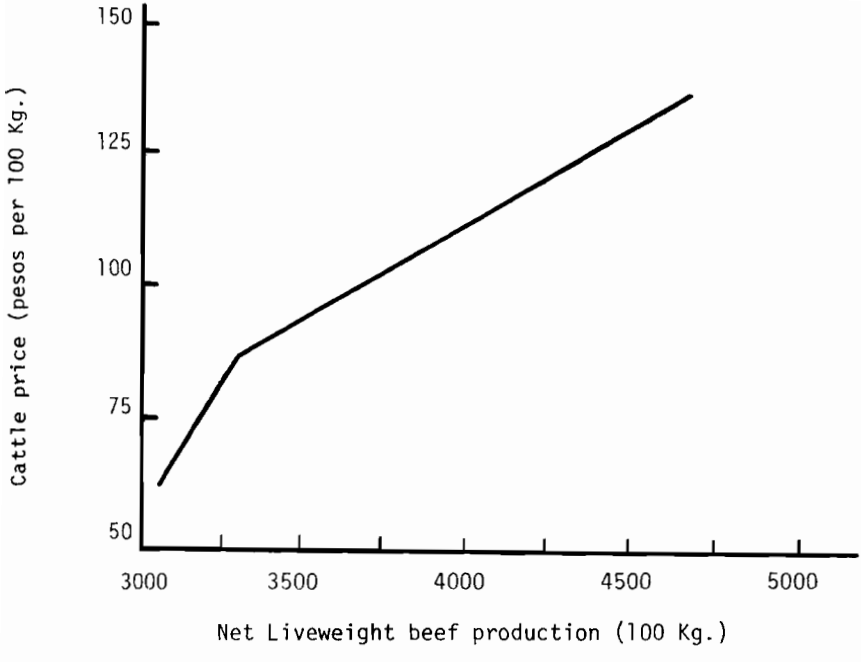


Figure 3. Beef production response to price change, the Central Pampean fattening area, Argentina (land area was fixed at 1000 hectares).

Source: (6)

Because the South is a surplus feeder calf producing area and a grain deficit area, the price of feeders would be expected to be the lowest in the areas most distant from the feeding areas. Dietrich (1971) estimated that the lowest price would prevail in Florida, although the difference among the South Atlantic states was small. Also, assuming markets reflected the relative costs of transportation and slaughter, the price of grain and fed cattle would be expected to be higher. Based on the relatively low cost of transportation during the late 1960s, the estimated differential due to lower feeder cattle prices and higher fed-cattle prices amounted to about $2.50 per cwt. ($0.055 per kg.) for the South Atlantic (2, p. 33). See Table 5.

Since fuel prices have substantially increased the cost of transporting cattle, this differential would be expected to widen to about $3.75 per cwt., or $0.083 per kg. ($2.50 x 1.50--the relative cost of transportation in 1975). Clearly this should increase the incentive to feed cattle in the South, but under what circumstances and for what kind of cattle would it be expected to be profitable?

Our hypothesis is that the South might have a competitive advantage in short fed heifers, fed to USDA Good grade. Furthermore, at times, short feeding of light, lower grade steers should be profitable; particularly when they have been backgrounded in the same area where they can be fed. The reasoning behind this is the cost of these animals would generally be more favorable compared to Choice steer feeders and short feeding would economize on grain, the input in which the South has a relative disadvantage.

Areas of Texas

Research conducted for the 1966-68 period attempted to document the principle that different areas could specialize in feeding to take advantage of price differences and economize on those inputs that were relatively higher priced. In the South, feeder cattle are relatively cheap, especially heifers, while grain and finished animals are relatively expensive compared to the surplus grain areas. This situation is also true for East Texas. Analysis of feeding in four areas of Texas was conducted where long fed steer operators generally were located in the Panhandle area of West Texas, whereas other areas fed mostly light heifers, and in East Texas thin cows were also fed for about 60 days until they could be upgraded to Utility grade. Williams and Farris were able to partially document the competitive advantage of feeding light heifers in East Texas. This area has many of the characteristics of other areas in the South. It is an area of lower feeder prices, higher grain and higher fed cattle prices than the Panhandle area of Texas. Apparently this difference in feeder and fed cattle prices was not sufficient because the Amarillo area had a slightly lower estimated total cost per pound of sale weight for each system except for cows than did East Texas. Furthermore, the systems in which Amarillo had a competitive advantage was light heifers and backgrounding steer calves on wheat pasture (Table 6).

Table 5. Regional price differentials for feeder cattle, feed grain, fed slaughter cattle and fed beef

Region	Feeder cattle	Feed grain	Fed slaughter cattle	Fed beef
		(dollars/cwt.)		
1. Wash., Oreg.	-.98	.30	1.26	1.42
2. Mont., Idaho, Wyo.	-.98	.09	.34	.90
3. Utah, Nev.	-.76	.21	.19	.75
4. Calif.	-.92	.47	.97	1.30
5. Ariz.	-.52	.31	.67	.72
6. N. Mex.	-.08	.15	.30	.35
7. W. Texas	0	0	0	0
8. E. Texas	-.51	.04	.43	.46
9. W. Oklahoma	.11	.02	.01	-.03
10. E. Oklahoma	-.06	.04	.75	.34
11. Colorado	-.30	.02	.19	.28
12. Kansas	-.12	-.04	.27	.26
13. Nebraska	.10	-.07	.31	.29
14. N. Dak., S. Dak.	-.48	-.11	.68	.87
15. Minn., Wisc.	-.45	-.11	1.25	.79
16. Iowa	-.18	-.11	.78	.63
17. Illinois	-.18	-.11	1.27	1.02
18. Mich., Ind. Ohio	-.42	-.11	1.25	1.23
19. Missouri	-.41	-.08	.98	.65
20. Ark., La.	-.60	.07	.60	.72
21. Miss., Ala., Ga.	-.78	.05	1.00	1.05
22. Fla.	-1.01	.19	1.47	1.53
23. NC, SC	-.99	.11	1.73	1.61
24. Ky., Tenn.	-.89	.06	1.15	1.06
25. W. Va., Va., Del., Md., Washington DC	-.92	.08	2.12	1.71
26. Penn.	-.60	.10	2.17	1.93
27. NE	-.79	.16	2.04	1.94

Table 6. Competitive advantage of four areas of Texas for 20 selected cattle feeding systems, 1966-68[a,b]

System	Annual reduced profit/ head of feedlot capacity (in dollars)[c] Area			
	Amarillo	Ft. Worth	San Antonio	Houston
Finishing				
Choice steer 600/1050	-55.69	-61.41	-61.13	-58.01
Good steer 600/1100	-52.00	-61.95	-63.26	-59.47
Good steer 400/900	-12.94	-24.28	-25.40	-23.35
Choice heifer 600/850	-31.21	-40.15	-45.41	-44.38
Good heifer 400/700	- .38	- 5.81	- 9.26	- 7.71
Slaughter calf				
Good steer 300/550	-29.08	-30.92	-28.81	-23.55
Good heifer 300/550	60833[d]	7.14	8.96	6.37
Thin cow 800/950	-47.24	-55.51	-54.84	-37.88
Backgrounding-in feedlot				
Choice steer 350/600	-36.98	-47.21	-48.55	-51.39
Good steer 350/600	-27.19	-36.93	-38.24	-40.40
Backgrounding-on pasture				
Choice steer 350/600	- 6.74	-18.58	-19.15	-19.66
Good steer 350/600	21901[d]	-11.96	-12.52	-13.22
Choice heifer 350/600	-14.25	-24.91	-24.91	-22.99
Warm-up--in feedlot				
Choice steer 350/600	-14.05	-27.62	-30.24	-33.89
Good steer 350/600	-2.66	-15.71	-18.37	-21.18
Combined pasture backgrouding and feedlot finishing				
Choice steer 350/1050	-16.84	-29.20	-29.78	-27.24
Good steer 350/1100	-12.35	-27.29	-28.64	-25.56
Choice heifer 350/850	- 6.72	-22.76	-24.42	-20.29
Combined feedlot warm-up and feedlot finishing				
Choice steer 350/1050	-25.51	-33.36	-34.57	-34.11
Good steer 350/1100	-20.34	-31.00	-33.15	-31.88

[a]In this (the State) model, all systems were programming activities competing for the same resources; therefore, the reduced profits from all possible area-system combinations can be legitimately compared. Fixed costs were included in the computation of profit; therefore a situation in which assets are not fixed was represented.

Table 6 (continued)

[b]The operating capital restriction used in this model was $3,754,554. This is the amount required for a 20,000 head capacity feedlot in the Panhandle Area to operate at 76 percent of capacity using the base system, choice steer 600/1050, assuming 1966-68 average milo and feeder cattle prices in the Panhandle Area of Texas.

[c]Annual reduced profit/head of feedlot capacity is the amount feedlot profit would be reduced if one head of feedlot capacity were used for a non-optimum system for the entire year.

[d]This is the number of head fed/year as determined in the optimum solution for each area model.

Source: (14).

If this research were to be repeated now reflecting higher transportation costs there likely would be more difference in price relationships between areas making it easier to document the original hypothesis that the advantage of feeding light heifers is south and east of the grain surplus areas. However, price variability in any short time period can confound results and current price relationships may not be the best evidence of the South's long-term position. Cattle prices were so distorted during the summer of 1975 that one might find (from hindsight) that the greatest advantage was in feeding to Choice grade only because of the large premium for Choice grade cattle.

The problem with any area not now feeding, and trying to expand, is that excess capacity in existing feedlots and packing plants in feeding areas will tend to keep margins quite low for new feedlots and slaughter plants because of the established advantage in lower fixed costs. The point of this discussion is that if the South has any long-term advantage in finishing cattle, the advantage is in the lighter weight, lower grade systems, and research on this question would appear to be very useful.

Areas of the United States

The increased cost of transporting cattle and grain is likely to adjust the competitive position of cattle finishing areas. First, this development apparently will tend to favor the farmer feeder in the Corn Belt since his key function is to minimize the cost of moving feed. His operation converts relatively low cost feed into a higher valued product per pound before it is moved.

Dietrich (1971) estimated that Kentucky and Tennessee had a competitive advantage in cattle feeding relative to the areas to the east and south. It may be that today's higher fertilizer and transportation costs will be enough to stimulate finishing in that area

(Figure 4). However, there is still the problem of excess feeding and slaughter capacity in the traditional grain surplus area. Very careful research will be required to document the changed advantage given current facilities. We are convinced that at 1975 prices and costs there has been a shift in the disadvantage of some of the areas in the South, but it is not clear whether this is enough to justify the relatively higher investment in facilities and equipment needed for finishing in the higher rainfall areas. It would appear that the area of greatest competitive advantage is not changed much from Dietrich's figure except to extend the eastern edge of the figure. Whether this change is temporary depends heavily on the relative cost of petroleum and the development of new slaughter capacity in the South.

Economics of Integration

The larger operator in the South who has both cattle and crops may find he can in the future cut back on soybean production and produce more forage for cattle. A stocker and short feeding operation to handle mostly heifers could provide a greater diversification of his operation without changing his cow herd. During periods of favorable soybean prices he can adjust back to soybeans and maintain his basic cow herd, or reduce the cow herd and maintain a stocker-finishing operation.

There are efficiencies possible from integrated cattle operations. Each time cattle change hands, there is a marketing cost, a transportation cost and losses due to stress. Farris and Williams (1974) estimated a cost saving of about $10 per head due to tighter coordination of cattle than exists through the open market. Savings in marketing charges accounted for about $5 of the savings (Tables 7 and 8).

Where custom lots are available, producers can maintain ownership through the feedlot, and for the near future have a strong chance of picking up a bonus from increased prices.

Fixed costs per head of capacity in forage feeding are substantially higher depending on the system to feeding. The East Texas and South Texas feedlot operators who feed light heifers generally feed grain, cottonseed hulls and a protein mix. They have a low fixed cost in their operation. Markets have been volatile and are likely to be for some time. If a small low cost feedlot must sit idle for a time, it is not a disaster. Careful analysis is needed before an investment in finishing is made. Experience with low cost facilities and equipment is desirable before moving to more elaborate facilities with the higher fixed costs associated with a forage feeding operation.

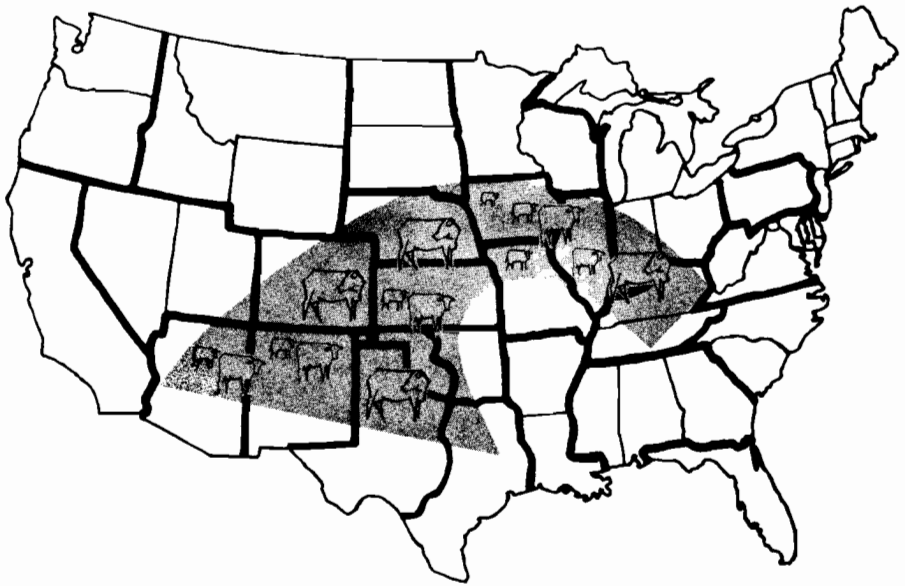


Figure 4. Cattle feeding belt as defined by regions with the highest competitive advantage in cattle feeding.

Source: (2).

Table 7. Summary of production and marketing costs for the Choice steer 350/600/1050 cattle feeding system, 1966-70[a]

Production-marketing phase	Open market system	Integrated marketing system	Difference[b]
		(dollars/head)	
Weaning phase	-	8.80	(8.80)
First marketing phase	7.82	3.70	4.12
Growing phase	38.87	30.70	8.17
Second marketing phase	4.51	2.05	2.46
Finishing phase	89.88	87.33	2.55
Interest expense	16.10	14.44	1.66
Total	157.18	147.02	10.16
Cost of feeder	114.87	114.87	-
Value of fat steer	285.60	285.60	-
Net returns per head[c]	13.55	23.71	10.16

[a]This system presents a Choice steer that is grazed on a rented grassland pasture and fattened in a commercial feedlot to a slaughter weight. The numbers 350, 600, and 1050 refer to the weaning weight and the feedlot starting and finishing weights, respectively.

[b]Advantage or disadvantage to the integrated marketing system.

[c]Net returns after all costs including a return to management and labor and an 8 percent annual return on fixed investments.

Source: (14).

Summary and Conclusions

It appears to us that most of the current feedlot operations will acquire more forage and reduce the level of concentrate in their rations, in some cases heavier cattle will be brought into the feedlots, and in other cases cattle will be fed to lighter weights than was the case for pre-1973. These shifts are already taking place. The market has already demonstrated that it can adjust fairly rapidly back to its

Table 8. Summary of cost differences between integrated and open market systems for Choice steers from 350 to 1050 pounds

Type of expense	Open market system	Integrated marketing system	Advantage (disadvantage) to the integrated system
		(dollars/head)	
Auction market fees	5.18	-	5.18
Feed for regaining shrinkage	4.83	2.90	1.93
Medication	4.34	2.49	1.85
Order buyer's fee	1.75	-	1.75
Interest	16.10	14.44	1.66
Pasture expense	15.91	14.41	1.50
Death loss	4.43	3.61	.82
Trucking expense	5.40	4.75	.65
Variable labor	10.84	10.29	.55
Loss to chronic sickness	.76	.57	.19
Subtotal			16.08
Feed for maintenance growth	82.86	87.28	(4.42)
Business trips	-	1.00	(1.00)
Fixed costs	3.47	3.97	(.50)
Subtotal			(5.92)
Total advantage to integrated system			10.16

Source: (3).

old habits of paying a substantial premium for Choice beef when it is scarce and where price is an overriding factor, many people are selecting the lower price product. This translates into more stockers and "two-way" calves being kept on forage in the South. The extent of finishing on forage in the South is very unclear to us.

An efficient economic system will make adjustments to change in costs on both the demand and supply side. The first conclusion that follows from a premise of higher cost is that less beef will be desired per capita. Secondly, the system will adjust to equate returns to grain and forage. Thirdly, increased forage will be fed but to what and where is a complex question. This leads to the fourth point of which we are less sure: Increased forage production may come from the non-South, because the South apparently requires higher levels of nitrogen fertilizer per unit of megacalorie from forage than other areas of the United States. Perhaps some research could be done to shed some light on this point. Research information on this matter is basic to

analyzing the future competitive position of forage finished cattle in the South.

Another more subtle consideration is the likelihood that the South's dairy industry--also faced with high grain cost--may be able to outbid beef for much of the extra high quality forage.

Clearly we are faced with a substantial adjustment in a whole set of economic and technical relationships that requires new analyses and new research efforts. Many of the necessary short-run adjustments are fairly obvious; however, some quick, intensive analyses along with the traditional longer run research projects would likely have a high payoff.

Problems and research needs have been identified previously but a few explicit statements on these matters are appropriate because they are fundamental to evaluation of the economic feasibility of forage fed beef in the South.

1. The economics of using land in the South for production of high quality forage required for finishing beef versus alternative use of land mainly cropland and pastureland for cow-calf enterprises. Representative farms could be programmed to derive the necessary price of forage required to equal the value of using land in different areas of the South for crops and for feeder cattle at a range of prices.
2. The effect of changing input prices required for beef finishing on: (a) systems of beef finishing; that is, the type of cattle, length of feed, etc., (b) levels of production, and (c) location of feeding; are some fundamental questions that the industry is constantly in need of to adjust to changing conditions.
3. An organizational problem that needs very careful research is the problem of coordinating planning of production of finished beef and providing the available packing plant capacity and assured favorable market relative to the Midwest and Plains. In scattered production of finished beef, different methods of vertical coordination may be required to take advantage of a favorable competitive position in forage-fed beef. In other words, it may be necessary to find ways to link the feeding and packing stages in ways that will encourage long-range planning and investment.

LITERATURE CITED

1. Brodnax, H. D., Jr., W. C. Couvillion and F. H. Tyner. 1975. Economics of winter grazing 300-600 pound calves in Mississippi. Miss. Agr. Ext. Serv. Publ. 932, 4 pp.

2. Dietrich, R. A. 1971. Interregional competition in cattle feeding economy with special emphasis on economies of size. Tex. Agr. Exp. Sta. Bull. 1115, 55 pp.

3. Farris, D. E. and Ed Williams. 1973. Potential efficiencies due to integrated cattle operations compared to the open market. Feedstuffs 45:23.

4. Farris, D. E. 1975. Cattle cycles--erratic and inescapable. Texas Cattle Feeders Annual. Tex. Cattle Feeders Association, Amarillo, Texas, 3 pp.

5. Gee, C. K. and J. K. Pursley. 1972. The economics of retained ownership of calves on Eastern Colorado cattle ranches. Colorado State Univ. Exp. Sta. Bull. 551S, 13 pp.

6. Heady, E. O., et al. 1963. Beef-cattle production functions in forage utilization. Iowa State Univ. Res. Bull. 517, 37 pp.

7. McGrann, J. M. and D. E. Farris. 1973. Potential for increasing beef production in Argentina, pp. 36-40. In Beef cattle research in Texas, 1973. Tex. Agr. Exp. Sta. Consol. Progr. Report 3220.

8. Nix, J. E. and J. W. Hubbard. 1974. Response of beef production in the South to changes in farm-level beef prices. So. Carolina Agr. Exp. Sta. Bull. 579, 108 pp.

9. Poenisch, K. R., R. D. Kay and F. M. Rouquette. 1975. Economic analysis of forage systems and beef production in East Texas, Tex. Agr. Exp. Sta. Dept. Tech. Report 75-5, 25 pp.

10. Saunders, F. B., et al. 1966. Costs and returns for alternative cattle feeding systems in Georgia. Ga. Agr. Exp. Sta. Bull. N.S. 163, 61 pp.

11. Walker, W. G. and T. D. Phillips. 1966. Costs and returns from drylot feeding of cattle in Mississippi. Miss. Agr. Exp. Sta. Bull. 732, 24 pp.

12. Whitson, R. E., R. D. Lacewell and J. Shipley. 1973. Economic analysis of irrigated wheat and stocker grazing alternatives in the Northern High Plains of Texas and Oklahoma. Tex. Agr. Exp. Sta. Dept. Tech. Report 73-3, 50 pp.

13. Williams, Ed and D. E. Farris. 1972. Budgeted costs and returns of fifteen cattle feeding systems in four areas of Texas. Tex. Agr. Exp. Sta. MP-1022, 35 pp.

14. Williams, Ed and D. E. Farris. 1971. Feed/cattle price relationships and the optimum system and location of cattle feeding in Texas. So. Jour. of Ag. Econ. 3:77-86.

DISCUSSION

ECONOMIC ASPECTS

Discussion of the papers by:
Ray F. Brokken, Donald E. Farris and Raymond A. Dietrich

MODERATOR: Odell L. Walker, Oklahoma State University

QUESTION: J. P. Fontenot, Virginia Polytechnic Institute and State University. Dr. Farris, what price basis did you use for the seven rankings in terms of the least cost for the use of forage?

ANSWER: Donald Farris, Texas A&M University. This was for the period 1966-1968 when fertilizer and grain prices were quite low.

QUESTION: J. P. Fontenot, Virginia. Did you try to guess how the results would be with today's prices?

ANSWER: Donald Farris, Texas. No! One of the points I tried to make is that pasture system was the cheapest, even then. Now it's bound to be the cheapest. But how the finishing versus the warm-up and feedlot rank is just not clear.

QUESTION: J. P. Fontenot, Virginia. I was interested in the fact that the system involving backgrounding of calves with a high ratio of corn silage to milo ranked fifth in cost. We usually find we get very good response with this. In fact, we can approach feedlot performance with this much grain. I was wondering what price was used for corn silage?

ANSWER: Donald Farris, Texas. The price used on corn silage was $8/ton.

QUESTION: Bruce Bullock, North Carolina State University. Perhaps I misunderstood what Dr. Brokken said, but I understood him to say that even with fairly high prices of corn, at least up to $3.50/bushel, that we would still see high energy rations fed to cattle. Yet Dr. Farris, on the other hand, kept saying that we are going to see increasing use of forages. I would like to hear your comment on what I thought was quite a contrast between your two points of view.

ANSWER: Ray F. Brokken, ERS, USDA, Corvallis, Oregon. I think very strongly that we will have high energy rations remaining in the feedlot sector. There are some points of departure in our analysis. We want to talk about equilibrium all the time but no one has an

equilibrium point here, apparently. Now, it's true that the prices being bid for feeder cattle aren't covering the cost of production. When cattle inventories are adjusted down, the prices of these cattle are going to go back up. It is not clear to me that the cost is so low in the grain sector. I think Texas may be one of the lowest in the region but we have to look at what is going on now with the cost of good feeder cattle around the country. The Southwest may be the very lowest cost region in the United States, so you can't really look there as a basis point for what cattle prices are going to be. But elsewhere the cost of growing calves is very high and so I don't agree that we will have lighter weight cows necessarily. When you get back to the high prices that we must have in order to put returns back into the cow-calf sector, these calves are not cheap. They are very expensive and cost curves that I was working with recently showed decreasing cost as the grade of finished cattle increases through the choice grade, and people talk about choice being high priced meat. That is not so! It has been the cheapest beef we have had in an equilibrium context. To have all good grade beef would have meant we would have had less meat per slaughtered animal. Slaughter costs on the good grade go up a little, too. And so, if you look at these average costs, it balances out. Costs are not increasing in the range of good. They are still decreasing. And so choice meat has not been an expensive meat--it has been our cheapest beef, and I think it will get back to that point if we start keeping our corn below $3.50/ bushel. So, there is a difference in our analysis.

On this matter of grain feeding, I do think that it does depend on the economics of substitution. It certainly varies, depending on what the price of forage happens to be in your region. The silage prices I used were more like $18 or $19/ton. That silage price has 6 bushels of corn in it. I don't think you will find alfalfa prices much cheaper anywhere than you will find in Eastern Nebraska, at $45/ton. This puts roughage on a very competitive price basis with corn, as compared to New Orleans where alfalfa is more like $70 to $80/ton.

COMMENT: Donald Farris, Texas. I think there is a point at which our comments can be reconciled, and that is, there are clearly times in the cattle cycle when you need to feed cattle to the choice grade, and a time in the cycle when a fairly large part of our feedlot cattle could be marketed at a good grade. I would like to see the data that says choice is cheaper than good. I am sure if you start back at the cow-calf operation, you are going to show that the cost continues to decline as the animal approaches 1000 pounds or more. However, we need more information on this and it should be disseminated.

COMMENT: Floyd Horn, ARS, USDA, El Reno, Oklahoma. I want to comment on something that Dr. Farris said with respect to the relative costs and gains in the High Plains. He indicated that the least expensive gain was from November through March, unless wheat prices exceeded $3.50/bushel. I submit that those gains would still have the best gain-cost relationship whether or not wheat exceeded $3.50, because

animals graze wheat during that period whether or not the feeder acknowledges it.

COMMENT: Donald Farris, Texas. Unfortunately, I was unable to explain that information in the detail that I should have been able to do. This was worked on by Ron Lathrow and some others. Their estimates were that grazing at that time of year did reduce wheat yield by some amount. As I recall, the reduction was about 12 bushels. This reduction would not deter you from grazing wheat until the price of wheat reached $3.50/bushel. I assume they were using 1975 cattle prices. When cattle prices improve, I am sure that answer would change.

COMMENT: John McCoy, Kansas State University. I'm inclined to comment on this forage topic in particular. Don Farris made the comment that there will be more forage in the ration. But I think he also said that economic systems adjust quite quickly or something to that effect. I am inclined to think that this just doesn't happen. In Southwestern Kansas cattle feeding areas, where we have the big lots, corn silage now costs about $26 to $30/ton. Hay is costing $55 to $60/ton. I talked to several of the managers of those lots in the last few days and they are skimping on forage. To them, it is a simple matter of relative price. If forage is cheap, they will feed it. It is not cheap right now and their rations are as high in concentrates as they have ever been. Now this, I think, can change quickly, and I think it did change earlier. They did cut down somewhat on grains; however, they are back to conventional levels at the moment.

COMMENT: J. P. Fontenot, Virginia. This relates back to the question about silage. If you calculate in our area 100 bushels of corn per acre and then relate it back to silage if corn is $3/bushel, silage would be $20/ton. If you calculate it on the basis of energy, using TDN for the basis of simplicity, this amounts to $71/ton in the case of corn silage or $133 in the case of corn grain. So you must put it back on an acre basis especially in the South where we do not have large acreages of corn.

COMMENT: Ray Brokken, ERS. There is a problem maximizing returns of productive feed per acre and gross errors have been made by doing this. What you are really trying to do is maximize the profits, or the annual rate of returns to your farm. Maximizing the returns per acre through beef production, i.e., maximizing beef production per acre, is not very closely related to maximizing the annual rate of return to that farm. This is a message that we must work with. I think this is one of the real problems we must watch. We need to economize, using the right objectives, and maximizing the beef produced per acre is not very often the right one, in my way of thinking.

COMMENT: Donald Farris, Texas. The problem is a question of alternatives. Can we make more money for the farm operation with the production of forage, or can we make more money with those same resources in the production of soybeans, cotton or some other crop? I think that the operator may be able to figure this out if he knew what the market was going to be, instead of having to figure it out after the fact.

QUESTION: Wayne Hanna, ARS, USDA, Tifton, Georgia. I understood Dr. Farris to say that the South is at somewhat of a disadvantage when it comes to producing high quality forage. I assume that this was based on the fact that later he stated it took more nitrogen to produce forage in the South than it did in other places. Do you think there are other disadvantages to producing high quality forage in the South?

COMMENT: Donald Farris, Texas. Well, I was hoping this would generate some answers instead of specific questions.

COMMENT: Wayne Hanna, ARS. The reason I bring this up is that I think the South has unlimited potential for producing high quality forage for a number of reasons. For example, the length of the growing season, the rainfall, the number of grasses and legumes that will grow in the South that fit into various management systems, and the amount of land that is available for improved forages. It seems to me that there are many advantages to producing high quality forage in the South. The potential is almost unlimited.

ANSWER: Donald Farris, Texas. But the large question seems to me to be the question of the cost of the inputs to produce that forage, even though you do have a long growing season, adequate rainfall, and a variety of improved forages.

QUESTION: Wayne Hanna, ARS. Is there data which indicates that it costs more or takes more nitrogen to produce a ton of forage in the South than it does in some of these other areas? Is it significantly different?

ANSWER: Donald Farris, Texas. This is certainly not my area and I was hoping to get an answer here from some of our agronomists.

COMMENT: Odell Walker, Moderator, Oklahoma State University. It seems to me that one of the points and one of the reasons agronomists and other scientists are together here today is that we do have different viewpoints. The question of physical potential versus economic potential must be resolved with additional research. There certainly is a difference much along the lines that Ray Brokken was talking about originally that tends to focus on the analysis.

QUESTION: Henry Gilliam, ERS, USDA, Raleigh, North Carolina. As a matter of clarification Dr. Farris, you quoted some estimated breakeven costs in 1975 for production of feeder calves, stocker cattle and grass-fat stock. I would like a little more information on what areas of cost were considered there. I doubt that they can cover all costs at $35 calves.

ANSWER: Donald Farris, Texas. The $35 breakeven point was exclusive of the cost of land and management.

QUESTION: Walter Wedin, Iowa State University. I would like to ask a question of Ray Brokken. If you look to the future and you are modeling and so forth, my hypothesis is that with Environmental

Protection Agency (EPA) restrictions on row crop land which by 1985 are supposed to make our streams fishable and swimmable, we are not yet including the true cost of corn production that we are likely to have. I am wondering if your $3.50/bushel is going to cover it in 1980 or 1985. I would just like your opinion.

ANSWER: Ray Brokken, ERS. Something probably will have to give on that. I haven't considered the EPA. It has a lot of impact on some of the things that they do in Oregon, too. I don't know if it is true that corn does have this cost. It is also true that if they start covering it, costs will go up.

QUESTION: J. R. Johnston, ARS, USDA, College Station, Texas. We look down the road, and we think in terms of maximizing the efficient use of resources going into beef. The question I have is, are we giving enough attention to slaughtering, packaging, and storing the beef at the right time because the producers, whether it is the slaughter calf, or the grain-fed beef, are constantly the victims of price fluctuations? What is going to be involved in slaughtering that animal at the right time, to maximize the efficient use of resources, and then, taking it out of storage in order to smooth out the ups and downs in prices? Are we giving any attention to this? I think it is very appropriate to this matter of producing forage-fed beef in the South because in specific regions that is going to be a certain period of the year.

COMMENT: Odell Walker, Moderator, Oklahoma. One of the things Wayne Purcell was saying this morning is that everything is open to question if you look at the system of approach. You cannot very well look at all possible alternatives.

COMMENT: Ray Brokken, ERS. I know it is being looked at in terms of efficient marketing of beef by my colleague, Jack Crow at Oregon State. For example, they might say that we have not marketed this many cattle in this amount of time in order to keep the price from doing something we don't want it to. If you look at these inventories and the demand functions and carry along the model over long time periods, with the time periods broken up into quarters, the approach suggests a more active role for the USDA and outlook work. It suggests a need for this kind of adjustment or this kind of treatment of marketing. I am not well grounded in this type of approach, but I do know that it is one aspect of the question that you are asking.

COMMENT: Donald Farris, Texas. I think that the current decentralization in the industry, and the current attitude of the industry sort of precludes doing a lot of fruitful work in this area until producers are interested in getting at the question.

QUESTION: Luther Keller, University of Tennessee. Several of the comments have been based on the assumption that the consumers are going to eat less beef and we are in a new ball game. I find this a little hard to understand. I know that the economy is depressed now. There is also the energy crisis which is a strange situation; however, is

there a strong inference that consumers are really different than what they have been in the past?

ANSWER: Donald Farris, Texas. In 30 minutes it is difficult to cover everything. I should have said that all other things being equal, an increased price of beef to cover the high cost of energy would result in less beef being purchased. Now, when you balance it against higher income, perhaps it is really not all that clear. Just looking at the higher cost of energy and working through the system, I think that you would have to conclude that consumers would be willing to purchase less beef at higher prices. If income increased enough to offset that, you would get a different result because beef purchases are very sensitive to income change.

STRUCTURE AND PERFORMANCE OF THE MEAT (BEEF) INDUSTRY*

Willard F. Williams**

The topic I have been assigned is broad in scope and complex. In addition, I am handicapped by economic terms with popular definitions which do not necessarily agree with their technical use by economists. Even the frequently repeated terms "demand" and "supply" seldom are used properly by the media or the public. For this audience of mixed disciplines, therefore, I am compelled to begin with some economic concepts and their definitions.

Market Performance and Related Concepts

"Market performance" is a term from an area of economics known as "market structure analysis." For present purposes, I will be applying it on an industry-wide basis rather than in strict reference to "a market." It refers to "end results" of economic activity. In a restricted sense, of course, there are no "end results" as economic activity is a continuous process. In using the term, however, we are referring to those things of vital importance to consumers or other buyers. These might include the level or nature of production. U. S. agriculture, for example, has been criticized recently for its failure to produce more food. Performance also would include dimensions such as the quality of output, the variety of types or qualities made available to buyers, durability, cleanliness, prices and progress of an industry in adopting new technology or methods. Performance of the market is concerned with results in providing necessary services such as transportation, processing, packaging, advertising, and promotion at reasonable cost. Remember that "performance" is concerned with results rather than with measures of it such as efficiency.

Structure and Conduct

Two other terms employed in connection with "performance" should be understood. These are "structure" and "conduct." Structure refers, basically, to those physical or organizational characteristics of an

*Paper delivered at The Southern Regional Forage-Fed Beef Research Workshop, New Orleans, October 20-22, 1975.

**Horn Professor, Texas Tech University.

industry segment affecting competition. These include the number of plants and firms, the size and distribution of firms, the types and type distribution of plants or firms and geographical location. "Number" and "size" are self-explanatory. "Type" includes legal classification (partnership, corporation, cooperative, etc.), the degree of specialization with respect to product mix, procurement patterns, supply patterns or type of customer, nature and degree of integration, product differentiation or other attributes of firms that distinguish them as to type. Thus, we are concerned from time to time about the rising dominance of large scale, horizontally integrated firms in food retailing. In meat packing, size, specialization, concentration and vertical integration are areas of interest. Structure refers to the physical makeup of the market or industry under consideration.

Market or industry "conduct" is what people do in business. More precisely, it is the competitive behavior or strategy of firms in buying, operating or selling. It includes decisions to change size or type of firm, to integrate or to alter strategy in production, pricing, advertising or promotion. In a word, it is the popular definition of "competition."

Conduct obviously may change the structure of an industry. The two, however, should not be confused. An FTC action resulting in the dissolution of firms within an existing market structure, for example, is quite a different thing from regulations confining the range of acceptable conduct. In earlier years, the emphasis in antimonopoly programs or policies was on structure. The ultimate aim was to alter the number, size or types of firms, the structure, more in line with our structural ideal of the "perfect market." More recently, the emphasis has been on defining the perimeters of acceptable conduct.

It generally is assumed that the dominant flow of effects is from structure to conduct to performance. A high concentration of few but relatively large firms, for example, is presumed to be associated with conduct which, in turn, leads to results, performance, not fully in accord with the public welfare. A reverse flow of effects, however, is recognized; i.e., consistently low profits or gross inefficiency in time likely would affect structure, again through conduct. Structure, however, also is affected by many otherfactors including (1) supply-demand characteristics of products produced, (2) barriers to the entry of new firms to the industry erected, possibly, through prior conduct, (3) natural advantages or disadvantages such as those associated with strategic locations, and (4) public laws, regulations or services such as those providing for patents, meat inspection, grading, market news, and research.

Measures of Performance

The public, politicians, economists and others have tried to apply many different yardsticks to performance of industries including the livestock-meat industry. On this score, however, confusion reigns. Much depends on end results desired. For example, do we or do we not

want all of the processing, packaging, parking, check cashing, advertising, and promotional services currently offered by modern retail food stores?

One of the most commonly applied measures of performance is efficiency, which, to distinguish it from another type, I shall call "operational efficiency." As an ideal, we expect the livestock-meat industry to produce, transport, process, fabricate, sell and provide all necessary services at the lowest possible cost. While conceptually simple, there are two or three major problems with operational efficiency as a measure of performance. First, we do not always know the costs--different firms have different costs. Whose costs are we talking about? Second, we seldom know the costs relative to what is possible or feasible. We also have problems with popular measures of costs or efficiency. For example, marketing margins, which consider only raw material costs relative to selling prices, are notoriously poor and often misleading measures of efficiency. Finally, operational efficiency does not necessarily insure reasonable profits and prices to consumers. A monopoly, for example, might be about as operationally efficient as possible but charge an exorbitant price for products or services.

In view of some of these problems, we have developed another concept of efficiency which I call "pricing efficiency." Pricing efficiency is concerned with (1) the accuracy, rapidity and effectiveness with which prices and other marketing information are developed and disseminated, and (2) the costs associated with providing and maintaining the levels of accuracy, speed and effectiveness attained. For example, pricing systems on feeder cattle, which I consider archaic and inefficient, undoubtedly could be improved substantially. The questions concern costs or inconvenience versus benefits.

"Accuracy" and "effectiveness" are key words in the definition of pricing efficiency. An efficient pricing system should generate prices which reflect true value. In the cattle industry, for example, generations of buyers and sellers have taken great pride in "out-dealing" one another or their competitors. This is fine, but if it results in prices "out of line" with fundamental values, then, regardless of who benefits, we have an inefficient pricing system. If consumers prefer one type of beef over another, an efficient pricing system will reflect these preferences through appropriate price differentials back through the marketing system to producers.

An efficient pricing system will effectively allocate producer resources to those products and to particular grades and qualities of these products most desired by consumers. Except as prevented by acts of God or absence of appropriate technology, it will effectively prevent gluts and shortages in the market over time and among the various types of products and services desired. This, of course, is a tall order.

Highest levels of both operational and pricing efficiency, as we shall see, are not necessarily found within the same industry structure.

Operational efficiency, for example, might be highest within the structural framework of a few large firms. Pricing efficiency, on the other hand, might be greatly improved with a structural change toward a larger number of much smaller firms. In this connection, the nation is schizophrenic. We are not certain whether we want industries of relatively few, large and operationally efficient firms or industries with a large number of more highly competitive firms. The solution probably must be some type of compromise. The public and most congressmen, however, probably are not aware of this.

The Critical Importance of Improved Pricing Efficiency

The concept of "pricing efficiency" deserves additional attention for several reasons. First, individuals and firms in all sectors of the industry, including researchers, are oriented toward physical activities and operational efficiency. Second, it is with respect to pricing efficiency that performance of the industry is most deficient. Producers and marketing firms seek operational efficiency of their own volition. Operationally, we receive relatively few complaints about the efficiency of the livestock-meat industry. Still, it is in the area of operational efficiency that we spend most of our research and extension dollars. One reason, I suppose, is that in considering pricing efficiency, the problems are more difficult to see or understand and it is here also that solutions are most elusive.

I do not mean to deemphasize the importance of operational efficiency. It could, and probably should, be improved substantially. Several papers, however, probably will dwell on subject matter closely related to operational efficiency. In fact, this may become the underlying theme of the entire conference. This, then, is another reason for briefly emphasizing pricing efficiency. Finally, much of the operational inefficiency that exists in the industry today, I believe, is at least partially a result of widely varying prices and incomes or, in other words, or pricing inefficiency.

Some of the industry, I am sure, would disagree pointedly with me on my assertions concerning pricing deficiencies of the industry and go further to claim that given the absence of government interference and considering the highly competitive nature of most, if not all, industry sectors, pricing accuracy and effectiveness are about as high as possible. If this were so:

- --why do we have such a thing as a cattle cycle with alternating periods of relatively high profits and severe losses?
- --why is it that bunching of cattle on feed or concentrated marketings and associated low prices are serious problems?
- --why are there long leads and lags among prices at the producer level, at wholesale, and at the retail level with associated wide variations in marketing margins?
- --why does so much beef move from packer to retailer on a formula basis without particular regard for actual value differences?
- --why are there wide unexplained regional differences in prices of feeder cattle of the same grade and quality?

--why are there wide variances, even at the same market on the same day, among auction prices of the same grade and quality of cattle?

All of these are evidences of inefficiencies in the functioning of the pricing system. In the "perfect market" of the economist with which the founding fathers of our nation were conceptually familiar, they would not exist. Quick and effective price adjustments both geographically and through time would produce immediate adjustments thus preventing serious gluts or shortages and unjustifiably wide price differences.

The Cattle Cycle

Among all of the factors or circumstances responsible for variations in producer prices and incomes, the cattle cycle has had the most severe, pervasive, and damaging effects. Cycles have been with us consistently for more than 100 years and are not likely to go away soon. They are the source of exceptionally high, as well as low, prices and the principal source of charges by consumers that the beef industry is performing inadequately in supplying desired quantities or qualities of beef.

Cycles are a result mainly of a popular assumption by producers and a biological fact of life. Producers tend to assume that whatever prices and price relationships exist today will continue this way indefinitely and they tend to make production plans and decisions on this basis. Once the decisions are made simultaneously by large numbers of producers, a necessary biological lag produces an illusion of well being. Higher prices on the assumption that these will continue entice others in the direction of expanding production.

Cycles produce operational inefficiency as they result in decisions inconsistent with the long-term economic well being of the industry. On the upswing, they result in excessive allocations of investment funds in breeding stock, in production facilities, and in marketing facilities and services. During the liquidation phase, breeding plans and programs are disrupted. Expensive breeding stock is necessarily liquidated at sacrifice prices. Facilities and services fall into disuse that later must be rebuilt or redeveloped.

The cattle cycle is an economic disease. We spend millions on research and treatment of animal diseases. How much do we spend on the real income killer, the cattle cycle? We assume that diseases can be cured but we view the cattle cycle like death and taxes as inevitable and here to stay. I deny this. Cycles are sufficiently predictable and their causes sufficiently well known that through research and education they could essentially be eradicated.

A problem is that when prices are rising, no one wants to talk about or consider the possibility of lower prices. When they are high, the emphasis, even among the professionals, is on beef shortages and

thoughts of a "brave new world" instead of on the economic Grand Canyon into which the industry is about to plunge. When prices are down at levels which are devastating the industry, the emphasis shifts to immediate short-term solutions rather than to possibilities of excessive liquidation and a return to price levels which will be generating another cattle cycle.

Cattle cycles exist because the pricing system, including interpretations by researchers and extension specialists, fail to provide accurate, adequate guidelines to consequences of current decisions. Remedies are needed and these, I am sure, can be developed.

Other Evidence or Major Sources of Pricing Inefficiency

Within shorter and narrower time frames, the bunching of cattle on feed and concentrated marketings produce effects on prices and incomes of cattle feeders almost as severe and devestating as those of the cycle. For example, severe cattle feeding losses in 1967, in 1970, and during late 1973 through early 1974 were not the effects of the cycle but of bunching and heavy backlogs of finished cattle on feed. Effects, however, are much the same. In fact, my data and analyses suggest that under normal conditions, there are three- to four-year cattle feeding cycles.

Again, the pricing system in these instances provides inadequate or misleading guidelines for decisions by producers. It is the producers themselves who suffer. Nothing is more destructive to producer bargaining power at any level of the system, as we have observed in recent years, than an excessive supply of cattle relative to market requirements for them. Bunching, as well as cycles, result in operational inefficiency. They also lead to decisions by packers as well as producers which compound the problem of pricing inefficiency. For example, packers generally do not begin to buy for future delivery when supplies are large and prices are low. They wait instead until supplies are tightening and it appears that prices are going significantly higher. This tends to shift future demand back toward the present, to boost prices to levels which generate consumer resistance and to produce severe downside reactions as demand drops and as packers begin drawing on supplies purchased earlier.

A variety of circumstances can lead to a backlog and bunching. Sometimes producers simply become too optimistic and place larger numbers on feed than are consistent with a reasonable expectation of continued price stability. In the winter of 1973, large numbers of lightweight cattle were placed on feed. A severe winter retarded gains on the heavier weights. Then in the spring, heavier weight steers off lush wheat pastures moved in large numbers to feedlots. Nearly all were scheduled for market during the second half of the year. Even in the absence of a consumer boycott in April and price ceilings into September, bunching and a severe deline in prices for late 1973 could hardly have been avoided after June.

A sharp and unexpected downturn in demand also is a possible source of bunching and one which producers can hardly be expected to anticipate

without help. Consumer demand, however, does not drop without reason. Techniques are needed for early detection and forecasting of variations in demand.

The growing incidence of formula pricing between packer and retailer is threatening pricing efficiency of the entire livestock-meat industry. This aspect of industry conduct also illustrates vividly the need for compromise between the goals of operational and pricing efficiency.

I had the opportunity several years ago of making a confidential study of formula pricing and the Yellow Sheet for USDA and accordingly, I have devoted some time and thought to these topics. I do not have the space here to explore thoroughly all of the ramifications of these considerations. A few points must suffice.

Formula pricing is operationally efficient as it saves time and is applied simply and easily. Typically, a formula arrangement calls for delivery at a specified time in the future, normally a few days ahead or on a particular day of the week, at an agreed upon discount or premium to the "Yellow Sheet." Once the formula is agreed upon, about the only decision that needs to be made each week is how many carcasses will be shipped. Even this sometimes is determined for an indefinite period into the future. The formula assures the packer of a market at competitive prices. It also assures the buyer of a continuing supply source at prices in line with those paid by competitors.

There are three major interrelated problems with formula pricing. First, it places the heavy burden of responsibility on the Yellow Sheet or other wholesale price reports for accuracy. Second, and more important, formula pricing tends to destroy the pricing basis itself. To illustrate the point; let us suppose that all major buyers and sellers of beef began trading on a formula basis. Who would be left to report prices to which the formula is to be applied? In large degree, this situation has already developed. The Yellow Sheet and USDA reporters cannot accept formula prices as bases for reporting; they would be reporting their own prices. As a result, the Yellow Sheet is forced to rely heavily on meat brokers and other fringes of the beef industry rather than on the mainstream for daily reports. USDA reporters encounter similar problems. Thus, formula pricing weakens the price making structure and makes it more vulnerable to manipulation. In fact, formula pricing, and this is the third difficulty, provides new incentives for manipulation.

Accurate and dependable information on wholesale prices, it seems to me, is the key to efficient pricing throughout the beef industry and at the producer level on live cattle. Once this pricing basis is destroyed, then the industry is immediately faced with the pricing problems of the egg industry with which many of you may be familiar. We arrive ultimately at some institutionalized pricing system.

The Beef Marketing System: Packer to Consumer

Most of you probably are familiar in one degree or another with the dramatic changes in structure and conduct in meat packing, wholesaling, and retailing that have taken place since World War II. These, in general, have contributed to improvements in operational efficiency but have led to increasingly serious questions concerning pricing efficiency. My own view is that both operational and pricing efficiency are greatly improved compared with pre-war conditions. Problems and deficiencies, nevertheless, are apparent.

Structural Changes

The structural revolution of the beef marketing system was not the result of arbitrary decisions of corporate giants or happenstance. In a large degree, they were necessary alterations in line with changes that were taking place among consumers. After World War II, tastes and preferences of consumers apparently shifted noticeably among the various meats as well as between meat and other foods. They began demanding increased quantities of the more expensive and higher quality meats. While they wanted variety available to them, consumers began demanding more uniformity within types and kinds. They began seeking "repeatability" in their experiences among units of meat products and overtime. They wanted each of several steaks or roasts to cook the same and eat the same and they wanted to be able to buy the same product week after week. Buying habits and practices of consumers also changed and they, accordingly, began demanding more services of retailers and others along with their meats. Consumer insistence on service, quality, and uniformity was nearly matched by the attention consumers gave to prices. The marketings system was presented with the necessity of meeting consumer demands at reasonable costs. Improved operational efficiency became essential.

The rise of the supermarket and of the large scale food chains is a matter of record. Less well known are the struggles of the independents through affiliated voluntary or cooperative groups to meet the competition of the corporate chains. The net result, as far as agriculture is concerned, is much the same, however, as if all operated as corporate entities. More than 90 percent of the food sold through grocery stores and a high percentage of beef is now retailed by the corporate chains or the affiliated groups. This has meant a shift in buying from purchases on a LCL basis from local suppliers to carlot procurement practices on a national basis. In line with consumer demands, quality and uniformity through tightening specifications were increasingly emphasized.

Recently, the incidence of mergers and consolidations among food retailers has slowed, but this could be temporary. It nevertheless is true that relatively few individuals at retail are responsible for the bulk of the beef purchases made in this country. On the other hand, any successful effort in the interest of increased competition and pricing efficiency to break the existing structure and substitute a

much larger number of smaller firms probably would reduce operational efficiency substantially. Since this is at least vaguely realized, the regulatory agencies have shifted emphasis to "hand slapping" and additional rules on competitive conduct.

At meat packer and wholesale levels, a counter trend toward a larger number of smaller firms developed during the 1940s and the 1950s. The "big four," once dominant, declined in relative importance. Although large numbers of very small local packers disappeared from the industry, we emerged with relatively large numbers of fairly efficient medium volume firms. I refer to the wholesale, "shipper type" packer operating independently on a carlot basis. Structural changes at retail levels contributed to these developments. National systems of distribution through the local packing house branches declined as large numbers of small stores and meat markets were replaced by fewer supermarkets supplied largely by corporate or affiliated food chains. Widespread use of the carcass grade standards also was a contributing factor. Those provided independent packers with more nearly equal access to national brand names such as "U. S. Choice" and to the burgeoning carlot market.

In the last ten years, the prevailing trend in meat packing and fresh meat distribution has again been reversed. A new generation of larger and more efficient packers has emerged. Despite the demise of ASP, the trend, I believe, will continue. I foresee the disappearance of large numbers of medium-, as well as small-volume packers in all areas of the country. The dominant packers in beef, as in pork, will be large-scale organizations capable of shipping easily and quickly to any areas of the country on a carlot basis according to specifications. They will have elaborate breaking and by-product handling facilities. Operationally, such firms will introduce new levels of operational efficiency but even more serious questions may arise concerning competition and pricing accuracy.

Recently, changes similar to those of the retail food store sector have been taking place in the restaurant industry. Large scale restaurant chains are rapidly replacing small, locally owned coffee shops, dining establishments, and clubs. Food franchising has become popular. While franchise outlets are locally owned or leased, most major problems of procurement, distribution and national advertising are handled by the parent organization. Franchising may be a phase in the structural reorganization of the restaurant industry. Ultimately, the parent organization probably will be exercising much more direct control.

Implications of the changing structure of the restaurant industry are only beginning to be realized. Many of these are utilizing lower quality beef much more effectively but tight specifications are developing. Vertical integration, control over supply and supply sources, and internal efficiency are receiving new emphasis. For example, one national restaurant chain is considering a program of placing bulls on feed, having these slaughtered on a custom basis, shipping the beef to a centralized cutting and processing facility, and distributing from this point on a national basis.

Operational Efficiency

Regardless of our attitudes concerning the structure of the beef marketing system, input-output ratios in meat packing, processing, transportation, and retailing must be rated high and they are improving. Technological innovations are being introduced every day. Automated and mechanical cutting and packaging techniques and flow-through systems continue to revolutionize the industry.

Most progress has recently been and in the near future probably will be made in the meat processing sector of the industry. Here, growth, changes and development are being required partly by alterations in structure and conduct of the restaurant and retail food store outlets. Larger and technologically superior meat processing plants are developing. Such firms as they develop, become much more concerned about a continuing stable source of supply. Considering historical variations in slaughter cow marketings, it may become necessary to produce breeds or types of steers and heifers especially for the processed beef market.

One of the major glaring areas of inefficiency in the beef marketing systems is the continued distribution of carcasses or primal cuts to retail stores. It is at that point still that most of the cutting to consumer-size portions is accomplished. The resistance of consumers to beef preserved through freezing or other methods, opposition by unions of retail butchers, and the absence of technological breakthroughs are mainly responsible. Still, some progress is being made through centralized warehouse cutting facilities and new methods of breaking which are leaving more bone and by-produce at the packing plant.

Price Efficiency

Aside from the matter of formula pricing and despite structural changes from meat packer to consumer, I would rate pricing efficiency of the beef marketing system relatively high. The market use of carcass quality and yield grade standards, food chain procurement specifications, and the acquired knowledge of specialists engaged in buying or selling beef every day tends to direct each carcass or cut toward its highest valued use and this is what pricing efficiency is all about. Nevertheless, it could be substantially improved here as elsewhere.

Each time a consumer is misled in buying beef, with respect to quality or through cutting or packaging practices, pricing efficiency drops. It drops because someone, to use the vernacular, is being "ripped off." Although progress is being made, a higher degree of uniformity with respect to cuts, cutting, and quality designations probably should be required. Deception is common, especially by independent meat markets and locker plants.

It is possible that quality and grade labeling should be made mandatory from packer to consumer. This, however, would involve costs and affect operational efficiency. Both benefits and costs, it seems,

deserve careful research study. With Nader on the loose, it is probably coming anyway.

Cattle Feeding and Implications of Rising Capital Requirements

In turning to consideration of performance in the cattle producing and feeding sectors of the industry, we must immediately introduce another factor which has been greatly affecting performance. Capital is a necessary input to production. Increasing inputs of capital are being required in production and feeding sectors as well as in marketing sectors of the industry, but implications of the capital requirements are more serious, it seems, in production activities than in marketing.

In the controversy over grain-fed versus forage-fed beef, what we are arguing about is not the efficiency of large-scale confinement systems as compared to others. The feedlots did not encounter serious financial problems and decline relatively in importance because they were less efficient. Given the goal of feeding cattle to a high level of quality as presently defined, the necessary risk capital and feed grain-cattle price relationships necessary for profits under any system, there probably is no more efficient system of producing beef for the mass market than through large-scale confinement facilities. The costs of procuring feeder cattle, the labor and fixed costs of feeding and the selling costs per pound of beef produced probably are lower in large scale confinement systems than in any of the others yet devised by man. Death losses, conversion ratios, feed waste, and other measures also attest to the efficiency of the large-scale confinement feeding system.

What then, are the sources of serious financial problems of the feedlots? Under the circumstances that developed during 1973-75, losses in all phases of beef production were inevitable. The losses were not confined to large-scale feedlots or to cattle feeders. Prices of feeder cattle and feed grain were bid up far out of line with beef prices. Events of 1973 produced a backlog of cattle on feed. This was followed about mid-1974 by the liquidation phase of the cattle cycle which began forcing large numbers of forage-fed steers and heifers and breeding stock to market. As losses developed and grew larger, the cattle feeding customers of commercial feedlots, the owner-risk takers, dwindled both in numbers and in terms of numbers fed. Traditional sources of financing disappeared with the customers. With downtrends in feedlot inventories relative to capacities, costs rose but this was a result rather than a cause.[1]

If ravages of the cattle cycle and other sources of wide variations in cattle and beef prices are permitted to continue, drastic changes are likely to take place in the structure and ultimate performance of the cattle industry--particularly at producer and feeder levels. For this reason, we focus attention on capital requirements.

[1] In the case of the feed grains, there were contributing international events. These, however, were well-known and external to my principal theme.

Capital requirements of production and feeding operations have skyrocketed and probably will continue higher. These alone are pressuring and impelling the industry at most levels toward fewer and larger operations. However, when large and rising capital requirements are combined with devastating periods of severe losses, implications become much more serious. Regardless of the level of efficiency attained by a rancher or feeder, this becomes unimportant if he does not have or cannot obtain the capital necessary to survive through the bad times to the good times. Survival and financial progress become a money game. This game, of course, is one in which the large non-farm corporations and the conglomerates are skilled players. The problem of sustained periods of severe losses in cattle production and feeding will be solved but it may take a much larger and more permanent infusion of outside capital along with disappearance of commercial ranching and feeding as we have known it.

At this point, many would direct attention to the strengths and advantages of the American family farm system. Within the past few years, however, the family farm system has lost much of its insulation from the hard facts of sharply rising cash costs and gyrating market prices. The typical commercial farmer, rancher or feeder has been thrust into direct confrontation with the harsh winds of economics. I fully anticipate a return of the surplus farm commodity conditions that existed for 50 years prior to 1972-73. This time, agriculture will find that the Great White Father, the government, will have receded into the wings.

We thought that our large-scale feedlots in West Texas were sufficiently efficient and financially strong enough to weather any economic storms. We were wrong. Even before the onset of the recent holocaust, trends toward consolidation and integration from within and from the outside mainly for financial security were clearly apparent. The commercial cattle feeding industry of the Southern Plains will recover but it will do so under conditions of a much higher degree of horizontal and vertical integration than before.

In a later section of this paper dealing more directly with forage-fed cattle feeding, we shall pick up threads of the discussion left dangling at this point.[2]

---

[2] In reviewing this section, Breimyer suggests a different orientation and emphasis on tax write-off financing techniques of the large feedlots. My position is that the extent to which tax shelters may have contributed to the buildup phase of the cattle cycle is a side issue which should be debated elsewhere. The principal points here are that, for whatever reasons, a cattle cycle existed (as they have for the past 100 years) and that rising capital requirements were and are a critical matter. Tax shelter financing was a result of a capital squeeze produced by industry efforts to meet what was termed at the time as an insatiable demand for beef. In the absence of tax shelter possibilities, the necessary capital might have been acquired through other avenues. If not, beef prices would have risen even higher thus increasing expansion incentives.

Producing and Marketing Stocker-Feeder Cattle

A wide array of views, ranging from belligerent support to condemnation, of performance in the cow-calf and stocker-feeder sectors of the industry undoubtedly is held. Prevailing attitudes probably are largely conditioned by views on the current structure and by goal priorities. Given a highly decentralized industry of fiercely independent producers and value systems which would preserve these at all costs, performance in the cow-calf and stocker-feeder sectors automatically would be rated "satisfactory," if not high. Those with more flexible attitudes toward change probably would rate performance much lower.

Operational Efficiency

My own view is that performance of the cow-calf and stocker-feeder marketing sector, even with little change in structure, could be substantially improved. Let us briefly consider operational efficiency.

A national average calf crop of 91-92 percent is commendable. It probably is among the highest of any of the developed nations of the world. As we all know, however, there are numerous instances of 60-70 percent calf crops. Cattle still are produced mainly on small farms and ranches where management capability often, even generally, leaves something to be desired. In many instances, nutrition and handling practices of breeding herds are little short of deplorable. Annual losses through deaths of 4 million calves and nearly 2 million other cattle are results of a whole host of problems and sources of operational inefficiency.

In marketing stocker-feeder cattle, excessive cross-hauling, the sale of the same calves through numerous auction facilities, mismanagement and handling in transportation, stress and loss of weight all are problems in which there seems to have been relatively little improvement. Livestock auctions probably are among the more inefficient facilities in the entire marketing chain. Convenient, yes, but what other industry can afford to utilize expensive fixed facilities only once or twice per week? There seems to be an excessive number of auctions in many locations and even on sale days, some are utilized much below capacity resulting in relatively high operating costs.

Inefficiency associated with the burgeoning growth of many different breeds of cattle is a "can of worms" which I shall only mention. In this respect, contrasts with the hog industry are striking. Hog producers began with established breeds and in working with these have greatly improved quality. In cattle, we are proliferating breeds almost endlessly. Some, undoubtedly, will bloom, wither, and pass out of existence. While I will not argue about claims for improvements through new breeds and cross breeding, costs of errors and floundering must be staggering.

Pricing Efficiency

Nowhere in agriculture is pricing efficiency so variable as in marketing stocker-feeder type cattle. Here, the old game among buyers and sellers of out-guessing and out-dealing one another persists, especially in country selling. Under such conditions, accuracy in the assignment of price according to value is questionable at best. In these modern times, it seems doubtful that we can continue to afford the luxury of ripping-off one another.

At auctions, cattle often are not adequately displayed or they are run through the ring in numbers too large for careful evaluation. Starting prices often are set too high or too low. Only one or two buyers sometimes are present for particular classes or there is collusion among them. At auctions in some areas, the cattle still are weighed as they leave the ring rather than before. Prior to that time, out-guessing one another is a popular pastime. From the standpoint of pricing efficiency, this is a little ridiculous. The auction, then, often falls short on the grounds of both operational and pricing efficiency.

One of the major problems and deterrents to improved pricing efficiency on stocker-feeder cattle is the lack of adequate, official, and uniform grade standards for such cattle. Despite all of the protestations of USDA, the official feeder grade standards are inadequate and in fact, practically useless.

Some of the large feeder cattle supply organizations, in an attempt to fill the void left by the official grade standards, have developed their own detailed specifications of classes, weights, and grades. The classifications and terms used, however, vary from one firm to another and are understood differently in various parts of the country.

The absence of adequate grade standards for feeder cattle result in other inefficiencies. For example, the accuracy, adequacy and usefulness of market price reports on feeder cattle appear to fall short of those on slaughter cattle. Descriptive shortcomings also may be at least partly responsible for wide regional differences in reported prices on feeder cattle. This, it seems to me, may be especially important for the South. I repeatedly encounter situations in the Midwest where potential feeder cattle buyers, generally farmer-feeders, are presented with high local or western prices substantially above those on comparable cattle in the South. These buyers find, however, that established market channels for buying in the South either are lacking or not well known. In the absence of reliable grade specifications, there are, of course, questions concerning quality.

Many high quality feeder cattle are produced in the South. A wide and well-known variation in quality and types available in the South, however, greatly emphasizes the importance of clear-cut distinctions and classifications. Although these may be apparent to experienced buyers, the feeder cattle sector of the industry, like most other

sectors and other industries, soon must surface into the world of trading in volume by description.

Despite recent tendencies, quality specifications at all levels from ranch to consumer remain important and this importance, I believe, will increase. When numbers are restricted and demand for feeder cattle is strong, most any quality will sell at a relatively high price but when supplies are large and demand restricted, everyone, it seems, prefers the higher grades.

The Forage-Fed Beef Sector

Since consumer and retailer specifications probably will become increasingly important, it is from this point of primary consideration that the issue of forage-fed beef production needs to be approached. The initial questions concern the extent and context within which forage-fed beef will meet retailer and consumer requirements. We have little solid information on this matter.

The forage feeder, obviously, has acquired a demand for his product, but there are indications that much of this was born of necessity. The buyers have had little choice. How much of this demand is retained as adjustments taking place in grain-cattle price relationships remains to be seen. After all, it was after the feedlot demand for feeders dropped and we began to wonder what we were going to do with the inflated and growing supply of stockers and feeders that the topic of forage-fed cattle became popular. It was then that we began to wonder about the goal of feeding to traditional levels of quality. We want to remember also that confinement grain feeding here in the South never has been particularly important. It is possible that given a demand for the final product, forage feeding, even in the South, is no more or less efficient or feasible now than earlier.

If, as seems likely, a strong consumer demand persists and will continue for beef fed to relatively high quality and assuming reestablishment of more normal price-cost relationships, prices of feeder cattle again will probably be bid up out of reach of the meat packer. If so, much of the demand for lower quality forage-fed beef will disappear and at least some grain will need to be fed for the higher qualities.

There also are questions about the most efficient sizes and types of operation for forage feeding. With the possible exception of the South, grass in most areas of the nation, contrary to popular assumptions, is expensive. Confinement may be more efficient for forage feeding as well as grain feeding and economics of large-scale operations are a fact of life. Here in the South, you may want to devote at least some thought to large-scale confinement forage feeding facilities. In any case, effects on operational efficiency of alternative forage feeding systems should be considered.

In directing the measure of pricing efficiency to forage-fed cattle, the question of grain-fed versus forage-fed again seems irrelevent.

The more relevant questions are those concerning marketing facilities, services, and production practices; i.e., with market structure and conduct. It may be operationally efficient to have large numbers of small-scale forage feeders selling independently to packer-buyers. This system, however, most certainly will result in a low and possibly unsatisfactory level of pricing efficiency. Quality variations and lack of uniformity will be contributing factors. Here, as elsewhere in the cattle feeding industry, "questionable" cattle will mean lower prices.

Centralized marketing facilities and organizations for such cattle, it appears, should be given serious consideration. Expanded and specialized market news reports also may be needed along with appropriate changes in the carcass grade standards. In this regard, the changes proposed by USDA, now delayed by court action, probably would have contributed significantly to pricing efficiency on forage-fed cattle at all levels of the system from farms to the consumer. Structural reorganization of marketing systems for feeder cattle and forage-fed cattle could involve a much higher degree of cooperation among the producers than has been realized. The ultimate answer may be production on grass to designated weights and then finishing in cooperative feedyards.

The Implications for Research

Suggestions or implications for research are sprinkled throughout this paper. In concluding, however, these perhaps can be summarized and elaborated upon.

I have already concluded, it seems, that performance of each major sector of the beef industry is deficient relative to potentials. I also have underscored the need for active programs of research designed to improve both operational and pricing efficiency, particularly the latter. I have also pointed toward and illustrated a major dilemma which, it seems to me, deserves direct rather than oblique research attention.

The problem of concentration in the food industry generated sufficient concern during the early 1960s that a national commission on food marketing was established. The Commission, intrigued with its subpoena power, concentrated on collecting masses of data. About all it accomplished was the placement of decimals on what we already knew. What is needed is research toward criteria that will help Congress and administrative agencies resolve the dilemma. The question is how much operational efficiency, born of concentration and large-scale operation, is too much? When or under what circumstances should we begin sacrificing operational efficiency for increased competition and pricing efficiency? Is it possible that there are compromise solutions that will maximize industry performance?

Following through from my discussion on cattle cycles and related issues, it seems that it is time and hopefully not too late to allocate

a considerable share of research funds to solution of the problem of price variation. "Coordination," it seems to me, should become an important goal in the cattle industry. A much greater effort to coordinate production and supply within market requirements at prices representing reasonable and consistent profits will be required to preserve the current decentralized structure of the cattle industry. Research is needed to determine most appropriate avenues toward insuring a high degree of coordination while, at the same time, preserving as much enterprise freedom as possible. In this connection, we might direct a relevant question toward forage cattle feeding enthusiasts. Is the turn toward forage feeding fully consistent with the goal of coordinating market supplies by types and qualities with market requirements?

Within the sector of the industry from packer to retailer, research is needed toward improvements in both operational and pricing efficiency. On the technological front, breakthroughs still are needed which will permit all major cutting activities to be shifted back to the packing plant or to other centralized locations. For some time now, we have had efficient techniques for quick freezing beef and other meats and we now have low-cost microwave systems of defreezing. What, then, are the technological possibilities of greatly increasing the use of storage as a price levelling mechanism? Defreezing, I understand, has been a major deterrent to increased use of frozen beef by processors. With modern facilities, would it be possible to freeze much larger quantities of cow beef during periods of drought or economic adversity for use much later when the supplies are in greater demand and prices are higher?

Research is needed on wholesale pricing, especially in connection with the Yellow Sheet and formula pricing. Several years ago in my report to USDA, I suggested the department usurp the powers of the Yellow Sheet by establishing a comprehensive wholesale price reporting system on all classes and cuts of meat, including by-products, at some central location such as Omaha. USDA probably should adopt the Yellow Sheet practice of reporting closing prices rather than price ranges. The price ranges reported by USDA are often so wide that meaning and usefulness are greatly reduced. Along with these changes, I would devote research attention to the question of prohibiting use of formula pricing where future delivery is involved.

Research is needed on present and future capital requirements of various sectors of the cattle industry as are studies concerned with structural implications of these requirements. We are accustomed to defining size according to number of acres owned, cows maintained, or cattle sold. What are the characteristics and attributes required for command of the necessary capital for economic survival? Is it possible that we need to explore new avenues of financing and capital formation? We now have had some experience in cattle feeding with public corporations, limited partnership funds, cattle feeding clubs, and vertical integration. All of these were introduced basically for purposes of attracting capital. I firmly believe, regardless of desirability, that all of agriculture will be moving inexorably in the direction of fewer, larger, more efficient operations. The major question then, is who

will own these operations? Will it be people from within agriculture or from the outside? The answer depends largely on the availability of necessary quantities of capital as needed. In this connection, however, business management capability will require increasing attention. There seems to be a direct link between the level and complexity of capital requirements and the need for business management capability.

Research definitely is needed in the direction of increased operational and pricing efficiency in marketing stocker-feeder cattle. The present system seems little short of chaotic. More highly centralized, organized and controlled systems of marketing apparently should be explored through research. For success in this direction, however, research will be required toward more useful and meaningful grade standards for feeder cattle. The goal in this connection should be grade standards which provide a high degree of predictability with respect to subsequent performance on grass or in the feedlot. Improved methods or forms of price reporting on feeder cattle also should be given consideration. Some imagination is essential with respect to marketing methods. For example, operational and pricing effects of possible new methods of marketing such as live color television auctioning from a central location, should be explored.

Assuming forage-fed beef production is here to stay, research will be needed, as mentioned earlier, on the most efficient sizes and types of operations. Research attention also should be directed toward capital requirements and sources, appropriate grades and standards, marketing facilities and systems designed to improve both operational and pricing efficiency, and more adequate market news coverage and reporting.

I leave a parting thought with you. My research strongly suggests that with the exception of periods of heavy liquidation, as at present, the nation is and will remain chronically short of beef designed especially for semi-processed and processed beef products. We will emerge from the present cyclical situation with a greatly expanded demand for each product. At the same time, cow-bull slaughter could drop 40-50 percent. Why not consider the possibility of designing some types of forage-fed cattle production and marketing systems toward the processed beef market. The alternatives will be expanded imports or increased use of pork.

LITERATURE CITED

1. Bain, J. S. 1959. Industrial Organization, John Wiley and Sons, Inc., New York.

2. Clodius, R. L. and W. F. Mueller. Market structure analysis as an orientation for research in agricultural economics, Journal of Farm Economics 43(3):519-520.

3. Kohls, R. L. 1964. Considerations of internal firm organization and behavior factors and their relation to research and structure, pp. 8-18. In Paul L. Farris (Ed.), Market Structure Research, The Iowa State University Press, Ames.

4. Moore, John R. and Richard G. Walsh. 1966. Cross sectional analysis of the agricultural industries, pp. 379-406. In J. R. Moore and R. G. Walsh (Eds.), Market Structure of the Agricultural Industries, The Iowa State University Press, Ames.

5. Paul, Allen B. 1964. Capital, finance and market structure--two approaches, pp. 19-43. In Paul L. Farris (Ed.), Market Structure Research, The Iowa State University Press, Ames.

6. Sosnick, Stephen H. 1964. Operational criteria for evaluating market performance, pp. 81-124. In Paul L. Farris (Ed.), Market Structure Research, The Iowa State University Press, Ames.

7. Williams, Willard F. and Thomas F. Stout. 1964. Economics of the Livestock Meat Industry, The Macmillan Company, New York.

8. Williams, Willard F. 1966. The meat industry, pp. 38-67. In J. R. Moore and R. G. Walsh (Eds.), Market Structure of the Agricultural Industries, The Iowa State University Press, Ames.

MARKET POTENTIAL FOR BLOCK AND PROCESSED BEEF

Robert Raunikar*

The U. S. beef industry has grown during the decades of the 1950s and 1960s at an unprecedented rate. During this period per-capita consumption of beef has almost doubled on a carcass weight basis increasing from 29.2 kilograms in 1950 to 53.0 kilograms in 1974. The reasons for this growth have received some attention through research efforts but certainly not sufficient attention to provide a clear understanding of how the market for beef functions under recent changing market conditions. Understanding the econonomics of the beef market did not command increased attention until changes in feed grain supply reflected in higher feed costs and consumer resistance to "high" retail prices occurred. These recent changes in the market have raised questions for which we have not been able to provide immediate answers. So it seems appropriate that issues facing the beef industry not only be confronted with ideas for their resolution but with a commitment of resources, i.e., funds and professional talent. In looking at the present and past, we should not be satisfied merely with charting changes in the beef industry, but we should attempt to determine why these changes occurred. By determining why changes occur and the interrelationships, surely some guidance can be provided for making adjustments in the various segments of the beef industry.

This paper addresses several aspects of the market for beef, particularly as it relates to consumer demand. Consumer demand represents the response of the ultimate user of a commodity which sends signals back through the marketing processes to the producer(s). This discussion will include setting forth some of the basic tools and measurements necessary for resolving issues now faced in the market. It is therefore essential to understand some elementary economic theory upon which the market functions, historical trends or changes in beef consumption, factors which have affected the magnitude of consumer demand, time and space dimensions of the market, and price relationships affecting the market for beef. Suggested ways of resolving problems in these critical areas need to be carefully assessed.

Theoretical Considerations

The conceptual basis for the theory of consumer demand has been discussed and established in previous writings (2, 3, 6, 7, 10, 30).

* Robert Raunikar is Associate Professor of Agricultural Economics, University of Georgia, Experiment (Griffin), Georgia 30212.

Certain elements of the theory of consumer demand warrant our attention to provide the framework upon which data generation and analyses must depend.

The theory of consumer demand attempts to explain the behavior of consumers under the influence of non-economic as well as economic considerations. The quantity of goods and services which the consumer obtains is dependent upon the set of economic and non-economic factors peculiar to the individual decisionmaking unit. This decisionmaking unit may consist of a single person or group of persons acting in concert (household or family) with each operating under various restraining factors. The primary factors associated with consumer demand theory are tastes and preferences, prices, and income. The reaction of the consumer(s) to changes in these primary factors can be measured using elasticities when certain assumptions are met; namely, complete information is known concerning the consumer's desires, ends to be maximized, and means for attaining these ends (23).

The price elasticity of demand is defined as the percentage change in the consumption of an item resulting from a 1 percent change in its price. In absolute terms, when the price elasticity is greater than 1, demand is elastic. When demand is elastic, an increase in quantity increases total expenditures. When price elasticity of demand is less than 1 (absolute value), demand is inelastic. Under the condition of an inelastic demand, an increase in quantity results in a decrease in total expenditures. This brief explanation illustrates the importance of knowing the price elasticity of demand for determining the effect of changes in production and related pricing policies.

The relationship of the price of a commodity to the price of a different commodity is measured by a cross-price elasticity of demand. This elasticity is defined as the percentage change in the quantity of an item demanded resulting from a 1 percent change in the price of a different item. The magnitude and sign of the cross-price elasticity reflects the extent to which one item substitutes for or complements a different item. When the cross-price elasticity is positive, an increase (decrease) quantity demanded results from an increase (decrease) in price of the substitute. When the cross-price elasticity is negative, an increase (decrease) in quantity demanded results from a decrease (increase) in price of the complement. A small cross-price elasticity means that the items are not close substitutes or complements.

The income elasticity of demand for an item is defined as the percentage change in the quantity of an item demanded resulting from a 1 percent change in income. A positive income elasticity means that increased quantity demanded results from increased income. Most foods have a low but positive income elasticity. When the income elasticity of an item is negative, increased income results in decreased quantity of that item demanded. The measurement of income elasticities has importance for the determination of the impact that changes in spending power (income) have on quantity demanded and at what levels these changes occur.

Consumer demand for a specified item is usually represented by a schedule which inversely relates quantities of the good taken to alternative prices with income and prices of other goods assumed constant at some level. When the price of the item increases (decreases), the quantity of the item taken will decrease (increase). Changes in income and in factors other than own price results in a change (shift) in the demand schedule. Each consuming unit is represented by a demand function and the sum of these demand functions represents a market demand function for a commodity. The conventional demand schedule, DD, and a change in the demand schedule, D'D', are depicted graphically as a functional relationship in Figure 1.

To satisfy market demand for a commodity, a market supply must be present. The market supply for a specified commodity is usually represented by a schedule which positively relates quantities of a commodity that will be produced to various prices. When the price of the commodity increases (decreases), the quantity produced will increase (decrease). The market supply curve under competitive conditions is the sum of producers' supply curves. The supply curve traces out for each level of output the marginal cost (change in total cost) resulting from a unit change in output. A change (shift) in the supply curve can be caused by technology or some other factor affecting costs of production. The conventional supply schedule, SS, and a change in the supply schedule, S'S', are depicted graphically as a functional relationship in Figure 2.

The market for a specified commodity under the assumption that all market forces other than the commodity's price remain constant is graphically represented by demand and supply functions (Figure 3). When the quantity produced equals the quantity taken, an equilibrium price is established. While actual economic conditions do not yield such a simplified market situation, there are forces within the market which operate to provide a continuous movement towards an equilibrium level. Limited adjustments to price changes can be made by the producer(s) in the short run; however, in the long run, the producer(s) can respond to price changes by exit from or entry into an industry. Consumer response to price changes, although usually lagged, is reflected in the market demand. It is the nature and magnitude of this market demand to which the forces of production ultimately respond.

Trends in Beef Consumption

The consumption of beef in the aggregate and on a per-capita basis has trended upward since the early 1950s (28). Aggregate civilian consumption of beef has increased from 4.32 billion kilograms in 1950 to 11.05 billion kilograms in 1974. While aggregate beef consumption increased 2 1/2 times, the U. S. population was increasing by less than 1 1/2 times. This difference is reflected in the sustained increase in per-capita beef consumption during this period. Increased per-capita civilian consumption of beef on a carcass weight (and retail weight) basis occurred primarily in the 1951-1956 and 1959-1972 periods (Figure 4). The 1972 per-capita consumption was approximately twice the amount consumed in 1951.

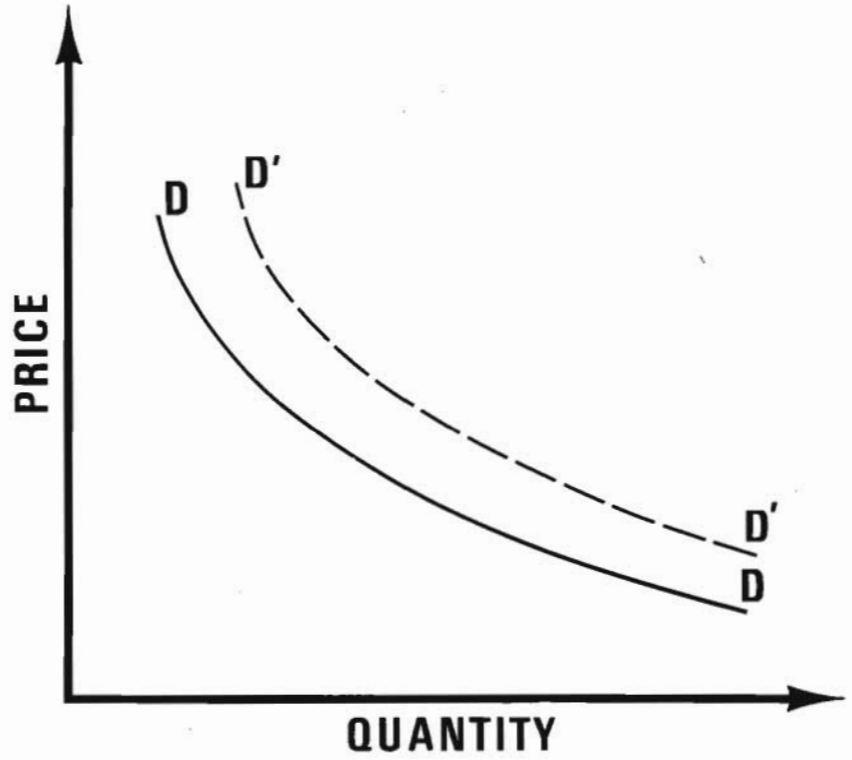


Figure 1. A conventional demand function, DD, with a change to D'D' resulting from the effect of changes in demand shifters

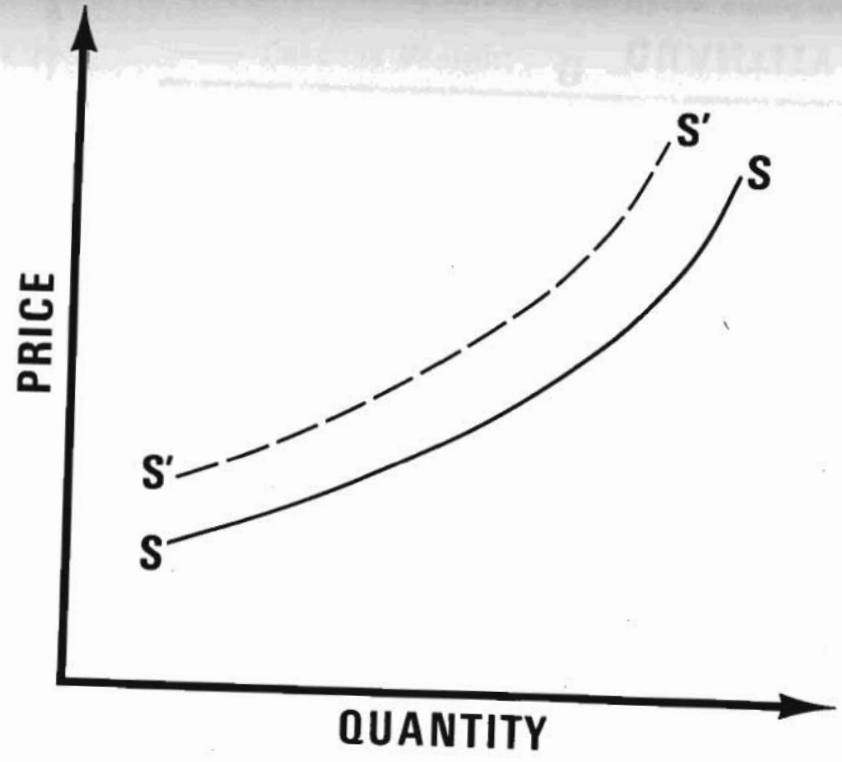


Figure 2. A market supply function, SS, with a change to S'S' resulting from the effect of changes in costs

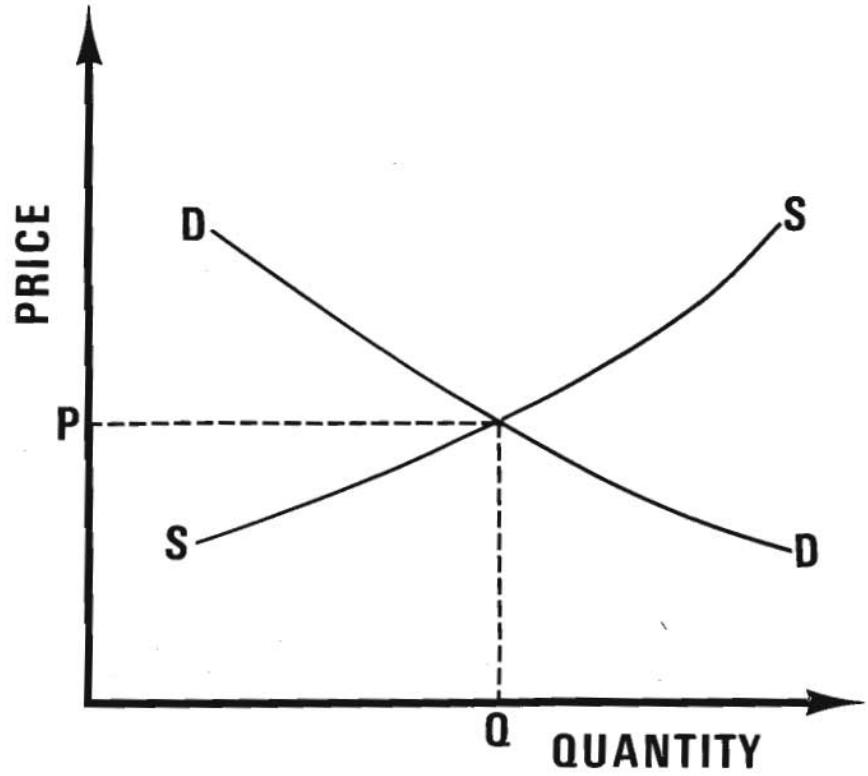


Figure 3. Market price as determined by equilibrium demand and supply

Figure 4. Per-capita consumption of beef, carcass and retail weight basis, U. S., 1950-1974
Source: (28)

Consumption in the short run is dependent on a predetermined supply of animals available for slaughter with adjustments made by the inclusion or exclusion of specific types of beef animals (17). These types include the cow-bull beef, steer-heifer beef, and veal. The quantity of cow-bull beef slaughtered is determined primarily by the number culled from the dairy and cow-calf herds. The number culled reflects the short-run outlook for dairy products and feeder calves. The availability of steer-heifer beef for slaughter can be altered in the short run by lengthening or shortening the growing and feeding periods. Much of the increase in beef available for consumption, particularly during the early 1960s, may be attributed to increased animal weight and yield (15). This occurred during a period when conditions were favorable for extending the feeding period.

The per-capita growth of beef consumption in the United States has occurred within the limitations imposed by the size of a person's stomach. This limitation is illustrated by the fact that during the period of 1958-1974, per-capita consumption of all foods on a retail weight basis ranged from 641 kilograms to 657 kilograms (28). While the average quantity of food consumed by the individual has been relatively stable in recent years, increased per-capita consumption of beef apparently has resulted in reduced per-capita consumption of other foods. The increased share of total food that per-capita consumption of beef has attained is illustrated in Figure 5.

To derive an indication of the magnitude of per-capita expenditure for beef, an estimate was made using retail price (1974 dollars) of choice grade beef and the per-capita retail weight of beef consumption (27, 28). The per-capita expenditure for beef generally increased throughout the 1950-1974 period (Figure 6). Since 1960, per-capita real income has increased except for the decline in 1974 which would be expected to result in decreased demand and, hence, account for the reduction in expenditure for that year because of the real income effects. However, the proportion of per-capita disposable income spent for beef generally has declined except for the last three years during which the price of beef increased (Figure 7).

This discussion of per-capita consumption of beef has not differentiated between block beef and processed beef. Block beef usually consists of the higher grade beef carcasses and is fabricated into various cuts; e.g., steak, roast, etc. The literature provides little basis for determining the quantity in either the block beef or processed beef classifications. The Census of Manufactures provides a breakdown of beef which includes whole carcass beef, and primal and fabricated cuts (24). The quantity of beef reported as carcass beef, and primal and fabricated cuts accounted for 72 percent in 1963 and 74 percent in 1967 of total U. S. civilian consumption of beef. The reliability of these estimates to represent block beef is certainly subject to question.

Determination of the quantity of beef classified as block or processed meat does not readily result from the simple assignment of certain classifications of beef animals. While it may be assumed that all

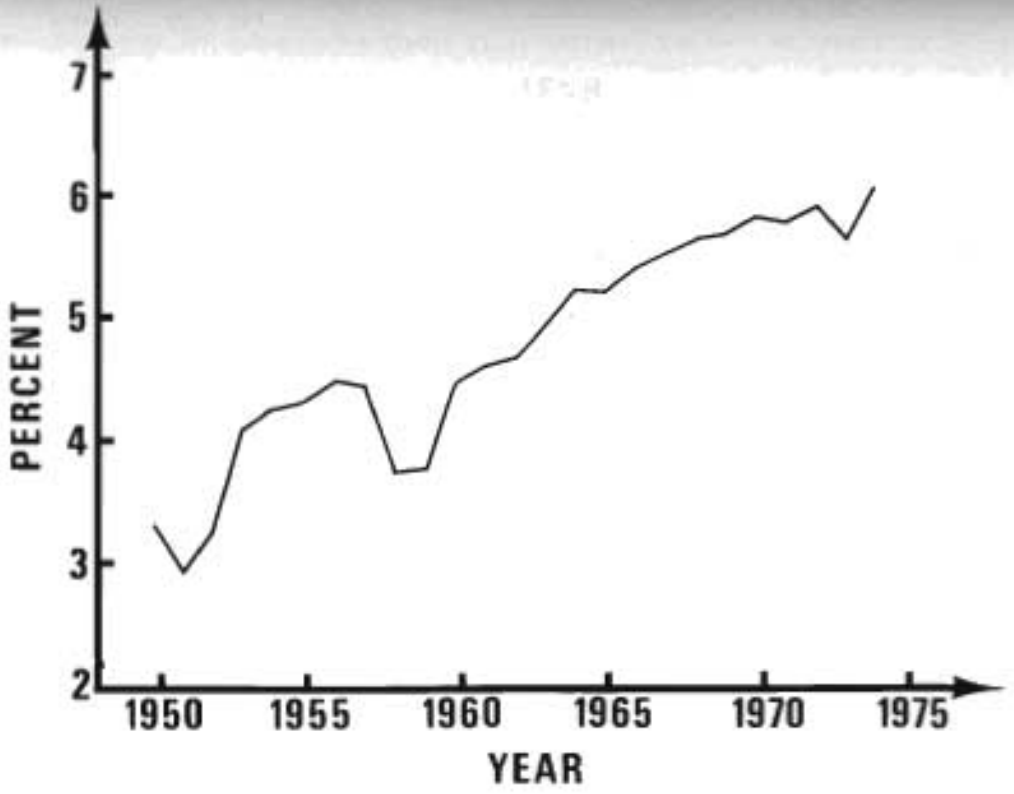


Figure 5. Per-capita consumption of beef as a proportion of per-capita consumption of all foods at retail, U. S., 1950-1974. Source: (27, 28)

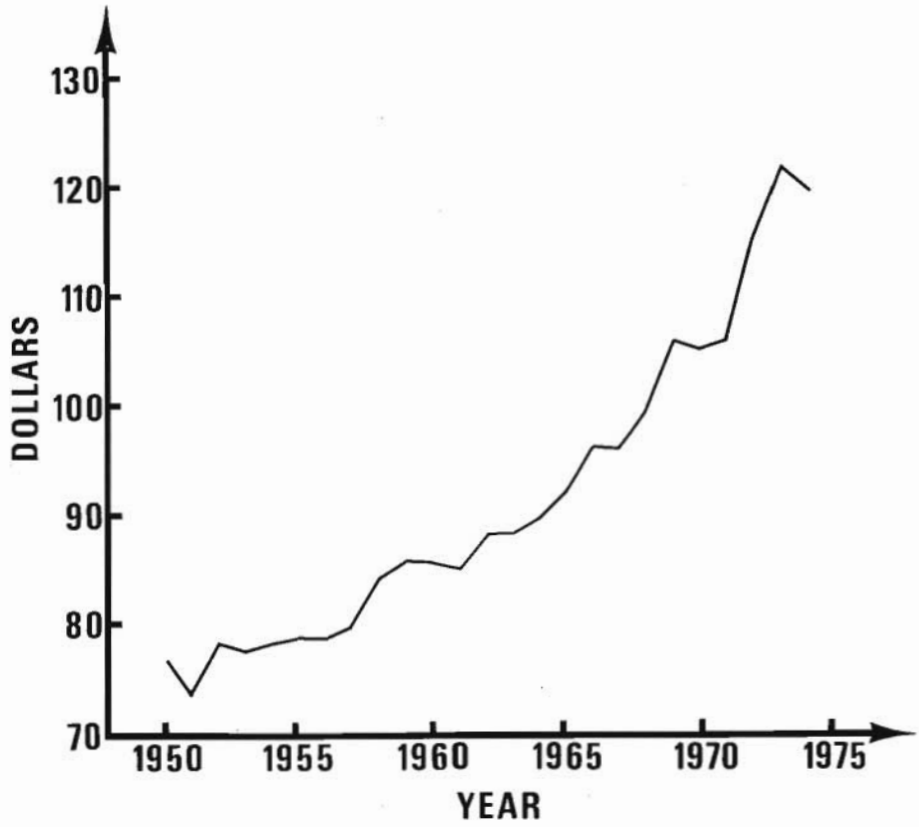


Figure 6. Estimated per-capita expenditure (1974 dollars) for beef at retail, U. S., 1950-1974
Source: (27, 28)

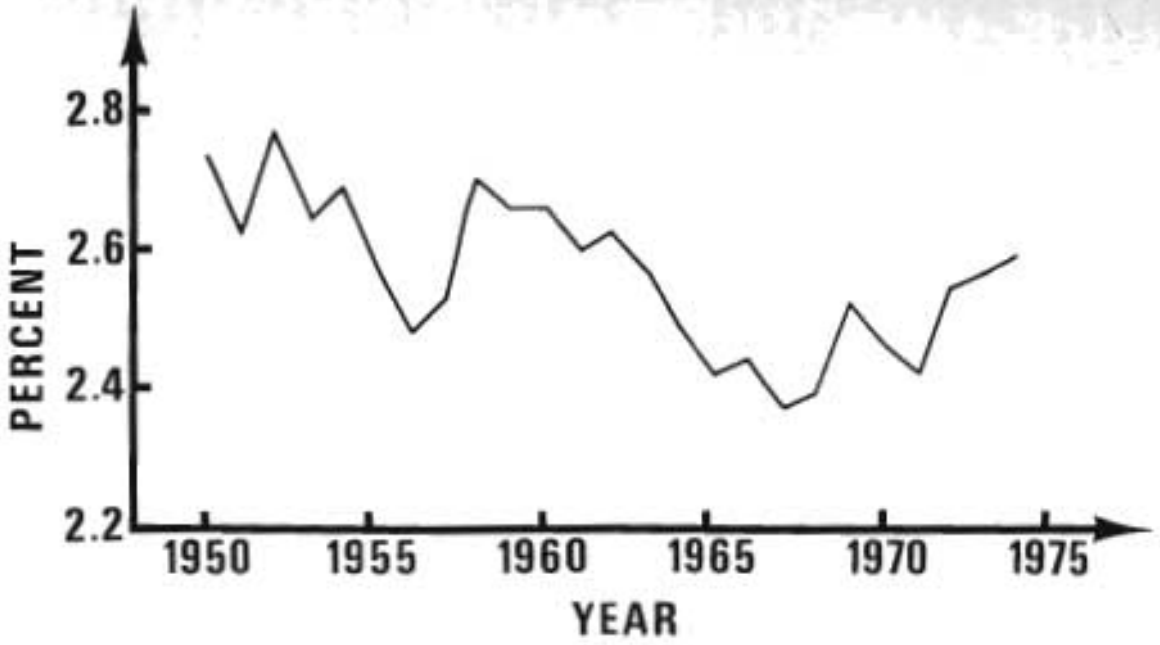


Figure 7. Per-capita expenditure for beef as a proportion of per capita disposable income, U. S., 1950-1974. Source: (27, 28)

fed beef comes from cattle which have been identified as being on feed for a minimum period of time and that fed beef can be considered as block beef, an undetermined quantity of nonfed beef goes to the block beef market. The validity of the assumption that steer-heifer beef is consumed as fresh block beef and cow-bull beef consumed as processed beef is questioned because of the substitutability between types of beef, especially the acceptability of steer-heifer beef for processing (17). Furthermore, imported beef increases the supply of processed beef which otherwise would likely be filled by steer-heifer beef. Yet, if trends of the past are to continue, the block beef component will be the dominant determinant of the level of beef consumption.

Non-Price Factors of Demand

The demand for beef is affected by non-price factors which cause it to change or shift as previously illustrated. Primary factors which have received attention are income and the age composition of the population. These factors are also important in estimating space dimensions (location) of the market discussed in a later section.

Income

Consumer response to changes in income has been measured by differing methods for beef. Data available for determining this response as measured by an income elasticity of demand for beef have been primarily in two forms: time-series and cross-section. The combination of time-series and cross-section has resulted from data collected from households over time.

A pioneering effort by Brandow provided a comprehensive set of income elasticity estimates for various foods (1). He estimated an income elasticity for beef at 0.47; i.e., a 1 percent increase (decrease) in income brings about a 0.47 percent increase (decrease) in the quantity of beef demanded. George and King more recently estimated the income elasticity of demand for beef at 0.29 (7). An estimate of the elasticity of demand for beef of 0.37 was derived from cross-sectional household data by Purcell and Raunikar (16). Each of these estimates is based on the assumption that it remains constant across the entire range of incomes. There is some evidence that this assumption has been valid for the time periods used in the analysis. Thus, increasing per-capita real income during the last two decades has contributed to the change in the demand for beef. Added buying power created by the food stamp program has also changed the demand for beef in recent years. The exact magnitude of this change is indeterminate in view of the differing estimates of income elasticity of demand for beef.

The response of consumers of processed meat, primarily beef and pork, to changes in income has been estimated from household data (21). For both wieners and luncheon meat, the response to income is positive in the lower ranges of income, attains a maximum between $8,000

and $9,000 income (1960 dollars), and then is negative with income increments above $9,000. To illustrate the response to income, the income elasticity for luncheon meat ranged from 0.26 at $3,000 to -0.13 at $12,000 income. A constant elasticity of 0.17 was derived from an equation in logarithms. These results provide evidence that at higher income levels other foods, primarily other kinds of meat, become the preferred substitutes.

Population and Its Location

The size and composition of the population have been demonstrated significantly to influence the demand for beef (21, 22). Major concentrations of people, and hence the major markets, are located in the metropolitan areas of the Northeast, Upper Midwest, Lower West Coast, and South Atlantic (Figure 8).

The actual growth rate of the U. S. population for 1970 and 1975 has been less than projections prepared during the 1960s indicated (26). The average annual rate of growth is estimated to range between 0.6 percent and 1.3 percent or a total increase in population from 1973 to 2000 ranging between 19 percent and 43 percent (25). Nevertheless, certain regions, including the South, Southwest, and Rocky Mountain areas, are expected to have a greater percentage increase in population than other regions. The expected increase in population, although less than previous projections, clearly signals a continuing need for increased food production in which the beef industry will share. The age and sex composition of the population is also expected to fluctuate from one period to another and, thus, will account for additional variation in per-capita demand for food.

Time and Space Dimensions of the Market

The market for domestically produced beef basically includes only the United States, especially the 48 contiguous states, since less than 0.5 percent is exported (28). Efforts have been made to determine the magnitude of the total market as well as a breakdown into varying sizes of its geographic components (e.g., states and regions) (2, 4, 5, 8, 12, 22, 29). Differences in beef consumption and demand due to space and time have been accounted for primarily by differences attributed to population characteristics, income, and prices.

A recent study of the demand for beef in the United States included estimates for three levels of geographic aggregations over time (22). Demand estimates for each market were based on size of the population, age composition, income distribution, ethnic makeup, urbanization, and location. Estimates were made on the assumptions that price relationships remained unchanged and that an adequate supply of beef was available in each projected year. The results showed that per-capita demand for beef would increase by 17 percent between 1965 and 1980 with aggregate demand increasing by 40 percent. The greatest market growth is expected to occur in the Southern, Rocky Mountain, and South Pacific regions.

Figure 8. Major population concentrations in the United States

Procedures in the Raunikar, Purcell, and Ford study (22) provide the basis for estimating domestic consumption of beef in the United States. The quantity slaughtered for consumption by region was obtained from USDA Livestock and Meat Statistic bulletins (27) for 1974 (Table 1). A comparison of the consumption and slaughter estimates indicates those regions which have a surplus or deficit of beef and veal slaughtered for domestic civilian consumption (Figure 9). Only the Denver, Minneapolis, Kansas City, and Dallas regions have a surplus of beef slaughtered. The location of surplus and deficit regions has been largely determined by the location of feedlots and associated enterprises. The magnitude and changes in demand estimates over space and time for surplus and deficit regions should be updated periodically to assess opportunities for changes in the production-marketing system.

Price Relationships

Each segment of the beef industry, including the producer, slaughtering firm, fabricator, processor, and distributor, is highly dependent on consumer demand for beef. For any quantity of beef marketed there is an associated market clearing price. Consumers are faced with a set of prices and price relationships under which each determines the quantity to be taken subject to a set of unique conditions or restraints. The quantity of beef in the short run is essentially determined by production decisions based on some previous period (lagged) price-quantity relationships (4, 9, 13). Then, current price becomes a function of this quantity and is expressed as a price flexibility (6). The relationship of price to quantity demanded may be expressed either as a price flexibility or price elasticity; however, care must be taken to assure their correct interpretation (11).

A graphical illustration of the relationship of retail real price for beef to the annual per-capita consumption for 1950 to 1974 reveals the occurrence of shifts in demand (Figure 10). Also, the price elasticity of demand was probably not constant over this period of time as was found by Breimyer from an earlier set of data in which estimates of the price elasticity of demand for beef from time series data for differing time periods yielded differing elasticities (2). Hence, differing model specification and variables included likely will result in differing elasticity estimates.

Using time series data, the price elasticity of demand for beef was estimated at -0.95 by Brandow (1). A price elasticity of demand for beef and veal of -0.97 was estimated from cross-sectional household data (18, 19). Size of the price elasticity for beef is negatively related to the length of the time period used in estimating consumer response; e.g., week, quarter, or year. Consumers also were found to have a greater response to negative price changes than to positive price changes for beef. Based on cross-price elasticities of substitute meats, changes in the price of pork had the greatest effect on quantity of beef demanded. Also from cross-sectional household data, the price elasticity of demand for processed meat (largely beef and

Table 1. Estimates of beef and veal (cattle and calves) production and civilian consumption by region, U. S., 1974

Region[a]	Consumption of domestic production[b] carcass wt.	Domestic production[c] carcass wt.	Surplus (deficit) production
		(million kilograms)	
Dallas	902	1,367	465
Nashville	550	345	(205)
Atlanta	1,207	339	(868)
Baltimore	279	26	(253)
Philadelphia	581	239	(342)
New York	1,312	192	(1,120)
Boston	615	39	(576)
Detroit	1,409	595	(814)
Chicago	891	775	(116)
Minneapolis	285	676	391
Kansas City	638	3,774	3,136
Denver	468	1,258	790
Seattle	338	226	(112)
Los Angeles	1,241	865	(376)
United States	10,716	10,716	0

[a] See Figure 9 for region delineation.

[b] Source: Georgia Agricultural Experiment Station (unpublished) estimates based on procedures in (22).

[c] Source: (27).

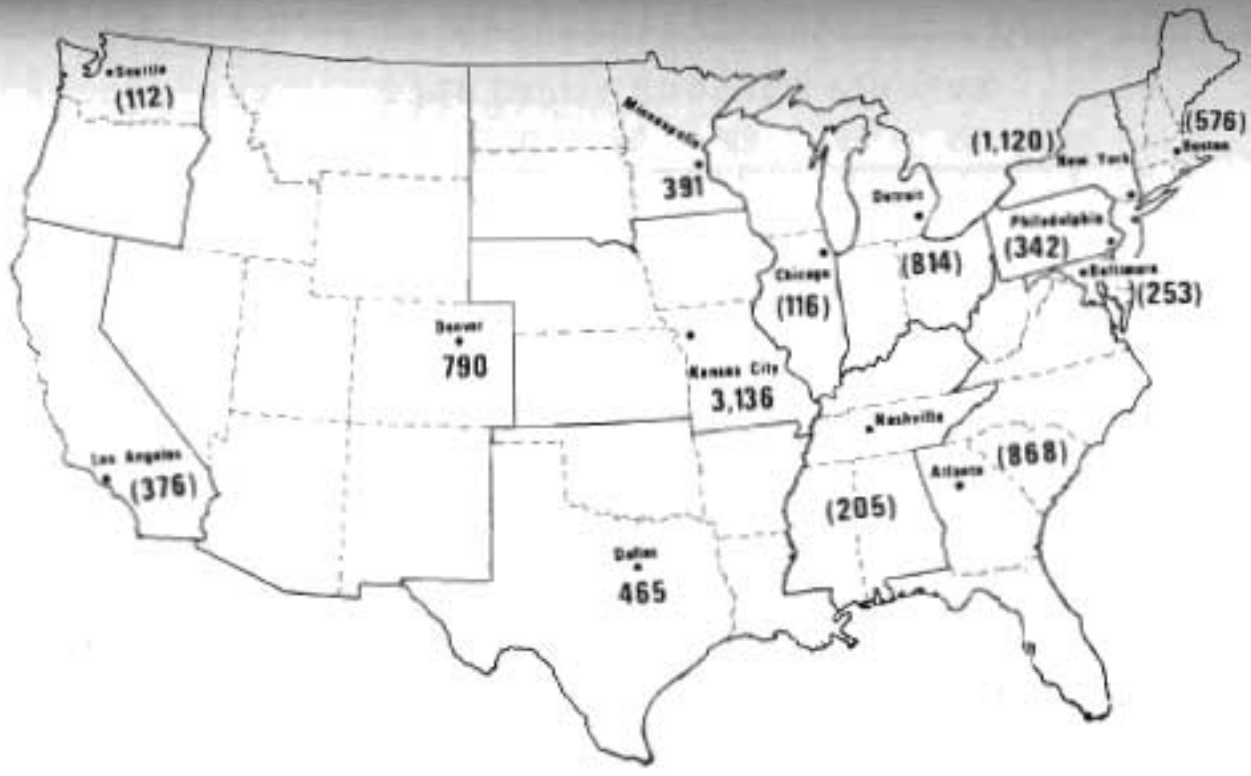


Figure 9. Estimates of million kilograms surplus (deficit) of beef and veal, carcass weight, slaughtered for domestic consumption by regions, U. S., 1974 (Source: See Table 1)

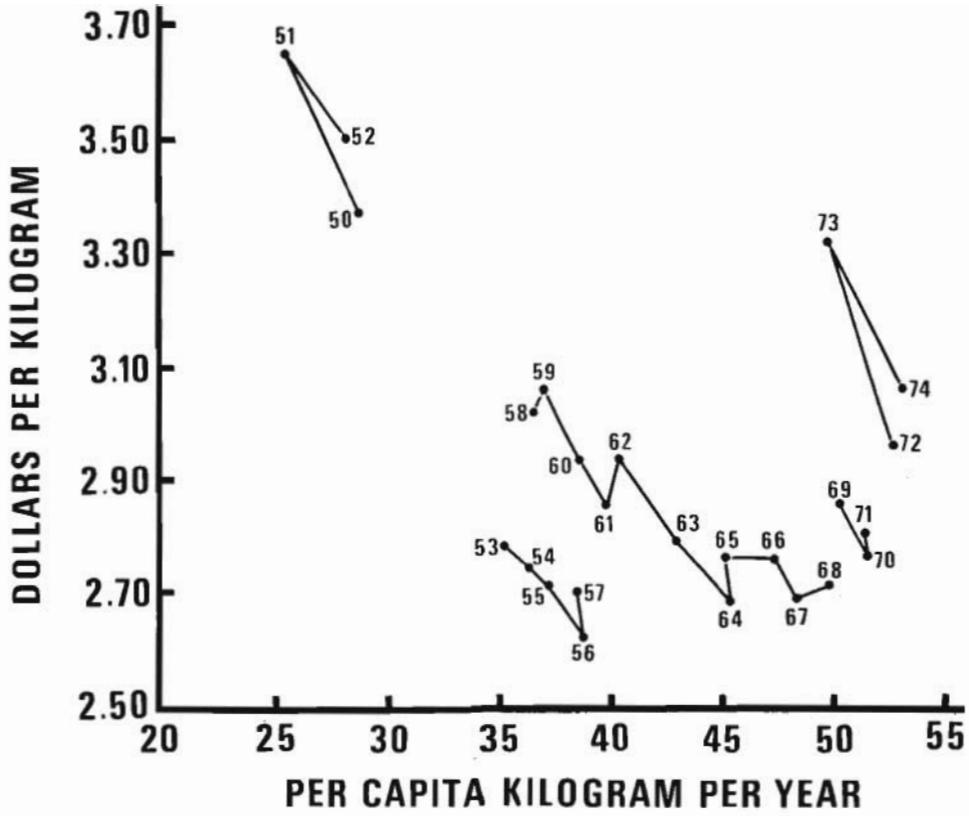


Figure 10. Retail price of beef (1974 dollars) related to per capita consumption of beef, carcass weight, U. S., 1950-1974 (Source: (27))

pork) was estimated to be lower than for beef and veal when based on week-to-week price changes (19).

Price relationships among various types of meat animals have changed during the 1950-1974 period in response to changes in the short-run supply. The level of supply for each year has resulted from production decisions based on expectation of the performance of the market with respect to price. Hence, the so-called cattle cycle (increasing and decreasing supplies) spanning several years is the primary determinant of variation in cattle prices (20). The level of per-capita consumption of beef and its associated retail price for the period of 1950 through 1974 reflects this variation in cattle prices (Figure 10).

Market prices for certain classes of livestock at the Omaha livestock market were obtained for peak price-low supply and low price-peak supply years corresponding to the cattle-beef price cycle (Table 2). Using these prices, ratios reflecting changes in the price relationships among classes of livestock were derived (Table 3). The price ratio for 408-499 kilogram choice slaughter steers (CSS) to 408-499 kilogram good slaughter steers remained relatively constant over the peak- and low-price years of the cycles. However, CSS prices were high relative to feeder steers and especially utility cows in periods of heavy beef supplies, the low phase of the price cycle (Figure 11). Conversely, CSS prices were high relative to hog prices in periods of small beef supplies, the high phase of the price cycle. The ratios reflect a relatively stable period between 1964 and 1973, a time during which cattle feeding increased (through 1972), the market for beef was strong and growing, and grain prices were stable. The stagnant-to-declining demand for beef and rising grain prices occurring during 1974 and 1975 provide some basis for explaining why the upward trend in cattle feeding was halted and a downward pressure was exerted on the demand for and prices of feeder cattle (especially calves). Thus, changes in the nature and magnitude of price relationships within the marketing segment of the beef industry have been reflected in its recent instability.

Future Analysis and Data Needs

For relevance, any future analysis of the beef industry or its segments should be designed to account for its relationship to the ultimate consumer demand for beef. The revenue which accrues to each segment of the beef industry depends on consumer demand for total beef and, to certain segments of the industry, on the changing composition of this demand. To satisfy the need for measuring consumer demand for beef and its components, the basic question relates to how much of a product will the consumer purchase at various prices under varying social and economic constraints. It is more than a question of determining what a consumer wants or prefers--the economics requires a determination of the extent to which consumers fulfill these wants or preferences.

Table 2. Market price for specified classes of livestock by year, Omaha livestock market

Classification	Year							
	1951	1954	1959	1964	1969	1972	1973	1974
	(dollars per quintal)							
408-499 kg. choice slaughter steers	77.78	52.38	61.00	49.41	64.93	78.88	98.19	92.35
408-499 kg. good slaughter steers	71.10	45.17	55.67	44.73	59.83	73.70	92.62	85.34
181-227 kg. good feeder steers	-	-	-	-	-	87.02	116.87	87.33
136-249 kg. good feeder steer calves	-	-	-	-	64.77	-	-	-
136-227 kg. good feeder steer calves	-	-	-	47.60		-	-	-
136-227 kg. good and choice feeder steer calves	83.44	45.61	76.68	-	-	-	-	-
227-363 kg. choice feeder steers	80.25	46.91	67.62	49.43	-	90.85	117.26	86.05
249-340 kg. choice feeder steers	-	-	-	-	71.50	-	-	-
227-363 kg. good feeder steers	73.15	41.62	59.72	45.04	-	80.67	105.91	75.71
249-340 kg. good feeder steers	-	-	-	-	62.43	-	-	-
Utility cows	52.98	24.49	38.51	29.19	44.73	55.58	72.36	56.35
91-100 kg. #1 & 2 barrow & gilts (Good & choice for 1951, 1954)	46.30	51.52	33.44	35.32	54.04	61.13	91.07	81.20

Source: (27) and unpublished USDA livestock detailed quotations, Omaha market.

Table 3. Selected price ratios relative to the U. S. beef sector for selected years, Omaha livestock market[a]

Price ratio	Year							
	1951[b]	1954[c]	1959[d]	1964[e]	1969[f]	1972[g]	1973[h]	1974[i]
	(percent)							
408-499 kg. choice slaughter steers/ 408-499 kg. good slaughter steers	109.4	116.0	109.6	110.4	108.5	107.0	106.0	108.2
408-499 kg. choice slaughter steers/ 136-249 kg. good feeder steers	93.2	114.8	79.6	103.8	100.2	90.7	84.0	105.8
408-499 kg. choice slaughter steers/ 227-363 kg. choice feeder steers	96.9	111.7	90.2	100.0	90.8	86.8	83.7	107.3
408-499 kg. choice slaughter steers/ 227-363 kg. good feeder steers	106.3	125.8	102.1	109.7	104.0	97.8	92.7	122.0
408-499 kg. choice slaughter steers/ utility cows	146.8	213.9	158.4	169.3	145.1	141.9	135.7	163.9
408-499 kg. choice slaughter steers/ 91-100 kg. #1 & 2 barrows & gilts	168.0	101.7	182.4	139.9	120.2	129.0	107.8	113.7

[a]Ratios based on prices obtained from (27) and unpublished USDA livestock detailed quotations, Omaha market.

[b]Near peak of 1949-1954 price cycle for cattle-beef (low to low) and low supply.

[c]Near bottom of 1951-1959 price cycle for cattle-beef (high to high) and high supply.

[d]Near peak of 1954-1964 price cycle for cattle-beef (low to low) and low supply.

[e]Near bottom of 1959-1973 price cycle for cattle-beef (high to high) and high supply.

[f]Premature high of 1964-1974 price cycle for cattle-beef (low to low) and low supply.

[g]Peak year for drylot cattle feeding.

[h]Peak of 1964-? price cycle for cattle-beef (low to low) and low supply.

[i]Sharp break in cattle (feeder) prices beginning in September 1973.

Figure 11. Ratio of prices for 408-499 kg (900-1,100) related to per capita consumption of beef, carcass weight, U. S., 1950-1974. Source: (27).

Past economic research has generally provided valuable but nevertheless limited information on the demand for beef. In addition to present data generation and analyses of time series data, future research would benefit from a market monitoring system wherein parameters of the market can be observed and evaluated continuously. Specifically, such a system should be designed to provide a basis for analyzing the dynamics of the market, particularly consumer demand. Further research needs relate to the determination of

- consumer response to changes in beef prices as they occur in the market.
- consumer response to changes in prices of substitutes as they occur in the market; e.g., pork, poultry, baby beef, textured vegetable protein, etc.
- consumer response to changes in income, demographic characteristics, and other demand shifters.
- the effect of pricing policies and stability of prices on consumer response over short, intermediate, and long periods of time.
- the net effect on consumer response due to location; i.e., geographic area and urbanization.
- the effect of promotional programs on consumer response over varying time periods.

The lack of a commitment of more resources for improving present data banks and for the generation of data by alternative methods specifically for economic analysis of the marketing system has led to the dearth and inadequacy of data needed for estimating consumer demand relationships. National aggregates are of limited value in the analysis necessary for determining specific market or sub-market requirements. Although considerable information is available on demand relationships estimated from aggregate time-series data, its limitations involve problems associated with the range of the data, multicollinearity, lagged adjustment in response, variation in response concealed in averages, changes in non-price variates, income distribution, and the composition and distribution of the population (14, 19).

A monitoring system which includes cross-sectional and time-series data developed from the direct observation of various segments of the market and consuming units can provide a data bank for analyzing the dynamics of the market for beef. For demand analysis, data on consuming units should be obtained from continuously reporting panels of families or households. The changing circumstances of the consumer in terms of income allocation among food and nonfood alternatives will likely have an impact on the kind and quantity of food demanded. Thus, the maintenance of a set of cross-sectional data involving a large geographic base of consuming units as a means of augmenting ongoing data sources warrants the attention of those involved in the economics of consumer demand.

LITERATURE CITED

1. Brandow, G. E. 1961. Interrelations among demands for farm products and for control of market supply. Pa. Ag. Exp. Sta. Bul. 680, 124 pp.

2. Breimyer, H. 1955. Demand and price for meat. U. S. Dept. of Ag. Tech. Bul. 1253, 110 pp.

3. Bressler, R. G., Jr. and R. A. King. 1970. Markets, Prices, and Interregional Trade. John Wiley and Sons, Inc., New York.

4. Crom, R. 1970. A dynamic price-output model of the beef and pork sectors. U. S. Dept. of Ag. Tech. Bul. 1426, 105 pp.

5. Dean, G. W., G. A. King, H. O. Carter and C. R. Shumway. 1970. Projections of California agriculture to 1980 and 2000. Calif. Ag. Exp. Sta. Bul. 847, 60 pp.

6. Fox, K. A. 1953. The analysis of demand for farm products. U. S. Dept. of Ag. Tech. Bul. 1081. 94 pp.

7. George, P. S. and G. A. King. 1971. Consumer demand for food commodities in the United States with projections to 1980. Calif. Ag. Exp. Sta. Giannini Foundation Monograph No. 26, 161 pp.

8. Goodwin, J. W. and J. R. Crow. 1973. The interregional structure of the American beef industry in 1975 and 1980. Okla. Ag. Exp. Sta. Bul. B-708, 60 pp.

9. Hayenga, M. L. and D. Hacklander. 1970. Monthly supply-demand relationships for fed cattle and hogs. Am. J. Agr. Econ. 52:535-544.

10. Hicks, J. R. 1956. A Revision of Demand Theory. Oxford at the Clarendon Press, London.

11. Houck, J. P. 1965. The relationship of direct price flexibilities to direct price elasticities. Am. J. Ag. Econ. 47:789-792.

12. Judge, G. G. and T. D. Wallace. 1959. Spatial price equilibrium analyses of the livestock economy. 1. Methodological development and annual spatial analyses of the beef marketing sector. Okla. Ag. Exp. Sta. Tech. Bul. TB-78, 64 pp.

13. Langemeier, L. and R. G. Thompson. 1967. Demand, supply and price relationships for the beef sector, post-World War II period. Am. J. Ag. Econ. 49:169-183.

14. Polopolus, L. 1967. Discussion: research needs in analysis of U. S. food demand, pp. 91-95. In Proceedings of Mkt. Sec., Assoc. of So. Ag. Workers.

15. Purcell, J. C. 1965. Sources of beef and veal supplies and prices of cattle and calves. Ga. Ag. Exp. Sta. Mimeo Series N.S. 233, 23 pp.

16. Purcell, J. C. and R. Raunikar. 1967. Quantity-income elasticities for foods by level of income. Am. J. Ag. Econ. 49:1410-1414.

17. Purcell, J. C. 1968. Trends and relations in the livestock-meat sector affecting prices and revenue to primary producers. Ga. Ag. Exp. Stas. Res. Bul. 35, 36 pp.

18. Purcell, J. C., R. Raunikar and J. C. Elrod. 1969. Analysis of demand for meat, Atlanta consumer panel, G. Ag. Exp. Stas. Res. Bul. 72, 24 pp.

19. Purcell, J. C. and R. Raunikar. 1971. Price elasticities from panel data: meat, poultry, and fish. Am. J. Ag. Econ. 53:216-221.

20. Purcell, J. M. and J. C. Elrod. 1974. Price related risk in the cattle-beef sector. Ga. Ag. Exp. Stas. Res. Rpt. 182, 28 pp.

21. Raunikar, R., J. C. Prucell and J. C. Elrod. 1965. Consumption and expenditure for meat, meat products, and eggs in Atlanta, Georgia. Ga. Ag. Exp. Stas. Tech. Bul. N.S. 46, 64 pp.

22. Raunikar, R., J. C. Purcell and K. E. Ford. 1969. Spatial and temporal aspects of the demand for food in the United States, II. Beef. Ga. Ag. Exp. Stas. Res. Bul. 63, 44 pp.

23. Stigler, G. J. 1947. The Theory of Price. The Macmillan Company, New York.

24. U. S. Bureau of the Census. 1971. Census of manufactures, 1967. Vol. II, Industry Statistics, Pt. 1, Major groups 20-24. U. S. Govt. Printing Office, Washington, D. C.

25. U. S. Bureau of the Census. 1974. Population of the United States, trends and prospects: 1950-1990. Current Population Reports Series P-23, No. 49. U. S. Govt. Printing Office, Washington, D. C.

26. U. S. Bureau of the Census. 1975. Projections of the Population of the United States: 1975-2050. Current Population Reports Series P-25, No. 601. U. S. Govt. Printing Office, Washington, D. C.

27. U. S. Department of Agriculture. 1957 and later. Livestock and meat statistics. Stat. Bul. 333 and Supplements.

28. U. S. Department of Agriculture. 1968 and later. Food consumption, prices and expenditures. Ag. Econ. Rpt. No. 138 and Supplements.

29. Wallace, T. D. and G. G. Judge. 1959. Spatial price equilibrium of the livestock economy, 2. Application of spatial analysis to quarterly models and particular problems within the beef marketing system. Okla. Ag. Exp. Sta. Tech. Bul. T-79, 39 pp.

30. Wold, H. and L. Jureen. 1953. Demand Analysis: A Study in Econometrics. John Wiley and Sons, Inc., New York.

DISCUSSION

STRUCTURE AND MARKETING

Discussion of the papers by:
Willard F. Williams and Robert Raunikar

MODERATOR: Richard J. Crom, ERS, USDA, Washington, D.C.

QUESTION: C. S. Hoveland, Auburn University. I would like to ask Willard Williams a question. In view of the energy crisis, cost of energy and the declining water tables in the irrigated high plains of Texas, what impact will this have on cattle feeding in this area? What are your projections?

ANSWER: Willard Williams, Texas Tech University. We do have some declining water tables. Studies that I have made in the last year indicated we could maintain the number of cattle on feed that we had in 1972. The energy problem is going to have a substantial impact. I think we must look at the marketing evidence of last year. There is a demand for high quality meat. We need to know what this demand looks like, not only the total demand but the different characteristics of this demand. If we are looking at forage-fed beef, we must know the characteristics of the demand before we can understand the nature of our market. Presently, we don't know that nature. We have seen massive consumption of low quality beef in the last few years by fast franchise food outlets and restaurants. What is going to happen in a couple of years when cow slaughter is only 50 percent of what it is now? Where is the lower quality meat going to come from? Do we need to start producing cattle for this market?

QUESTION: Dale Huffman, Auburn University. Assume we do produce cattle for this market. Is there a pricing mechanism that will reward the producer for it?

ANSWER: Willard Williams, Texas. If we were to look at the structure of our southern cattle feeding industry and ask, what kind of a market producing market structure is it going to take? What kind of services the government in the form of market news reports, grade standards and so forth, is it going to take to provide a demand and to provide a proper marketing system? A week rarely passes that I do not receive a call from a Midwestern Corn Belt farm feeder who indicates that he has heard cattle were selling much lower in a certain area, and how can he get them? There is no organized market system for moving the

kind of cattle they want from this area to the midwestern feeder. Even in Texas, we have a 15 percent price difference on the same type of cattle between East and West Texas.

QUESTION: Dale Huffman, Alabama. My question, or my problem, relates to the high demand for boning bulls, for example. If you look at the price that is paid the producer for boning bulls, whether they be young bulls or mature bulls, and then look at the demand and value of this product for processing beef, there is something inconsistent here. Do we have a mechanism to reward the producer?

ANSWER: Willard Williams, Texas. You are going to get only what can be pulled out of the system. Let's look at an example of the marketing position of the packer versus the producer. You have a widely decentralized marketing system for cows and bulls at the producer level in which there is no organization whatever, with no resistance and no bargaining power there. The producer must sell and the packer is in a position to decide the amount of the producer's supply and what he wants to handle. The packer is in a strong marketing position and until we face up to what kind of change in structure it is going to take, things are going to continue the way they are. It seems to be a matter of changing the whole marketing structure.

COMMENT: Donald Farris, Texas. I would like to elaborate on this point. I think we do have a marketing system that rewards the producer. It won't reward the producer when we have excess supplies as we have now. Boning bulls were bringing more than choice steers in some regions during 1973. I think the point Willard Williams is trying to make is that our system is so disorderly that at times it rewards the producer for a product more than it should. At other times, such as this year, it is rewarding him much less than it should. The marketing system is in a position to pay for that product. Yet, when the product is in larger supply relative to other beef, for example, then the market is obviously going to discount it.

COMMENT: Roy Blaser, Virginia Polytechnic Institute and State University. I have not heard anything here today on the influence of the news media, especially TV. It seems to me that the impact here, at times, upsets the economic aspects that were alluded to.

ANSWER: Willard Williams, Texas. No, this is the first time that I can remember that we have made page 1. I think there are some impacts and it is probably a good thing. Food chains and other media do influence consumer demand and prices.

COMMENT: Robert Raunikar, Georgia Experiment Station, Griffin, Georgia. We know that the advertising does have some impact, but we don't have measurements on this. How do you get this unless you develop some sort of monitoring system of the market?

COMMENT: Richard Crom, Moderator, ERS. In addition, we must look at the gaps in our market system and consumer information. We have a responsibility to educate the people, because the kinds of calls we

get from consumer-oriented groups indicate that they are well meaning, but they are often totally misinformed. We must recognize the deficiencies in our information.

QUESTION: *John Moore, University of Florida.* There have been some very interesting discussions about alternatives. Forage, however, for many of the speakers seems to be corn silage and alfalfa hay. Many of us don't have these feedstuffs available. Is there information available on the economics of pasture utilization? Isn't this something we should be concerned about? Is this an alternative that is going to be useful or could work?

COMMENT: *Willard Williams, Texas.* I would like to offer this suggestion. I would like to see some time spent initiating an experiment involving eight or more classes of feeder cattle, homogenous within each class with handling and feeding conducted the same. Then, follow them all the way to the consumer. We can then find out the differences between these classes. Right now, we don't know. I think we need several experiment stations cooperating on this project.

QUESTION: *J. J. Guenther, Oklahoma State University.* I am happy to learn that we have a marketing system that rewards the producer. I have always thought that here is a guy that takes his cattle to the market and says, "Boys, what will you give me for them?" I just found out this morning that we have a system that rewards the producer. My real question evolves around the point that we at this conference believe in the average everyday housewife. Do we think there is such a thing as consumer demand and if so, who sets the demand? The consumer?

ANSWER: *Richard Crom, Moderator, ERS.* I think we have a consumer demand but we have individual problems.

COMMENT: *J. J. Guenther, Oklahoma.* We hear quite a lot about consumer demand and satisfying all the wishes and desires of this consumer. Let me give one possible answer. The retailer puts something up and says, "Here it is, take it or leave it."

ANSWER: *Richard Crom, Moderator, ERS.* Yes, they do say that. You see, every consumer is a price taker and quantity adjuster. And remember, to the extent that they don't like that product at that price, they don't take it, and the retailer must adjust. I do think that we do have a consumer demand for T-bone steak, hamburger, ham, etc. However, consumer knowledge is often limited; for example, if you were to ask a large portion of consumers in New York City or Hawaii if ham and T-bones came from the same animal, many might say yes.

COMMENT: *Willard Williams, Texas.* Well, there very definitely is such a thing as consumer demand. Over a long period of time you can see it the best. However, within shorter periods of time such as day-to-day, week-to-week, month-to-month, and sometimes longer periods, there are other forces we have not faced up to, or have not been able to. I do not know if we said that there is definitely a system of rewards to

the producer. In the competitive framework, you get about what you deserve given the circumstances in which you exist. If you are fragmented and do not have bargaining power, you are going to get the "shaft." That is the way it is going to be until you get well organized or know enough about your product to put yourself in the position where you have the bargaining power to demand a just reward. They cannot hold back. Until they gain something or some position where they can demand what they deserve, they are not going to be properly rewarded.

COMMENT: Robert Raunikar, Georgia. To say there is no consumer demand is to say that the individual has no control or has no ability to make a decision with the funds that he has available. One of the recent things that disputes this was when the housewives boycotted beef. Isn't that an instance when they were exercising their control, either individually or cooperatively? Has your wife exercised her right to change her buying patterns of certain types of food? I am sure that there is a consumer demand that we all exercise. The household is the basic unit with one or more persons. Decisions revolve around this group, and the decisions are made as to how the expenditures are made under the budget constraints that they face.

QUESTION: Stanley Wilson, Auburn University. If we assume that the future will bring higher corn prices and higher feeder prices, then what will be the price of choice beef? Can we produce a good product, maybe good grade, that the consumer can buy? What kind of consumer resistance are we going to have to higher priced beef in the future as compared to what consumers have seen in the past? Also, can't we produce an acceptable product, maybe not choice, but good grade, utilizing either all forage or a high percentage of forage? I think this could be done. Everything that we have heard since we have been here implies that we are going to continue doing something similar to what we have done in the past. I question that and would like to have some comments on that.

ANSWER: Willard Williams, Texas. It looks to me like there will be a continuing demand for forage-fed beef, provided we meet the requirements of the consumer in terms of not only quality but repeatability of experience throughout the system. To consumers, repeatability of experience is important. Consumers know exactly what they want the next time. They want a repeatability of experience, that they can go back and depend on. If you can provide that, exploit that market.

COMMENT: Stanley Wilson, Alabama. Can we produce forage-fed beef cheaper now? You keep talking about some sort of differential in quality between forage- and grain-fed beef. Within a grade, I would argue that this difference does not exist. We are probably talking about good or high-good beef. Forage-fed beef would simply be as high quality as grain-fed beef within that grade. Maybe this is the grade we will be selling in the future. Everything you say sounds fine and I agree with it, but can we produce, for example, high-good beef on forage cheaper than we can produce it with grain?

ANSWER: Willard Williams, Texas. Well, let us hope so. But one of the greatest myths in the beef industry is that prices of prime beef are higher than choice because more people prefer prime, or that prices of choice are higher than good because more people prefer choice. The prices differ because there is a difference in cost of production. The question is whether or not there is a big enough market, and stable enough market that costs of efficiency are going to be sufficiently in line such that you can compete and continue to build a market.

COMMENT: Henry Gilliam, ERS. I wonder if Willard Williams would like to reconsider that last statement, that the cost of production is what determines prices of beef. You are not suggesting that it costs more to feed choice beef than the other grades?

ANSWER: Willard Williams, Texas. What I mean is that price adjusts over time to cause the various grades to be produced.

CARCASS CHARACTERISTICS, MEAT QUALITY AND CONSUMER ACCEPTANCE

GROWTH AND DEVELOPMENT OF BEEF CATTLE WITH REFERENCE TO THE EFFECT OF BREED AND SEX

J. J. Guenther*

Introduction

The ultimate objective of this workshop is to accumulate the basic information necessary to devise and implement the technology to produce quality beef from forage. Among the many questions which evolve from this objective are: Why do we wish to persue this? Can it be done? Will it be more economical? Who will benefit from any savings? Will forage be fed in confinement, on the range or a combination of both? How will animal growth be affected by these practices? What do we mean by quality beef? Will future quality standards for beef be changed? How will certain new processing techniques influence future beef production practices?

The intent of this paper is to outline some growth and development concepts in beef cattle. Moreover, it is believed that an understanding of the basic factors involved in animal growth is prerequisite to the devising of management practices seeking to improve beef production.

Growth Phases in Market Cattle

The two major phases of growth, or life span, of beef animals may be defined as 1) pre-natal and 2) post-natal. These major phases may then be subdivided into their respective increments as shown in Figure 1.

The pre-natal phase is divided into: 1) the ovum state (about 10 days); 2) the embryonic state (about 40 days) and 3) the fetal state (about 230 days). The pre-natal phase totals about 280 days or 9.3 months and represents about one-third of the market animal's total life span, that is, from conception to slaughter. During the pre-natal phase little direct influence can be exercised on growth and little research has been conducted in this area. Indirect influence, of course, is exerted via the germ plasm of the sire and dam and the nutrition of the dam. It is important to note that during this growth

*Oklahoma State University, Stillwater, Oklahoma.

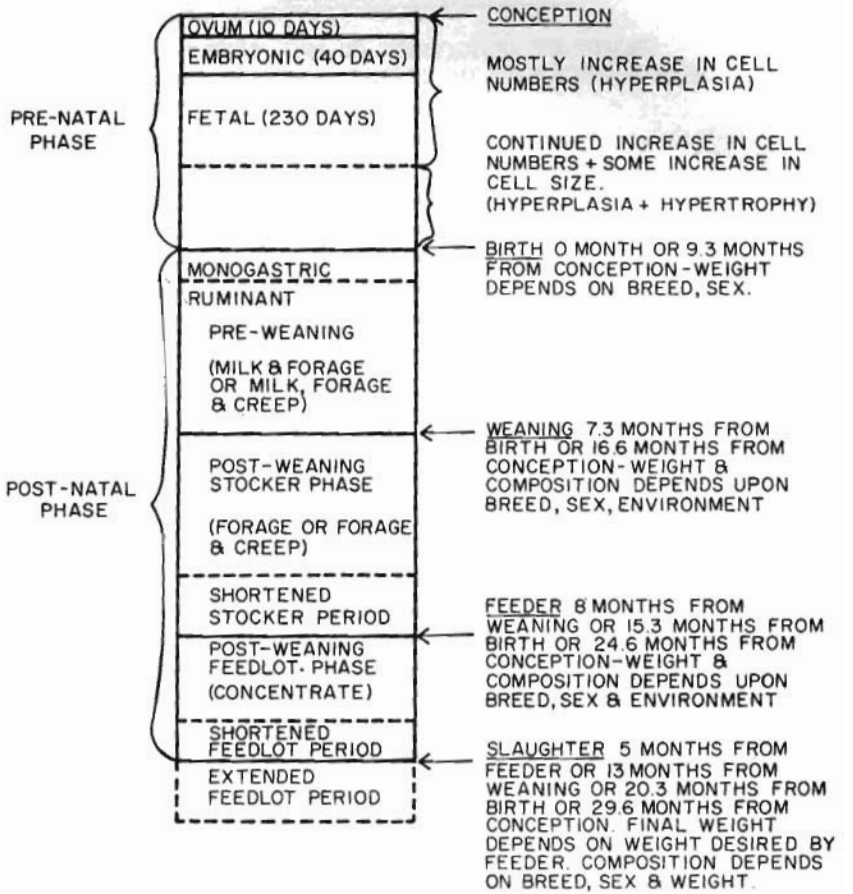


Figure 1. The growth phases and general management procedures of market cattle from conception to slaughter

phase cells that will eventually make up the various tissues of the beef animal are undergoing extensive differentiation and that the extent of cellular differentiation during this phase is very critical in determining the potential amount of a particular tissue, such as muscle, the animal will be capable of producing.

It is believed that during the first five-to-six months of pre-natal life, muscle cells or fibers increase mostly in number (hyperplasia); while during the last three-to-four months the cells begin to increase in size (hyperthrophy). Thus, at birth the beef calf has already accumulated its approximate total allocation of muscle fibers.

One might ask the question, "Doesn't it seem odd that what transpires during the relatively uncontrolled and short pre-natal life phase has such a profound effect on the course of growth events during the relatively long and controlled post-natal life phase of the beef calf?"

Post-natal growth can be divided into three phases: 1) pre-weaning; 2) post-weaning stocker, and 3) post-weaning feedlot phases. It is realized that the handling of beef calves during pre- and post-weaning may vary widely, but, in general, management procedures tend to follow those outlined in Figure 1.

The pre-weaning segment consists of allowing the calves to remain with their dams until weaning at about 220 days or 7.3 months of age. During the early part of the pre-weaning period, the beef calf functions as a monogastric animal and its diet is primarily milk, with small amounts of concentrate and/or roughage. About eight weeks post-natally, however, the calf's rumen becomes fully functional and the animal can tolerate roughage. Technically, the calf could be weaned at this time, but this is not economically feasible under present conditions due to cow management and other overhead costs. The question arises then, "Under what conditions, if any, could this early weaning be economically feasible?" After all, this amounts to about five and one-half months time and in the beef business time is money.

The post-weaning stocker phase entails grazing of beef calves, with or without supplemental concentrate, until the calves are deemed ready to go into the feedlot. The overt objective of the stocker phase is to permit the beef calf to make efficient use of "cheap" feed (roughage) thereby obtaining cheap weight gains. There is no question that the calf will make efficient use of roughage at this time in its life. For that matter, it will make efficient use of any feedstuff at this time. The key factor here is the uniform availability of the roughage over an extended period of time. The stocker phase could range from five to twelve months, but it usually averages about eight months. In any event, the question here is, "Should the roughage (processed) be brought to the calf or the calf to the roughage (grazing)?" Which method is the most economical in the long run and what are the agronomic and engineering problems involved?"

The final step in getting beef calves ready for market or slaughter is the post-weaning feedlot phase. This involves feeding the calves in confinement on a high energy "grain" diet for a given period of time until the desired weight and grade (choice) are obtained. Feedlot time varies but averages about five months. At this stage in its life, the beef calf is probably at its least efficient period in converting energy into desirable edible tissue, assuming the stocker phase was imposed. Obviously this is a costly operation and one which this entire workshop is attempting to circumvent or at least curtail. For during this phase of "finishing" beef cattle, the admittedly inefficient animal is in direct competition with humans for high quality grain feedstuffs. The question at this point is, what are the alternatives to this situation?

Growth, Development and Deposition of the Major Carcass Tissues in Beef Cattle

At this conference we are probably more interested in how the major tissues comprising the beef carcass grow and develop during the post-natal life of the beef calf than we are in total weight changes and all tissue growth of the intact animal. After all, the relative ratios of these carcass tissues are of primary concern to consumers, our ultimate clientele.

Beef carcass consists of three major tissues; bone, muscle and fat. Before discussing the growth and deposition of these tissues, it would seem in order to establish a simple growth concept; the order of deposition and demand for nutrients of the major carcass tissues is bone, muscle, then fat. Bone has top priority for the available nutrients. If nutrients are supplied in amounts exceeding that required for optimal bone growth, especially during early post-natal life, then the excess goes for muscle growth. If nutrients are supplied in amounts exceeding that required for the maximal rate of bone and muscle growth, the excess is utilized in the formation of adipose or fat tissue. Finally, when a particular tissue approaches its mature state which is the tangent on its growth curve, the growth impetus shifts to the next higher order tissue.

Bone Growth and Development

Bone, particularly long bone, though it may seem to be rather dense, inert and inelastic is actually a very dynamic tissue, being extremely responsive to existing environmental conditions. Thus, bone growth is influenced by breed, sex and nutritional level, as well as various metabolic and physiological conditions.

This paper proposes not to present an exhaustive treatise on bone growth (or muscle and fat growth), but rather to cover only a few general concepts which might be applicable in "every day" beef production practices. To illustrate these concepts for bone growth, let's use one of the more commonly known, easily accessible long bones, the metacarpus or fore cannon bone.

The architecture of this bone is shown in Figure 2. The bone consists of two epiphyses (ends) separated from the diaphysis (shaft) by growing cartilage (epiphyseal cartilage). At either end of the diaphysis are located the active sites for increases in long bone length, called the metaphyses. At the extreme ends of the diaphysis are located the epiphyseal plates. The medullary cavity is actually the core of the diaphysis and it contains the bone marrow. The endosteum delineates the outer periphery of the medullary cavity. The periosteum completely surrounds the outer periphery of the diaphysis. For convenience, those entities which occur towards the top of the bone are referred to as proximal (i.e., proximal epiphysis), while those towards the bottom are referred to as distal (i.e., distal epiphysis).

Bone growth takes place when minerals are added to existing tissue at a rate faster than they are withdrawn. Generally, there are three types of ossification processes: cartilaginous or endochondral, membranous and remodeling.

An increase in length of long bone is accomplished by adding new tissue to the surfaces of pre-existing bone in the area of the epiphyseal plates. Bone deposition in this region, the metaphysis, is referred to as cancellous or spongy bone and the growth process continues as long as the animal is growing epiphyseal cartilage. When this cartilage ceases to grow and becomes complete ossified, the epiphyseal plates close. (See example on the right in Figure 3). At this time, no additional increases in bone length can occur and the stature or scale of the animal is fixed.

Increases in thickness of long bone occur by adding new tissue to pre-existing bone at the periosteum-endosteum region. Bone deposition in this area is referred to as cortical or compact bone.

Basically, the bone remodeling process involves structural changes and a turnover of the constituents of bone. This process is continuous and is active not only in the skeleton of the early post-natal calf but also in the adult animal.

As previously stated, bone growth rate and, ultimately, the attainment of physiological maturity in bone is influenced by various conditions. For instance, the rate of growth is accelerated by pituitary growth; hormone and bone growth ceases in the absence of this hormone. Thyroxine is also required for endochondral ossification. The gonadal and adrenal hormones influence growth and maturation of the epiphyseal plates. Certain dietary deficiencies retard ossification.

Differences in size, weight and composition among various breeds of cattle may be directly attributed to the time in life when a particular breed approaches maturity in skeletal growth. Sex and sex condition also have a marked effect on skeletal size for this reason. Within a breed the bull is larger than the steer which, in turn, is larger than the heifer. This is due to the fact that androgenic hormones tend to delay epiphyseal plate closure and hence, long bone growth may continue for a longer period of time. Conversely, estrogenic

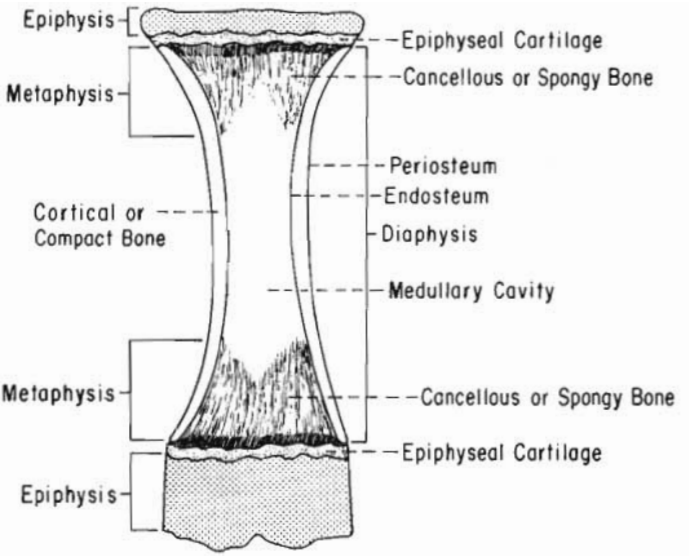


Figure 2. A schematic of A-P section of long bone

hormones tend to hasten plate closure, precluding extensive long bone growth. This raises many questions not the least of which are, "Assuming hormonal treatments were permitted, which hormone would be best for a specific type or breed of cattle? At what time in the animal's life should the treatment be imposed?"

In the beef breeds, bone growth has considerable influence on total muscling, total fat content and carcass grade at any given live-weight. Long bone growth is one of the major keys to the phenomenon of "early maturity." Indeed, many of the important production traits in cattle might be reflected back to the rate of bone maturation. For, as you may recall from the discussion on the order of tissue deposition, after bone growth slows with approaching maturity, muscle deposition seems to be triggered and when muscle growth subsides, fat deposition accelerates.

Some experimental data indicating the course of linear measurements and weight changes during bone growth will now be presented. The data

Figure 3. Distal metacarpal epiphyseal lines

shown in Figures 4, 5 and 6 portray changes in linear measurements of bone as affected by increased age and breed size. These results are expressed on a percent of final measurement basis in Figures 7, 8 and 9.

It is evident from these data that pre-natal bone growth in beef calves is quite extensive. Note the high percentages of potential body length (52 percent, avg.), body depth (50 percent, avg.) and particularly metacarpus length (74 percent, avg.) already attained at one month. Moreover, by weaning age (7 months) the calves had amassed, on the average, 84 percent, 77 percent and 89 percent of their respective final body length, body depth and metacarpus length. These results strongly suggest that if bone growth is not attained early in post-natal life, or at least by weaning, beef calves are not likely to attain it in later life. Our experience is that if one takes a small framed calf to the typical slaughter weights of today's feedlot cattle, one will probably wind up with a "butterball," considering the order of tissue deposition.

The above results also indicate that breed and type have a marked effect on the rate of bone growth, as evidenced by the fact that the smaller scale (Angus) calves matured more rapidly in these skeletal measurements than did the larger scale calves (Charolais). In addition, it can be observed from the data in Figures 5 and 6 that the longer legged cattle were a little deeper bodied than the shorter legged cattle. The point here is that long-legged cattle are not necessarily shallow bodied. We tend to confuse this issue when "eyeballing" live cattle.

Sex and sex condition within a breed also influence the rate of bone growth, primarily due to the hormonal effects outlined earlier.

Changes in total carcass bone weight during growth are shown in Figure 10. If these data are compared to the above linear skeletal measurements, it may be observed that the two are closely related; however, bone increases a little more rapidly in length than in weight.

Skeletal Muscle Growth and Development

Skeletal muscle, to say the least, is a very complex and dynamic tissue. Much has been reported about the various factors influencing growth of skeletal muscle in the last decade, yet certain of these factors still remain to be more completely elucidated. Since muscle is the most abundant carcass tissue and is considered to be the primary product of the beef industry, it is logical that continual effort be expended on the study of this tissue and that every aspect of muscle growth be examined. As with bone, the intent of this paper is to present only a few accepted generalities concerning muscle structure and growth.

In Figure 11 are shown the major entities comprising mature skeletal or "striated" muscle. Notice that the epimysium (a sheath of connective tissue) surrounds the entire muscle. Proceeding from the epimysium, another type of connective tissue, the perimysium, invaginates

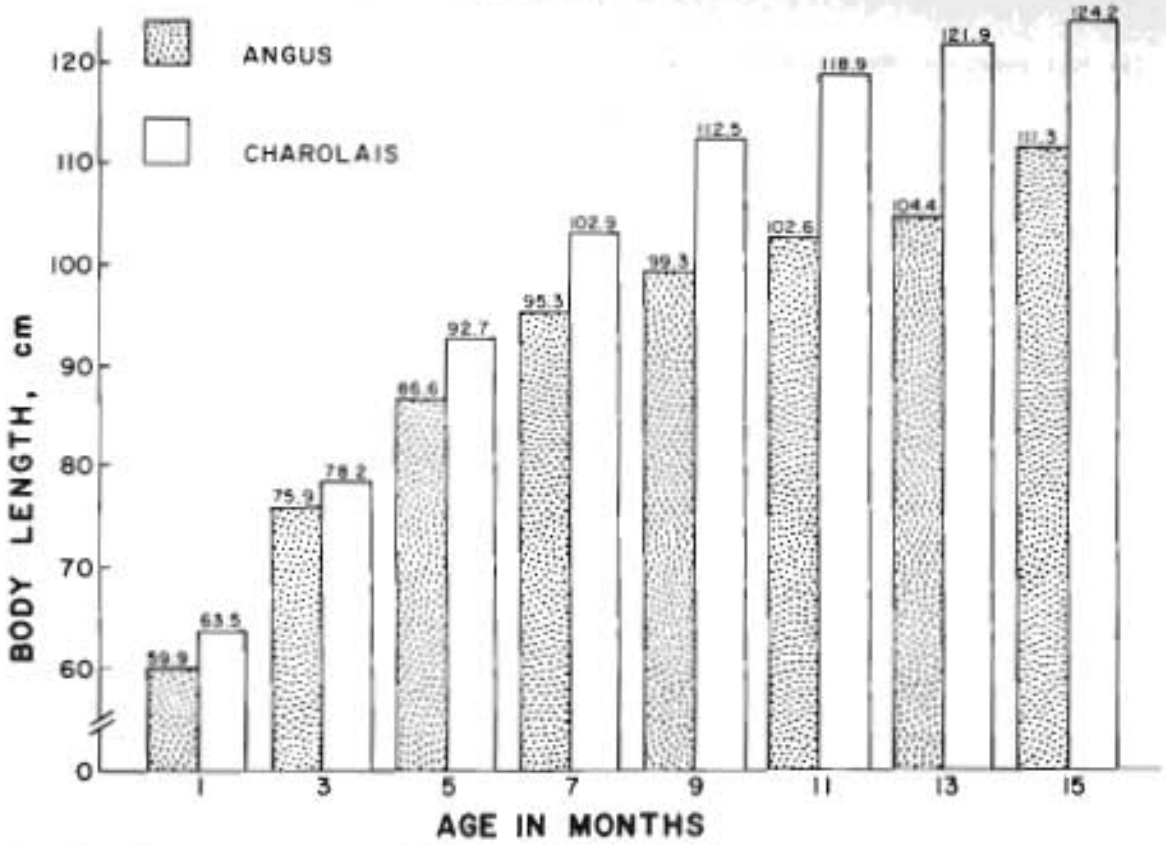


Figure 4. Linear measurements of body length as affected by increased age and breed size (8)

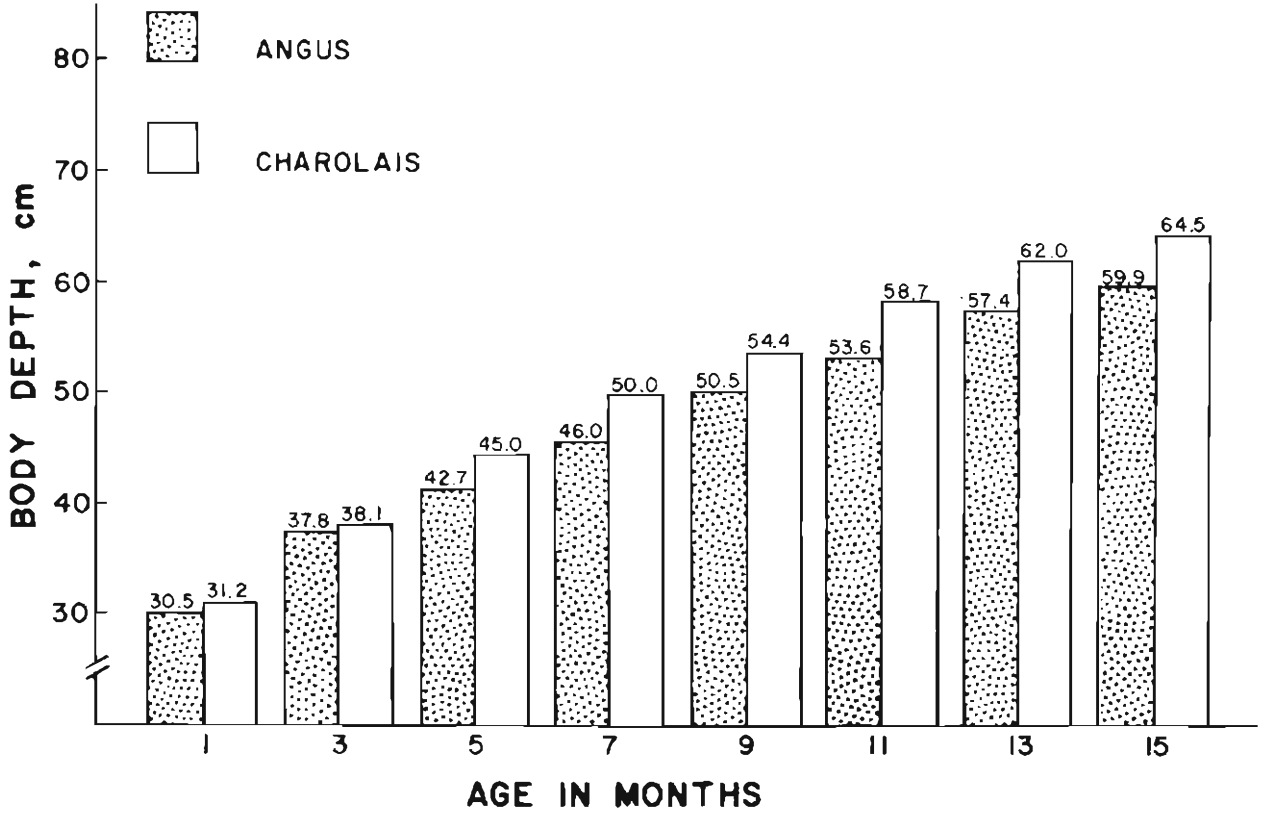


Figure 5. Linear measurements of body depth as affected by increased age and breed size (8)

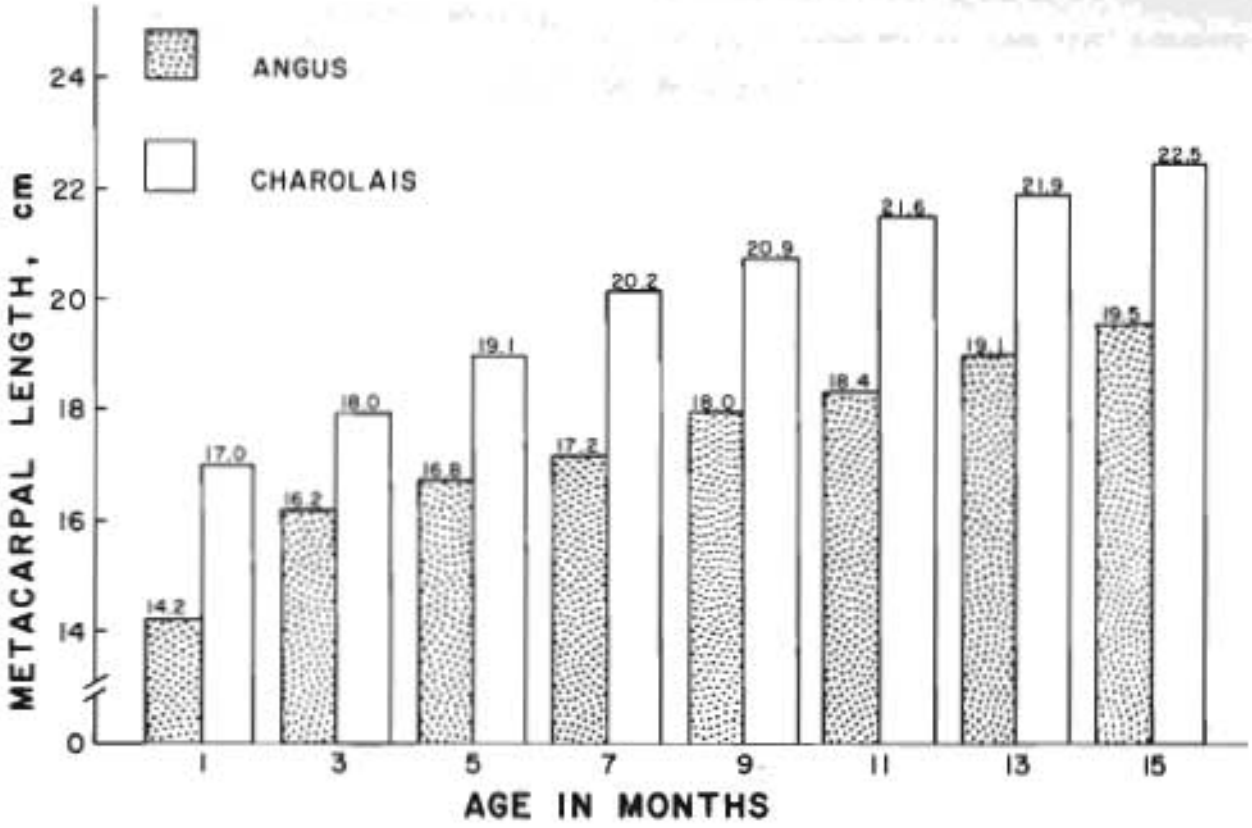


Figure 6. Linear measurements of metacarpal length as affected by increased age and breed size (8)

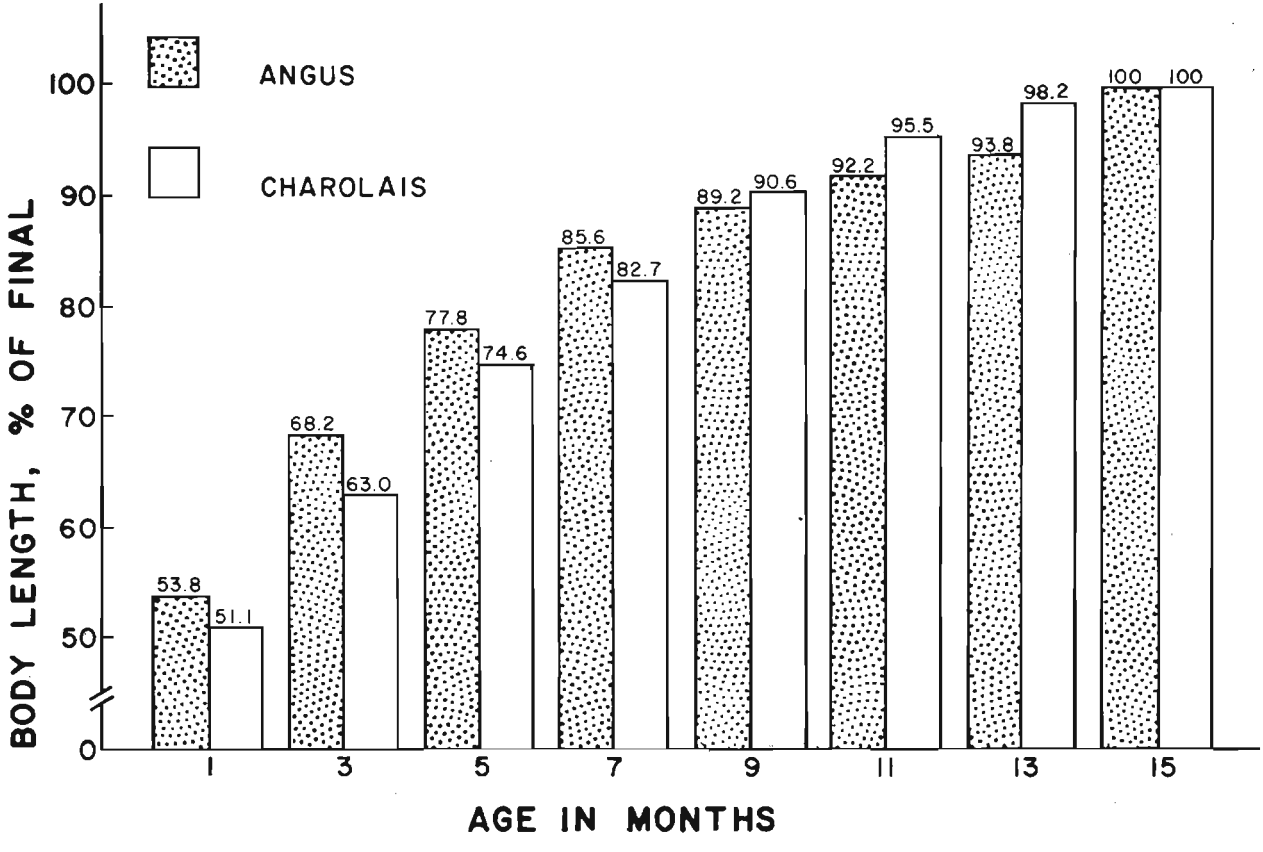


Figure 7. Linear measurements of body length as affected by increased age and breed size, expressed as a percent of final measurements (8)

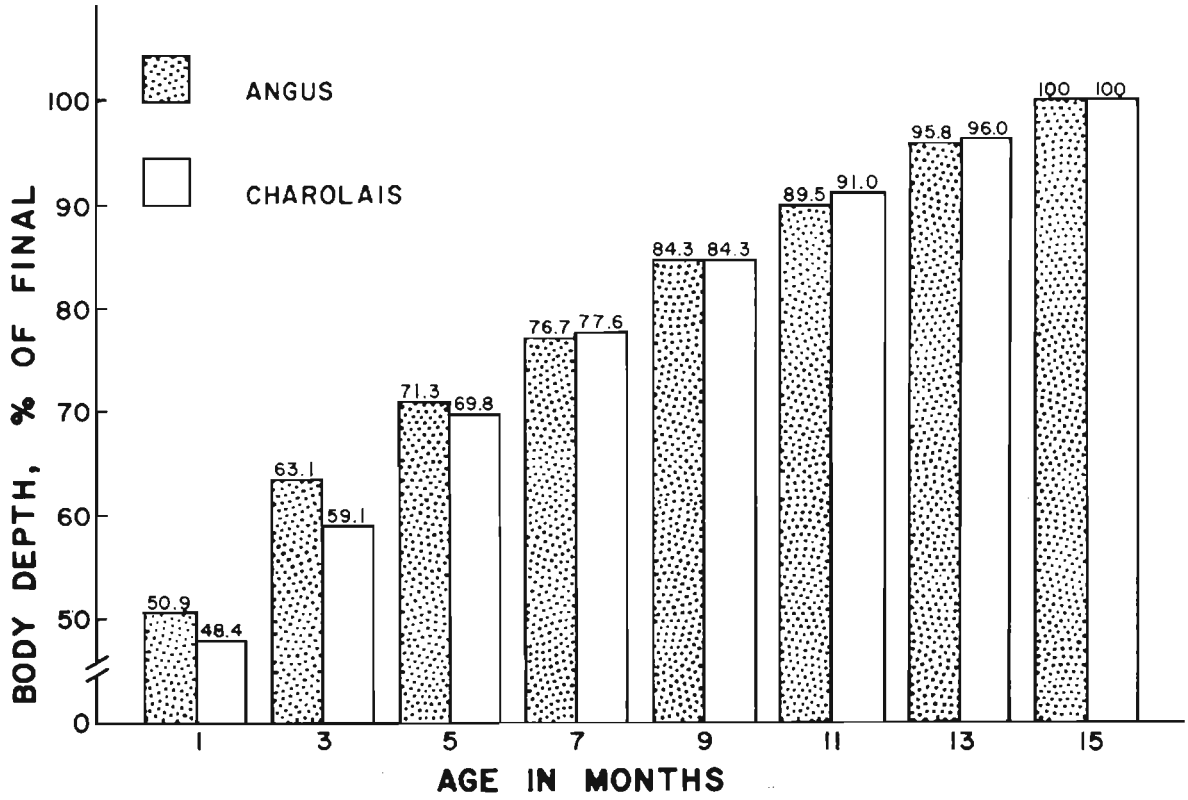


Figure 8. Linear measurements of body depth as affected by increased age and breed size, expressed as a percent of final measurements (8)

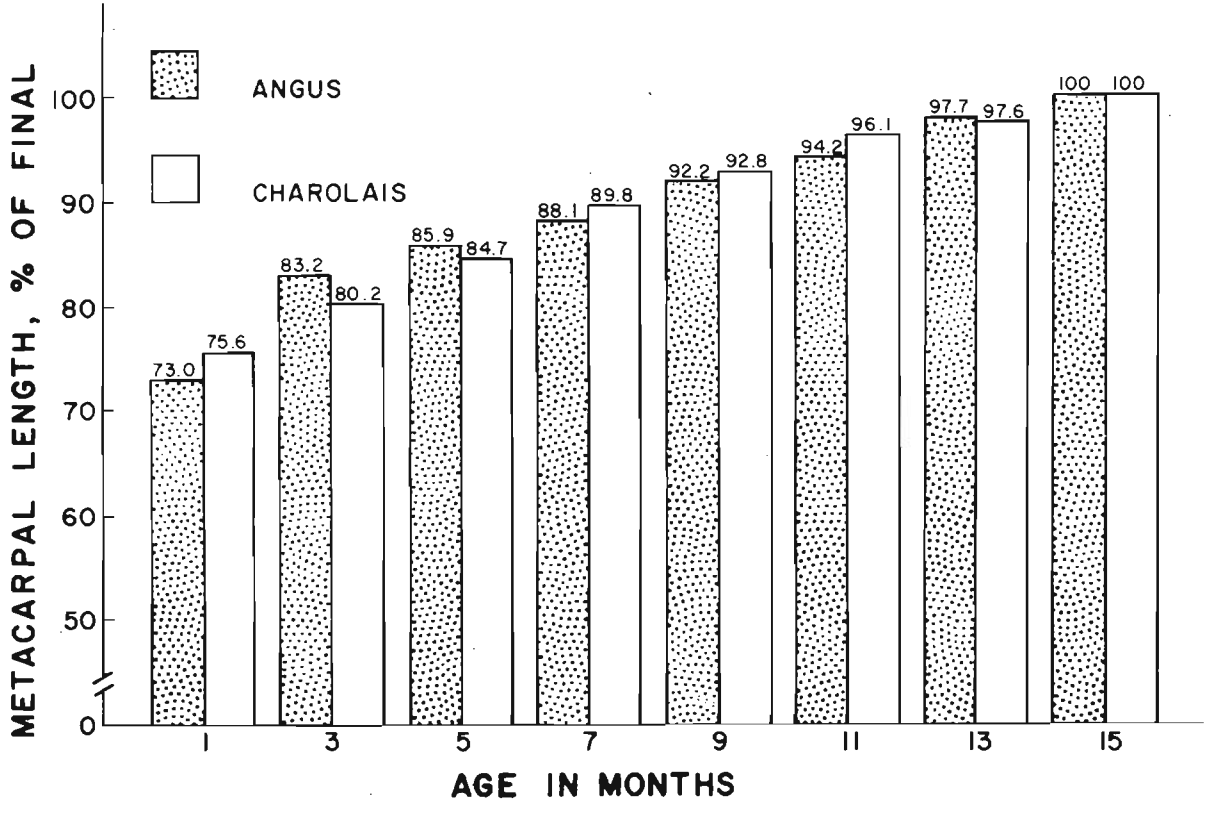


Figure 9. Linear measurements of metacarpal length as affected by increased age and breed size, expressed as a percent of final measurements (8)

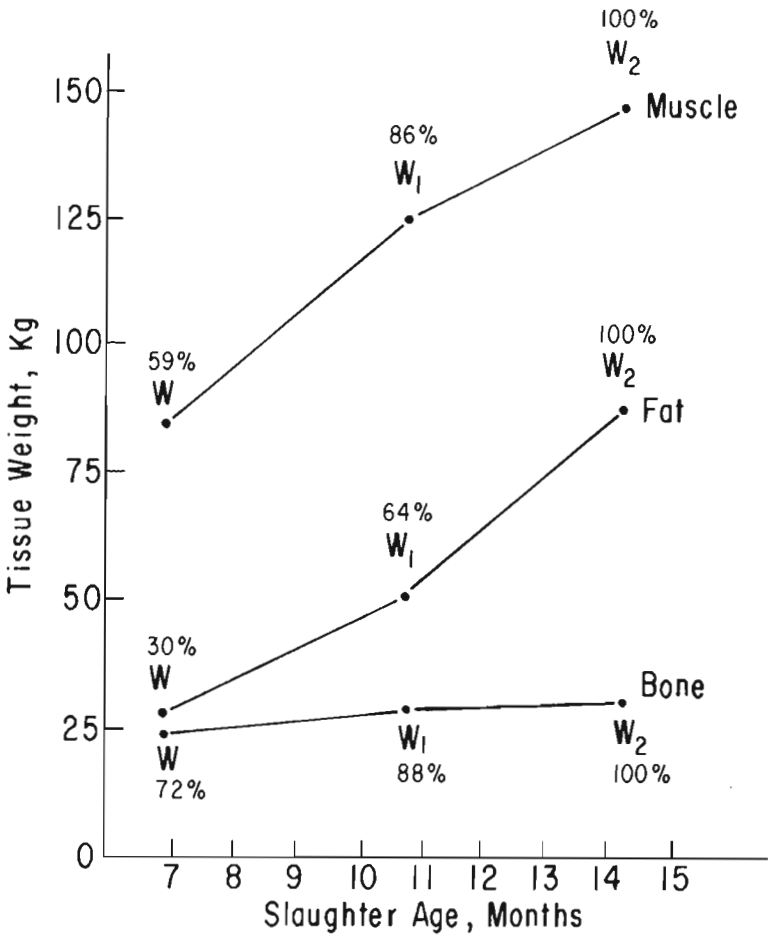


Figure 10. Growth of carcass bone, muscle and fat at W (weaning), W_1 (weaning plus 114 kg), and W_2 (weaning plus 228 kg) (7)

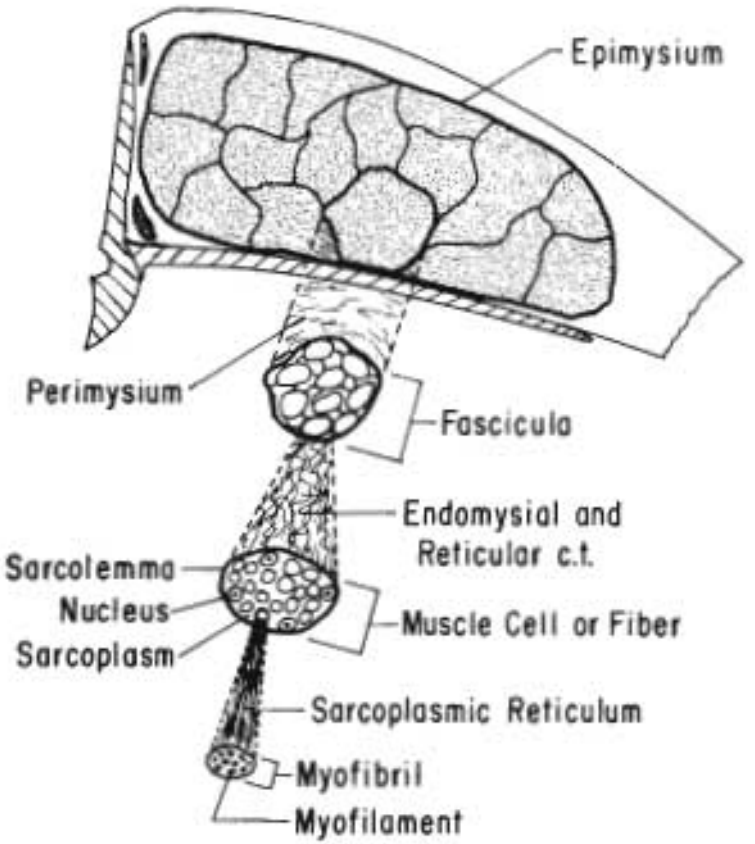


Figure 11. A schematic of a transverse section through the longissimus muscle

the muscle, subdividing it into smaller units called the fasciculi. The fasciculi of muscle vary in size and shape and each fasciculus is surrounded by perimyseal connective tissue. Within the fasciculus are contained the muscle cells or muscle fibers. Each muscle cell is surrounded by a membrane called the sarcolemma. Around the sarcolemma of an individual muscle cell and extending to the sarcolemma of adjacent muscle cells occurs a loose network of endomysial and reticular connective tissue fibers. In comparison to other cells, muscle cells are quite large (and formed by myotube fusion), hence they are multinucleated. The nuclei of mature muscle cells are located just beneath the sarcolemma. Within the muscle cells are contained the myofibrils. The myofibrils are "bathed" in a viscous fluid referred to as the sarcoplasm. Situated around the myofibrils is the sarcoplasmic reticulum. Within each myofibril numerous myofilaments occur. These are actually polymeric "strands" of the myofibrillar proteins, primarily myosin and actin. Post-mortem, these proteins become tightly linked forming the major protein of "dead" muscle tissue, actomyosin. The physical state of this protein has a great influence on tenderness. To show the sub-units of the myofibril more clearly it would be appropriate to examine an electron micrograph of a longitudinal section of a muscle fiber (Figure 12). In this figure the myofibrils within the muscle fiber, the sarcoplasmic reticulum, nuclei, sarcolemma, L and T systems and mitochondria can be seen. Along each myofibril can be observed successive light and dark areas. These are the I Bands (light areas) and A Bands (dark areas), which give the striated appearance to skeletal muscle. Bisecting each I Band is a narrow, dark line called the Z disc or line. Also, one might discern a distinct "zone" at the center of the A Band. This is the H Zone. The entities contained between successive Z discs comprise the sarcomere, which is truly the functional unit of muscle. Figures 13 and 14 show the units of the sarcomere, and sarcoplasmic reticulum, in more detail. Note the inter-digitating thick and thin filaments.

Although there still exist differences of opinion as to how muscle cells are formed and how myofibrils accumulate, the general course of events seems to be as follows. The early embryonic cell which eventually differentiates into a muscle cell is the myoblast. Myoblasts originate from the mesenchyme, a connective tissue (or layer) of the mesoderm. The mono-nucleated myoblasts, which are destined to become skeletal muscle cells, elongate and fuse with one another to form myotubes, producing cylinder-like structures which are now multinucleated. The myotubes, the primitive muscle fibers, apparently are capable of synthesizing the myofibrillar proteins myosin and actin which, in turn, are organized into, and thus form, the myofibrils. As the myotube continues to elongate and additional myofibrils accumulate within it, the nuclei are pushed to the periphery of the cell and the myofilaments become organized (longitudinally) along the myofibrils. This latter event results in the formation of the sarcomere.

Replication of the above processes during pre-natal life results in an increase in muscle cell numbers (hyperplasia) as well as an increase in muscle cell size (hypertrophy). It is believed that most of the pre-natal muscle cell hypertrophy occurs during the latter part

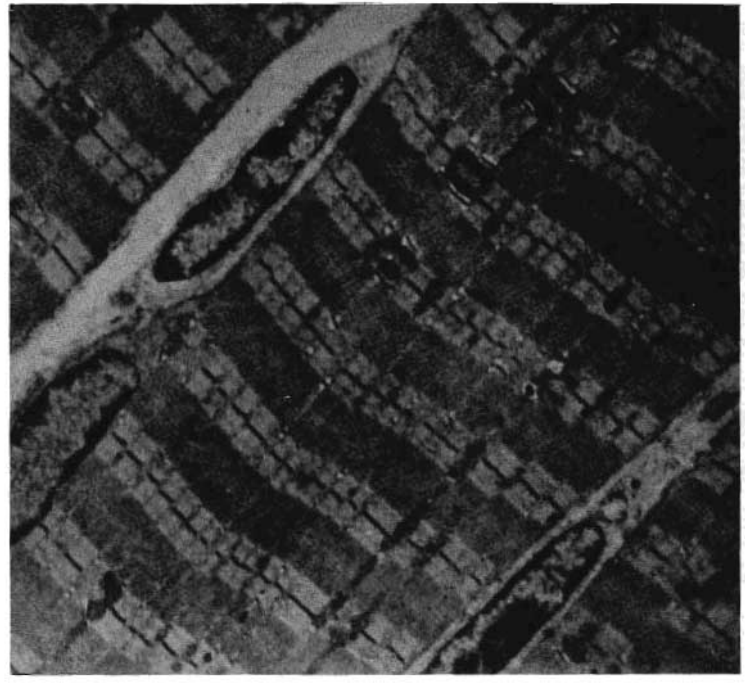


Figure 12. Electron micrograph of a longitudinal section of a bovine muscle fiber

of the fetal state. Also, it is thought that muscle cells, or more particularly the myofibrils, increase in length, pre-natally, by adding complete sarcomere units at the ends of the myofibrils.

The extent of intrauterine or pre-natal cellular differentiation in mammals has been related to the length of the gestation period. This has a direct influence on the state of development of the fetus at parturition and limits the amount of extrauterine or early post-natal cellular differentiation.

Since beef calves are born at a relatively late stage in their development, the extent of post-natal muscle cell hyperplasia (or increase in numbers) is believed to be minimal. Thus, the potential number of cells in cattle is pretty much established at birth or shortly thereafter.

Post-natal muscle growth, then, is a result of increases in cell size (hypertrophy). Muscle cells or fibers grow in both diameter and length. The increase in diameter is due primarily to an increase in the number and size of myofibrils within the muscle cell. The increase in number of myofibrils is believed to occur by longitudinal "splitting" of existing myofibrils to form new ones, while the increase in size of the myofibrils seems to result from the incorporation of newly synthesized myofibrillar proteins, myosin and actin, into the myofilaments. Increased muscle fiber diameter also results by accretions of sarcoplasmic proteins in the sarcoplasm, but this effect is thought to be minor.

Muscle fiber diameter in cattle may be influenced by such variables as breed, sex, level of nutrition, exercise and the amount of vascularization. Moreover, the state of physiological maturity of the animal can have a direct influence on the degree of expression of each of these variables. A consideration of these factors raises some interesting questions as to the selection and management of beef cattle for maximum muscle production.

Increases in muscle fiber length may occur via two major processes, the addition of new sarcomeres to the myofibrils and a decrease in the amount of overlap or interdigitation of the thick and thin myofilaments. Present evidence suggests that the former process exerts the most influence.

Finally, as the muscle mass increases, the number of nuclei also must increase to maintain the muscle. It is not clear as to whether the increase in nuclei is due to nuclear mitosis or satellite cell incorporation. Even though nuclei increase in number, there seems to be a steady increase in the ratio of muscle; nuclei with growth in beef animals.

Beef muscle is a heterogenous mixture of red, white and intermediate-type fibers. Each of these fiber types differs in its growth

potential, growth impetus and metabolic capabilities. In general, the red fibers are slow acting (ATPase activity), small in diameter, rich in oxidative (aerobic) enzyme activity and relatively low in glycolytic activity. The white fibers are fast acting, large in diameter, high in glycolytic (anaerobic) enzyme activity and low in oxidative capacity. Some studies show that the red fibers predominate in early post-natal life and that during the major surge in muscle growth many of these fibers are "transformed" into the white type, which predominates in later post-natal life. It is believed that this transformation is due mostly to the fact that the fibers are adapting to a change in muscle metabolism from aerobic to anaerobic conditions. From a number of nutritional aspects, it is important to know when this transformation takes place in the growing beef calf's life. As the amount of myoglobin pigment increases in muscle with age, the "changeover" cannot be assessed by color evaluation, but rather it requires extensive tissue enzyme studies.

Data in Figure 15 show the changes occurring in bovine muscle fiber diameter from one month to fifteen months of age. These results suggest that the maximum rate of increase in fiber diameter commenced after the seven months period, or during the post-weaning phase of life. Changes in muscle metabolism also tend to follow this pattern. This surge in fiber diameter growth occurred subsequent to the time when the skeletal measurements and long bone growth had attained a major portion of their potential linear growth and weight increase (see Figure 7, 8, 9 and 10). These results tend to support the supposition made earlier in this paper that muscle tissue had the second priority in post-natal growth impetus. Thus, after bone attains a high percentage of its potential growth or maturity, muscle growth is enhanced.

It may also be observed from the data in Figure 15 and 16 that the total post-natal increase in muscle fiber diameter for these experimental cattle exceeds that occurring pre-natally. If the data are extrapolated to zero months or birth, there was about a 2.3-fold increase in fiber diameter from birth to slaughter age. It is pointed out that these cattle were slaughtered about 68 kg lighter than normal. Nevertheless, these results do indicate that newborn calves have already attained a significant percentage of their potential muscle fiber diameter, a fact that might be utilized in "early selection indexes."

There seems to be no question that small-scale cattle mature earlier in fiber diameter than large-scale cattle. Hence, it may be concluded that breed and type within a breed have a significant influence on the rate of maturation of muscle fiber diameter. Considering animal scale only, the same might be said for the influence of sex.

It is pointed out that the large scale cattle used in this experiment yielded a greater quantity of muscle. Considering this and the fact that there was very little difference in fiber diameter between the two breeds at the fifteen-months period (Figure 15), it might be said that the variation observed in total amount of muscle in cattle is due to differences in the total number of muscle fibers rather than

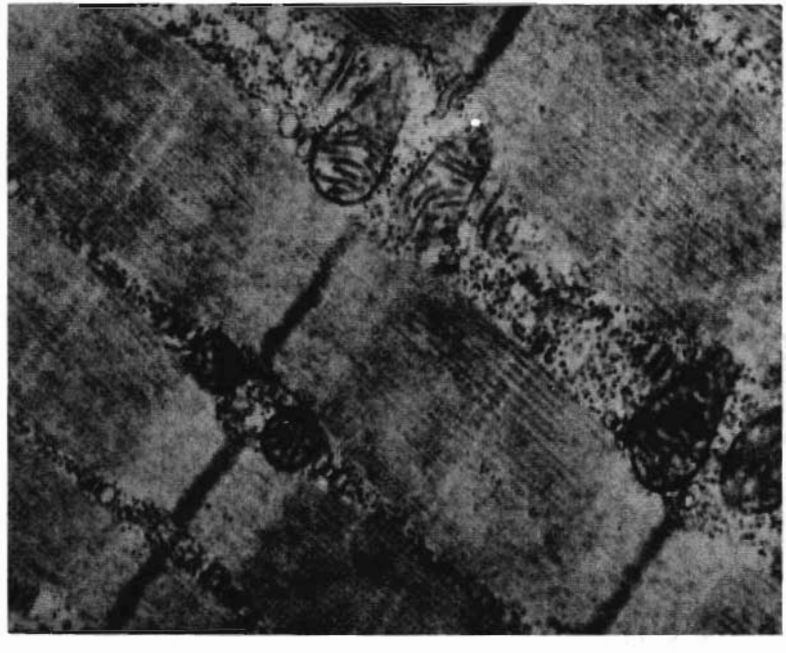
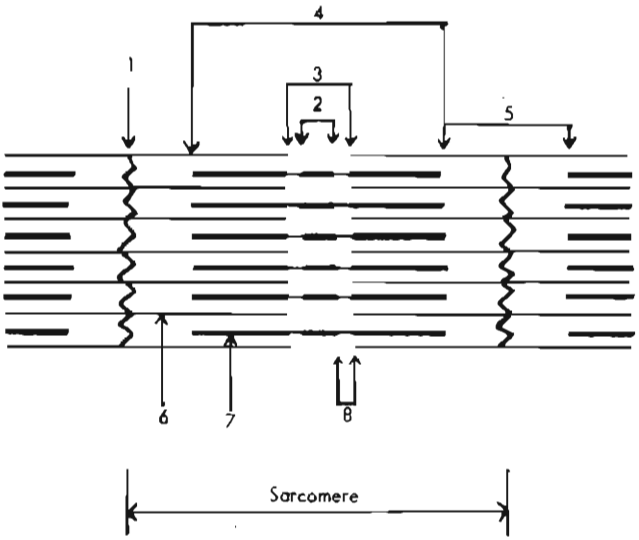


Figure 13. Electron micrograph of a longitudinal section of a bovine sarcomere



1: Z line (tropomyosin, troponin, α-actinin)
2: M-line
3: H or pseudo H zone
4: A band
5: I band
6: Thin filament (actin, α-actinin, β-actinin, tropomyosin, troponin)
7: Thick filament (myosin)
8: L line

Figure 14. A schematic of the sarcomere

the size or diameter of the fiber. To say the least, this may be an important consideration in the beef production business.

Total protein nitrogen of muscle may be partitioned into its major components: myofibrillar protein nitrogen, which is associated with the protein of the myofibrils; sarcoplasmic protein nitrogen, which arises from the proteins of the sarcoplasm, and stroma protein nitrogen, which makes up the connective tissue proteins. The results portrayed in Figures 17 and 18 show that the myofibrillar and sarcoplasmic protein nitrogen displayed generally increasing trends with increased age of the test animal. The increases were greater for the myofibrillar than for the sarcoplasmic protein nitrogen. Stroma protein nitrogen decreased pre-weaning then increased when the animals were

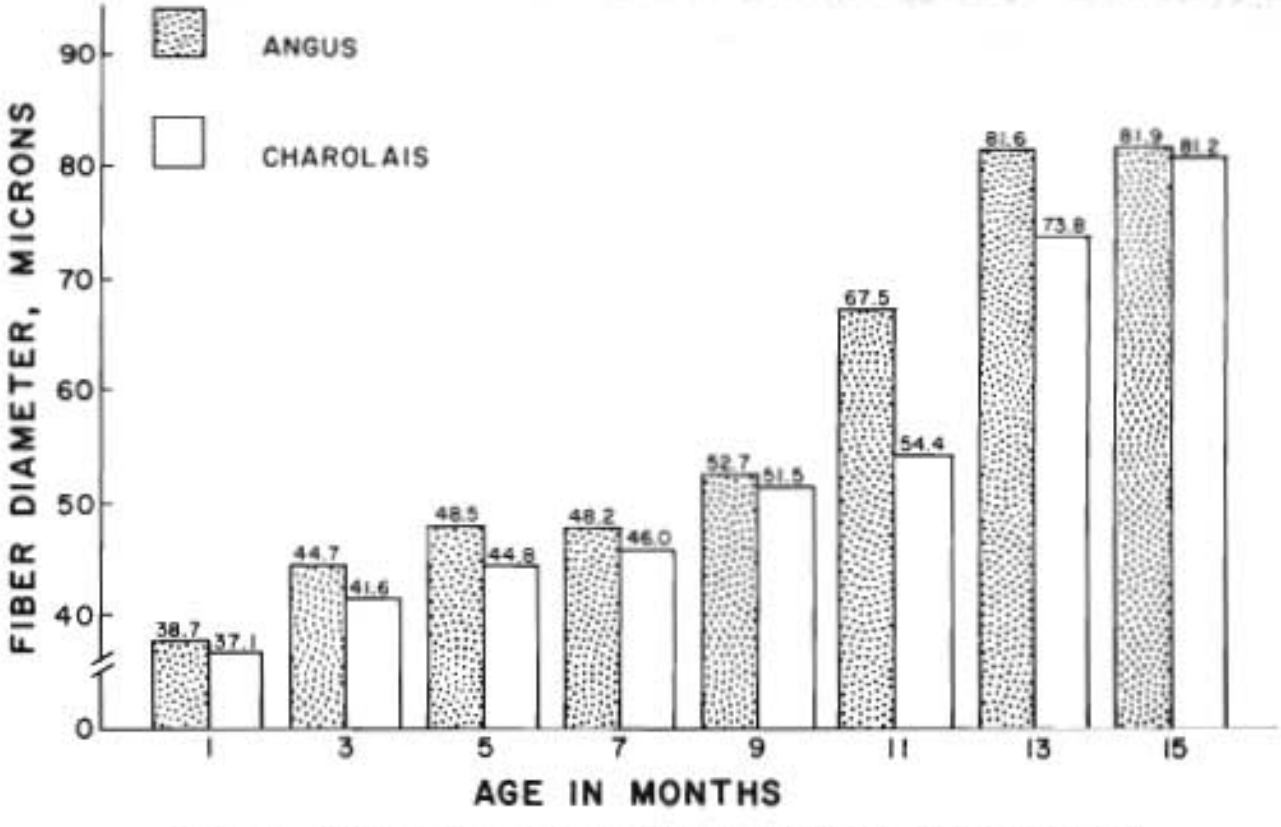


Figure 15. Muscle fiber diameter as affected by increased age and breed size

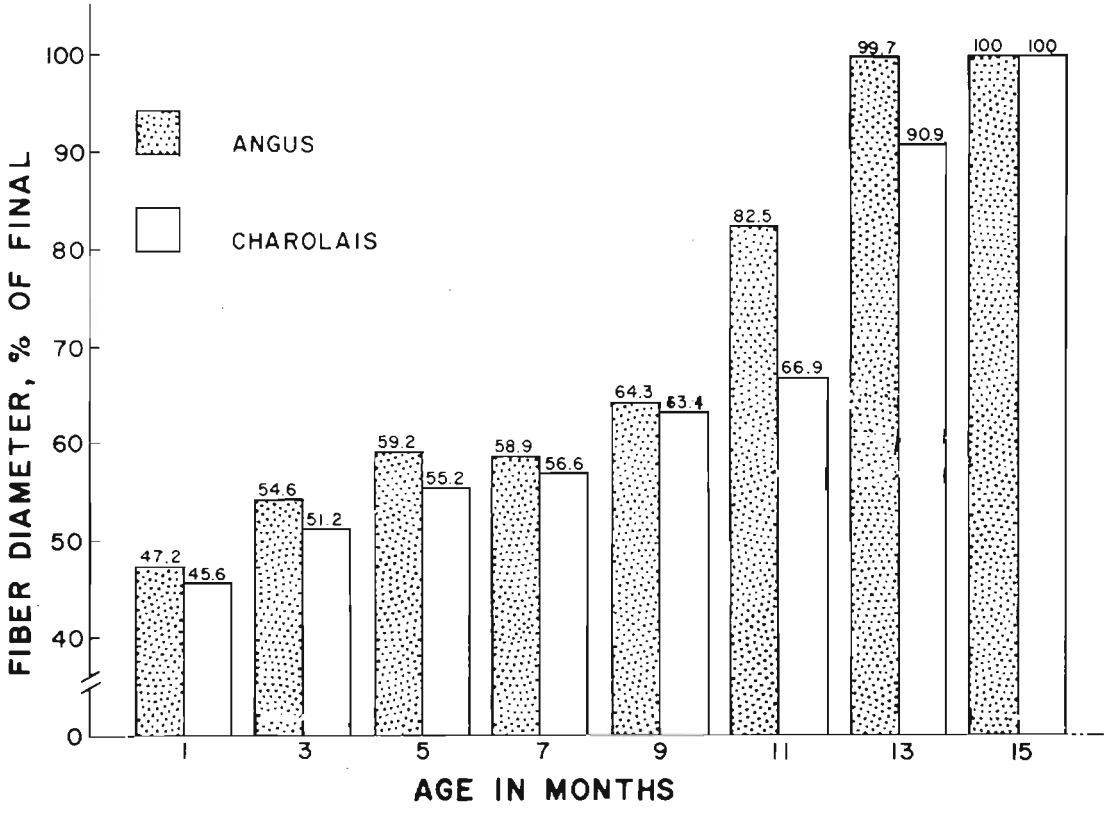


Figure 16. Muscle fiber diameter as affected by increased age and breed size, expressed as a percent of final measurements

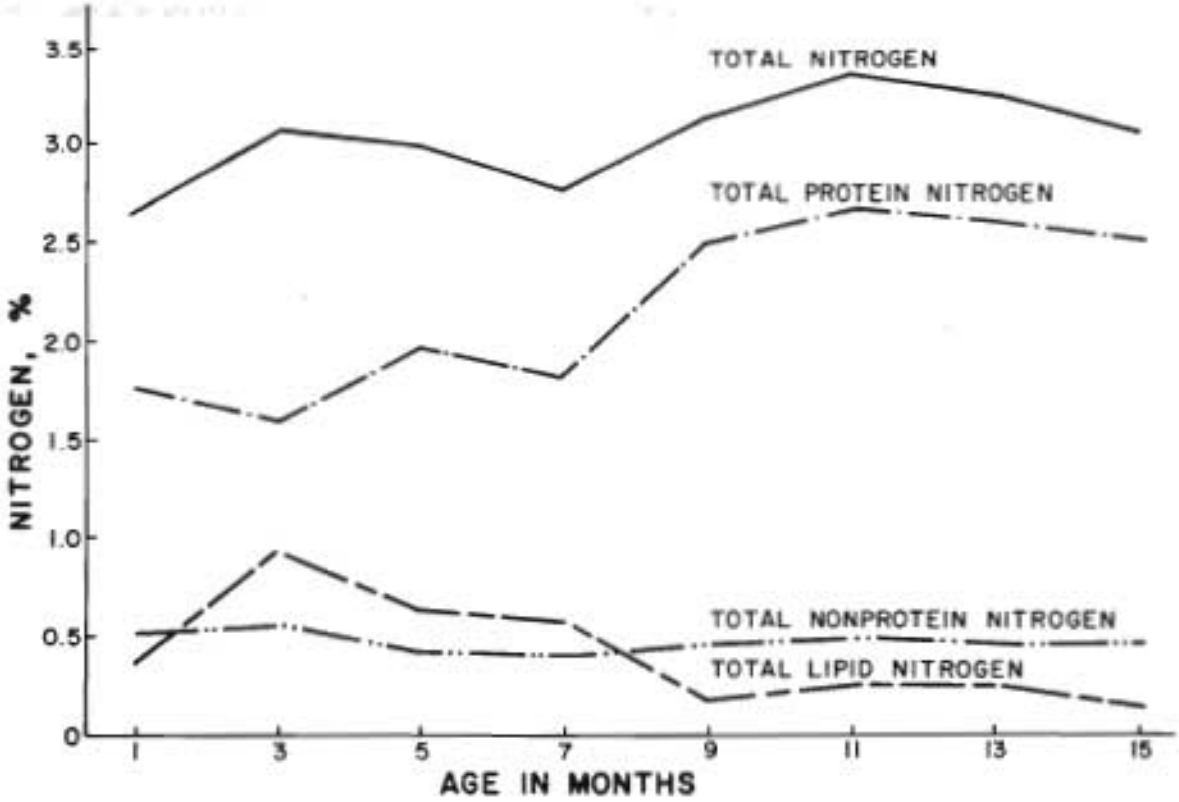


Figure 17. Major components of muscle tissue nitrogen as affected by increased age of Angus cattle

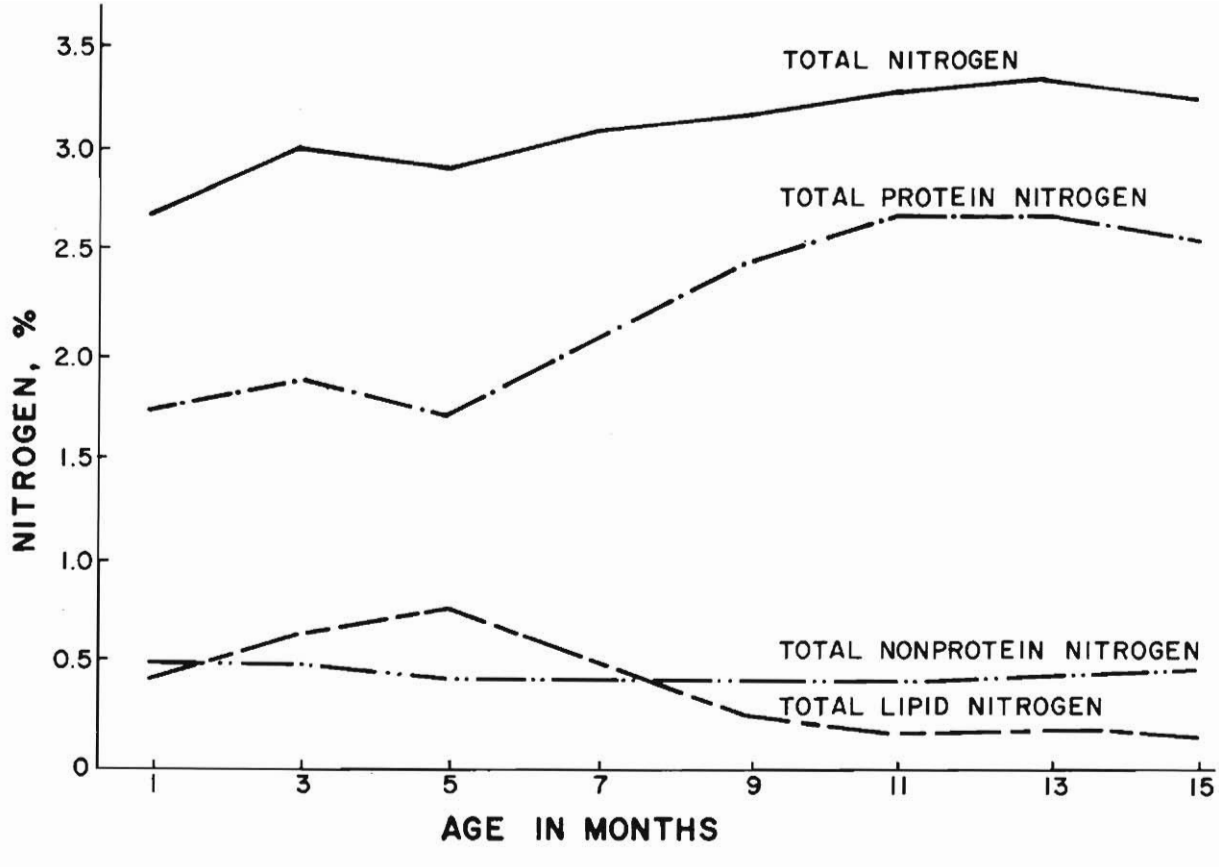


Figure 18. Major components of muscle tissue nitrogen as affected by increased age of Charolais cattle

about nine months old and remained relatively static thereafter. No significant breed differences were noted in these nitrogen components when expressed on a percent basis.

These results tend to support earlier statements on post-natal muscle cell hypertrophy in that increases in cell diameter are, in part, brought about by the incorporation of newly formed myofibrillar protein into existing myofilaments which make up the myofibrils (the major effect at this level) and by accretions of sarcoplasmic proteins in the sarcoplasm (the minor effect).

Fat Growth and Deposition

Though fatty tissue may appear to be a stable entity, it is continually subject to periods of lipid accumulation and mobilization, which in turn are dependent upon periods of nutrient sufficiency and insufficiency. This state of flux occurs prenatally as well as post-natally.

As previously stated, the mesenchymal cells originating from the mesoderm may be stimulated to form various types of cells. The mesenchymal cells which are destined to become fat cells are thought to be more densely located in the connective tissue network near the vascular system. As these cells accumulate droplets of lipid, they are transformed to adipoblasts. As the process of lipid accretion continues, these cells eventually develop into adipose or fat cells (Figure 19). Mature fat cells vary in size, ranging to more than 100 microns. When sufficient nutrients are available and numerous fat cells accumulate in connective tissue to the point of domination, the area is known as adipose tissue or fat depots (Figure 20). As fat depots increase in the animal's musculature, they do so at the expense of other constituents such as moisture, protein, etc.

The general order of adipose or fat tissue deposition is presented in Table 1. Obviously, marbling is the fat that we are most interested in obtaining in cattle, for the amount of marbling is the most critical factor in present-day standards for carcass quality grade in "finished cattle." Unfortunately marbling is the last fat to be deposited and perhaps the first to be mobilized. Of course, we have all observed carcasses with minimal fat in other areas and maximal marbling, but this is the exception rather than the rule. Perhaps researchers need to seek out these exceptions and determine the causative agent(s). Again, it is unfortunate that with our present technology these animals can be recognized only after it is too late, when the animal is slaughtered.

Marbling fat is located predominantly between the muscle fasciculi or in the perimysial connective tissue (Figure 21). Desirable marbling is uniformly distributed throughout the musculature. Very dense deposits of marbling fat, fat in only a few areas, are objectionable because of the excess connective tissue required to support the fat. Also, marbling fat tends to be situated near the arterial system which permeates the muscles (Figure 22). Thus, it might be said that

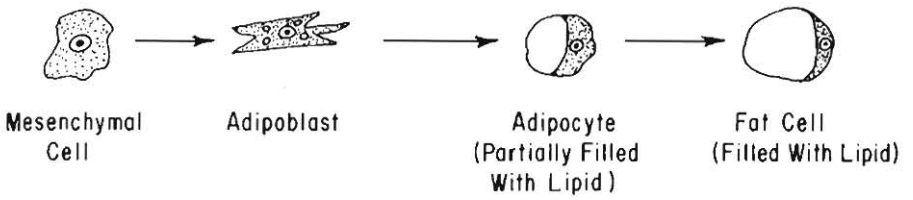


Figure 19. A schematic of fat cell growth

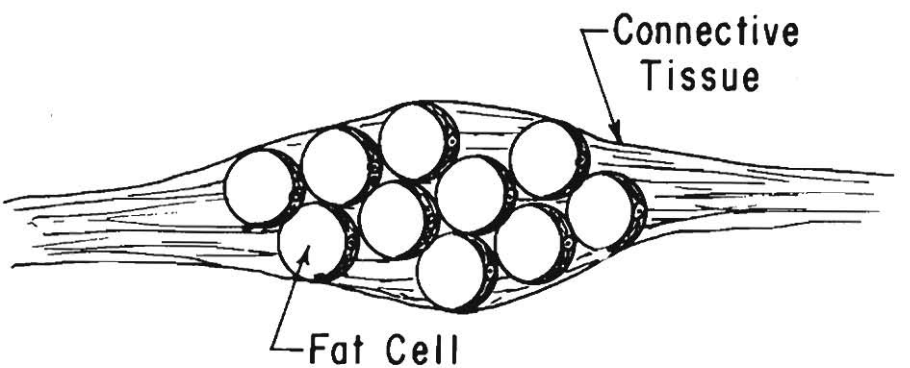


Figure 20. A schematic of adipose tissue

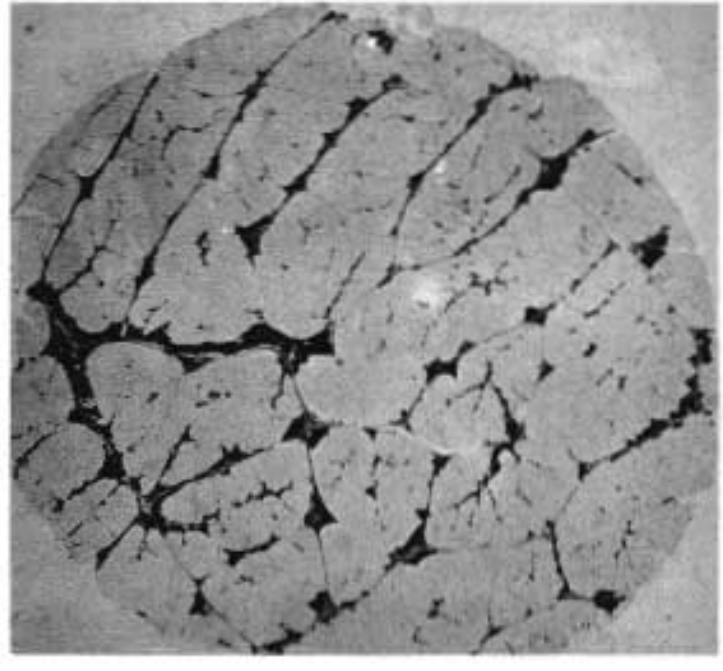


Figure 21. Photomicrograph of a cross section of bovine muscle showing areas of fat deposition (dark areas)

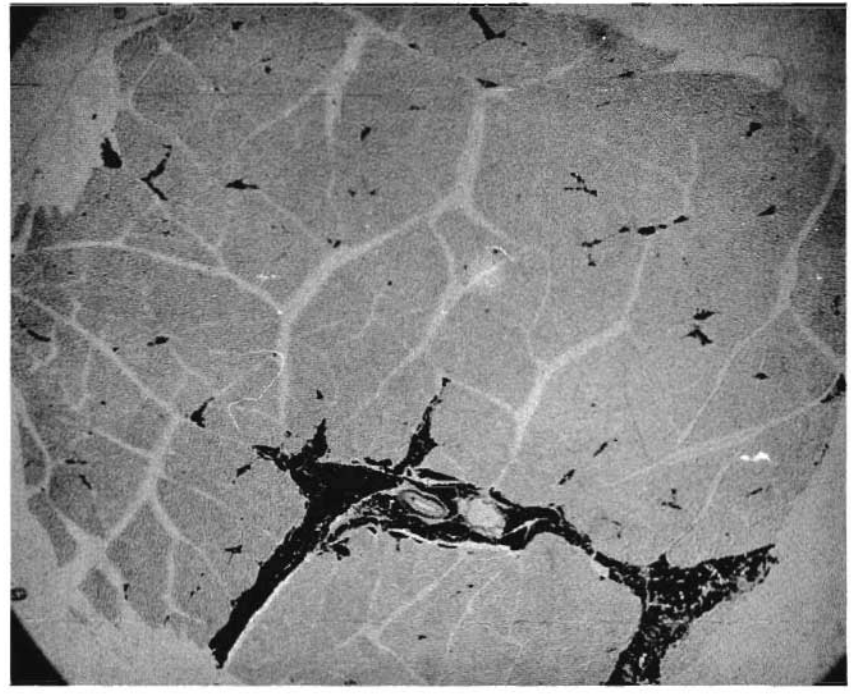


Figure 22. Photomicrograph of a cross section of bovine muscle showing fat deposition around the arterial (thick walled, left center) and venous (thin walled, right center) systems

Table 1. Order of deposition of adipose or fatty tissue during post-natal life of the beef calf

Order of deposition	Tissue
1	Perirenal fat (kidney knob)
2	Caul fat (fat around stomach)
3	Ruffle and mesentery fat (fat around intestines)
4	Fat around heart and in pelvic cavity
5	Intermuscular fat (seam fat)
6	Sibcutaneous fat (back fat, beneath skin)
7	Intramuscular fat (marbling)

this fat is located "where the action is" and consequently it is more liable to be mobilized than other fats. Moreover, as marbling fat represents a potential storehouse of energy or nutritive material for muscle metabolic functions, its quantity would be expected to vary with the level of nutrition of the animal. That is, it could accumulate during times of high levels of nutrition and be mobilized or decrease in quantity during times of low levels of nutrition of the animal. Hence, an important task of the animal nutritionist would be to maintain a level of nutrition in the animal that permits neither too rapid nor too slow a fattening process.

If animals are allowed to "slip" they'll most likely mobilize a portion of their marbling fat. This phenomenon, then, casts doubt on the practice of "holding beef animals back" to let the frame and some muscle develop in early life, then putting them on full feed later in life to take advantage of compensatory growth and rapid gains, if maximum quality grade (and top dollar for the carcass) is desired.

Considering the rather constant muscle:bone ratio that exists in cattle following the attainment of physiological maturity, fat content might be considered the major factor influencing the overall carcass composition of cattle in later post-natal life. For, as pointed out, as the percent fat increases, the percent water, protein, bone and muscle decreases.

What about the effect of breed? If we assume a particular breed to have a certain skeletal scale and mature weight and that these factors determine the advent of physiological maturity which, in turn, directly influences the order of deposition of the major carcass

tissues (Figure 10), then the effect of breed on fat deposition becomes obvious. The large breeds will have less fat at a given weight and chronological age when compared to the small breeds.

Since the same general line of reasoning holds for sex effects, fat deposition would be expected to be as follows: bull < steer < heifer at any given weight and chronological age. However, heifers tend to accumulate greater amounts of fat in the hip, brisket, plate and flank areas.

What about the effect of climate on fat and marbling deposition? If low temperatures give rise to greater energy retention and the animal's heat regulation mechanism decreases the rate of blood circulation within the muscle, does this result in less fat mobilization and more marbling?

What about cattle that are foraging extensively and consequently are more highly exercised than cattle in confinement? Does this result in increased vascularization and blood circulation? If so, would this environment tend to increase fat mobilization and result in less marbling?

In closing, it is pointed out that continual effort must be exerted to take full advantage of the genetic potential of our present breeds of cattle. In addition, environmental and management factors seem to exert a great influence on growth rate and beef carcass composition. To exploit these factors it is necessary to utilize fully the basic growth and development information on beef cattle that has evolved from the growth studies conducted throughout the United States.

LITERATURE CITED

1. Boyd, J. D. 1960. Development of striated muscle. Vol. 1, p. 64. In G. H. Bourne (ed.), The Structure and Function of Muscle, Academic Press, New York.

2. Denny-Brown, D. E. 1929. The histological features of striped muscle in relation to its functional activity. Proc. Royal Soc. Lond. 104:371.

3. Dickerson, J. W. T. and E. M. Widdowson. 1960. Chemical changes in skeletal muscle during development. Biochem. J. 74:247.

4. Dubowitz, V. 1963. Enzymatic maturation of skeletal muscle. Nature 197:1215.

5. Duesberg, J. 1960. Cited by J. D. Boyd, 1:63. In G. H. Bourne (ed.), Structure and Function of Muscle, Academic Press, New York.

6. Goldspink, G. 1968. Studies on post-embryonic growth and development of skeletal muscle. J. Cell Research 3:539.

7. Guenther, J. J., D. H. Bushman, L. S. Pope and R. D. Morrison. 1965. Growth and development of the major carcass tissues in beef calves from weaning to slaughter weight, with reference to the effect of plane of nutrition. J. Animal Science 24:1148.

8. Guenther, J. J. 1974. Physiological maturity evaluation of cattle differing in mature size, pp. 28-53. In Proceedings 27th Annual Reciprocal Meat Conference.

9. Hedrick, H. B. 1968. Bovine Growth and Development. Missouri Agricultural Experiment Station Research Bulletin 928.

10. Helander, E. 1957. On quantitative muscle protein determination. Acta Physiol. Scand. 41:Suppl., 141.

11. Holtzer, H., J. M. Marshall and H. Finck. 1957. An analysis of myogenesis by the use of fluorescent antimyosin. J. Biophys. Biochem. Cytol. 3:705.

12. Moody, W. G. and R. G. Cassens. 1968. Histochemical differentiation of red and white muscle fibers. J. Anim. Sci. 27:961.

13. Needham, A. E. 1964. The Growth Process in Animals. D. Van Nostrand Company, Inc., Princeton, New Jersey.

14. Nelson, O. E. 1953. Comparative Embryology of the Vertebrates. The Blakiston Company, New York.

15. Winnick, R. E. and T. Winnick. 1960. Protein synthesis in skeletal muscles with emphasis on myofibrils. J. Biol. Chem. 235:2657.

16. Growth and Development of Mammals. 1967. Plenum Publishing Corp., New York, NY.

17. Animal Growth and Nutrition. 1969. Lea and Febiger, Philadelphia, Pa.

QUALITATIVE ASPECTS: TENDERNESS, FLAVOR, JUICINESS, COLOR OF LEAN AND FAT

Robert F. Kelly*

Introduction

Consumers in the United States are concerned about meat palatability--tenderness, flavor, juiciness, color of lean and fat. Population increases may mean increased competition for cereal grains. Roughages and forage not used by humans are important adjuncts to human food supply when converted by ruminants to meat. What is the quality of meat produced primarily from forages and crop residues? Will this meat find acceptance by the consumer in the United States? Because we are talking about a particular feeding or regimen, that is, forage feeding, I will discuss the influence of age, breed, sex and ante- and post-mortem treatment on the quality of the animal/carcass in this discussion. Quality simply defined may be "what the consumer will buy."

The consumer is a complex and little understood factor in our meat system. For example, meat research workers tend to cook meat for palatability studies using methods which can be standardized as to time, temperature, size of cut and other factors. Many consumers do not follow our meat preparation procedures. Juillerat et al. (27) found consumers used many methods of preparing round steak ranging from pan fried to broiled, tenderized and not tenderized, well done and not well done as alternatives for cooking meat in their home. One of our problems may be trying to relate our research to this consumer in a meaningful manner. Also, we need to be more specific in our research aims as this conference has set out to do. For example, when one goes to the literature to review a subject such as this to draw conclusions and map out future plans, one is impressed with the large amount of work that has been done with beef, the source of which is unknown. Many works cite "ribs of choice grade were purchased from a packer" as their description of the meat used in several types of studies to relate meat acceptability to various factors. No background data are available to help determine what the breed, sex or ration may have been which was used to produce this meat.

In this discussion, tenderness, juiciness, flavor and color of lean and color of fat were an intimate part of many projects. Therefore,

* Professor of Food Science and Technology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.

these factors will be discussed as a group of attributes that may be influenced by age, breed and sex with an attempt being made to cite mostly works which involved forage feeding or treatments similar to this practice.

Effect of Age

Barbella et al. (2) found that the effects of age and sex were principally that the meat from both steers and heifers under 11 months of age had poorer juice quality than other groups. The age and feeding regimen are many times cited as having an adverse effect on consumer preference. Meyer and Ensminger (34) found consumers 1) had no preference for federally graded or packer branded beef; 2) preferred medium colored lean and showed a slight preference for light color over dark; 3) had no objection to yellow fatted beef; and 4) preferred the leaner, lower quality grades of beef. Fontenot et al. (14) found rate of gain during the grazing season decreased as plane of nutrition (and gain) increased during the preceding drylot feeding period. Figure 1 shows the experimental design of the Fontenot et al. (14) work. In the fall, 72 steer calves were purchased and allotted to four treatment groups as follows:

Lot 1 - maintenance,
Lot 2 - hay,
Lot 3 - hay plus limited grain,
Lot 4 - full fed in drylot.

Each spring 12 steers were slaughtered (three from each treatment) and 12 were put on pasture. In the fall, the pasture steers were slaughtered as well as 12 from drylot. This was repeated with the remaining steers the next year. This experiment was repeated two times. In the drylot fed cattle, carcass grade, yield and percent meat (lean and fat) in the carcass were significantly ($P < .01$) affected by nutrition or age. These values increased as nutrition or age increased. Pasture had an equalizing effect on most attributes. That is, the maintenance (Lot 1) and the hay (Lot 2) steers improved in grade, yield and percent meat, while the limited grain (Lot 3) and full fed (Lot 4) steers decreased in these characteristics. Graham et al. (16) evaluated the meat quality characteristics on the meat from these steers. Figure 2 shows the average carcass grade for the two trials. The carcasses of the maintenance (Lot 1) steers graded low utility throughout this study. The hay-fed steers (Lot 2) graded high utility. The steers fed hay plus limited grain (Lot 3) graded from high standard to high-good. Carcasses from the full fed drylot steers graded from average choice to average prime. Placing the steers on pasture improved the carcass grade of the maintenance and hay fed steers (bars in Figure 2). The carcass grade of cattle previously full fed in drylot decreased.

Figure 3 shows the taste panel juiciness scores (Graham, (16)). Highly significant differences in juiciness due to nutrition and age were noted. Generally, the steers receiving grain (Lots 3 and 4) increased in juiciness from 10 months to 23 months of age. This was

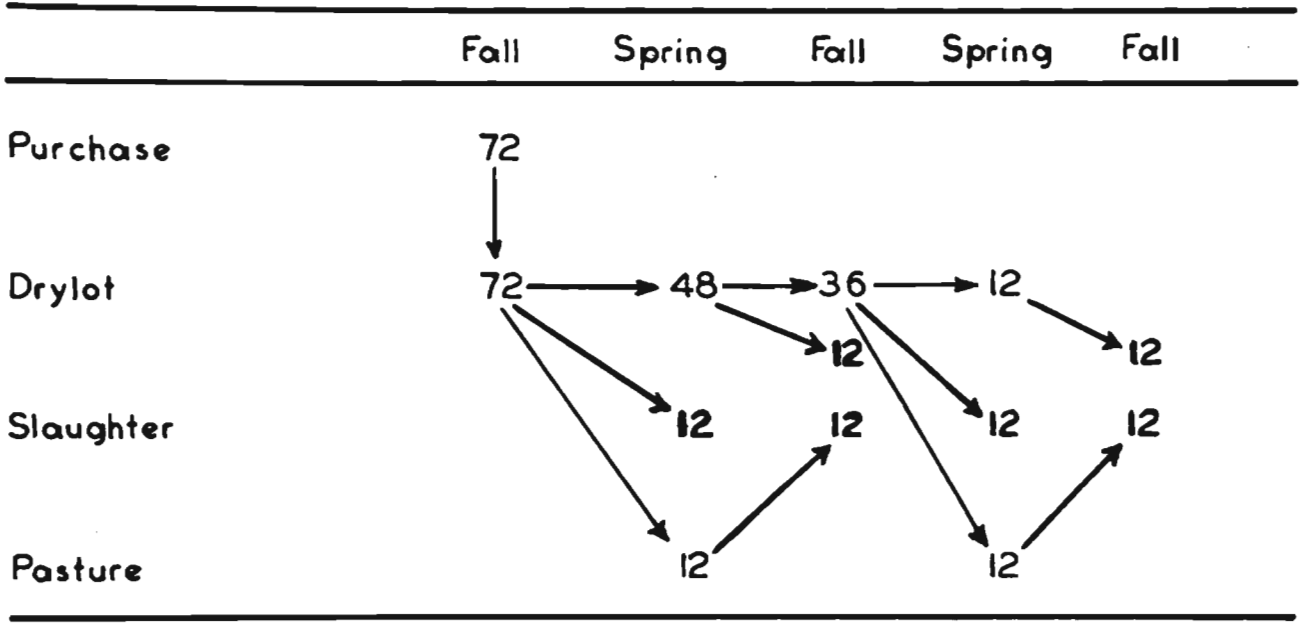


Figure 1. Experimental design used by Fontenot et al. (14).

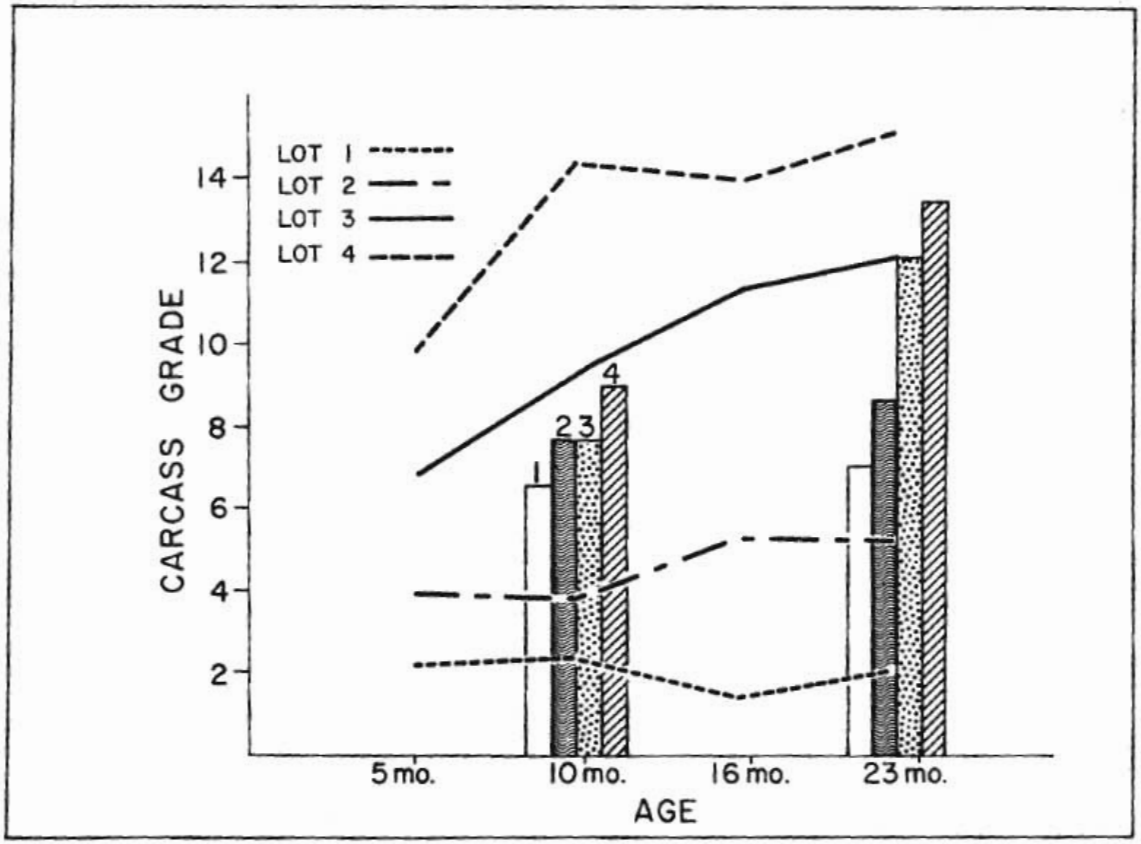


Figure 2. Average carcass grade for two trials, Graham et al. (16). Ten = average good, 11 = high good, etc.

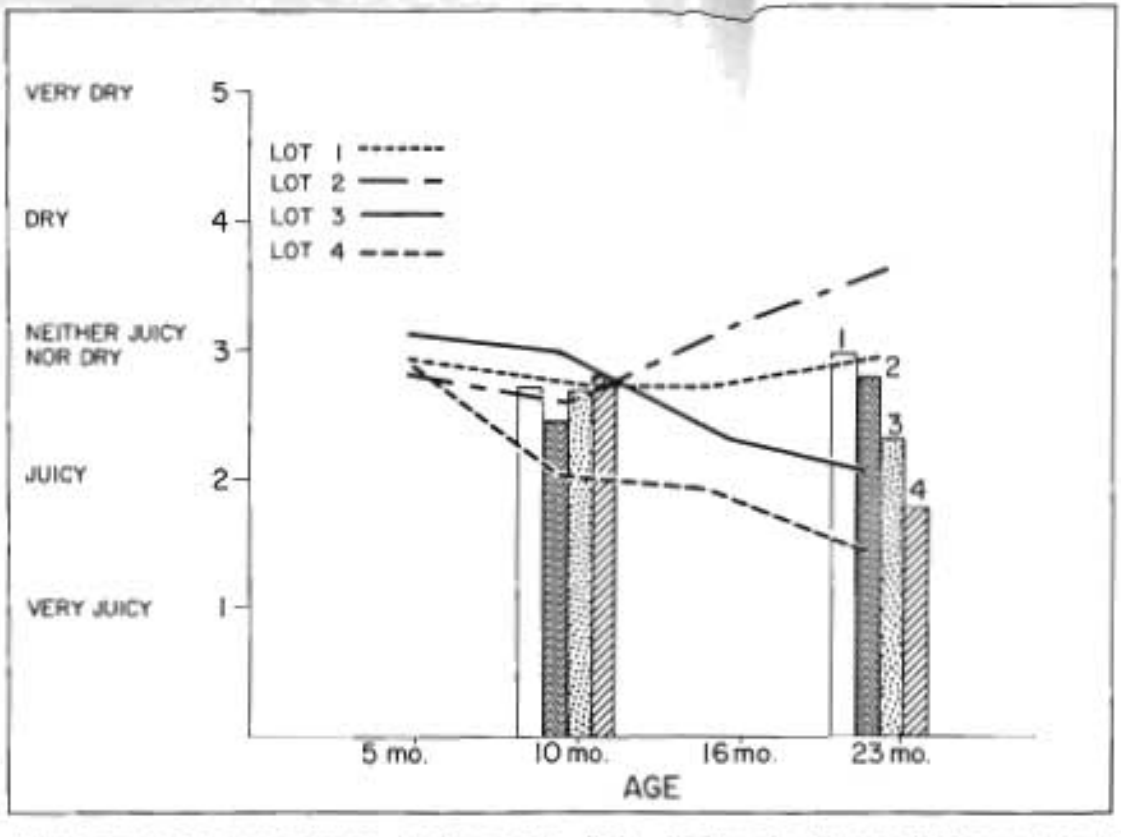


Figure 3. Taste panel juiciness scores, Graham et al. (16). Highly significant differences in juiciness due to nutrition and age were noted in drylot steers (lines).

not noted in the maintenance or hay (Lots 1 and 2, respectively) steers which were judged to be neither juicy nor dry.

Figure 4 shows that tenderness increased with nutrient level but was not significantly affected by age in the drylot (lines) or pasture (bars) groups.

This work demonstrates that even though extreme feeding regimens (maintenance versus full fed) are employed in a management system, the use of pasture (bars) can improve significantly the quality of the product in terms of grade, tenderness and juiciness.

Craig et al. (11) also studied the effect of pasture versus drylot. They noted that meat from drylot cattle was brighter in color ($P < .05$) but that pasture per se did not appreciably affect pigment concentration in meat. The amount of yellow color in the fat was greater in the carcasses from the pasture-fed steers than in those on drylot.

Tuma et al. (50) studied influence of animal age on factors associated with beef quality. Taste panel flavor and juiciness scores did not appear to be related to animal age (18-42-90 months), marbling level, or aging period. Tenderness of longissimus steaks decreased significantly with increasing animal age. The greatest difference in tenderness was observed between the 18- and 42-month old animals. Walter et al. (51) reported that B maturity was favored in flavor over E maturity. Romans et al. (46) selected 80 beef ribs from four maturity groups (A, B, C and D) and two marbling levels (slight and moderate). Differences between A, B and C maturity groups for tenderness were nonsignificant. D maturity meat was less tender and had the highest shear values. The flavor of B maturity meat was more acceptable than that from D maturity. It is the commonly accepted hypothesis that marbling and maturity tend to counterbalance one another with regard to their effect on beef tenderness (5, 7, 38). This was not evident at the maturity and marbling levels studied. In the same study, Romans et al. (47) reported that there were no differences in percent total pigment (myoglobin and hemoglobin) in each of the four maturity groups. Highly significant differences existed in myoglobin content among the maturity levels studied. Only the A maturity level in each case was significantly ($P < .01$) different from that of the other three groups. Myoglobin values did increase with increasing maturity. Pigment content did not differ significantly between moderate and slight marbling levels. Goll et al. (15) demonstrated that increased quantities of marbling did not compensate for increased maturity; i.e., there was no maturity-marbling interaction.

In addition to the above cited works which related age to palatability attributes, one can add the work of Breidenstein et al. (9). Using carcasses from cattle of unknown background but selected on the basis of USDA maturity groups A, B, E and USDA marbling scores of slight, modest, slightly abundant and abundant, these workers showed little difference between A and B maturity while E was found to be less desirable. Increased marbling improved palatability but only when wide

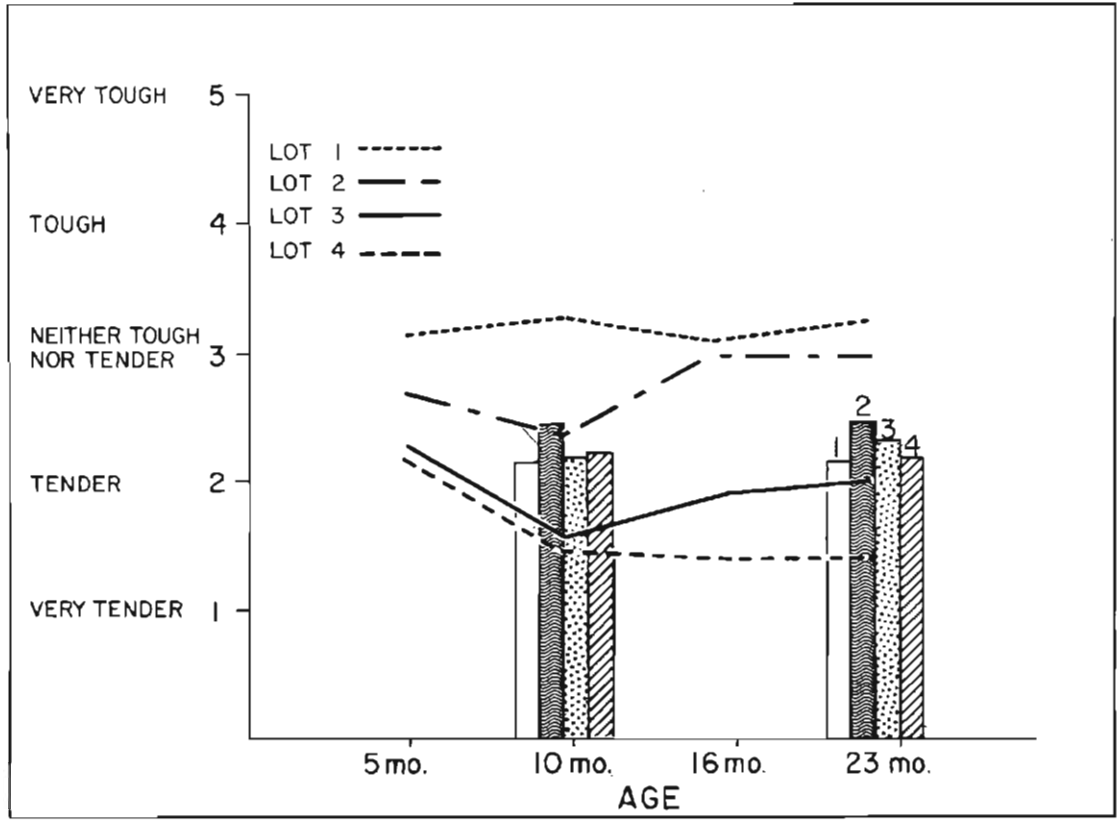


Figure 4. Taste panel tenderness scores, Graham et al. (16). Tenderness increased with nutrient level but was not affected by age in drylot (lines) or pasture (bars).

differences were considered. Tenderness differences were not significant between A and B maturity but were significantly ($P < .01$) different for E. Juiciness and flavor were significantly influenced by marbling but not by maturity. The E maturity was significantly ($P < .01$) darker than A maturity. Color score was not related to panel tenderness.

Marbling and its relationship to meat tenderness has been discussed as thoroughly as any attribute could be. Parrish (38) recently reviewed the many studies on marbling's effect on palatability and cited reviews of others (5, 7, 41, 26, 35, 1) on this same topic. Parrish et al. (39, 40) also reported that the internal temperature to which meat was cooked was an important effector of palatability and cooking loss. As internal temperature increased, palatability characteristics for flavor, tenderness and overall acceptability decreased and the percentage cooking loss increased. These workers were the first to report no interaction between degree of marbling and internal cooking temperature. Increasing amounts of marbling will not compensate for a reduction of palatability attributes when broiled to higher temperatures. Regardless of amount of marbling, the most desirable rib steak was obtained when broiled at 60°C internal, and greater internal temperature only reduced palatability. They concluded that "Our study shows that internal cooking temperature of rib steaks is a much more important factor in palatability than marbling and that degree of marbling, and its interaction with internal cooking temperature, have essentially no effect on palatability characteristics. These two lines of evidence, no marbling-maturity interaction and no marbling-internal cooking temperature interaction, do not support the significance placed on marbling in grading carcasses, nor do they support the thesis that increased marbling improves palatability."

Schmidt and Parrish (48) studied molecular properties of postmortem muscle. This study considered meat from carcasses from three maturity groups as follows:

Veal - 3 to 6 months of age,
A - 12 to 20 months of age,
D - 54 to 60 months of age.

They found that heating rib steaks to an internal temperature of 60°C solubilizes collagen and improves tenderness, but increased heating only further "toughens and dries" fibrillar proteins, and this toughening and drying effect observed by the panel cannot be compensated for by increased intramuscular fat content. Furthermore, greater internal temperatures (above 60°C) increases percentage fat, and this may not be desirable for the calorie conscious consumer who cooks meat well done.

Light Microscopy

Sections from all maturity groups contained many collagenous and reticular fibers, but only a few elastic fibers. Collagenous and reticular fibers appeared within the endomysial and perimysial spaces.

Elastic fibers were irregularly dispersed and were most frequently observed in and adjacent to blood vessels and nerve ganglia. Heating to an internal temperature of 50°C resulted in decreased muscle fiber diameters. An internal temperature of 60°C caused further muscle fiber and endomysial and perimysial connective tissue shrinkage. At internal temperatures of 70°C and above (80° and 90°C), a progressive increase in connective tissue shrinkage and fragmentation was evident. Thus, connective tissue shrinkage begins at approximately 50°C and continues until fragmentation eventually occurs at higher temperatures. Light microscopy observations also showed that the size and degree of aggregation of connective tissue fibers increased with carcass maturity. Moreover, the effect of heat on connective tissue fibers was age dependent, since the more highly aggregated fibers of D maturity were more resistant to heat than the less aggregated fibers of veal and A maturity. This observation may partially explain why longissimus from D maturity usually required higher internal temperatures (70°C) than veal or A maturity (50-60°C) to reach maximal tenderness. Thus, to the extent that tenderness is affected by connective tissue, meat from older animals would have to be heated to a higher internal temperature or for longer periods of cooking time than meat from younger animals to produce the same degree of tenderness.

Phase-contrast microscopy results indicate that morphological features of muscle cells, such as myofibrils, nuclei and extracellular stellate cells remained relatively intact at all internal temperatures; however, cellular shrinkage due to extrusion of myofluids, and endomysial connective tissue shrinkage began at 50°C. Perimysial connective tissue shrinkage occurred at 70°C and above (80 and 90°C). Thus, the major structural change associated with improved meat tenderness observed with phase-contrast is a change in connective tissue and this change is manifested by decreased shear force.

From electron microscopy studies the following conclusions are made:

1. Z-line integrity is lost during post-mortem aging;

2. heating muscle causes progressive myofibrillar shrinkage and degradation;

3. heating muscle to 60°C causes major myofibrillar structural alterations including loss of M-line structure, initiation of thin filament disintegration and thick filament coagulation;

4. heating muscle to 70°C and above causes progressive and severe thin filament coagulation and, finally

5. the conventional banding patterns of muscle were observed at all internal temperatures.

The composite results of light, phase and electron microscopy indicate that the effect of increasing internal temperatures on the

structural components of muscle is significantly related to tenderness and shear resistance changes in bovine longissimus.

Light and phase-contrast micrographs showed that increasing internal temperatures caused a progressive connective tissue fiber shrinkage and fragmentation. Thus, heating should increase the tenderness of the connective tissue components of meat. But progressive heating also caused an increase in myofluid extrusion that eventually resulted in a compressed, hardened structure. At an internal temperature of 60°C and above, myofibrillar proteins coagulated and hardened. The tenderness of meat should initially increase to a maximum because of connective tissue fragmentation. With further heating, a decrease or no change in tenderness results because of the hardening and drying effects by fluid loss and myofibrillar protein coagulation. These latter effects would probably offset any favorable tenderness effect of further connective tissue fragmentation by increased heating.

Effect of Forage Systems

Within the past several years, beef from forage systems has been examined by several researchers (4, 12, 33, 43, 10). A low-energy ration consisting of corn silage ad libitum and 0.7 kg cottonseed meal per day and a high energy ration consisting of corn ad libitum, 4.5 kg corn silage, and 0.7 kg cottonseed meal were fed to Hereford steers by Bayne et al. (4). The low-finished carcasses graded low good and had a fat thickness at the twelfth rib of 4 mm. High-finished steers had mean fat thickness of 10.8 mm and graded low choice. Tenderness scores and shear values were not affected by finish. However, flavor scores of the high-finished steers were significantly ($P < .01$) higher than those of the low-finished steers. Dube et al. (12) fed steers on silage alone to 409 kg or hay to 340 kg and then silage to 409 kg. Corn silage, as compared to hay during the early feeding period resulted in more desirable broth flavor ($P < .01$) and steak flavor ($P < .01$) as well as greater intensity of broth flavor ($P < .05$) in the longissimus. No direct association between flavor and intramuscular fat levels existed in spite of the fact that the silage-fed cattle were younger. Steers fed corn silage were more tender than those fed hay. Steaks scored higher in juiciness from corn silage than hay-fed steers.

McCampbell et al. (33) evaluated beef ribs from cattle managed as follows: Lot 1--silage-grain feeding; Lot 2--winter (cereal) pastures and self-fed grain supplement; Lot 3--winter pasture alone; and Lot 4--winter pasture plus a short summer drylot feeding period. Cattle from Lot 3 were slaughtered at the end of the winter grazing period at approximately 386 kg liveweight and a slaughter grade of good. The other lots were fed until they reached 400 kg and graded good-plus. Taste panel scores for tenderness were significantly lower for Lots 3 and 4. Significant differences in flavor intensity, flavor desirability and composite scores also indicated that beef produced by winter pasture alone or with a short drylot feeding period was less desirable than beef produced by either drylot or self-fed grain on winter pasture. Purchas and Davies (43) fed Friesian steers

either a predominantly cereal (barley) diet or a pasture diet for at least 160 days. Those on cereal diet grew 31 percent faster than the animals on pasture so that the latter group was an average 69 days older. Flavor of top-side roasts from cereal-fed animals was more acceptable. Warner-Bratzler (W-B) shear values were higher for the pasture-fed animals. Generally, this study confirms that cattle fed on pasture tend to produce leaner carcasses and tougher meat, with a less acceptable flavor, than cattle fed on cereals. Corah et al. (10) reported that the carcasses of steers receiving oat grain on pasture when compared to those of steers receiving a comparable ration with pasture hay in the feedlot, had significantly less crude fat, less dissectable fat and more lean. In general, carcasses from the groups given hay alone had lower scores for marbling, coarser textured lean meat, and softer appearance than carcasses of steers fed hay-grain rations.

Table 1 shows work by Bowling et al. (6) who used a technique of pairing of grain-fed carcasses with forage-fed carcasses with identical marbling and maturity scores. Flavor, tenderness, shear force and overall satisfaction were superior for grain-fed steers.

Table 2 shows work by Huffman and Griffey (21) where no difference was found to exist between forage-fed and grain-fed beef.

Table 3 shows work by Allen of Kansas (unpublished) showing grass-fed beef was lower in grade, flavor score, juiciness, tenderness and overall compared to grain-fed cattle.

Wheeling et al. (53) reported on the effect of forage versus grain feeding on beef palatability. Table 4 shows that W-B shears and tenderness values were in favor of forage-fed cattle. Flavor, juiciness and overall satisfaction scores were similar among forage-fed, low-quality grain-fed and high-quality grain-fed samples.

Effect of Sex

The influence of sex on beef palatability has been investigated by Field et al. (13). They reported the following results:

1. Taste panel results showed no significant difference between bulls, steers and heifers, 300-399 days old.

2. Steers and heifers 400-499 days old had slightly higher palatability ratings than bulls of similar age and marbling.

3. Bulls 500-599 and 600-699 days of age were tougher than steers or heifers of comparable ages.

4. Flavor and juiciness from steers and heifers were superior to bulls.

The influence of double muscling on palatability traits was studied by West et al. (52). Forty-three bulls, steers and heifers

Table 1. Palatability of forage versus grain-fed beef[a]

Trait	Forage	Grain
Flavor	5.2[c]	6.0[b]
Juiciness[d]	5.6[b]	5.8[b]
Muscle fiber tenderness[e]	5.4[b]	6.1[c]
Shear force, kg	8.4[c]	5.6[b]
Overall[d]	5.0[b]	6.1[c]

[a]Bowling et al. (6).

[b,c]Means in same column bearing different superscripts differ significantly ($P < .01$) n = 36 for forage-fed and 36 for grain-fed.

[d]Sensory panel parameters: 8-point scale: 8 = extremely desirable, 4 = dislike slightly.

[e]Muscle fiber (subjective): 8 = extremely tender, 1 = extremely tough.

Table 2. Palatability by type of feed

Trait	Forage	Grain
Quality grade	G+	G+
Tenderness	6.6	6.2
Juiciness	7.0	6.4
Flavor	7.6	7.6
Shear, kg	7.5	8.8

Source: Huffman and Griffey (21).

Table 3. Consumer response to grain- and grass-fed beef

Treatment	Grade	Flavor	Juiciness	Tenderness	Overall
Grass-fed	G-	5.1	4.4	4.3	4.6
Grain-fed	G+	6.7	6.1	6.6	6.8
Grain-fed	C+	6.9	6.5	6.7	6.7

Source: Allen et al., personal communication.

Table 4. Palatability of grain-fed and forage-fed beef rib steaks

Factor	High quality[a]	Low-quality[b]	Forage-fed
Shear force, kg	2.36[d,e]	2.84[d]	1.94[e]
Tenderness[c]	5.52[d]	4.98[d]	6.58[e]
Flavor	5.59[d]	5.25[d]	4.50[e]
Juiciness[c]	5.68[d]	5.10[d,e]	5.02[e]
Overall satisfaction[c]	5.54[d]	5.17[d,e]	4.86[e]
Cooking loss (percent)	19.60[d,e]	21.60[d]	18.05[e]

[a]Steaks selected from carcasses possessing modest, moderate marbling.

[b]Steaks selected from carcasses possessing traces, slight marbling.

[c]Based on an eight-point hedonic scale where 6 = like moderately, 5 = like slightly, 4 = dislike slightly, and 3 = dislike moderately.

[d,e]Means on the same line bearing the same superscripts are not significantly different (> .05).

Source: Wheeling et al. (53).

of known genotype relative to the double muscling (DM) syndrome (homozygous DM, Heterozygous DM, and homozygous normal) were slaughtered at 453 kg. Homozygous DM bulls and heifers were found to yield carcasses with significantly ($P < .01$) larger ribeyes and higher estimated percent boneless major cuts, but had significantly ($P < .05$) less marbling than heterozygous DM bulls and heifers. Heterozygous DM steers had significantly less fat over the ribeye, larger ribeyes and higher estimated percents of boneless major cuts than did those from normal steers. The longissimus from heterozygous DM steers was found to have significantly lower W-B shear values, higher juiciness scores and higher connective tissue softness scores than normal steers. Semitendinosus muscles from heterozygous steers had significantly lower W-B shear values, higher average taste panel scores and lower percents of fat than the normal steers.

Purchas (42) showed that meat from Friesian-Brahman cross bulls was significantly tougher than that from Friesian bulls. Brahmans and

Brahman crosses have been shown previously to produce tougher meat than British breeds (37, 44). However, Howard (24) noted that animals from Brahman sires produced more tender meat than those from British sires. The tenderness characteristic which differed the most between the two genotypes was the response to two-week aging which implies that the meat from the two groups differed in the characteristics which are responsible for tenderness changes during aging. These bulls were on pasture prior to slaughter.

Color of Lean and Fat

Shenk et al. (49) reported that "Grass or grass plus grain, increased the myoglobin content of beef beyond that in meat from animals fed only grain. This may have been due to greater activity of the grazing animals." While Longwell (30) reported that grass feeding had no effect upon the color of the lean meat, Jacobson and Fenton (23) reported an increase in redness or hue with increased levels of nutrition. This was significant for the semimembranosus muscle both before and after cooking. A highly significant increase in the hue of both the raw and roasted beef was noted with the increase in age of the animals from 32 to 80 weeks. Total iron content of muscles increased with levels of nutrition and with age from 32 to 80 weeks of age.

Bray et al. (8) reported that iron and copper supplementation in the milk of veal calves greatly increased concentration of myoglobin in the tissues. This may be used to enhance color of pasture fed beef if color is shown to be of great influence on consumers' choice of meat. MacDougall et al. (31) reported that color and pigment of muscles from veal calves was directly related to dietary iron intake. The myoglobin content of veal from calves receiving 100 µg iron/g of milk powder was twice that of calves receiving 40 µg iron/g. Jeremiah et al. (25) conducted a study to identify subjective visual color standards which could be utilized at various locations (packer, retailer, etc.) to define these color standards in terms of hue, value and chroma, and to test representative steak samples for consumer acceptability (see Table 5). Darker colored steaks had coarser texture than those that were light in color (high pH = darker color).

Consumer acceptability visual scores of 7 were rated extremely undesirable by 27 percent of the consumers interviewed while 29 percent of the consumers rated steaks which were assigned a color score of 3 as extremely desirable. Eighty-three percent of the consumers rated steaks with a visual score of 3 as desirable and 77 percent of the consumers rated steaks with a score of 4 as desirable. However, only 56 percent and 13 percent of the consumers assigned desirable ratings to steaks which were scored 2 and 7 in visual color, respectively. These data indicate that consumers prefer steaks which are neither extremely dark nor extremely pale. Palatability ratings for steaks assigned to various color score groups were studied. Mean scores for flavor, juiciness and tenderness did not differ among steaks in different color score groups. These data suggest that muscle color may not be an accurate indicator of beef palatability.

Table 5. Description of standard scale for beef muscle color

Color score	Description
1	Very pale pink
2	Pale pink
3	Pink
4	Slightly pale red
5	Cherry red
6	Slightly dark red
7	Moderately dark red
8	Dark red
9	Very dark red

Source: Jeremiah et al. (25).

Hunt and Hedrick (22) devised four quality groups for beef selected 24 hours post-mortem. These were: normal in color, firmness and exudation (NOR); normal in color, soft and exudative (NSE); pale in color, soft and exudative (PSE); and dark cutting beef (DCB). Average yield grade and degree of marbling were similar for all groups. Sensory analysis indicated DCB was more tender than the other three groups, while W-B shear values revealed DCB and PSE were more tender than NOR and NSE. No significant differences were observed in juiciness or flavor among the four groups. NSE and PSE had greater cooking losses. These data indicate there are populations of beef carcasses, in addition to "dark cutter," which possess undesirable longissimus muscle characteristics. Perhaps some ideas of color associated with beef acceptability need to be changed. Dark colored lean should not be downgraded in young cattle.

Kropf et al. (29) showed long-fed cattle and short-fed cattle had white fat whereas grass-fed cattle had slight yellow fat. Table 6 shows that grain-fed beef had the most desirable lean color, forage- or grass-fed had the least desirable color. After display for three days, the color of lean was still in favor of the long-fed beef.

More recent work suggests that a different approach should be taken to assess cooked beef tenderness, Purchas (42) and Reagan et al.

Table 6. Longissimus color scores

Muscle color	Long-fed	Short-fed	Grass-fed
Day 0	1.9^{a}	2.2^{b}	3.0^{c}
Day 3	2.5^{a}	3.0^{b}	3.8^{c}

Source: Kropf et al. (29).

^{a,b,c}Means in same row with same superscript letter do not differ ($P < .05$).

Muscle color: 1 = very bright red,
2 = bright red,
3 = slightly dark red or brown,
4 = dark red or brown,
5 = extremely dark red or brown.

(45). Purchas (42) suggests a simple theoretical quantitative model for tenderness changes during cooking. Meat is considered to be a two-component system comprising connective tissue (CT) and nonconnective tissue (NCT). It is assumed that the tenderness of these two components contributes additively and independently to overall tenderness so that:

$$T = ax + b(100 - x) ,$$

where T = overall tenderness ((force/area) x 100),
x = percent CT in cross-section area;
a = tenderness of CT (force/area); and
b = tenderness of NCT (force/area).

A new way of assessing tenderness may lead to better evaluation of forage-fed cattle.

Reagan et al. (45) suggests a method which involves grinding, homogenization, filtering and centrifugation of filtrate at 31,000 x G for 10 minutes and weighing muscle tissue residue. The results are expressed as muscle fragment weight. According to Reagan et al. (45), as residue increases, tenderness increases. Muscles which yield fragment weights of 1.16 ± 0.17 and 1.94 ± 0.28 may be classified as tough or tender, respectively.

Recently, Batcher and Deary (3) reported on the quality characteristics of broiled versus roasted beef steaks. Cooking time for roasted steaks was twice as long as that for broiled steaks to reach the desired internal temperature but less than half the kilowatt-hours

were needed for the roasting method. Cooking losses, evaporation and drippings were much lower in roasted steaks than broiled steaks. When cooked to either 60 or 71°C, roasted steaks were scored more juicy and tender, and less mealy than steaks broiled to the same internal temperature.

The most significant work to be done in the past several years in regard to meat tenderness is that which has elucidated the effect of prerigor changes. Newbold and Harris (36) discussed this in their review article as follows:

> It has been established that tenderness is related to postmortem shortening and processing methods should therefore be aimed at minimizing this shortening.
>
> Experiments with lamb and beef have shown that one way of reducing processing toughness is to hold the carcass for about 20 hours in a room at 15-20°C before placing it in a freezer. A disadvantage of this method is that bacteria can grow well at this temperature and a distinct health risk may be introduced. If the humidity is reduced to a level which discourages the growth of salmonella, evaporative losses from the carcass can be high.

Hostetler et al. (18), (19) and (20), have studied the effects of post-morten treatment of the carcass on the tenderness of beef muscles. In an early work, Hostetler et al. (19) compared usual suspension of the carcass with suspension from a hook through the ischium. They reported that suspension from the obturator foramen was preferred since it improved tenderness of the longissimus and semimembranosus muscles while keeping an acceptable tenderness of the psoas major muscle. The response of the semitendinosus muscle was more variable but its tenderness was also improved by this technique.

Sarcomere length can be altered by the above procedures and Hostetler et al. (20) reported on work which studied effects of method of suspension of the carcass on sensory panel scores. Their conclusions on this test were "In spite of the randomization, the panel preferred samples from muscles with the longest sarcomeres. A detectable difference in tenderness in a paired comparison test would justify the adoption of one of the experimental suspension methods. Since improvement in tenderness is as obvious to the panel under conditions less favorable for detecting differences, it makes the use of a method such as suspension from the obturator foramen (hip-free), which is relatively easy to do, even more strongly justified."

Other works which cover post-mortem processing effects are Parrish et al. (41), Hearp et al. (17), MacFarlane (32) and Kastner and Russel (28).

The work that we need to do in the future is to take advantage of our recently gained knowledge on post-mortem muscle changes such as

cold-shortening, and influence of prerigor temperature effects on cattle that presently originate from forage systems.

Summary

1. We need to take advantage of the leveling effect of pasture on meat tenderness and juiciness and carcass grade.

2. Marbling may be replaced by other factors of muscle composition such as myofibrillar condition and connective tissue reaction to temperature as quality indicators.

3. Light, phase and electron microscopy and molecular study of fibrillar protein of muscle should be included in new cattle forage evaluation programs.

4. Breed differences offer great opportunities for improved meat quality characteristics when combined with the above techniques.

5. Post-mortem handling of meat may greatly influence ultimate quality. New research should be initiated in this area.

6. USDA grades used alone as a sole evaluation of carcass beef will not help us to measure progress as carefully as needed for solid progress in producing desirable meat efficiently.

LITERATURE CITED

1. Anderson, D. B. 1972. The cellular development of adipose tissues. Proc. 25th Annual Reciprocal Meat Conf., p. 9.

2. Barbella, N. J., B. Tannor and T. G. Johnson. 1939. Relationship of flavor and juiciness of beef to fatness and other factors. Proc. Am. Soc. Anim. Prod. 32:320-325.

3. Batcher, Olive M. and Patricia Deary. 1975. Quality characteristics of broiled and roasted beef steaks. J. Food Sci. 40:745.

4. Bayne, Barbara H., Bernadine H. Meyer and J. W. Cole. 1969. Response of beef roasts differing in finish, location and size to two rates of heat application. J. Anim. Sci. 29:283-287.

5. Blumer, T. N. 1963. Relationship of marbling to the palatability of beef. J. Anim. Sci. 22:771.

6. Bowling, R. W., T. R. Dutson, Z. L. Carpenter and G. C. Smith. 1975. Personal communications.

7. Bray, R. W. 1964. A study of beef carcass grading criteria. Proc. 17th Annual Reciprocal Meat Conference, p. 7.

8. Bray, R. W., E. H. Rupnow, F. M. Manning, N. N. Allen and R. P. Needermeir. 1959. Effects of feeding methods on veal production and carcass quality. II. Carcass grades, liver, hide, specific gravity, yield and chemical analysis of muscle. J. Anim. Sci. 18:732.

9. Breidenstein, B. B., G. C. Cooper, R. G. Cassens, G. Evans, and R. W. Bray. 1968. Influence of marbling and maturity on the palatability of beef muscle. I. Chem. and organoleptic considerations. J. Anim. Sci. 28:1532.

10. Corah, L. R., Sarah A. Jackson and A. H. Bishop. 1974. Growth and carcass composition of yearling cattle fattened on combinations of hay, grain and NPN in a feed lot and on grain supplemented pastures. Australian J. Exp. Agr. and Anim. Husb. 15:279-307.

11. Craig, H. G., T. N. Blumer and E. R. Barrick. 1959. Effect of several combinations of grass and grain in the ration of beef steers on the color characteristics of lean and fat. J. Anim. Sci. 18:241.

12. Dube, G., V. D. Bramblett, R. D. Howard, B. E. Homler, H. R. Johnson, R. B. Harrington and M. D. Judge. 1971. Dietary effects on beef composition. J. Food Sci. 36:147-154.

13. Field, R. A., G. E. Nelms and C. O. Schoonover. 1966. Effects of age, marbling and sex on palatability of beef. J. Anim. Sci. 25:360.

14. Fontenot, J. P., R. F. Kelly, W. S. Wilkinson, C. M. Kincaid and J. C. Taylor. 1959. The effect of nutrition and age on the carcass composition of beef steers, (Abstr.), J. Anim. Sci. 18:1536.

15. Goll, D. E., A. F. Carlin, L. P. Anderson, E. A. Kline and M. J. Walter. 1965. Effect of marbling and maturity on beef muscle characteristics. II. Physical, chemical and sensory evaluation of steaks. Food Technol. 19:163.

16. Graham, P. P., R. F. Kelly and J. P. Fontenot. 1959. The effect of nutrition and age of beef steers on the cooking and eating characteristics of the meat, (Abstr.), J. Anim. Sci. 18:1475.

17. Hearp, W. F., R. Y. Cannon and D. L. Huffman. 1973. Effect of lipid infusion on quality of round steak, (Abstr.), J. Anim. Sci. 36:201.

18. Hostetler, R. L., B. A. Link, W. A. Landmann and H. A. Fitzhugh, Jr. 1972. Effect of carcass suspension on sarcomere length and shear force of some major bovine muscles. J. Food Sci. 37:132.

19. Hostetler, R. L., Z. L. Carpenter, G. C. Smith and T. R. Dutson. 1975. Influence of carcass position during rigor mortis on tenderness of beef muscles: Comparison of two treatments. J. Anim. Sci. 31:47-50.

20. Hostetler, R. L., Z. L. Carpenter, G. C. Smith and T. R. Dutson. 1975. Comparison of postmortem treatments for improving tenderness of beef. J. Food Sci. 40:223-226.

21. Huffman, D. L. and Wallace Griffey. 1975. Cattle finished on winter pasture rate high in carcass quality. In "Highlights of Agricultural Research." Ala. Agr. Exp. Sta. 22:3

22. Hunt, M. C. and H. B. Hedrick. 1973. Properties of bovine longissimus muscle from four quality groups, (Abstr.), J. Anim. Sci. 37:263.

23. Jacobson, Marion and Faith Fenton. 1955. Effects of three levels of nutrition and age of animal on the quality of beef. II. Color, total iron content, and pH. Food Res. 21:427-435.

24. Howard, A. 1963. Carcass composition and appraisal of meat animals, ed. Tribe, E. E. Paper No. 15, CSIRO, Australia.

25. Jeremiah, L. E., Z. L. Carpenter and G. C. Smith. 1972. Beef color as related to consumer acceptance and palatability. J. Food Sci. 37:476-479.

26. Jeremiah, L. E., Z. L. Carpenter, G. C. Smith, and O. D. Butler. 1970. Beef Quality. 1. Marbling as an indicator of palatability. Tex. Agric. Exp. Sta. Res. Rep. 22.

27. Juillerat, M. E., R. F. Kelly, D. L. Harris, C. Y. Dramer, and P. P. Graham. 1972. Consumer preference for beef as associated with selected characteristics of the meat. Va. Polytechnic Institute and State University Res. Div. Bull. 72, p. 87.

28. Kastner, C. L. and T. S. Russel. 1975. Characteristics of conventionally and hot-boned bovine muscle excised at various conditioning periods. J. Food Sci. 40:747-750.

29. Kropf, D. H., D. M. Allen and G. J. Thouvenelle. 1975. Short-fed, grass-fed and long-fed beef compared. KSU Progress Re. 23, pp. 78-87.

30. Longwell, J. H. 1936. Color of lean of beef affected by grass and grain feeding. W. Va. Agr. Exp. Sta. Bull. 274.

31. MacDougall, D. B., B. I. Bremmer and A. C. Dalgorns. 1973. Effect of dietary iron on the color and pigment concentration of veal. J. Sci. Food Agr. 24:1255.

32. MacFarlane, J. J. 1973. Pre-rigor pressurization of muscle: Effects on pH shear value and taste panel assessment. J. Food Sci. 38-294-298.

33. McCampbell, H. C., B. E. Green and R. S. Lowrey. 1972. Cooking and palatability of beef from winter pasture with and without grain and dry lot fed cattle, (Abstr.), J. Anim. Sci.:200.

34. Meyer, T. O. and M. E. Ensminger. 1952. Consumer preference and knowledge of quality in retail beef cuts. Wash. Agr. Exp. Sta. Circ. 1681 (Rev.).

35. Moody, W. G. 1967. Lipid accumulation and method for measuring marbling. Proc. 20th Annual Reciprocal Meat Conference, p. 28.

36. Newbold, R. P., and P. V. Harris. 1972. The effect of pre-rigor changes on meat tenderness. A review. J. Food Sci. 37:337.

37. Palmer, A. Z. 1963. Relation of age, breed, sex and feeding practices on beef and pork tenderness. Proc. Meat Tenderness Symposium, p. 161. Campbell Soup Company, Camden, New Jersey.

38. Parrish, F. C., Jr. 1974. Relationship of marbling to meat tenderness. Proc. Meat Ind. Res. Conf. Issued by American Meat Inst. Found. 1600 Wilson Blvd., Arlington, Virginia.

39. Parrish, F. C., Jr., R. B. Young, B. E. Miner and L. D. Anderson. 1973. Effect of postmortem conditions on certain chemical morphological and organoleptic properties of bovine muscle. J. Food Sci. 38:690-695.

40. Parrish, F. C., Jr., D. G. Olson, B. E. Miner and R. E. Rust. 1973. Effect of degree of marbling and internal temperature of doneness on beef rib steaks. J. Anim. Sci. 37:430-434.

41. Pearson, A. M. 1966. Desirability of beef--its characteristics and their measurements. J. Anim. Sci. 25:843.

42. Purchas, R. W. 1972. The relative importance of some determinants of beef tenderness. J. Food Sci. 37:341-345.

43. Purchas, R. W. and H. Lloyd Davis. 1974. Carcass and meat quality of Friesian steers fed on either pasture or barley. Australian J. Agr. Res. 25:183-192.

44. Ramsey, C. B., J. W. Cole, B. H. Meyer and R. S. Temple. 1963. Effects of type and breed of British, Zebu and dairy cattle on production, palatability differences and cooking losses as determined by laboratory and family panels. J. Anim. Sci. 22:1001.

45. Reagan, J. O., T. R. Dutson, Z. L. Carpenter and G. C. Smith. 1975. Muscle fragmentation indices for predicting cooked beef tenderness. J. Food Sci. 40:1093-1094.

46. Romans, J. R., H. J. Tuma, and W. L. Tucker. 1965. Influence of carcass maturity and marbling on the physical and chemical characteristics of beef. I. Palatability, fiber diameter and proximate analysis. J. Anim. Sci. 24:681-685.

47. Romans, John R., H. J. Tuma and W. L. Tucker. 1965. Influence of carcass maturity and marbling on the physical and chemical characteristics of beef. II. Muscle pigments and color. J. Anim. Sci. 24:686-690.

48. Schmidt, J. G. and F. C. Parrish, Jr. 1971. Molecular properties of post-mortem muscle. 10. Effect of internal temperature and carcass maturity on structure of bovine longissimus. J. Food Sci. 36:110.

49. Shenk, J. H., J. L. Hall and H. H. King. 1934. Spectrophotometric characteristics of hemoglobin. I. Beef blood and muscle hemoglobins. J. Biol. Chem. 105:741-752.

50. Tuma, H. J., R. L. Hendrickson, D. F. Stephens and Ruby Moore. 1962. Influence of marbling and animal age on factors associated with beef quality. J. Anim. Sci. 21:848-851.

51. Walter, M. J., D. C. Goll, L. P. Anderson and E. A. Kline. 1963. Effect of marbling and maturity on beef tenderness, (Abstr.), J. Anim. Sci. 22:1115.

52. West, R. L., Z. L. Carpenter, T. R. Dutson, R. L. Hostetler, G. C. Smith and N. M. Kieffer. 1973. Double muscling: Carcass and palatability traits, (Abstr.), J. Anim. Sci. 37:273.

53. Wheeling, M. R., B. W. Berry, and J. A. Carpenter. 1975. Effects of breed and forage vs. grain feeding on beef palatability and shelflife, (Abstr.), J. Anim. Sci. 26:98.

THE NEW BEEF: REVIEW OF HANDLING AND PROCESSING TECHNIQUES TO ENHANCE CONSUMER ACCEPTANCE

H. Russell Cross and Gary C. Smith*

When prices of feed grains are high, fewer grain-fed cattle and more forage-fed and/or limited grain-fed cattle are marketed. We will not deal with the economics of forage-fed beef or with predictions as to the probable supply of this "new product." We are concerned with the problems associated with palatability or consumer acceptability of beef in the marketplace. The ultimate goal of the meat industry is to supply the consumer with reasonably priced beef that has a high degree of eating satisfaction. The consumer's acceptance of a cooked meat is determined by his responses to the aroma, flavor, juiciness and tenderness of that product (Jeremiah et al., 1970). Studies have shown that tenderness is the most important palatability factor in acceptance of beef (Bratzler, 1971 and Smith, 1972).

Four recent research reports document some of the problems associated with forage-fed beef. Kansas State University scientists compared display color and palatability characteristics of beef cuts from long-fed, short-fed and grass-fed cattle. Long-fed cattle were on concentrates for 150 days, short-fed for 70 days and grass-fed cattle were on pasture without any supplemental feeding until slaughter. Mean ratings for fat and muscle color are presented in Table 1. As expected, fat on T-bone steaks from grass-fed cattle was more yellow. A "slight" degree of yellowing probably is not a marketing problem. Muscle color of freshly packaged (day 0) beef steaks was most desirable for long-fed cattle and least desirable for grass-fed cattle. All cattle were fasted 18 to 24 hours before slaughter. The rapid color deterioration in muscles of grass-fed cattle indicates that they are more sensitive to pre-slaughter stress than grain-fed cattle. Research is needed to ascertain if shortening the preslaughter fasting periods or some other pre-slaughter treatment would alleviate off-color problems in beef from grass-fed cattle. Tenderness ratings from the three treatments are presented in Table 2. Assuming that a tenderness score of 4.9 or less is "unacceptable," the steaks were 100 and 90 percent acceptable from the long- and short-fed cattle, respectively, but were only 40 percent acceptable from grass-fed cattle.

*Research Food Technologist, U. S. Department of Agriculture, Agricultural Research Service, Meat Science Research Laboratory, Beltsville, Md. and Professor, Meat Science, Department of Animal Science, Texas A&M University, College Station, Texas 77843, respectively.

Table 1. Fat and muscle colors from long-fed, short-fed and grass-fed cattle

Trait	Mean fat and muscle color ratings		
	Long-fed	Short-fed	Grass-fed
Fat color[d]	1.20[a]	1.35[a]	2.20[b]
Muscle color[e]			
Longissimus			
Day 0	1.94[a]	2.19[b]	3.00[c]
Day 3	2.46[a]	2.96[b]	3.81[c]
Psoas major			
Day 0	2.26[a]	2.44[b]	2.74[c]
Day 3	3.29[a]	3.55[b]	3.58[b]
Gluteus medius			
Day 0	1.99[a]	2.34[b]	2.72[c]
Day 3	2.91[a]	3.45[b]	3.49[b]

Adapted from Kropf et al. (1975).

[a,b,c]Means in the same row bearing different superscripts differ significantly ($P < .05$).

[d]Fat color: 1 = white, 2 = slightly yellow, 3 = moderately yellow.

[e]Muscle color: 1 = very bright red, 2 = bright red, 3 = slightly dark red or brown, 4 = dark red or brown, 5 = extremely dark red or brown.

Texas A & M University researchers evaluated sensory characteristics of beef from cattle of similar physiological maturity and marbling (Table 3). One group of cattle was finished on forage and the other on grain (Bowling et al. 1975). Steaks from grain-fed beef were higher in flavor, desirability and overall satisfaction than steaks from forage-fed beef. Even though maturity and marbling were nearly identical for the grain- and forage-fed cattle, beef from grain-fed cattle was significantly more tender as measured by sensory panel and Warner-Bratzler Shear (Table 4). These differences in tenderness were attributed in part to differences in sarcomere length (state of muscle contraction). The authors attributed the differences in contraction to the thickness of fat on the carcasses of grain- versus grass-fed cattle. Smith et al. (1974) indicated that external fat acts as an insulator thereby inhibiting any significant cold shortening during chilling.

Table 2. Tenderness ratings of steaks from long-fed, short-fed and grass-fed beef

Ranked individual tenderness ratings[a]		
Long-fed[b]	Short-fed[b]	Grass-fed[b]
5.8	4.9	3.7
6.9	5.9	3.8
7.0	6.0	3.8
7.2	6.3	4.3
7.2	6.8	4.5
7.7	7.0	4.9
7.9	7.3	5.7
8.0	8.2	6.8
8.0	8.2	7.7
8.5	8.3	7.7

Adapted from Kropf et al. (1975).

[a]Tenderness score: 9 = extremely tender, 7 = moderately tender, 6 = slightly tender, 5 = acceptable, 4 = slightly tough, 3 = moderately tough, 1 = extremely tough.

[b]Horizontal line is indicative of point between "acceptable" and "unacceptable" tenderness.

Table 3. Sensory panel flavor, juiciness and overall satisfaction ratings of beef

	Beef rib steaks			
Treatment	Flavor[a] desirability	Flavor[a] intensity	Initial[a] juiciness	Overall[a] satisfaction
Forage-finished	5.2[c]	6.0[b]	5.6[b]	5.0[c]
Grain-finished	6.0[b]	6.0[b]	5.8[b]	6.1[b]

Adapted from Bowling et al. (1975).

[a]Sensory panel parameters; 8-point scale; 8 = extremely desirable, 4 = dislike slightly.

[b,c]Means in the same column bearing different superscripts differ significantly ($P < .01$).

n = 36 forage-fed and 36 grain-fed cattle.

Table 4. Sensory panel tenderness ratings and shear force values

Beef rib steaks			
Treatment	M.F. tenderness[a]	C.T. amount[b]	Shear force (kg)
Forage-finished	5.4[d]	5.7[d]	8.4[d]
Grain-finished	6.1[c]	6.2[c]	5.6[c]

Adapted from Bowling et al. (1975).

[a]M.F.: Muscle fiber (subjective) 8 = extremely tender and 1 = extremely tough.

[b]C.T.: Amount of connective tissue (subjective) 8 = none and 1 = abundant.

[c,d]Means in the same column bearing different superscripts differ significantly ($P < .05$).

n = 36 forage-fed and 36 grain-fed cattle.

Auburn University scientists compared beef from forage-fed and grain-fed cattle (90 days) for differences in palatability (Huffman and Griffey, 1975). They reported, in contrast to the Kansas and Texas scientists, higher (though non-significant) sensory ratings and slightly lower shear values for the forage-fed beef (Table 5). Sensory ratings for both treatments were well above the 4.9 that could be considered "acceptable." Carcasses from forage-fed cattle had slightly more (1.02 cm versus .89 cm) outside fat than grain-fed cattle, the reverse of findings in the Texas and Kansas studies. Forage-fed cattle grazed high-quality, well-fertilized, rye-ryegrass and arrowleaf clover pastures during the entire experiment. The difference in fat thickness might explain the differences in the tenderness ratings in these three studies.

Colorado State University scientists compared the effects of forage and grain feeding on beef palatability and shelf-life (Wheeling, Berry and Carpenter, 1975). They evaluated steaks from three groups of cattle: 1) high-quality grain-fed (modest and moderate marbling), 2) low-quality grain-fed (traces and slight marbling), and 3) forage-fed cattle (traces and practically devoid marbling). Shear force values were lowest and tenderness ratings highest for steaks from forage-fed cattle with the toughest meat from the low-quality grain-fed group (Table 6). The authors indicated that the high degree of tenderness of steaks from forage-fed cattle might be explained by carcass maturity, since carcass maturity characteristics indicated that these carcasses were more youthful than were those of the grain-fed

Table 5. Comparison of carcass traits of cattle finished on forage and high-energy rations

Trait	Forage[c]	High-energy[c]
USDA quality grade	Good +	Good +
Marbling score	Slight +	Slight +
Fat thickness, cm.	1.02	.89
Sensory panel scores[a,b]		
Tenderness	6.6	6.2
Juiciness	7.0	6.4
Flavor	7.6	7.6
Mechanical evaluation[a]		
Armour Tenderometer, kg.	7.38	7.15
Warner-Bratzler Shear, kg.	7.51	8.82

Adapted from Huffman and Griffey, 1975.

[a]Scale of 1-9; 1 is least desirable.

[b]Panel size (trained) = 6.

[c]All means were not significantly different ($P < .05$).

cattle. Few differences in tenderness from cattle up to 30 months of age have been reported by Berry et al. (1974), Breidenstein et al. (1968), Romans et al. (1965), and Norris et al. (1971). Wheeling et al. (1975), however, reported that flavor of forage-fed beef was rated significantly lower (unacceptable) than that of grain-fed cattle and that rates of muscle surface discoloration of steaks were significantly higher for forage- than for grain-fed cattle.

The above and other investigations indicate the type and frequency of consumer acceptance problems the industry can expect with beef from forage-fed cattle. Not all beef from forage-fed cattle will be unacceptable to the consumer. Further research is necessary to (1) identify cattle and carcasses that yield beef which is unacceptable in palatability and shelf-life, (2) ascertain and circumvent the factors responsible for inferior palatability and/or shelf-life and (3) develop ante-mortem or post-mortem techniques to improve the consumer acceptability of beef from forage-fed cattle.

Variability in tenderness appears to be a major problem in beef from forage-fed cattle. A brief discussion of the factors associated

Table 6. Mean shear force and palatability ratings of grain-fed and forage-fed beef rib steaks

Trait	High quality grain-fed	Low quality grain-fed	Forage-fed
Shear force, kg.	2.36[b,c]	2.84[b]	1.94[c]
Tenderness[a]	5.52[b]	4.98[b]	6.58[c]
Flavor[a]	5.59[b]	5.25[b]	4.50[c]
Juiciness[a]	5.68[b]	5.10[b,c]	5.02[c]
Overall satisfaction[a]	5.54[b]	5.17[b,c]	4.86[c]
Cooking loss, (percent)	19.60[b,c]	21.60[b]	18.05[c]

Adapted from Wheeling et al. (1975).

[a]Based on an 8-point hedonic scale where 6 = like moderately, 5 = like slightly, 4 = dislike slightly and 3 = dislike moderately.

[b,c]Means on the same line bearing different superscripts differ significantly ($P < .05$).

n = 30 carcasses.

with tenderness may be appropriate. Tenderness differs among muscles or samples of meat as a result of one or more recognized phenomena which have been broadly classified (Smith et al., 1973) as follows: (a) actomyosin effects--contractile state of actomyosin and/or integrity of the Z line; (b) background effects--amounts of connective tissue and/or strength of the inter- and intramolecular crosslinking in collagen; and (c) bulk density or lubrication effects--amount, distribution and chemical or physical state of intramuscular fat and moisture. Berry et al., (1974) further indicated that smaller diameter muscle fibers, longer sarcomeres, shorter muscle fiber fragments following homogenization and lower percentages of wavy fibers (actomyosin effects) decreased collagen content, increased percentages of soluble collagen and lower myofibril fragmentation scores (background effects); and increased percentages of fat, decreased percentages of moisture and smaller quantities of expressible juice (bulk density or lubrication effects) were associated with increases in the tenderness of the beef longissimus muscle.

According to Lawrie (1966), the degree of tenderness can be related to three categories of protein in muscle--the myofibril (actin,

myosin, tropomyosin), connective tissue (collagen, elastin, reticulin, mucopolysaccharides of the matrix), and the sarcoplasm (sarcoplasmic proteins, sarcoplasmic reticulum). The importance of the relative contribution of each protein type depends on specific circumstances. The importance of the degree of contraction of the myofibrillar proteins in relation to tenderness has been emphasized by several researchers. Hostetler et al. (1970), and Smith et al. (1971) demonstrated that changes in the manner of carcass suspension and in the rate of post-mortem chilling increased the tenderness of beef by more closely maintaining or even increasing the length of the sarcomeres in muscle and/or by disrupting the integrity of the Z lines in muscle fibers. Marsh and Leet (1966) reported similar findings for tenderness of lamb carcasses regarding post-mortem chilling rate and manner of carcass suspension. These studies were all designed to identify procedures which would counteract the effects of cold shortening in muscle fibers, which decreases the tenderness of the cooked meat.

Although consumers generally associate connective tissue with less tender meat, total concentrations of connective tissue components (collagen and elastin) are not closely related to sensory panel ratings for tenderness (Cross et al., 1973). Percent soluble collagen, which is a measure of the susceptibility of collagen to heat, is significantly related to the toughness of meat, whereas elastin concentration is not (Cross et al., 1973). Cooking generally makes connective tissue more tender by converting collagen to gelatin, but heat coagulates and tends to toughen the protein of the myofibril (Lawrie, 1966). Both of these effects depend on time and temperature of cooking; time is more important for the softening of collagen, thus cooking methods combining a long heating period and a moist atmosphere are chosen. For muscles with only small amounts of connective tissue (tenderloin), cooking methods that apply dry heat for a short time are used to minimize the toughening effect on the muscle fibers (Bratzler, 1971 and Marsh and Leet, 1966).

Smith et al. (1974) have offered the most recent theory regarding the mechanism by which increased fatness enhances the tenderness of meat animal carcasses. These scientists, working with goat carcasses of widely varying sizes and degrees of finish, noted that carcasses from very small and very lean animals sustained extensive shortening of the myofibrils when subjected to the cold temperatures encountered during post-mortem chilling. Smith (1968) reported that increased quantities of kidney knob and pelvic fat in lamb carcasses were highly associated with the tenderness of loan chops. Many scientists have reported that cores of cooked beef and pork longissimus muscle from the post peripheral and most lateral locations in the cross-section (those nearest the outside surfaces of the carcass) were the least tender. A number of scientists have suggested that a decrease in the rate of post-mortem chilling was associated with a marked improvment in the tenderness of beef carcasses. These studies led Texas scientists to hypothesize that the real effect of fatness (subcutaneous, kidney knob and pelvic, and intramuscular fat) in enhancing tenderness resulted from the ability of fat to insulate muscle fibers against cold shortening during post-mortem chilling.

Results from an experiment designed to test this insulation hypothesis are presented in Table 7 (Smith et al, 1974). Lamb carcasses with a thick subcutaneous fat covering chilled more slowly, had muscles with slightly longer sarcomeres and produced more tender chops than carcasses with a thin fat cover. In subsequent experiments with both lamb and beef carcasses, the hypothesis has been modified to influence the possibility that the naturally-occurring proteolytic enzymes in muscle remain active for longer times post-mortem when chilling is delayed and thereby increase the tenderness of cooked meat (Moeller et al., 1975). Increased quantities of subcutaneous fat and/or marbling insulate the muscles or muscle fibers during post-mortem chilling, decrease the rate of temperature decline, delay development of rigor mortis, enhance the activity of proteolytic enzymes in muscle and lessen the extent of muscle fiber shortening and thereby increase the tenderness of cooked muscle.

The results from Texas are supported by data from Michigan State University. Merkel and Pearson (1975) showed that cattle which had 1.27 cm or less fat at the 12th rib were less tender than those with more than 1.27 cm. Among cattle in which subcutaneous fat exceeded 1.27 cm, essentially no differences in tenderness were observed. The toughening effects of cold shortening were greatest in cattle with less than 1.27 cm of fat and became progressively more pronounced as fat thickness decreased below this amount.

Shortening of muscles and sarcomeres is induced by cold and occurs prior to the development of rigor mortis. Prerigor shortening is most severe at conventional chilling temperatures of about 0° C. Cold-induced shortening and associated toughness were first demonstrated by Locker and Hagyard (1963) in prerigor beef. Marsh and Leet (1966) and McCrae et al. (1971) have demonstrated that cold shortening in lamb can be prevented by holding the carcass at about 16° C until rigor mortis develops.

Some shortening occurs in all muscles during chilling. The amount of tension on individual muscles differs because most muscles are attached to bones thus limiting the extent of cold shortening. The conventional practice of suspension by the Achilles tendon places considerable tension on some muscles and none on others. Thus, many muscles are free to contract during chilling while others, under tension, are not. Many muscles of the round, which are frequently criticized for toughness, are free to contract when the carcass is suspended by the Achilles tendon. In addition, the round is usually protected by a minimum of fat so that these muscles are probably more likely to undergo cold shortening than is common in the loin and rib. The cold shortened muscles become tough. This shortening, toughening effect has been counteracted experimentally by altered-posture methods, such as those described by Herring et al. (1965), Hostetler et al. (1970) and Davey et al. (1971). These methods alter the shape of the carcass, which poses special problems in developing new procedures for fabricating and merchandizing the meat product. Much additional research effort is needed to find the optimal post-mortem conditions for control of cold shortening and enhancement of tenderness.

Table 7. Temperature, tenderness and sarcomere length data for lamb carcasses in three subcutaneous fat thickness groups

Time post-mortem	Subcutaneous fat thickness group		
	Thick	Intermediate	Thin
	Longissimus muscle, temperature (°C)		
0 hr	30.7	26.3	26.0
1 hr	19.0	15.6	11.5
2 hr	13.8	10.8	6.5
4 hr	7.9	3.8	2.4
6 hr	3.6	0.9	0.7
	Leg steak, shear force (kg)[a]		
72 hr	5.8	7.2	7.8
	Rib chop, shear force (kg)		
72 hr	4.6	6.1	7.5
	Biceps femoris muscle, sarcomere length (μm)		
72 hr	1.86	1.83	1.80
	Longissimus muscle, sarcomere length (μm)		
72 hr	1.78	1.78	1.69

Adapted from Smith et al. (1974)

[a]All muscles combined.

Meat scientists from Auburn, Texas A&M and Purdue Universities have recently investigated the use of mechanical needling machines on fresh meat. Davis, Huffman and Cordray (1975) found that mechanical tenderization improved tenderness little when the initial steak quality was high. Glover et al. (1975) found that the mechanical process significantly increased tenderness of U. S. Good beef rounds. Bowling et al. (1975) reported substantial increases in tenderness of lamb and goat cuts when mechanically tenderized. Carpenter (1975) also reported increased tenderness of tenderized beef round muscles. Different cooking characteristics have been reported for mechanically tenderized meat; cooking time is shortened because of increased heat transfer. Tenderized steaks that are cooked the same length of time as non-tenderized cuts, probably would be overdone and have greater cooking losses. The optimum cooking method for mechanically tenderized meat

should be determined. Additional research will be required to determine the best procedures for use of the equipment, i.e., number of passes of the meat through the machine, time from slaughter, temperature, tenderization before or after vacuum packaging, etc.

Every beef carcass has a certain portion of edible lean that is generally high in connective tissue or tough and might be improved in acceptability by further processing. Further processing might involve mechanical tenderization or it might consist of grinding, chopping or emulsifying the meat in order to form it into another product to increase acceptability. A new process in comminuting meat has been developed which involves chopping and slicing of the meat into flakes. This new process is commonly referred to as flake cutting. The cohesive properties are usually greater in flaked than in ground meat. This cohesiveness of flaked meat has opened new areas for the use of muscle meat. With this new process, less tender, low grade meat might be converted into tender items that resemble whole or solid muscle steaks and roasts in appearance and texture.

University of Nebraska scientists have been very successful with flaked or restructured pork products. Cross and Stanfield (1975) have investigated the consumer acceptance of a restructured beef steak from U. S. Utility forequarters. Consumer preference was greatest for restructured steaks with 30 percent fat and added salt (Table 8). The addition of salt to the formulation enhanced the consumer response to all palatability traits regardless of fat level, which confirmed the findings of Mandigo (1975) with restructured pork chops. Researchers have just begun to make headway into the restructured meat area. More than 50 cutting heads are available on the flaking machine that does the cutting, and only a few have been tested. The full effect of muscle temperature during processing on textural properties of the finished product is unknown. No data are available to indicate the proper cooking method for these restructured meat items.

Closely paralleling mechanical tenderization and flake cutting is the shaping, forming and slicing of whole or flaked muscle. Huffman (1975) outlined the following steps in a boneless portion-control system: (1) fabrication of boneless cuts from primals and sub-primals; (2) mechanical tenderization (if desired); (3) preforming of cuts into the approximate shape desired; (4) freezing; (5) tempering to the desired internal temperature (-3 ± .5°C for muscle meats); (6) mechanical tenderization (if desired); (7) pressing into the desired shape; (8) slicing with a vertical slicer or band saw; and (9) packaging. The flaked or restructured meat product could fit into the scheme outlined above beginning with step 3. Pressing significantly reduces the separation of muscles but creates other problems related to texture and water loss during cooking. The effect of pressing on the structural properties of muscle should be determined so that optimal conditions can be identified. Some investigators also have theorized that the pressed steaks differ in heat transfer properties from conventional muscle and should be cooked in a different manner.

Table 8. Mean values for consumer response to restructured beef steaks

Trait[a]	Without salt 20% fat	With salt 20% fat	Without salt 30% fat	With salt 30% fat
Appearance	4.5^{d}	$5.0^{b,c}$	$4.7^{c,d}$	5.3^{b}
Aroma	$4.9^{c,d}$	$5.1^{b,c}$	4.7^{d}	5.2^{b}
Flavor	4.4^{d}	5.0^{c}	4.4^{d}	5.3^{b}
Juiciness	3.7^{c}	5.2^{b}	5.0^{b}	5.2^{b}
Ease of cutting	4.9^{c}	5.0^{c}	5.3^{b}	5.4^{b}
Tenderness	4.2^{d}	4.8^{c}	$4.9^{b,c}$	5.1^{b}
Overall acceptability	3.8^{d}	4.3^{c}	4.1^{c}	4.6^{b}

Source: Cross and Stanfield, 1975.

[a]Appearance, aroma and flavor: 1 = dislike very much and 7 = like very much; juiciness: 1 = very dry and 7 = very juicy; ease of cutting: 1 = very difficult and 7 = very easy; tenderness: 1 = very tough and 7 = very tender; and overall acceptability: 1 = I would eat this only if forced to, 4 = I would eat this if available but would not go out of my way, and 7 = I would eat this every opportunity I had.

[b,c,d]Means in the same row bearing different superscripts differ significantly ($P < .05$).

n = 90 panelists.

Another exciting new concept in total use of animal products is mechanical deboning. The term "mechanical deboning" as commonly used in the meat industry means the separation of meat from bone by the extrusion of meat from a preground mixture of meat and bone particles. University of Wyoming scientists estimated that if all carcasses of animals slaughtered in the United States in 1973 had been mechanically deboned, 737 million extra pounds of beef, 374 million pounds of pork and 19 million pounds of lamb and mutton would have been made available for human consumption. Mechanically deboned meats would appear to be suited for incorporation into ground meat products as well as into finely comminuted sausage products. Marshall et al. (1975) used mechanically deboned goat, mutton and pork in wieners. Consumer sensory panel ratings are presented in Table 9. For flavor and juiciness, panelists rated wieners containing 40 percent old goat, 10-40 percent mutton and 10 and 25 percent pork significantly ($P < .05$) higher than the control. Wieners containing 40 percent mechanically deboned pork received the lowest mean scores for flavor, juiciness and texture and for overall satisfaction. Research with mechanically deboned meat in beef products is almost non-existent. Data concerning palatability, shelf-life and color deterioration of products containing mechanically deboned meat are needed.

Table 9. Consumer sensory panel ratings for control and substituted wiener formulation

Meat source	Percent added mechanically deboned meat	Palatability characteristics			
		Flavor	Juiciness	Texture	Overall satisfaction
Control		4.4^{c}	5.0^{c}	4.6^{c}	$4.5^{c,d}$
Old goat	10	4.5^{c}	$5.3^{b,c}$	$4.8^{b,c}$	4.7^{c}
Old goat	25	$4.8^{b,c}$	$5.3^{b,c}$	5.1^{b}	$5.0^{b,c}$
Old goat	40	$5.3^{a,b}$	$5.8^{a,b}$	$5.3^{a,b}$	$5.4^{a,b}$
Young goat	10	4.3^{c}	$4.8^{c,d}$	4.4^{c}	4.4^{d}
Young goat	25	4.3^{c}	5.1^{c}	4.6^{c}	$4.5^{c,d}$
Young goat	40	5.1^{b}	$5.3^{b,c}$	5.1^{b}	5.2^{b}
Mutton	10	5.7^{a}	6.0^{a}	5.8^{a}	5.8^{a}
Mutton	25	5.7^{a}	6.2^{a}	5.5^{a}	5.7^{a}
Mutton	40	5.1^{b}	5.5^{b}	$4.8^{b,c}$	5.1^{b}
Pork	10	5.1^{b}	5.4^{b}	4.9^{b}	5.1^{b}
Pork	25	5.1^{b}	4.7^{d}	3.2^{d}	3.5^{e}
Pork	40	3.1^{d}	3.2^{e}	1.8^{e}	2.4^{f}

Adapted from Marshall et al. (1975).

^{a,b,c,d,e,f}Means in the same column bearing different superscripts differ significantly ($P < .05$).

Conclusion

When the price of grain is high, beef undoubtedly is produced more efficiently and more economically from forage-fed than from grain-fed cattle. However, we can expect to have consumer acceptance problems unless we can identify carcasses that will yield meat that is tough or unacceptable in flavor, juiciness and color. Such carcasses, if they could be identified, might be treated by various nonconventional processing or handling techniques to yield acceptable beef products for the consumer. New concepts require thorough investigation before they can be put into common practice. As meat scientists, we must take the carcass produced by animal scientists and make it into a marketable commodity.

LITERATURE CITED

1. Berry, B. W., G. C. Smith and Z. L. Carpenter. 1974. Beef carcass maturity indicators and palatability attributes. J. Anim. Sci. 38:507.

2. Bowling, R. A., W. H. Marshall, G. C. Smith, Z. L. Carpenter, M. Shelton and R. L. Hostetler. 1975. Mechanical tenderization of ram lamb and goat cuts (Abstr.), J. Anim. Sci. 41:1.

3. Bowling, R. A., T. R. Dutson, Z. L. Carpenter and G. C. Smith. 1975. Sensory evaluation of beef of identical physiological maturity and marbling--Finished on forage or grain. J. Food Sci. (Submitted).

4. Bratzler, L. J. 1971. Palatability factors and evaluations. In The Science of Meat and Meat Products. W. H. Freeman and Company, San Francisco, California.

5. Breidenstein, B. B., C. C. Cooper, R. G. Cassens, G. Evans and R. B. Bray. 1968. Influence of marbling and maturity on the palatability of beef muscle. I. Chemical and organoleptic considerations. J. Anim. Sci. 27:1532.

6. Carpenter, Z. L. 1975. Mechanical tenderization of fresh meats. Presented at "Meat Processing Seminar," Texas A&M University, College Station.

7. Cross, H. R., Z. L. Carpenter and G. C. Smith. 1973. Effect of intramuscular collagen and elastin on bovine muscle tenderness. J. Food Sci. 38:998.

8. Cross, H. R. and Marilyn S. Stanfield. 1975. Consumer evaluation of restructured beef steaks. (Unpublished data).

9. Davey, C. L., K. V. Gilbert and P. Curson. 1971. The effect of carcass posture on lamb tenderness. Ann. Res. Rep. Meat Ind. Res. Rep. of New Zealand, p. 41.

10. Davis, K. A., D. L. Huffman and J. C. Cordray. 1975. Effect of mechanical tenderization, aging and pressing on beef quality. J. Food Sci. 40:1222.

11. Glover, E., J. C. Forrest, H. R. Johnson, V. D. Bramblett and M. D. Judge. 1975. Palatability and cooking characteristics of mechanically tenderized beef (Abstr.), J. Anim. Sci. 41:1.

12. Herring, H. K., R. G. Cassens and E. J. Briskey. 1965. Further studies on bovine muscle tenderness as influenced by carcass position, sarcomere length and fiber diameter. J. Food Sci. 30:1049.

13. Hostetler, R. L., W. A. Landmann, B. A. Link and H. A. Fitzhugh. 1970. Influence of carcass position during rigor mortis on tenderness of beef muscles: Comparison of two treatments. J. Anim. Sci. 31:47.

14. Huffman, D. L. 1975. Shaping, forming and tenderizing meat. Proc. 11th Annual Meat Industry Res. Conf., Chicago, Illinois.

15. Huffman, D. L. and W. Griffey. 1975. Cattle finished on winter pasture rate high in carcass quality. Highlights of Agri. Res. Ala. Agri. Exp. Sta. 22:3.

16. Jeremiah, L. E., Z. L. Carpenter, G. C. Smith and O. D. Butler. 1970. Beef quality. I. Marbling as an indicator of palatability. Texas Agr. Exp. Sta. Rep. No. 22.

17. Kropf, D. H., D. M. Allen and G. J. Thouvenelle. 1975. Short-fed, grass-fed, and long-fed beef compared, pp. 78-87. In 62nd Annual Cattlemen's Day Report.

18. Lawrie, R. A. 1966. The eating quality of meat. In Meat Science. Pergamon Press, London, England.

19. Locker, R. H. and C. J. Hagyard. 1963. A cold shortening effect in beef muscles. J. Sci. Food Agr. 14:787.

20. Mandigo, R. W. 1975. Restructured meat. Proc. 11th Annual Meat Industry Res. Conf., Chicago, Illinois.

21. Marsh, B. B. and N. G. Leet. 1966. Studies in meat tenderness. III. The effects of cold shortening on tenderness. J. Food Sci. 31:450.

22. Marshall, W. H., G. C. Smith, T. R. Dutson and Z. L. Carpenter. 1975. Utilization of mechanically deboned goat, mutton and pork in wieners. J. Food Sci. (Submitted).

23. McCrae, S. E., C. G. Seccombe, B. B. Marsh and W. A. Carse. 1971. Studies in meat tenderness. 9. The tenderness of various lamb muscles in relation to their skeletal restraint and delay before freezing. J. Food Sci. 36:566.

24. Merkel, R. A. and A. M. Pearson. 1975. Slow chilling could produce tender beef from lean carcasses. Meat Industry, May, p. 27.

25. Moeller, P. W., P. A. Fields, T. R. Dutson, W. A. Landmann and Z. L. Carpenter. 1975. Effect of high temperature conditioning on subcellular distribution and levels of lysosomal enzymes. J. Food Sci. (Submitted).

26. Norris, Helen L., Dorothy L. Harrison, Lois L. Anderson, Bettina von Welck and H. J. Tuma. 1971. Effects of physiological maturity of beef and marbling of rib steaks on eating quality. J. Food Sci. 36:440.

27. Romans, J. R., H. J. Tuma and W. L. Tucker. 1965. Influence of carcass maturity and marbling on the physical and chemical characteristics of beef. I. Palatability, fiber diameter and proximate analysis. J. Anim. Sci. 24:681.

28. Smith, G. C. 1968. Effects of maturational, physical and chemical changes on bovine carcass composition, quality and palatability. Ph.D. dissertation. Texas A&M University, College Station.

29. Smith, G. C., T. C. Arango and Z. L. Carpenter. 1971. Effects of physical and mechanical treatments on the tenderness of the beef longissimus. J. Food Sci. 36:445.

30. Smith, G. C. 1972. Relationship of the cow-calf producer to the consumer. In Commercial Beef Cattle Production. Lea and Febiger. Philadelphia, Pennsylvania.

31. Smith, G. C., G. T. King and Z. L. Carpenter. 1973. Anatomy. In Laboratory Exercises in Elementary Meat Science. 2nd Ed. Kemp Publishing Company, Houston, Texas.

32. Smith, G. C., T. R. Dutson, R. Hostetler and Z. L. Carpenter. 1974. Subcutaneous fat thickness and tenderness of lamb. (Abstr.), J. Anim. Sci. 39:174.

33. Wheeling, M. R., B. W. Berry, J. A. Carpenter, Jr. 1975. Effects of breed and forage vs. grain feeding on beef palatability and shelflife. Proc. West. Sect., ASAS, V. 26.

DISCUSSION

CARCASS CHARACTERISTICS, MEAT QUALITY AND CONSUMER ACCEPTANCE

Discussion of papers by:
J. J. Guenther, Robert F. Kelley, and H. Russell Cross and Gary Smith

MODERATOR: Dale L. Huffman, Auburn University

QUESTION: Curtis Absher, University of Kentucky. What type of cattle are best adapted to a high forage diet, and what type are best adapted to a high concentrate diet?

ANSWER: J. J. Guenther, Oklahoma State University. That is a good question to which I don't have an immediate answer. It depends on what you want to produce.

QUESTION: M. E. McCullough, University of Georgia. We keep talking about forage. There has been little or no differentiation between top quality and low quality forage, yet we classify as forage everything from straw which may have a digestibility of 45 percent to corn silage which has a digestibility of about 70 percent. If we really are talking about energy concentration or what causes the animal to respond, I don't know that an animal can tell the difference. Why is there any reason to think that an animal will respond differently to rations of the same energy concentration, where one ration might be 20 percent forage and another 60 percent forage?

ANSWER: J. J. Guenther, Oklahoma. I don't think there is a difference if the nutrient level is the same. You are not going to change the order of tissue deposition.

COMMENT: M. E. McCullough, Georgia. We can't keep talking or referring to forage-fed beef as something on the low end and grain-fed beef as something on the other end.

COMMENT: J. J. Guenther, Oklahoma. I certainly agree with you. We must stop talking about so many acres of arable land that could be utilized by ruminants. In the Southeast, much of this arable land is producing pine trees. We don't grow much forage under pine trees, yet processed forage could be used to raise dietary energy levels of animals produced under these conditions.

QUESTION: Anonymous. On the basis of tissue deposition, should cattle be grown and then finished, or pushed hard all the way regardless of the feeding program?

ANSWER: J. J. Guenther, Oklahoma. It would depend on the available feeding program, region of the country and type of cattle. Small-type cattle could be placed in the feedlot immediately following weaning. With large-type cattle, one may want to take advantage of some low energy feeding to obtain growth before finishing. It really depends on the type of cattle and feeding program available.

QUESTION: Floyd Horn, ARS, USDA, El Reno, Oklahoma. In our genetics and breeding program we have been selecting for performance in the feedlot. Do we need corrections in our breeding and selection programs to find animals that deposit the right amount of fat?

ANSWER: J. J. Guenther, Oklahoma. Select early in life. Muscle cells are already developed at birth. Some biopsy work indicates that samples taken early in life can give a good indication of what an animal will look like at later stages.

COMMENT: William G. Moody, University of Kentucky. To me the term forage- or grain-fed is confusing. Many forage-fed cattle that go to market are just as palatable and nutritious as grain-fed cattle. This was pointed out by a previous speaker, but it needs to be reemphasized. The point I really want to make is that much of the heterogeneity in forage-fed beef during the past year is due to the wide variation in cattle marketed because of the glut of cattle. I think that this is a short-term problem and not the type of thing we should expect in the future. I believe that we should address ourselves to the question of what end-points should be considered in producing a forage-fed animal? It is heterogeneous when we think of marbling and other characteristics that we normally relate to grain-fed cattle, but when one considers protein, water and nutrient content, I am not sure that it is a heterogeneous product, it may even be homogeneous. We should be looking at a quality forage-fed product when making comparisons.

COMMENT: Russell Cross, ARS, USDA, Beltsville, Maryland. I assume that was not a question.

COMMENT: William G. Moody, Kentucky. No, it really wasn't a question but a statement pertaining to your opening remarks in which you stated that forage-fed animals were more heterogeneous than grain-fed animals.

COMMENT: Russell Cross, ARS. I agree. The way we are operating now, forage-fed cattle are heterogeneous because of the different management systems being used. Perhaps we need to identify the best systems that will give us the most acceptable product.

QUESTION: William G. Moody, Kentucky. Dr. Cross, sometimes we are confused about alternative uses of our products which you pointed out very nicely with slides. Maybe you should say more about these products in relation to beef from the different feeding systems. Do these products apply to forage-fed as well as grain-fed cattle?

ANSWER: Russell Cross, ARS. Definitely, the restructured area applies to both. I think mechanical tenderization applies more to the less palatable meats. Mechanical deboning applies to everything.

QUESTION: Harold B. Hedrick, University of Missouri. I wonder what influence high temperature aging would have on internal quality, mainly bone souring? Under present low temperature aging, packers have problems with bone souring.

ANSWER: Russell Cross, ARS. It depends on the sanitary conditions of a particular plant at a given time. Most work hasn't shown much of a problem to my knowledge. I don't know of any research in packing plants that has shown this.

COMMENT: Harold B. Hedrick, Missouri. I don't think this is a sanitation problem.

COMMENT: Dale L. Huffman, Moderator, Auburn University. I had some experience with bone souring at Swift and Company. They still have some problems with this along with every other packer. Bone souring is not fully understood. It is strongly suspected that it is not a microbiological problem. Therefore, sanitation would have little effect on bone souring particularly along large bone in rounds. I too, wonder what would happen under practical plant conditions if we go to a high temperature aging.

COMMENT: Anonymous. This is not my field, but Kroger and Company used high temperature aging for years and as far as I know they had no problems.

COMMENT: Russell Cross, ARS. They are working with ozone and ultraviolet lights which controls the surface, not the organisms.

COMMENT: Dale L. Huffman, Moderator, Alabama. They also chilled the carcass before using high temperature aging.

COMMENT: Milton Wise, Virginia Polytechnic Institute and State University. The only argument that I would have with Dr. Cross is that on one of his slides he stated, "The best system ..." that would produce palatable and tender beef. We have many different types and weather conditions. The system that fits one area will not fit another. We will never come up with one system. In terms of grain versus pasture, there is no argument. In the Southeast, there are certain conditions under which pasture can be a tremendous asset in finishing cattle. On the high plains of Texas, I would be surprised if producers go to a high pasture finishing system. So it becomes a matter of degree, a matter of fitting the production systems to a given area. Coming back to the question of whether it is cheaper to use pasture, in all economic evaluations I have seen thus far, it seems that the most economical way to produce nutrients is from pasture and it also seems that in terms of finishing cattle in the Southeast, we need to take advantage of high quality pasture. The only limiting factor is energy, so if we can produce necessary energy in addition to

the high quality pasture, I am convinced this is the most economical way to go, particularly in the Southeast. This may not be true for the high plains of Texas.

COMMENT: Russell Cross, ARS. I certainly did not mean that there was just one answer. However, sometimes I think we forget what we are producing. One can produce something great from a live-animal point of view, but it may taste terrible, it may be tough or dry or off-flavor. We may need to do something to it either before or after death.

COMMENT: Dale L. Huffman, Moderator, Alabama. Dr. Wise, the slides shown from Auburn illustrated two sets of cattle, there were no differences between those cattle. Both groups received high energy rations, one from forage and the other from grain. I would like to think we are talking about finished cattle weighing from 1,000 to 1,150 pounds, regardless of how you get them there.

QUESTION: Stanley Wilson, Auburn University. Within a grade and age group is there a palatability difference between forage- and grain-fed beef?

ANSWER: Russell Cross, ARS. At the present time there is little information on this for the various grades.

COMMENT: Willard Williams, Texas Tech University. I did not say that cost determines price. I said that cost determines price differences. In connection with forage and grain feeding, the real criteria that we must face is whether forage-fed beef is competitive with grain-fed beef at the retail store. If it isn't, then there is no future for forage-fed beef.

COMMENT: T. N. Blumer, North Carolina State University. We are really concerned about extremes in tenderness and flavor. These are important because they influence the consumer the most. Those factors that are in the middle range of acceptance are not too important. We have an opportunity as researchers to find out if and why there are differences in tenderness. If we can't find differences in extremes, we won't find differences in the middle of the scale.

FUNDAMENTAL ASPECTS OF FORAGE AND BEEF PRODUCTION

ENERGY REQUIREMENTS OF BEEF CATTLE

W. C. Ellis*

Introduction

The objective of beef production should be to produce beef at a maximum profit. Since nutrient cost is the predominant cost of beef production, decisions concerning feed sources have a major influence on production cost. To identify most profitable feeding systems requires the ability to accurately predict animal performance as a function of alternative feeds, whether they be forages, roughages or varying combinations thereof. This, in turn, requires quantitative knowledge of a) functional nutrient requirements of beef cattle and b) factors affecting the efficiency of feed nutrient utilization for the various animal functions. This and other information combined with the capability of high speed computers with memory capabilities not only offers opportunities for evaluating many alternatives, but also enables the determination of most critical areas which limit profit and justify research emphasis.

Nutrient Requirements, Qualitative

Beef cattle require more than 30 nutrients which are equally essential in supporting normal growth and function. Fortunately, most of these nutrients are sufficiently concentrated in feedstuffs that only a few are commonly deficient and require primary consideration. Most commonly deficient nutrients include energy, protein, phosphorus and vitamin A. Deficiencies of vitamin A, phosphorus and protein can be predicted rather accurately as functions of the feedstuff and its vegetative state and, where deficient, can frequently be economically corrected by supplementation or management. In contrast, the magnitude of commonly existing energy deficiencies often preclude supplementation of this nutrient.

Thus, for most forage-fed beef production systems, functionally and economically, energy can be considered the first limiting nutrient and the level and efficiency of animal performance predictable as functions of dietary energy intake and the animal's functional energy requirements. This review will be directed to assessing the adequacy of our quantitative knowledge concerning factors influencing nutritive energy requirements and energy supply for beef cattle.

*Department of Animal Science, Texas A&M University, College Station, Texas 77843.

Feed Energy Utilization

The digestion, metabolism and utilization of feed energy involves a number of energy losses which vary in magnitude as a function of the feedstuff, the animal function, the environment and interactions among the three. An ideal system of feedstuff energy evaluation must then account for all these losses, or at least those which are largest and most variable, in order to express the feedstuff's content of nutritionally useful energy; i.e., net energy. The losses associated with feed utilization by a cow for the net energy purposes of maintenance, body weight gain and lactation are schematically partitioned in Figure 1.

An animal's functional requirement for net energy is equal to the energy lost (maintenance), gained (tissue gain) or secreted (milk) by the functional process. This may be conceived as a requirement for a flow of energy to 1) replace energy losses due to continuing tissue turnover and work (maintenance) and 2) to support accumulation and secretion rates of various products such as tissue gain and lactation. The quantity of net energy flow is determined by a number of factors which can be expressed as rate functions to specify the rate of feed energy intake and its efficiency of conversion to nutritionally useful components. These rate functions are not constants but vary widely and must be relatable to attributes of the feed-animal-environment complex if the flow of net energy and thereby, animal performance, is to be predictable. The more important rate functions and factors affecting them are illustrated in Figure 2.

Digestibility k_d

Losses of feed energy due to indigestibility and undigestibility (see Figure 4) are the largest and most variable of energy losses and hence basic to any system of feedstuff-energy evaluation. Digestible energy is usually determined as the difference between the chemical energy consumed and the chemical energy lost in the feces. This is an apparent digestibility since some of the fecal chemical energy was derived from the animal's maintenance process rather than undigested feed. Due to measurement difficulties, this is usually not partitioned and therefore the flow of apparently digestible energy is reduced by an amount equal to this maintenance loss of chemical energy. By difference then, apparently digestible energy consists of 1) chemical energy capable of subsequent metabolism, 2) chemical energy not capable of subsequent metabolism (methane and urinary energy losses), and 3) small amounts (3-5 percent of digestible) of heat of nutrient hydrolysis and fermentation (Figure 1).

Variations in digestibility of feed energy are primarily attributable to variations in digestibility of different feedstuffs' structural constituents referred to as membrane substances (29) or cell wall constituents (30, 33). Digestibility of these constituents is determined by their composition and a number of dynamic processes illustrated in Figure 4. Thus, in reference to Figure 4, the rate that feed energy is converted to digested energy (k_d) is determined by:

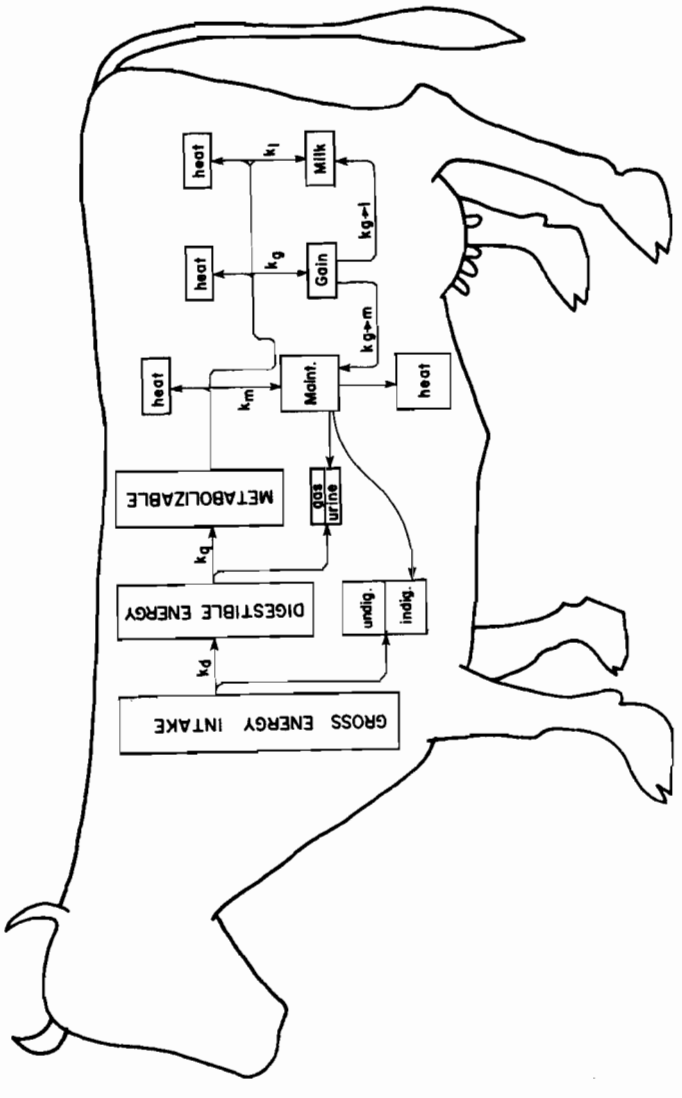


Figure 1. Energy losses and utilization of feed energy

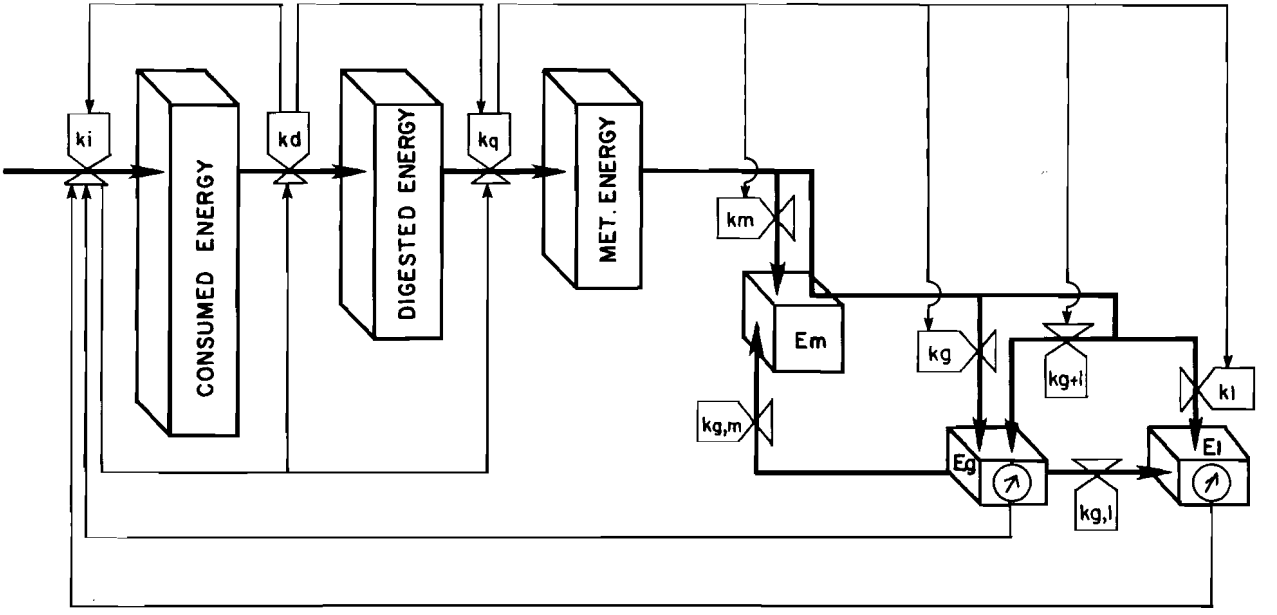


Figure 2. The flow of nutritionally useful components of feed energy and its regulation. Feed energy intake (k_i) and its conversion to energy required for maintenance (E_m), energy of gain (E_g) and/or energy of lactation (E_l) is determined by a number of rates involved in digestion (k_d), metabolism (k_q) and utilization of feed metabolizable energy for maintenance (k_m), gain (k_g), gain plus lactation (k_{g+l}) and lactation (k_l) or utilization of body energy for maintenance ($k_{g,m}$) or lactation ($k_{g,l}$). Factors determining these rates are indicated by arrows. Thus, fate of digestion determines k_i, k_q, k_m, k_g, k_{g+l}, and k_l. The genetic capabilities for growth and lactation rates (encircled arrows) also determine k_l.

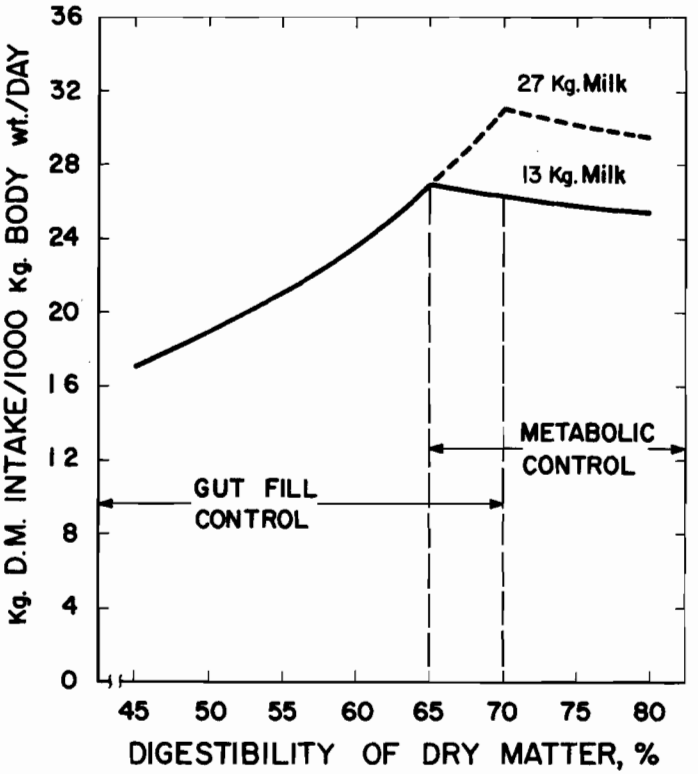


Figure 3. The relation between relative feed intake and ration digestibility (Adapted from Conrad et al., 1964)

1. The feedstuff's content of indigestible cell wall contituents (CWC_i), (37);

2. The feedstuff's content of potentially digestible cell wall constituents (CWC_d) and their rate of digestion (k_d)(37);

3. The residence time ($1/k_p$) of the CWC_d at their digestive sites (6). None of these determinants can at present be reliably predicted from measurable chemical attributes of the feed (34). However, determinants 1 and 2 can be determined by *in vitro* (39) or *in situ* (32) methods and residence times *in vitro* can be chosen or standardized so that *in vitro* estimates of k_d can be obtained which closely simulate *in vivo* k_d.

The k_d determined *in vivo* or *in vitro* for a given feed may be altered by feeding practices such as fine grinding or level of intake which alters rate of passage (k_p) and the residence time ($1/k_p$) of the

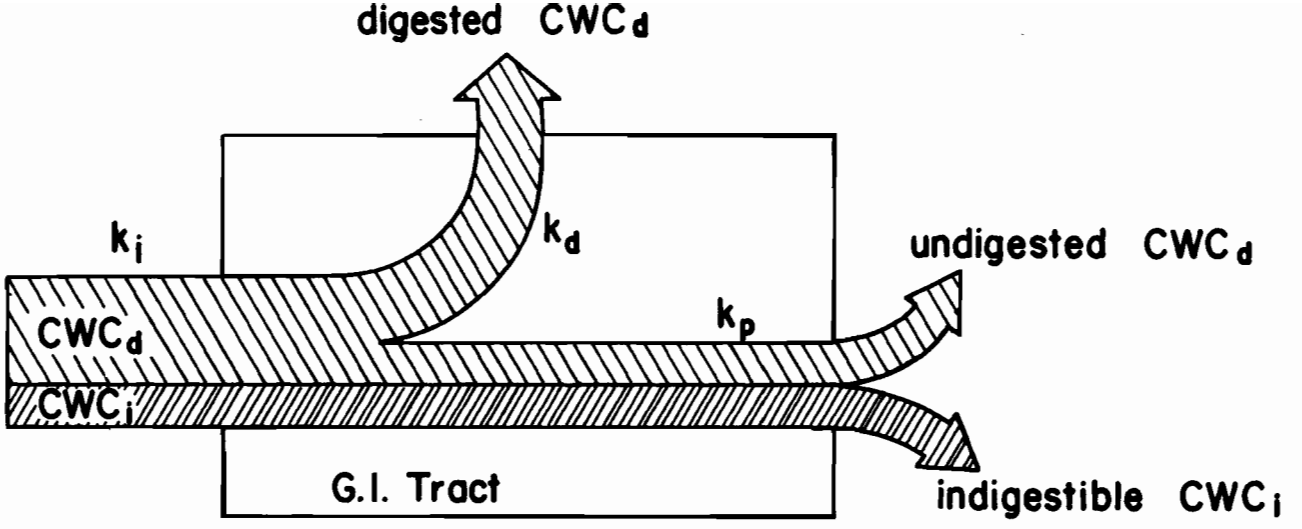


Figure 4. The partition of feed cell wall contents (CWC) within the gastrointestinal tract into indigestible cell wall constituents (CWC_i), digested cell wall constituents (CWC_d) and undigested cell wall constituents

CWC_d at their digestive sites (6). Reductions in dietary particle size or increases in feed intake further reduces residence time and hence extent of digestion of CWC_d due to its relatively slow rate of digestion. This depression is greater for feedstuffs higher in cell wall constituents (CWC) and therefore less digestible. Blaxter (10) described the depression in apparent digestibility of energy on increasing feed intake from maintenance to twice maintenance (ΔA) as a function of percent apparent digestibility at maintenance (A_m):

$$\Delta A = 11.9\text{-}0.119A_m$$

Metabolizability, k_q

Metabolizable energy is usually determined as the difference between gross energy intake and chemical energy losses in the feces, urine and as methane (Figure 1). Similar to apparent digestibility, this determination is apparent metabolizability since some losses in both the feces and urine are derived from the body but deducted from the feed. If the small heat losses of nutrient digestion are disregarded, then metabolizable energy represents the quantity of feed energy capable of being metabolized to other forms of chemical energy specifically required for the animal's energy requirements.

Digested energy is converted to metabolizable energy at rate k_q which is relatable to k_d and k_i (Figure 2). As k_d and k_i increase, there is a decrease in the proportion of digested energy lost as methane and urine. Armstrong (3) summarized extensive data to indicate k_q to be rather constant 0.8 of the digested energy at maintenance intakes. Increasing feed intake from maintenance to twice maintenance gave different results with different feeds, but generally resulted in an increase in k_q by 0.02 to 0.035 per multiple of maintenance.

The effect of increasing intake on k_q is counter to the effects on k_d and apparently counterbalance each other for feedstuff containing less than 16 percent crude fiber, the metabolizability of the diet ($k_d \times k_q$) is reduced by increasing feed intake.

Net Availability

The net availability of metabolizable energy (NAME) is the efficiency with which metabolizable energy is converted to net energy. It is difficult to measure since it requires 1) measurement or estimation of a thermal energy loss and 2) partitioning this thermal energy loss of feed energy from body maintenance thermal energy losses (Figure 1). If it is assumed the fasting heat loss is a measure of the maintenance heat loss, then the difference in heat production of the fed and fasting animal can be taken as the increment of heat derived from the increment of feed (heat increment of feeding). This heat increment, within a thermoneutral environment, is a measure of inefficiency of feed energy utilization and (1-heat increment) equals efficiency or NAME.

Since the heat production of fasting metabolism is derived from tissue catabolism, its use as a baseline results in values for efficiency of feed nutrient utilization relative to tissue nutrients. Therefore, the relative net availability of body tissue utilization for maintenance becomes 1.0.

Determination of NAME for multiple, and frequently simultaneous functions, such as maintenance, tissue gain and lactation is difficult due to 1) problems in quantitating the heat increment associated with each function, 2) the conversion of tissue energy to milk energy, and 3) the possibility that the maintenance requirement as measured by fasting metabolism is not applicable to the producing animal. An alternative approach to estimating NAME for multiple and concurrent functions is a multiple regression approach utilizing the general model:

$$ME = a + b_1x_1 + b_2x_2 \cdots b_nx_n$$

where ME = measured metabolizable energy (ME),

a = a statistical intercept,

$b_1, b_2 \cdots b_n$ = partial regression coefficients expressing the units of ME associated with the production of a unit of $x_1, x_2 \cdots x_n$, respectively,

$x_1, x_2 \cdots x_n$ = measured units of product $x_1, x_2 \cdots x_n$ maintained, gained, secreted or lost; equal to net energy (NE) required for maintenance (NE_m), gain (NE_g) or lactation (NE_l) for example.

When applied to a sufficiently large number of observations containing adequate ranges in ME intake and measured independent variables (x), solutions can be obtained for the coefficient terms (b) which, when divided by the product's unit caloric value, (net energy), equals the function's NAME. This approach has been applied to extensive energy balance data on dairy cows in the United States and the Netherlands and some results are summarized in Table 1.

The Beltsville data (Table 1) indicate a higher maintenance requirement for lactating than for non-lactating cows. Since the quantity of heat loss derived from maintenance processes cannot be resolved from the total heat loss, it is impossible to determine if this higher maintenance requirement for ME was due to a higher NE_m requirement or due to a lower NAME for maintenance. Therefore, the maintenance requirement is expressed in terms of metabolizable energy.

The Beltsville data as well as other data (4) indicate a greater NAME utilization for tissue gain concurrent with lactation (0.75) than in the dry cow (0.60). In contrast to the Beltsville data in Table 1, earlier Beltsville data, that of Armstrong and Blaxter (4) and the Wageningen data in Table 1 indicate a similar NAME for milk production and concurrent body tissue gains which is higher than that for body tissue gains independent of lactation.

Table 1. Metabolizable energy utilization in dairy cows

Function	Net availability		ME required	
	A[a]	B[b]	A[a]	B[b]
Maintenance, dry	-	-	100[c]	-
Maintenance, lactating	-	-	122[c]	110[c]
ME ⟶ tissue, dry	0.64	0.60	1150[d]	1200[d]
Tissue ⟶ milk	0.82	0.90	-	-
ME ⟶ tissue, dry	0.60	-	-	-
ME ⟶ tissue, lactating	0.75	0.60	-	-
ME ⟶ tissue ⟶ milk	0.62[e]	0.54[e]	-	-

[a]Beltsville, data of Moe et al., (23).

[b]Wageningen, data of Van Es et al., (31).

[c]kcal/kg $^{.75}$/day.

[d]kcal/kg 4 percent fat corrected milk.

[e]Derived as product of ME ⟶ tissue ⟶ milk.

There is a very good fit to a linear relationship between retained energy as body gain plus milk vs. metabolizable energy intake over a wide range in milk production and energy gain (4, 12). This further suggests similar NAME for lactation and body gains concurrent with lactation and that this occurs even with low levels of milk production concurrent with appreciable gain, such as occurs in beef cattle.

Both the Beltsville and Wageningen data in Table 1 indicate greater NAME for milk synthesis from tissue than from the usual feed ME. However, the combined efficiency of tissue gain and loss in the lactating cow (.75 x .82 = .62) is not appreciably different than for direct utilization of feed ME for milk (.64).

The NAME is treated as a rate function (k) in Figure 2 to indicate factors which affect it. Blaxter (10) has quantitatively related variations in NAME to the metabolizability (Q) of the feedstuff's gross energy. Since k_d and k_q are determinants of Q, these are shown in Figure 2 as determining k_m, k_g, k_l, and k_{g+l}. The quantitative relations are as follows with Q_m being the percent metabolizability of the gross energy at maintenance intake levels (9).

$$k_m = 54.6 + 0.3\ Q_m$$

$$k_g = 0.85\ Q_m$$

A comparison of these two equations indicates that not only is k_m a more efficient process than k_g, but it is also much less affected by changes in Q_m. Net availability of ME utilization for lactation (k_l) is generally of a similar order of efficiency as k_m and also similarly less affected by variations in Q_m than k_g. As previously mentioned (Table 1), k_g is increased when weight gains are concurrent with lactation (k_{g+l} in Figure 2) and this is also less influenced by Q_m than when independent of milk production. Although the effects of Q_m on k_l and k_{g+l} are significant (22, 27), they are small and no consistent quantitative prediction equations have been proposed.

Energy Units

To be most useful in feeding practice, the animal's requirement for energy and the various feeds' supply of nutritive energy should be in the same energy unit (digestible, metabolizable or net energy). Since the quantity of net energy required by the animal is equal to the energy lost, gained, or secreted from its tissues, net energy is the most direct unit for expressing energy requirements. If net energy is also the feed energy unit, then a feed would have a different numerical value for its net energy content when used to support animal function of different NAME. Thus, a feedstuff's content of NE for maintenance (NE_m), NE for gain by non-lactating cow (NE_g), NE for gain by lactating cow (NE_{g+l}) and NE for milk (NE_l) would be in reference to Figure 2.

Let $NE_m = ME_m \times k_m$

$NE_m = ME_m \times (54.6 + 0.3\ Q_m)$

$NE_g = ME_g \times k_g$

$NE_g = ME_g \times (.85\ Q_m)$

$NE_{g+1} = ME_{g+1} \times k_{g+1}$

$NE_l = ME_l \times k_l$,

where ME_m, ME_g, ME_{g+1}, and ME_l are the metabolizable energy content of the feed when fed at intake levels sufficient to support maintenance, gain, gain plus lactation, and lactation, respectively.

The California Net Energy System (21) and its adoption by the National Research Council Nutrient Requirements for Beef Cattle (24) express the net energy value of feeds as NE_m and NE_g. The National Research Council Nutrient Requirements for Dairy Cattle (25) utilizes NE_m and NE_g for non-lactating cattle and a single NE for lactating cows which assumes k_m, k_l, and k_{g+1} are numerically equal in all feeds.

To avoid the confusion of a single feedstuff having multiple net energy values, various groups, and especially the East Germans (26) have proposed the net energy of feeds be expressed as a single, standard net energy. Net energy for fattening (NE_f) was proposed for a number of reasons. The animal's functional requirement for net energy can then be expressed as NE_f as follows:

$$\text{Maintenance requirement for } NE_f = NE_m \times \frac{k_f}{k_m}$$

$$\text{Function z requirement for } NE_f = NE \times \frac{k_f}{k_z}$$

Another approach is to express the nutritive value of feeds as ME and compute the animal's functional energy requirements for ME as follows:

$$ME_m = \frac{NE_m}{k_m}$$

$$ME_g = \frac{NE_g}{k_g}$$

$$ME_{milk} = \frac{NE_l}{k_l}$$

$$ME_{lactation} = \frac{NE_l}{k_l} + \frac{NE_g}{k_{g+1}} + \frac{NE_m}{k_m}$$

This approach was suggested by Blaxter (8) and adopted by the Agricultural Research Council, (ARS), Technical Committee on the Nutrient Requirements of Farm Livestock (1). It has the considerable logic of:

1. Metabolizable energy as a feed unit reflects a single unit which is primarily an attribute of the feed, i.e., not confounded by its functional net energy utilization.

2. Metabolizable energy as a functional energy requirement is primarily an attribute of the animal (functional NE) and, secondarily, an interaction between the functional energy requirement and composition of the metabolizable energy, i.e., NAME for the animal function-feedstuff ME interaction.

Other feed energy units such as digestible energy could be used equally as well, provided an accounting was made of variations in all losses and efficiencies. One system would be as accurate as the other if each had provided correct prediction of energy feed losses, efficiencies and animal requirements.

Energy Requirements and Utilization: Validation

The validity of current energy requirements and assumptions made concerning feed energy utilization can be tested by comparing predicted to observed performance of animals fed known amounts of feed digestible energy.

Data were available on 18 cows individually fed recorded amounts of hay in confienment over several years. The weight of the cow and pre-weaning weight of the calf were predicted as a function of information given in Table 2 and the 1970 National Research Council, (NRC), nutrient requirements for digestible energy.

There was a systematic overestimation of cow weight which was probably due to underestimation of milk production (by weigh-nurse-weigh) and consequently, overallocation of nutrient flow for cow weight. Similarly, pre-weaning calf weight was underestimated and could be a consequence of milk production. The correlation between observed and predicted performance was good with 93 percent and 82 percent of the variation respectively in cow and calf weight gains being accounted for in terms of nutrient intake and predicted requirements. It should be noted that extravital activity of these confinement animals was minimal as compared to expected locomotion cost of grazing activities; so, it appears the NRC maintenance requirement of 135 kcal DE/kg$^{.75}$ is a minimal maintenance requirement.

Table 2. Performance of cows and nursing calves[a] as predicted from their digestible energy intakes[b] and variables affecting energy requirements (16)

Variable	Range in variable	Performance		R^2
		Predicted	Observed	
Initial cow wt., kg	280-603	-	-	-
Daily milk prod., kg[c]	1.4-10.4	-	-	-
Subsequent calf birth wt.[d], kg	29-44	-	-	-
Subsequent cow wt.[e,f], kg	-	463	435	0.93
Pre-weaning calf gain[e,f], kg	-	223	233	0.82

[a]Eighteen cow-calf pairs.

[b]Cows fed in confinement, ration containing 2.2 mcal. DE/kg in amounts to maintain constant condition; calves fed ad libitum ration containing 2.9 mcal. DE/kg.

[c]Milk production measured monthly; DE required calculated over 8 monthly intervals as: DE_1 = 1700 kcal. x kg 4 percent fat corrected milk.

[d]kcal. DE required for products of conception = 800 x birth wt. x $2^{(\text{month pregnant} - 2)}$.

[e]kcal. DE required for cow or calf maintenance = 135 x $kg^{.75}$ x days.

[f]kcal. DE required for cow or calf gain = 175.5 x $kg^{.75}$ x kg gain.

Although the energy losses associated with locomotion are rather accurately known (1), there are considerable problems in measuring and relating these activities to common and definable management methods. Certain grazing activities have been reported to increase the maintenance cost by 1.65 times (8).

Knox and Handley (18) utilized extensive records for feedlots in northern Colorado to evaluate the gain prediction accuracy of the California Net Energy System (CNES) (21), which is essentially that of the National Research Council (24). Some of their results are summarized in Table 3. Their results in general indicate considerable

Table 3. Observed versus predicted feedlot performance based on the California Net Energy System (Adapted from Knox and Handley, 1973)

Study	Number of steers	Initial weight	Final weight	Actual-predicted gains	
				Mean difference	Percent of actual
		kg	kg	kg	
1[a]	95,278	374	525	-4.8	8.2±1.7
2A[b]	3,658	189	268	-11.2	19.1±4.5
2B[b]	910	239	469	-5.0	5.8±2.0

[a]Observed performance data obtained from steers in northern Colorado feedlots fed 40-85 percent concentrate finishing rations.

[b]Observed performance data obtained from steers in northern Colorado feedlots fed growing (2A) or finishing (2B) rations.

precision where applied to a large population of similar animals (British cross steers) fed in similar confinement and for similar weight increments as was used in developing the system (21). However, rather large negative deviations in gains (ranging to -12.6 percent of actual) occurred for cattle started during the winter months with positive deviations (ranging to 15.4 percent of actual) occurring in cattle started during spring months. Consideration of the environmental components of wind, moisture and temperature reduced, but did not eliminate, this seasonal variation.

Another source of error in the CNES appears related to the initial weight and possibly composition of the weight gains made. Data in Table 3 indicate much larger deviations between actual and predicted weight gains for lighter cattle than for heavier cattle upon which the system was primarily developed.

Although environmental effects accounted for some of the deviations between expected and observed performance, the largest source of variation appears related to a) other stresses that are probably unrelated to nutrient utilization and b) requirements for which the system does not account. Thus, one must conclude the CNES is of very practical accuracy when applied to similar animals and confinement feeding procedures under which it was developed. It is not applicable nor has it been recommended (24) for beef cows, calves and less confining feeding programs which would have a higher extra-vital activity cost and hence, a higher maintenance requirement.

Alderman et al. (2) reported a comparison of observed versus predicted performance based on known feed intake and digestibility and the nutrient requirements of beef steers according to the Agricultural Research Council (1). Some of their results are summarized in Table 4. Predicted performance exceeded observed performance progressively with increasing body weight both in the results summarized in Table 4 and more extensive results reported by Alderman et al. (2).

Webster et al. (38), using an extrapolation technique to estimate maintenance requirement in fed steers, reported a maintenance requirement of 105 kcal ME/kg$\cdot^{75}$/24 hrs. which was constant from weaning to slaughter (50-450 kg). This was in contrast to fasting metabolism which declined exponentially with age as assumed in the maintenance requirements by ARC. Webster et al. (38) pointed out that the progressive deviations observed by Alderman et al. (2) between performance observed and predicted from ARC could be largely accounted for by assuming a constant maintenance requirement of 105 kcal ME/kg$\cdot^{75}$ rather than the age dependent requirement given by ARC (1).

Feed Intake

Although some uncertainties exist about certain aspects of energy utilization and requirements, the above results indicate the general adequacy of our knowledge in predicting performance from known intakes and digestibilities of feed. The greatest uncertainties associated with predicting animal performance as a function of available food is associated with predicting feed intake. Nutritionally, the greatest opportunity for increasing efficiency of animal production exists in maximizing feed intake which is also the most variable and important determinant of productive efficiency (E_{g+1}/GE, Figure 2).

A number of investigators have demonstrated a general relation between digestibility and voluntary intake (VI). Lehmann (20) and Conrad et al. (12) have reported extensive data indicating that dairy cattle consume an amount of feed which yields 0.94 kg undigested organic matter (OM) per 100 kg body weight. Then the relative voluntary intake (RVI) is:

$$\text{RVI}_{\text{(kg/100 kg body wt.)}} = \frac{0.94}{\text{1-fractional dig. of OM}}$$

A plot of RVI expected from this relation versus the ration's digestibility is given in Figure 3.

In general, the RVI increases with increasing ration digestibility to the point where the animal's requirement for NE is equal to or less than that provided by an RVI yielding 0.94 kg of undigested OM. Below this point, the processing capacity of the tract (0.94 kg undigested OM) limits RVI and this range is referred to as gut fill control in Figure 3. Above this point, the productive ability of the animal (genotype and extra-nutritional environment) and hence its productive

Table 4. Observed versus performance which would be predicted based on Agricultural Research Council nutrient requirements and known digestible energy intake by steers (Adapted from Alderman et al., 1970)

Diet	No. fodders	No. animals	Liveweight range kg	Observed daily gain kg/day	Predicted minus observed gain kg/day
Conc: fodder					
1:2	8	168	117-156	0.55	-.15 ± .08
2:1	8	168	127-172	0.81	-.04 ± .08
0:1	8	98	290-396	0.54	.00 ± .23
1:2	12	139	306-406	0.94	.15 ± .14
2:1	12	127	309-407	1.09	.35 ± .12
1:0	-	99	314-401	1.21	.34 ± .04

NE requirement limits VI and is referred to as metabolic control in Figure 3. The transition point between these control sites varies with the level of production but, for dairy cattle receiving mixed diets, is in the range of diets containing 65-70 percent digestible dry matter.

Blaxter (8) has reported the general relation between VI of roughages and their percent metabolizability (Q) at VI to be:

$$VI_{g\ DM/kg^{.75}} = 9.1\ Q - 0.0740^2 - 194\ .$$

The quadratic nature of this relation is due to an increasing importance of metabolic control with forages of higher digestibility, a control site which is regulated by the animal's production requirements. Hence, this relation confounds attributes of the diet with attributes of the animal and would therefore be expected to vary with the age and growth potential of meat animals as indeed has been demonstrated (21).

Although the relation between intake and digestibility appears to have general applicability, there are numerous and systematic quantitative deviations from that proposed by Conrad et al. (12). This is not surprising if it is realized that 1) digestibility is the net result of a number of different relations to digestibility, and 2) VI is a dynamic consequence of flow whereas digestibility is a ratio between two flows and therefore not a dynamic response attribute. This is illustrated in Figure 4 which is based on concepts proposed by Waldo and Smith (37).

Only cell wall constituents (CWC) are considered in Figure 4 since they are essentially the only feed residues appearing as undigested residues (37) and they comprise the bulk of the residues within the tract. A certain portion of the CWC is completely indigestible and is referred to as indigestible CWC (CWC_i) to distinguish it from the potentially digestible CWC (CWC_d). Potentially digestible CWC are capable of being completely digested but at a relatively slow rate (k_d) and therefore a portion is undigested due to passage (k_p) from the digestive site. Fractional digestibility of CWC_d ($DCWC_d$) is:

$$DCWC_d = k_d/(k_d + k_p)$$

Digestibility of the total CWC is:

$$DCWC = \frac{CWC_d \times k_d/(k_d + k_p)}{CWC_d + CWC_i}$$

Thus, digestibility of CWC, and hence ration dry matter, is determined by 1) the proportion of CWC_d of total CWC and 2) the ratios between k_d and k_p.

If the flow of CWC residues (k_p) represents the physical flow limiting VI, the VI should be positively related to:

1. Factors which increase k_p, such as reduction in dietary particle size and increasing level of feed intake (6).

2. Factors which increase the rate of CWC_d digestion (k_d) and thereby reduce the flow of undigested CWC_d, such as correction of a dietary protein deficiency (13). Van Soest (33) has pointed out that to increase VI such increased k_d must effectively reduce the bulky structure of the tissue CWC. Forage attributes related to ease of physical fragmentation would expectedly be important (18).

3. A reduction in CWC_i would materially increase VI since, due to their digestibility, they may contribute 1 to 3 times the CWC residues as CWC_d (37).

The results of Laredo and Minson (19) conform to expectations based on the concepts in Figure 4. Some of their results are summarized in Table 5. The mean VI of leaves was considerably higher than that of stems although the two plant parts were of similar mean digestibility. The higher VI for leaves was associated with a shorter retention time ($1/k_p$) in the reticulorumen and less energy required to grind leaf as compared to stem through a laboratory mill. These results confirm the importance of flow and suggest physical factors apparently related to rate of physical reduction in effective bulk contributing to such. The overall similar digestibility for leaf versus stem could be attributed to a reduced rate of flow (k_p) of stem residues allowing a longer residence time and hence a similar extent of digestion for the two plant parts.

The data of Laredo and Minson (19) exemplifies the need for more basic consideration of the diet with regard to its physical and anatomical attributes as well as its chemical composition. This must then be combined with dynamic, quantitative measures of its digestive fate before consistent methods can be expected to predict VI as a function of attributes of the available forage. This is unquestionably the area of greatest need in nutrition research related to forage utilization.

Other Factors

Considerable variation is observed in performance among apparently similar animals in similar nutritional and physical environments. Much of this can be attributed to:

1. Compensatory growth induced by previously restricted growth which is primarily, but not always, manifested by increased feed intake during the compensatory period (40).

Table 5. Voluntary intake and digestibility by sheep of leaf and stem fractions (Adapted from Laredo and Minson, 1973)

Species	Voluntary intake		Digestibility	
	Leaf	Stem	Leaf	Stem
	gm/kg$^{.75}$		percent	
Digitaria decumbens	58.3[a]	39.7	52.6[a]	54.0
Pennisetum clandestinum	50.5	34.6	50.9	52.1
Chloris gayana	57.4	45.4	53.2	57.7
Setaria splendida	58.8	31.5	55.7	58.8
Panicum maximum	63.9	46.7	50.7	56.3
Overall Mean	57.8	39.6	52.6	55.8

[a]Each value a mean of three successive maturity cuttings.

2. Differences in composition of gains due to differences in physiological ages and potential mature weight.

3. Relatively small genetic differences in temperament affecting the maintenance requirement.

Interesting differences in energy utilization by Brahman as compared to British cross steers have been reported by Vercoe (35) and Vercoe and Frisch (36) as illustrated by some of their results summarized in Tables 6 and 7.

Vercoe noted Brahman cross steers achieved a greater equilibrium weight than did British cross steers having the same initial weight and fed 4.28 kg/day of the same hay. The two hybrids utilized the hay with a similar digestive and metabolic efficiency although the Brahman cross steers produced slightly less methane. The two hybrids had a similar fasting heat production and presumed maintenance requirement, which suggested differences in efficiency of metabolizable energy utilization for maintenance (k_m) favoring the Brahman cross.

In a subsequent trial, Vercoe and Frisch (Table 7) employed a greater number of animals and Africander cross steers, all of which were fed a forage at levels to allow 10-15 percent feed refusal. The Brahman and Africander cross steers achieved more rapid gains than did

Table 6. Energy utilization by different breed cross steers (Adapted from Vercoe, 1970)

Breed cross	No. steers	Equilibrium weight achieved[a]	DDM[b]	Urinary N	CH_4	Fast heat prod/$kg^{.75}$	k_m
		kg	%	gm/day	l/day	kcal/day	
BX[c]	3	328	54.8	27.5	103	78.8	0.77
SH[d]	4	291	54.0	28.0	115	78.5	0.70

[a]Equilibrium weight of initially equal weight steers after receiving 4.28 kg/day of a hay.

[b]Digestibility of dry matter, apparent.

[c]Brahman x British.

[d]Shorthorn x Hereford.

Table 7. Energy utilization by different breed cross steers (Adapted from Vercoe and Frisch, 1974)

Breed cross	No. steers	Fast heat prod/kg	Maximum forage intake		Avg. daily gain	
			Body weight adj.[a]	Fast heat prod. adj.[a]	Observed	Forage intake adj.[a]
		kcal/day	kg/day			
BX[b]	11	20.0	7.7	8.3	0.18	0.17
AB[c]	12	20.3	7.9	8.3	0.15	0.14
SH[d]	11	21.2	8.1	7.9	0.07	0.08

[a]Response adjusted to equal body weight, fasting heat produced or forage intake.

[b]Brahman x British.

[c]Africander x British.

[d]Shorthorn x Hereford.

British cross steers, even though there were no significant breed type differences associated with fasting heat production and maximum forage intake per unit body weight or per unit fasting heat production. A similar superiority in gain for Brahman cross steers, as compared to European straightbred, has been observed for steers grazing Coastal bermuda but not winter pasture at the North Louisiana Hill Farm Experiment Station (27).

These differences suggest certain breed hybrids are more efficient utilizers of metabolizable energy for maintenance and production if fasting metabolism is an adequate reflection of maintenance. The more efficient utilization of energy for production may be associated with composition differences in gain, the efficiency of energy utilization for fat synthesis being considerably less than that for protein (17, 5, 27).

Summary

Prediction of animal performance requires knowledge of 1) rate of feed intake, 2) rate of conversion of feed energy to nutritive energy, 3) rate of energy loss, gain or secreted by the animal (requirements), and 4) how these quantities and rates are quantitatively related to attributes of the feed-animal-environment complex. With the composition of performance being most uncertain, knowledge in these areas is of considerable practical adequacy in predicting animal performance as functions of digestible energy intake. Inadequacies in knowledge concerning factors determining rates of feed digestion and intake most limit accuracy in predicting animal performance. Acquisition of such knowledge should then have high priority and will require research which considers the physio-chemical and dynamic aspects of the feed and its digestive processes.

LITERATURE CITED

1. Agricultural Research Council. 1965. Nutrient Requirements of Farm Livestock. No. 2, Ruminants. Agricultural Research Council, London.

2. Alderman, G., D. E. Morgan, and W. J. Lessells. 1970. A comparison of live-weight gains of beef cattle with values predicted from energy intakes measured as starch equivalent or metabolizable energy. In Proc. V. Symposium on Energy Metabolism of Farm Animals held at Vitzhau, Switzerland; Juris Bruck and Verlag, Zurich,

3. Armstrong, D. G. 1964. Evaluation of artificially dried grass as a source of energy for sheep. II. The energy value of cocksfoot, timothy and two strains of rye-grass and varying stages of maturity. J. Agri. Sci. 62:399.

4. Armstrong, D. G. and K. L. Blaxter. 1965. Effects of acetic acid and propionic acids on energy retention and milk secretion in goats. In: Proc. III. Symposium on Energy Metabolism, held at Troon; Academic Press, London.

5. Baldwin, R. L. 1968. Estimation of theoretical calorific relationships as a teaching technique. A Review. J. Dairy Sci. 51:104.

6. Blaxter, K. L., N. M. Graham and F. W. Wainman. 1956. Some observations on the digestibility of food by sheep and on related problems. Brit. J. Nutr. 10:69.

7. Blaxter, K. L. 1961. The utilization of the energy of food by ruminants. In: Proc. II. Symposium on Energy Metabolism held in Wageningen; European Assoc. Anim. Prod. Publ. No. 10, Rome.

8. Blaxter, K. L. 1962. The Energy Metabolism of Ruminants. Charles C. Thomas, Springfield, IL.

9. Blaxter, K. L. 1964. The utilization of the metabolizable energy of grass. Proc. Nutr. Soc. 23:62.

10. Blaxter, K. L. 1967. The efficiency of energy transformations in ruminants. In: Proc. IV. Symposium on Energy Metabolism of Farm Animals held in Warsaw; Oriel Press, Newcastle upon Tyne.

11. Blaxter, K. L. 1974. Metabolizable energy and feeding systems for ruminants. In: Proc. Feed Manuf. Conf.; University of Nottingham, England.

12. Conrad, H. R., A. D. Pratt, and J. W. Hibbs. 1964. Regulation of feed intake in dairy cows. I. Changes in importance of physical and physiological factors with increasing digestibility. J. Dairy Sci. 47:54.

13. Flatt, W. P. and C. E. Coppock. 1965. Physiological factors influencing the energy metabolism of ruminants. In: Proc. II. International Symposium on the Physiology of Digestion in the Ruminant held in Ames, Iowa; Butterworth, Washington.

14. Freer, M., R. C. Campling, and C. C. Balch. 1962. Factors affecting the voluntary intake of foods by cows. 4. The behavior and reticular motility of cows receiving diets of hay, oat straw, and oat straw with urea. Brit. J. Nutr. 16:279.

15. Hungate, R. E. 1966. The Rumen and Its Microbes. Academic Press, New York.

16. Joandet, G. E. 1973. Personal Communication.

17. Kielanowski, J. 1965. Estimates of the energy cost of protein deposition in growing animals. In: Proc. III. Symposium on Energy Metabolism held at Troon; Academic Press, London.

18. Knox, K. L. and T. M. Handley. 1973. The California Net Energy System: Theory and application. J. Anim. Sci. 37:190.

19. Laredo, M. A. and D. J. Minson. 1973. The voluntary intake, digestibility and retention time by sheep of leaf and stem fractions of five grasses. Aust. J. Agri. Res. 24:875.

20. Lehman, F. 1941. Die Lehre Vom Ballast. Z. Tierernahr. Futtermittelk. 5:155.

21. Lofgreen, G. P. and W. N. Garrett. 1968. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. J. Anim. Sci. 27:793.

22. McCullough, T. A. 1970. A study of the effect of supplementing a concentrate diet with roughages of different quality on the performance of Friesian steers. I. Voluntary food intake and food utilization. J. Agri. Sci. 75:327.

23. Moe, P. W., H. F. Tyrrell, and W. P. Flatt. 1970. Partial efficiency of energy use for maintenance, lactation, body gain, and gestation in the dairy cow. In: Proc. V. Symposium on Energy Metabolism of Farm Animals held in Vitzhau, Switzerland; Juris Bruck and Verlag, Zurich.

24. National Research Council. 1970. Nutrient Requirements for Beef Cattle. IV. Edition; National Academy of Sciences, Washington, D. C.

25. National Research Council. 1971. Nutrient Requirements for Dairy Cattle. IV. Revised Edition; National Academy of Sciences, Washington, D. C.

26. Nehring, K., R. Schremann, and L. Hoftmann. 1967. A new system of energetic evaluation of food on the basis of net energy for fattening. In: Proc. IV. Symposium on Energy Metabolism of Farm Animals held in Warsaw; Oriel Press, Newcastle upon Tyne.

27. Oliver, W. M. 1976. Grazing stocker cattle on Coastal bermudagrass--A Progress Report (Mimeograph Hill Farm Facts, Beef Cattle No. 18, May 1976.

28. Orskov, E. R. and I. McDonald. 1970. The utilization of dietary energy for maintenance and for fat and protein deposition in young growing sheep. In: Proc. V. Symposium on Energy Metabolism of Farm Animals held at Vitzhau, Switzerland; Juris Bruck and Verlag, Zurich.

29. Paloheimo, Lauri and Irja Paloheimo. 1949. On the estimation of the total of vegetable membrane substances. J. Scient. Agri. Soc. of Finland 21:1.

30. Salo, M. L. 1965. On the content of cell wall constituents in various plant materials. J. Scient. Agri. of Finland 37:127.

31. Van Es, A. J., H. J. Nijkamp, and J. E. Vogt. 1970. Feed evaluation for dairy cows. In: Proc. V. Symposium on Energy Metabolism of Farm Animals held in Vitzhau, Switzerland; Juris Bruck and Verlag, Zurich.

32. Van Hellen, R. W., W. C. Ellis, and J. H. Matis. 1974. Intraruminal digestion kinetics of NDF. J. Anim. Sci. 38:214.

33. Van Soest, P. J. 1967. Development of a comprehensive system of feed analysis and its application to forages. J. Anim. Sci. 26:119.

34. Van Soest, P. J. 1974. Physio-chemical aspects of fiber digestion. In: Physiology of Digestion and Metabolism in the Ruminant. I. W. McDonald and A. C. I. Warner, Eds., pp. 351-365. University of New England Press, Armidale, Australia.

35. Vercoe, J. E. 1970. Fasting metabolism and heat increment of feeding in Brahman x British cross cattle. In: Proc. V. Symposium on Energy Metabolism of Farm Animals held at Vitzhau, Switzerland; Juris Bruck and Verlag, Zurich.

36. Vercoe, J. E. and J. E. Frisch. 1974. Fasting metabolism, liveweight and voluntary intake of different breeds of cattle. In: Proc. VI. Symposium on Energy Metabolism of Farm Animals held at Hohenheim; Universität Hohenheim, Stuttgart.

37. Waldo, D. R. and L. W. Smith. 1972. Model of cellulose disappearance from the rumen. J. Dairy Sci. 55:125.

38. Webster, A. J. F., J. M. Brockway, and J. S. Smith. 1974. Preduction of the energy requirements for growth in beef cattle. I. The irrelevance of fasting metabolism. Anim. Prod. 19:127.

39. Wilkens, R. J. 1969. The potential digestibility of cellulose in forages and feces. J. Agri. Sci. 73:57.

40. Wilson, P. N. and D. F. Osbourn. 1960. Compensatory growth after undernutrition in mammals and birds, Biol. Rev. 35:324.

MEETING THE NUTRIENT REQUIREMENTS OF BEEF CATTLE WITH FORAGE

Ethan C. Holt*

The nutritive value of some southern forages will be characterized and factors influencing nutritive value identified, rather than attempt to develop a system of meeting beef cattle nutrient requirements. A wide range of environmental conditions exist in the Southern Region, and a broad array of adapted tropical to temperate forage species has been developed in the region. Tropical grass species tolerate temperatures only a few degrees below freezing and are dormant during the cool winter months. Temperate grass species are adapted to climates where rainfall distribution is relatively uniform and where plants may stay green the year round, but where growth cessation occurs because of both low or high temperatures. The region also includes grasses adapted to arid conditions where dormancy periods occur because of drought or low temperatures. Under tropical or semitropical conditions, few, if any, legumes are adapted to the summer growth period. Temperate legumes may be grown with temperate grasses and with tropical grasses during the cool months.

The nutritional quality of forage plants varies among species and with changes in environmental conditions such as temperature, moisture, light and fertility. Economic practices may influence dry matter production and, to a lesser extent, nutritional quality.

The objective of this paper is to document the seasonal pattern of nutritional quality of various forage species and the potential effects of agronomic, cultural and management practices on that pattern. The relationship to nutrient requirements of beef cattle will also be discussed.

Dr. W. C. Ellis has reviewed the nutrient requirements of various classes of beef animals. These requirements are met by a combination of the available nutrient concentration in the feed and intake of the feed. While intake is a component of forage feeding value, this paper will emphasize forage quality as measured by digestibility in meeting the nutrient needs of beef cattle. Lippke (H. Lippke, unpublished data) has suggested the following ranges in forage digestibilities that meet the requirements of various classes of beef cattle: dry

*Professor, Soil and Crop Sciences Department, Texas A&M University, College Station, Texas 77843.

cows, 46-56 percent; cow with calf, 56-66 percent; heifer with first calf or 270+ kg steer, 62-68 percent; 113 kg steer, greater than 70 percent. These digestibility ranges will be used in this paper. Average daily gain will be used to indicate quality when information on forage digestibility is not available, on the assumption that forage availability was not limiting.

Total forage dry matter production and the consistency of production over a period of years are important goals in a forage program. Major inputs to achieve production goals are adapted species, improved varieties, utilization management, fertility practices, and supplemental irrigation. Practices which maximize dry matter production frequently also will maximize nutrient production per acre. Thus, more animals may be carried per acre and generally more gain per acre produced but gain per animal may not follow the same pattern. The latter is highly important in a forage-fed finished-beef program and is influenced by the quality as well as quantity of available forage. The data in Table 1 indicate that Coastal bermudagrass production is increased by increasing amounts of nitrogen fertilizer and by decreasing frequency of harvest or utilization. The production of digestible organic matter per unit of area follows essentially the same pattern. However, nutrient concentration [in vitro digestible organic matter (IVDOM) and crude protein (CP)] do not follow the same pattern as total production. Thus, maximizing forage production does not necessarily provide forage that meets the nutrient requirements of beef cattle. Too often we have been concerned only with total animal production and not with production per animal which is more nearly an indicator of forage quality. Thus, maximizing and stabilizing forage production, while highly desirable, are not adequate goals for a forage-fed finished-beef program.

Seasonal Quality Patterns

Quality of available forage of Coastal and Common bermudagrass and bahiagrass in continuously grazed pastures at Overton, Texas (F. M. Rouquette, Jr., 1973, unpublished data, Figure 1) shows an early spring high of 72 to 76 percent in vitro digestible dry matter (IVDDM), a decline to 36-42 percent in early August, an increase to 56-60 percent in early October and a decline to 30-36 percent in late November. By mid-June IVDDM values for all species had dropped below 60 percent. In vitro digestible organic matter (IVDOM)values (Figure 2) for Coastal from a plot study (29) show a similar pattern except that the values did not drop as low in mid-summer as in the pasture study. Age of forage being sampled in the pastures was no doubt a factor in addition to seasonal effects.

Weeping lovegrass (Figure 3) has acceptable quality for a few weeks in the spring. Growth is initiated in late February or early March in Texas and Southern Oklahoma and IVDDM is above 60 percent until about May 1 (E. C. Holt and R.L. Dalrymple, 1974-75, unpublished data). Some cultivars show a recovery in IVDDM in late August to levels almost equal to spring values. Weeping lovegrass also is used for wintering cattle, but by early winter it is below the requirements

Table 1. The influence of harvest frequency and nitrogen fertilization on dry matter (DM) yield, digestible organic matter (Dig. OM) and crude protein (CP) of Coastal bermudagrass, College Station, Texas

Harvest frequency	N/ha/month	DM/ha	Dig. OM/ha	IVDOM	CP/ha	CP
weeks	kg	MT	MT	percent	MT	percent
2	20	4.8	2.83	59	0.61	12.8
	50	7.4	4.66	63	1.12	15.2
	100	13.5	8.78	65	2.70	20.0
4	20	7.8	4.60	59	0.83	10.7
	50	12.2	7.32	61	1.39	11.4
	100	17.5	11.20	64	2.75	15.7
8	20	11.2	6.27	56	0.96	8.6
	50	14.9	8.20	56	1.31	8.8
	100	18.1	10.14	56	2.10	11.6

Source: Villanueva, M. R. (29).

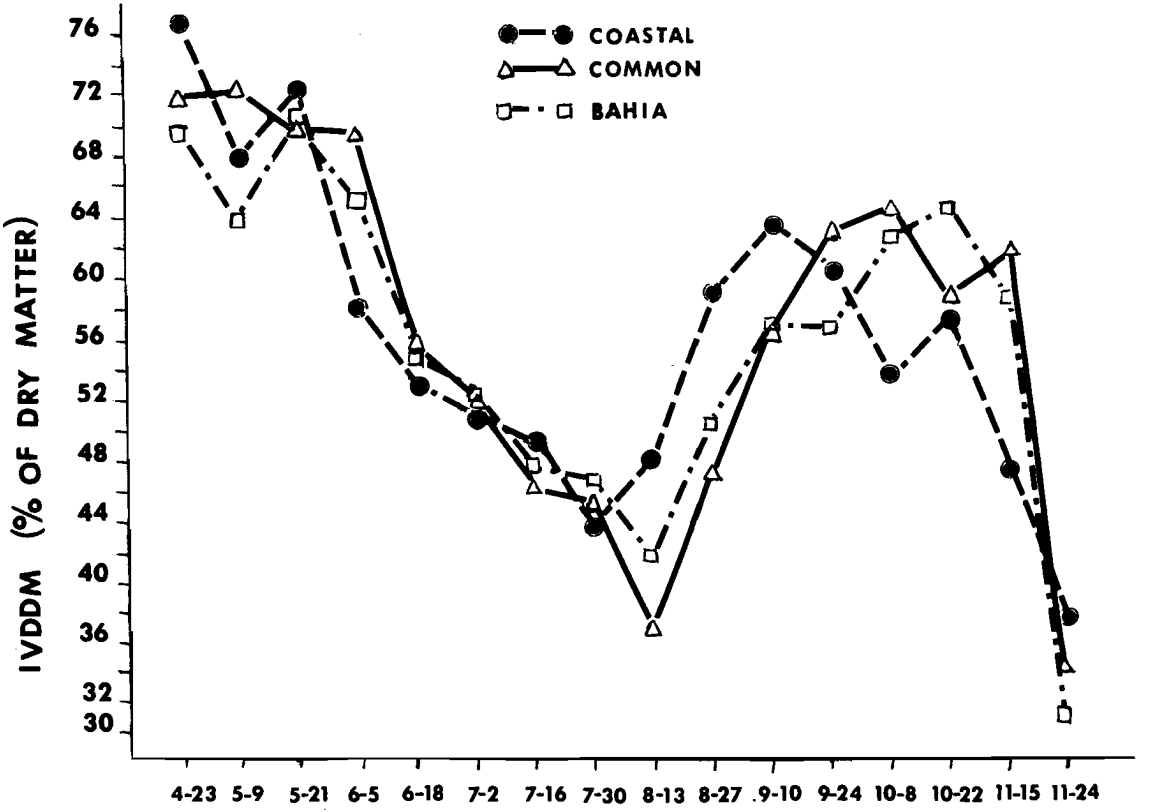


Figure 1. Seasonal pattern of in vitro digestible dry matter of available forage in experimental pastures, Overton, Texas (F. M. Rouquette, Jr., 1973, unpublished data)

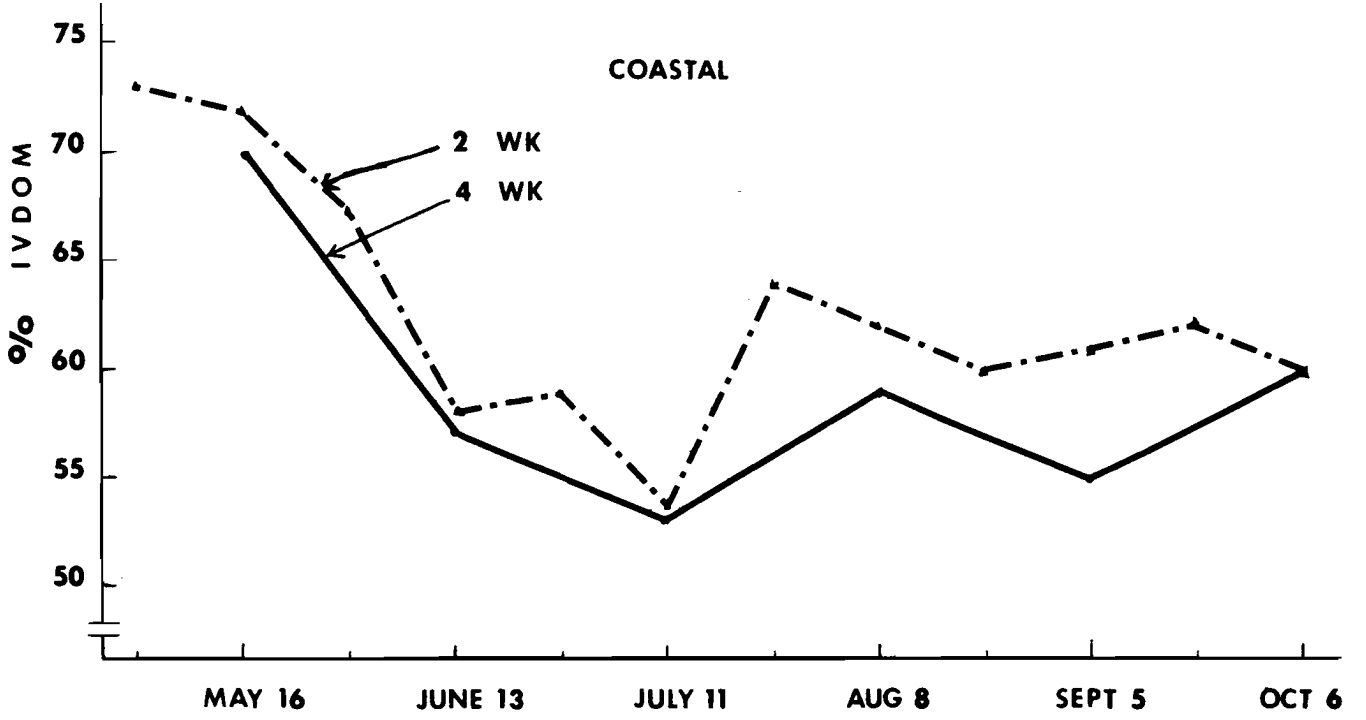


Figure 2. Seasonal pattern of in vitro digestible organic matter of Coastal bermudagrass harvested at two intervals, College Station, Texas (Villanueva, M. R. [29]).

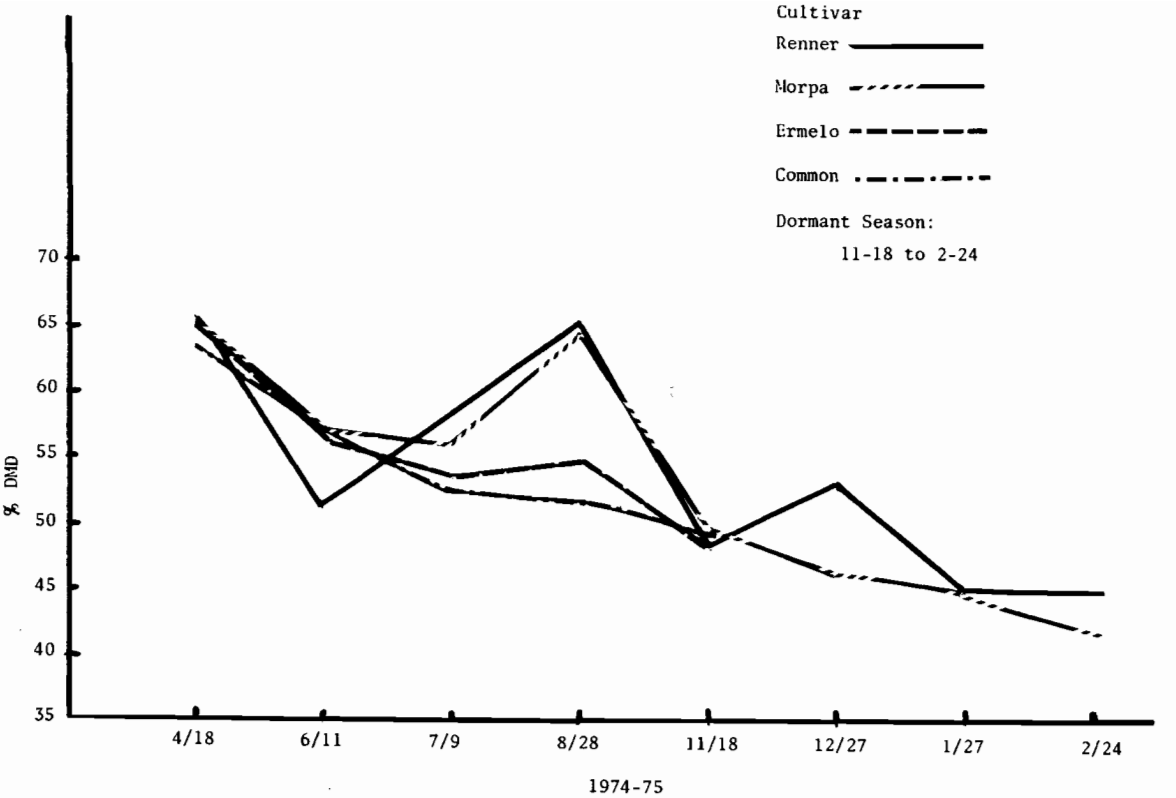


Figure 3. Seasonal pattern of in vitro digestible dry matter of weeping lovegrass cultivars at Ardmore, Oklahoma (E. C. Holt and R. L. Dalrymple, 1974-75, unpublished data)

listed above for most classes of cattle. Buffelgrass and kleingrass (Figures 4 and 5), both semi-arid land grasses, decline slightly in digestibility as the season progresses and rapidly after dormancy (7). Kleingrass initiates growth early and earlier samplings likely would have shown even higher digestibility values than shown in Figure 5.

High digestibility values were obtained for pangolagrass harvested monthly in Brazil (S. C. Schank, 1974, unpublished data, Figure 6). The in vitro organic matter digestibility (IVOMD) values ranged from 62 to 66 percent during the growing season with only a slight downward trend as the season progressed. IVOMD dropped rapidly in the dormant season to 52-54 percent. IVODM values for 30-day old pangolagrass in Florida were 54, 44, 48 and 63 percent in March, June, September and December, respectively (Paul Mislevy, 1974, unpublished data). Corresponding values for bahiagrass treated the same as pangolagrass were 59, 46, 46, and 56, respectively.

The performance of calves (with cows) on dallisgrass-Regal clover pasture declined from 1.3 kg gain per day in the spring to a low of .75 kg in early August followed by an increase in late August and early September (17). Calf gain on Serala declined from a high of 1.1 kg daily in May to a low of .31 kg in July-August and was erratic after May.

Tall fescue and hardinggrass declined in IVDDM from 77 to 67 percent and 73 to 58 percent, respectively from late February to April (19). Orchardgrass-clover forage in Tennessee showed a slow but steady decline in digestibility from a high of 65 percent in May to approximately 62 percent in September (2). On the other hand, fescue-annual lespedeza forage declined from 60 percent DDM in May to 57 percent in June with a subsequent increase to about 60 percent in September. Brannon, Reid and Miller (4) showed both July and September declines in DDM of a pasture consisting of a mixture of temperate grasses and legumes, the July decline reaching 59 percent DDM. Only a slight summer decline in IVDDM of tall fescue forage (Table 2) harvested at three different ages (amounts of growth) was obtained in North Carolina (J. C. Burns and D. S. Chamblee, 1969-70, unpublished data). The in vitro values also are higher than usually reported for tall fescue but were corroborated by cell wall content of the forages and by in vitro digestibility of a standard forage of known in vivo digestibility.

Yuchi arrowleaf clover declined in quality from approximately 80 percent IVDDM in mid-winter to approximately 69 percent in early June (18, 20). Age of tissue, from 1 to 6 weeks during the growing season had little influence on percentage digestibility of Yuchi.

Data on both warm-season and temperate grasses indicate a decline in quality in mid-summer with or without fall recovery. Winter growth generally is high in quality, especially on the winter annuals, but winter quality of dormant (warm-season) forage is low and declines with weathering. Temperate legumes show some decline in DDM in early summer but the decline is slower and DDM does not reach the critical low level of grasses. According to the results reviewed, most of the forages

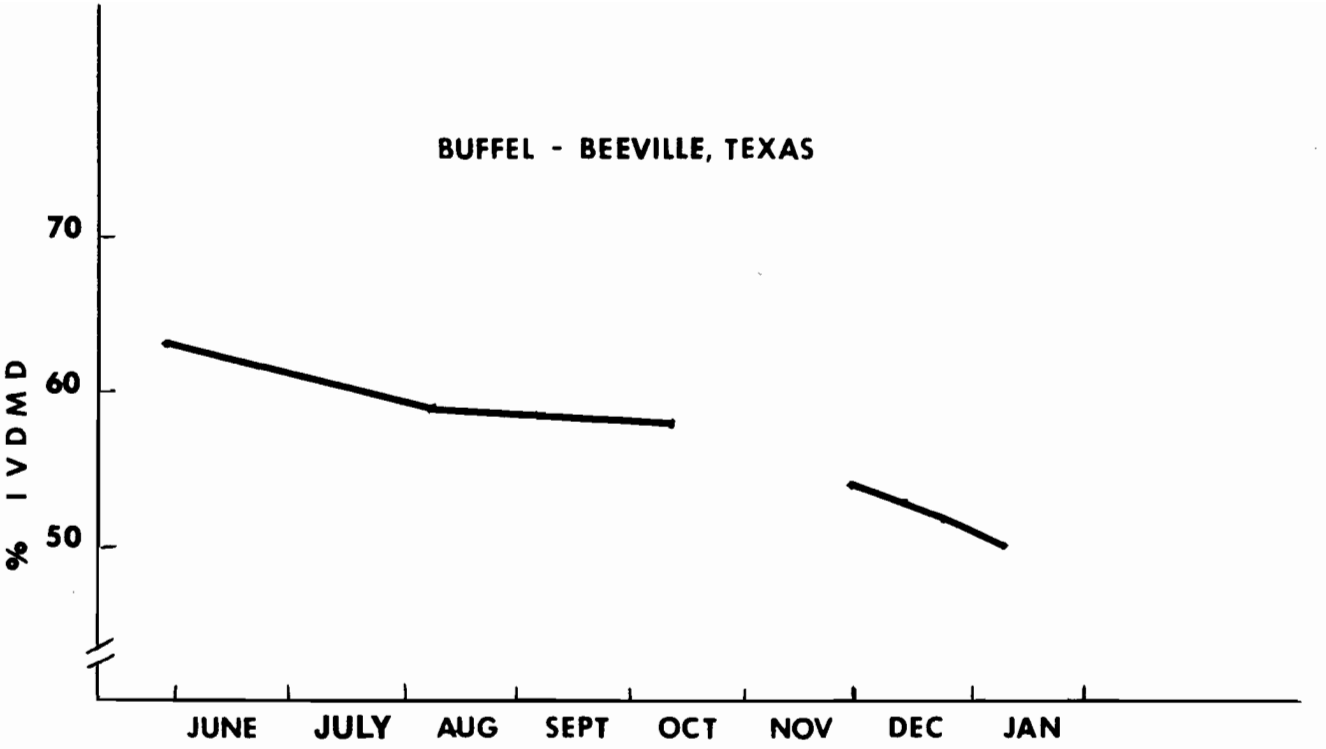


Figure 4. Seasonal pattern of <u>in vitro</u> digestible dry matter of buffelgrass at Beeville, Texas (Conrad, B. E., [7])

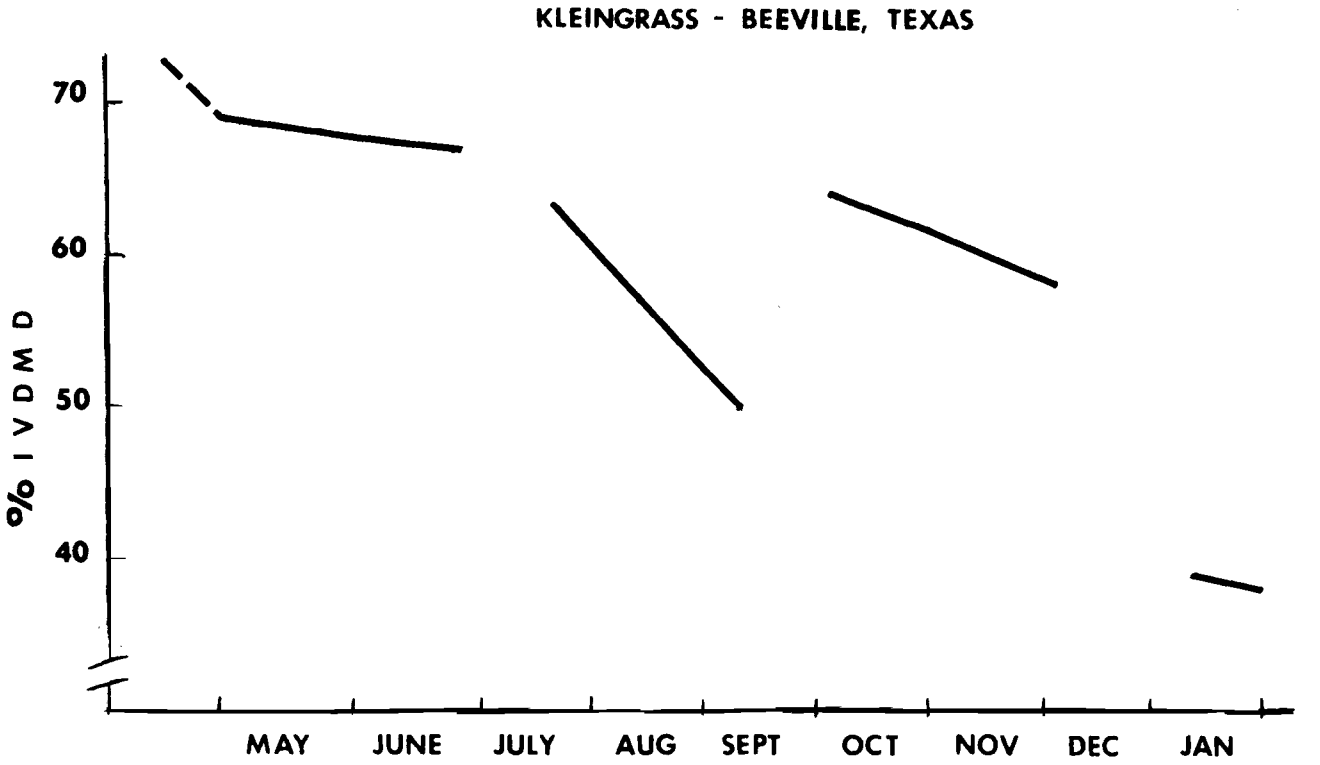


Figure 5. Spring, summer, fall and winter (dormant season) pattern of in vitro digestible dry matter of kleingrass with aging effects within each season at Beeville, Texas (Conrad, B. E. [7])

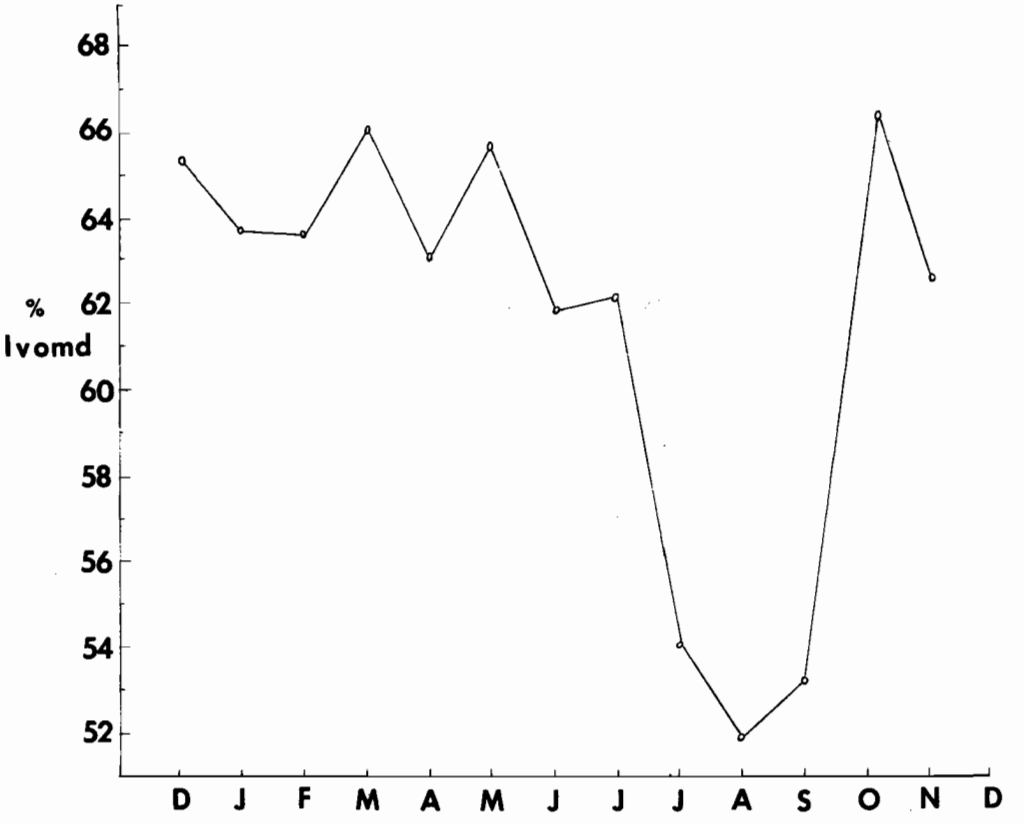


Figure 6. Season pattern of in vitro organic matter digestibility of pangolagrass in Brazil (S. C. Shank, 1974, unpublished data)

Table 2. The influence of season and harvest practice on in vitro digestible dry matter of tall fescue[a]

Cutting treatment[b]	Year	Season			
		Spring	Early summer	Late summer	Fall
		percent IVDDM			
30-5	1969	79	66	66	77
	1970	70	--	60	79
15-5	1969	80	73	67	77
	1970	72	--	63	80
7.5-5	1969	78	71	69	78
	1970	74	--	69	81

[a]Source: J. C. Burns and D. S. Chamblee, 1969-70, unpublished data.

[b]Height of growth and stubble height after cutting (cm).

meet the requirements for weaned calf production during some or most of the growing season. The winter annual grasses and grass-legume mixtures in areas where winter growth is expected, meet the nutrient requirements of growing animals. While the perennial grasses have acceptable quality in the spring, few of them meet the nutrient requirements, even of heavy stockers, during mid-summer. Tropical grasses in the dormant season generally are too low in digestibility to meet the nutrient requirements of grazing animals.

Management Effects on Quality

Is it possible through production and management practices to alter the patterns in forage production and quality? Among the management factors which may influence forage quality or quality patterns are fertility, utilization frequency (age of plant tissue), grass-legume mixtures, and irrigation.

Fertilization

That seasonal distribution of dry matter production can be altered by time of nitrogen (N) fertilization has been demonstrated by Holt and Lancaster (16). Also, under conditions where crude protein and/or specific minerals are deficient, the correction of such deficiencies by fertilization improves forage nutritive value. However, numerous studies have shown no direct effect of fertilizer nutrient application on forage quality where such nutrient deficiencies do not exist.

Extensive work on Midland bermudagrass (8) showed that nitrogen fertilization was a far less important factor in determining forage digestibility than was frequency of harvest. Villanueva (29) found that young Coastal bermudagrass forage fertilized with 100 kg N/month had slightly higher digestibility than that fertilized with 20 kg N/month, but the same relationship did not hold for older forage (Figure 7). Weeping lovegrass forage showed no significant difference in IVDDM due to nitrogen either during the growing season or the subsequent dormant season (E. C. Holt and R. L. Dalrymple, 1974-76, unpublished data, Figure 8 and 9). Work in Oklahoma (27) showed increases in IVDDM of Midland bermudagrass, Morpa lovegrass and Plains bluestem as N application was increased from 0 to 289 kg/ha but showed no effect with increased P. Researchers reasoned that N increased vegetative growth and reduced seed head production under moisture stress and that this might account for the improved digestibility. No significant influence of N, P or K on DDM or on the seasonal pattern of DDM of winter cereal-ryegrass forages was reported in Louisiana (1).

Rate of N had no influence on nutritive value on first-cut orchardgrass but did increase slightly the digestibility of aftermath growth (24). Absence of a consistent effect of N on total digestible nutrients (TDN) of orchardgrass has been reported (5) as well as similar findings on smooth bromegrass (6).

Nitrogen had no significant effect on quality of Common bermudagrass forage based on average daily calf gains over a three-year period in Oklahoma (12). Nitrogen increased percent IVDDM of stockpiled tall fescue forage during the winter and early spring months in a Mississippi study (V. H. Watson, unpublished data, Figure 11).

In general, these reports agree with the conclusion reached by Blaser (3) in a review paper that nitrogen fertilization improves the protein content and its apparent digestibility but does not influence TDN or digestible energy of grass forage. Nitrogen fertilization may influence the ratio of soluble cell components but does not influence the cellulose or crude fiber content of the cell walls. There may be specific conditions, such as stockpiled forage or stress conditions, under which N has an indirect effect on digestibility, probably through growth rate or the time at which growth is made.

Age of Forage

Forage grasses generally decrease in digestibility with advancing age, thus management practices may have a profound effect on forage quality. Villanueva (29) measured IVDOM of Coastal bermudagrass forage cut biweekly versus monthly throughout the growing season (Figure 2). The two-week forage ranged from 1 to 6 digestibility units higher than four-week forage. Forage cut at eight weeks was even lower in IVDOM. Variations in IVDOM were positively related to *in vitro* digestible neutral detergent fiber (IVDNDF) and cellulose content and negatively to hemicellulose. The results suggest that practices which would reduce hemicellulose content and/or the lignification of hemicellulose would increase digestibility. Age is one such factor but N fertilization did not have this effect.

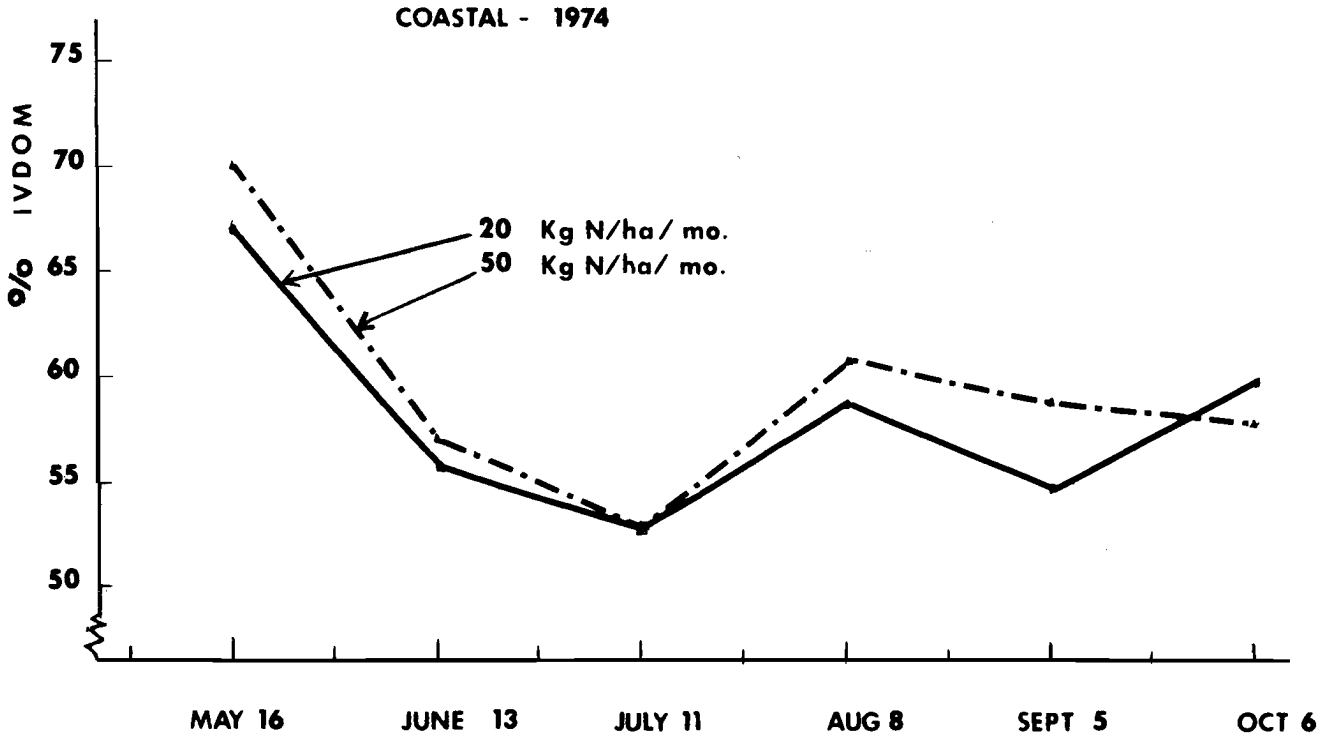


Figure 7. The influence of nitrogen fertilization on in vitro digestible organic matter of Coastal bermudagrass, College Station, Texas (Villanueva, M. R. [29])

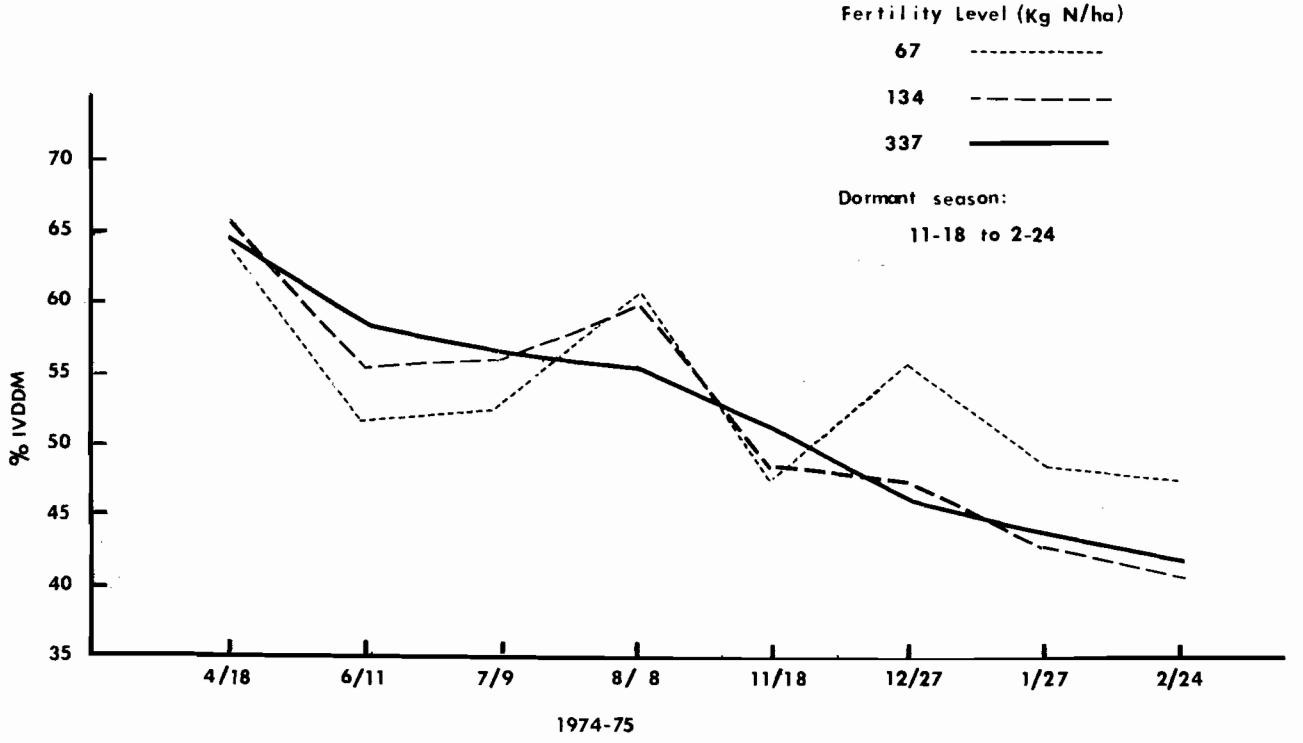


Figure 8. The influence of nitrogen on in vitro digestible dry matter of weeping lovegrass, Ardmore, Oklahoma, 1974-75 (E. C. Holt and R. L. Dalrymple, 1974-75, unpublished data)

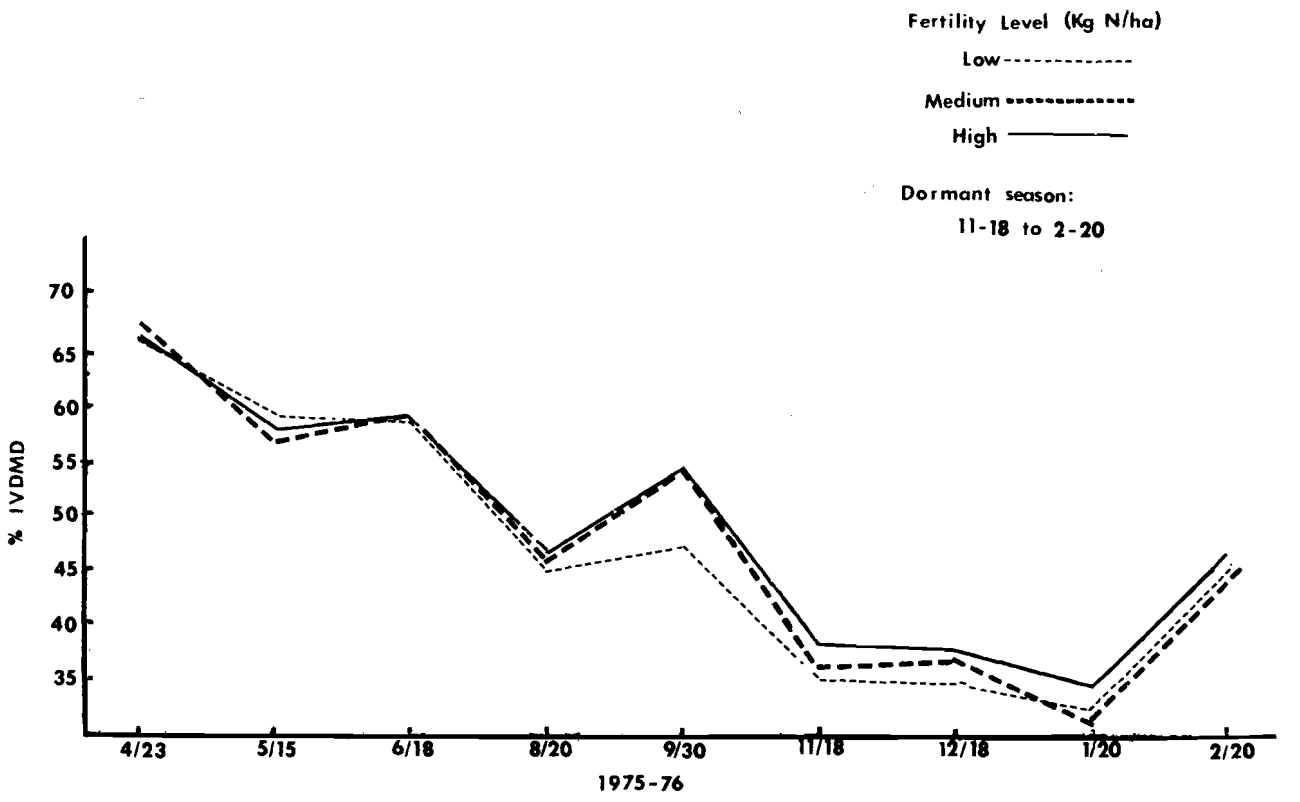


Figure 9. The influence of nitrogen on in vitro digestible dry matter of weeping lovegrass, Ardmore, Oklahoma, 1975-76 (E. C. Holt and R. L. Dalrymple, 1975-76, unpublished data)

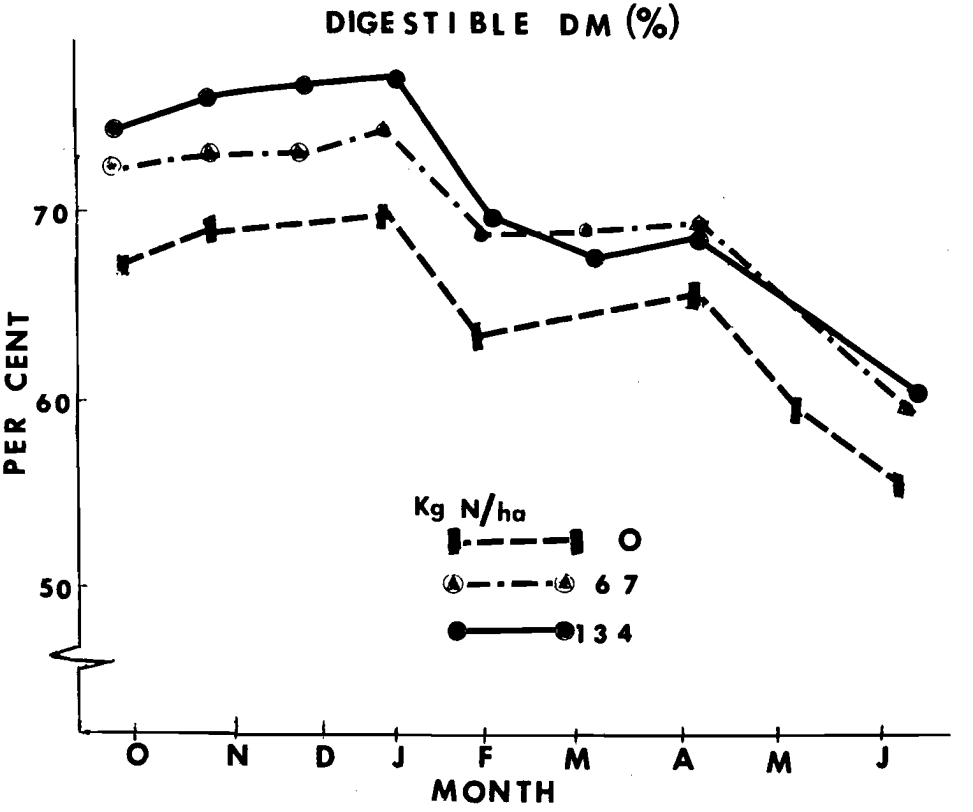


Figure 10. The influence of nitrogen on digestible dry matter of stockpiled tall fescue forage, Mississippi State, Mississippi (V. R. Watson, unpublished data)

Midland bermudagrass forage decreased in digestibility from 67 percent at 15 days of age to 55 percent at 53 days of age in Maryland (8). The effect of age was much more critical than the effect of season (early summer versus late summer). In 1966, there appeared to be a reasonably close negative relationship for DDM with cellulose and acid detergent fiber (ADF), and essentially no relationship with cell wall content (CWC) or hemicellulose. In 1967, none of the relationships accounted for an appreciable amount of the variation in DDM.

Johnson and Pezo (21) reported a reduction in the *in vitro* true digestible dry matter (IVTDDM) of pangolagrass forage from 83 percent at 14 days growth to 66 percent at 112 days. (The digestibility values were not adjusted to an *in vivo* standard.) Ventura *et al.* (28) found that pangolagrass forage digestibility remained fairly constant at ages up to six weeks following which digestibility declined rapidly up to 10-12 weeks of age. Crude protein content declined from approximately 18 percent at 2-4 weeks of age to 4-6 percent at 11-12 weeks of age. Voluntary intake also declined as age increased and digestibility decreased. Supplemental protein improved intake of low protein hays but not digestibility of these hays. Johnson and Pezo (21) also reported that hybrid sudangrass, Sordan 67, decreased from 81 percent IVTDDM in early vegetative stage to 62 percent in the mature stage.

A decrease of 10 to 15 percentage units in estimated TDN of orchardgrass from the boot stage to the full head stage has been reported (5) as well as a decline of 15 percentage units in TDN of bromegrass between early and late harvests (6).

Tall fescue forage decreases in digestibility with age, particularly in the summer months (J. C. Burns and D. S. Chamblee, 1969-70, unpublished data, Table 2). Forage cut when it reached a 12-inch height from a 2-inch base was considerably lower in IVDDM than forage only allowed to grow to a 6-inch or 3-inch height. The high IVDDM values suggest that it is possible to produce high quality fescue forage under some conditions; the challenge is to identify those conditions.

Legumes, particularly temperate legumes, are generally higher in nutritive quality than grasses and also retain this quality better with age. Johnson and Pezo (21) found that white clover forage declined only from 94 to 85 percent IVTDDM from 14 days to 112 days of age. The IVDDM of Yuchi arrowleaf clover was only slightly influenced by age of tissue (1 to 6 weeks cutting frequency) during the period from December to June (18). Similarly, a decline of only 5 to 6 IVDDM units was observed in Siratro, a tropical legume, from 6 to 18 weeks of age (26). Continued collections up to 26 weeks of age showed a further decline of about 8 IVDDM units for Siratro.

While additional literature could be cited, these citations demonstrate the vulnerability of forage grasses and to a lesser extent legumes to declines in digestibility with age. Obviously if the grasses, even the temperate grasses, are to meet the nutrient needs of growing

animals, they must be utilized at a relatively young age. The application of this principle to harvested forages is direct and relatively simple. However, frequent harvest (young forage) has a negative effect on DM yield, thus both cannot be optimized. A still greater challenge is to apply the principle of early utilization under grazing conditions, so as to provide forage of acceptable nutritive quality to meet the needs of the grazing animal but at the same time not to restrict available forage and intake by the procedure.

Grass-Legume Mixtures

Establishment of cool-season legumes in warm-season grass sod can lengthen the grazing season as much as a few weeks and possibly several months. This has been demonstrated by numerous studies (16; 20; F. M. Rouquette, 1974, unpublished data).

Yuchi arrowleaf clover not only lengthened the grazing season of Coastal bermudagrass but also improved the calf gain in a cow-calf program in Alabama over that of grass alone fertilized with nitrogen (20). Calf gains were high until Yuchi disappeared from the mixture in late June or early July each year. Similar results were reported for dallisgrass-Regal clover except that Regal provided grazing through much of the summer resulting in better calf gains.

Forage collected from Common bermudagrass-crimson clover pastures in East Texas in April ranged from 70 to 78 percent IVDDM (F.M. Rouquette, Jr., 1974, unpublished data). By early June after disappearance of the clover, IVDDM of the grass alone dropped rapidly to 56-58 percent and continued to decline to about 50 percent by mid-July. Calf gains (calves with cows) in excess of 1.13 kg per day have been obtained on crimson clover-ryegrass seeded on Coastal until the disappearance of the clover and ryegrass. Gains after the clover disappeared from the pastures decreased rapidly to .7 kg. per day and less. Obviously the change in forage quality cannot be attributed entirely to the disappearance of clover and ryegrass from the pastures. The quality of bermudagrass normally decreases as the season progresses as shown earlier in this paper. However, a significant part of the reduction in rate of calf gain is likely due to the disappearnace of the legume from the mixture.

Siratro-kleingrass forage mixture at 3, 5 and 7 weeks of age had average IVDDM values of 67, 67 and 65 percent, respectively, which were only slightly higher than kleingrass alone which had value of 66, 63 and 62 percent, respectively (25). The IVDDM of the mixture is in the range of that required for satisfactory performance of heavy stockers.

Harris et al. (14) reported results of grazing wheat, oats, and rye with Yuchi arrowleaf clover. Four-year average daily gains (ADG) and hectare gains (kg), respectively were: rye-ryegrass, 0.74 and 559; oats-ryegrass, 0.79 and 558; wheat-ryegrass, 0.79 and 638. Yuchi arrowleaf clover was included in each mixture in the last two years. Both the average daily gains and hectare gains indicated satisfactory

forage quality for stocker production. Average length of grazing ranged from 152 days (oats-ryegrass) to 169 days (wheat-ryegrass).

These results show that legumes generally improve the quality of a forage mixture or that the nutritive quality of grass-legume mixtures under many conditions is adequate to meet the nutrient needs of most classes of beef cattle. The contribution of legumes to quality of winter annual grasses was not quantified but results indicate that the quality of the grasses and/or mixtures is adequate to produce ADG's in excess of .75 kg. The need for additional adapted and improved legumes for use in the South is obvious.

Irrigation

Information on the effect of irrigation on forage quality is limited. Work in Tennessee with orchardgrass and Kentucky bluegrass pastures showed no influence of irrigation on animal performance (15). Individual animal daily gains averaged approximately .66 kg for the season, ranging from approximately .9 kg in April to .54 kg in August.

In Texas, a somewhat lower ADG of stocker steers grazing supplemental irrigated Common bermudagrass pastures was obtained than with unirrigated pastures at equivalent stocking rates (E. C. Holt, 1956-58, unpublished data). In a plot study, Coastal bermudagrass produced with and without irrigation showed no significant difference in IVDOM. The irrigated Coastal averaged 1.4 digestibility units lower than the non-irrigated Coastal (29).

There seems to be little evidence that irrigation has a direct effect on improving forage quality. An indirect effect of irrigation on quality could result from the induction of new growth which, because of being of younger age, could have a higher digestibility. However, such an effect was not reported.

Environmental Effects

A seasonal pattern of forage nutritive quality has been demonstrated, apart from aging effects. Deinum, Van Es and Van Soest (10) concluded that the influence of light intensity and N on digestibility of perennial ryegrass is positive but rather small, the effect of N not being significant, while the effect of temperature and stage of growth is negative and large. Opposite effects of temperature on the cell wall fraction were found which would explain the negative effect on digestibility since cell walls are the least digestible. They concluded that summer harvested forage would be expected to be about 7 units lower in digestibility than spring harvested forage of the same stage of development because of higher summer temperatures.

Successive maize leaves, produced under increasing temperatures, showed a decrease in digestibility (9). Similarly, tall fescue leaves of similar age but produced under temperature regimes of 15/10°C and 25/20°C averaged about 94 and 88 percent *in vitro* true digestibility,

respectively. It is suggested that high temperature results in a higher concentration of cell wall constituents and lower digestibility of tall fescue.

The IVDDM of Panicum maximum var. trichoglume Jacq. and Setaria sphacelata Stapf and Hubbard, and two cultivars of Lolium perenne L. grown under controlled environments was found to decrease as temperature increased (30) .

A later study (31) included the influence of temperature in controlled environments on the digestibility of 11 temperate grasses and 13 tropical or subtropical grasses at the fifth leaf stage. Temperate grasses consistently declined about 5 digestibility units as temperature increased from 21/13°C to 32/24°C. The decline was attributed to a reduction in soluble carbohydrates at the higher temperature. There were no temperature effects on digestibility of tropical and subtropical grasses at this young stage mainly because tropical grasses are lower in soluble carbohydrates than temperate grasses. At later stages of maturity, digestibility of tropical grasses was consistently lower at 32/19°C than at 21/13°C and this was attributed to a more advanced growth stage at the higher temperature. Other workers (11) report that sudangrass forage may be equal to oat forage, particularly when grown at low temperatures. Sudangrass digestibility responded negatively to increasing temperature and this was associated with a decreasing soluble carbohydrate content. The same relationship did not hold in oats, possibly because soluble carbohydrate content is much lower at advanced stages of maturity in oats than in sudangrass. Minson and McCloud (22) found a close relationship between temperature and digestibility and evaporation and digestibility of both the tropical and temperate grasses.

The proportion of structural (cell wall) components in warm-season grasses is higher than in temperate grasses. This may be due to the greater water, nutrient and photosynthate transport requirements and lignification, protective mechanisms and other factors associated with high light intensity, high temperatures, and high evaporation under which these plants developed. If the lower digestibility of tropical grasses is the resultant of climatic factors, then the potential of breeding tropical grass with as high digestibility as temperate grasses is limited because of the differences in the environments in which they grow in the South. If the reduction in summer quality is not a response to temperature, the causative or related factors need to be identified. The forage quality response of temperate plants to high temperatures may be largely reduced net photosynthesis and increased respiration which would result in a reduced cell content-cell wall ratio. Obviously, results reported are not completely consistent, probably because of differences in stage of maturity at harvest, differing light levels and other factors. Thus, the response mechanisms to increasing temperatures in forage grasses require further elucidation through research in order to develop methods of further improving quality under higher temperature conditions.

Hacker and Minson (13) found as much as 4.9 digestibility unit differences in Setaria genotypes among production (test) sites. The differences were associated with ash content of the forage but only 23 percent of the variation could be attributed to ash. These results would suggest that soil differences might have some effect on digestibility.

Genetic Manipulation

Genetic factors have been shown to influence nutritional quality of forage plants. The feasibility of improving forage quality through breeding was demonstrated by the development of Coastcross-1 bermudagrass. Genotype differences in weeping lovegrass are shown in Figure 3. Whether breeding can provide the level of improvement required to meet the nutrient requirements of beef cattle probably will depend on extent and heritability of variation for quality within the species and the amount of improvement required. This aspect of forage quality is presented in depth in a separate paper.

Combined Animal and Pasture Management Factors

The preceding discussion has enumerated various factors that influence forage nutritive quality, some of which can be manipulated by production, management, or breeding programs, in an attempt to provide forages that meet the nutrient needs of cattle for beef production. An alternative concurrent approach is to alter cattle production programs to more nearly match the nutrient production characteristics of the forage. These may include calving date to bring into phase maximum animal load with maximum carrying capacity of the pasture, calving date to match animal nutrient requirements with nutrient production potential of the pasture, calving date to bring into phase weaning date with availability of high quality forage for weaned calves, pasture grazing management favorable for heavy weaning weights to provide a weaned calf more capable of utilizing the forage available, and utilization systems for stockers to provide the most nutritious forage possible.

Fall or early winter calving in the lower South and the use of appropriate pasture production and grazing management programs can result in the production of heavy calves (270-320 kg) at weaning (F. M. Rouquette, 1973-74, unpublished data) which are better able to use forages of lower quality beginning in mid-summer than are calves of usual weaning weights. Late winter calving in the lower South would result in a minimum gap between weaning and availability of high quality winter pastures, though resulting in lighter weaned calves because of lower forage quality in late summer. Compensatory winter gain on high quality winter pasture can be realized on spring calves.

Intensive grazing management may provide forage of adequate quality to produce acceptable gains in stocker animals in summer months. Oliver (23) reported gains averaging .8 kg daily in two out of three years on stocker steers grazing Coastal bermudagrass in a rotation system in which the animals were on a paddock for three days and off six or seven days for a period exceeding 150 days.

Information on management practices will be developed in greater depth in a separate paper.

Summary

Meeting the nutrient requirements of beef cattle with forage remains a challenge. Dry matter digestibility is highest in the spring (and winter if winter growth is produced), lowest in late summer, and shows some recovery in the fall. Dormant forage is generally low in quality. Warm-season grasses are higher in cell wall composition, and generally lower in digestibility than temperate grasses while temperate grasses are higher in percent of cell content than warm-season grasses. Both warm-season and temperate grasses decrease in digestibility upon aging. They also decrease in digestibility with increasing temperature, evidently because of reduced soluble carbohydrate content in temperate grasses but the reasons are less understood in warm-season grasses. Legumes generally are higher in digestibility than grasses, decline less with age and offer potential for improving forage quality through grass-legume mixtures. The real need is for more and better adapted pasture legumes in the South. Grasses respond to breeding for improved digestibility.

Most of the forage plants meet the nutrient requirements of some classes of livestock. However, for those classes of livestock having high nutrient requirements in terms of concentration in the feed source, fewer forage plants meet the needs. Combinations of grasses and legumes, use of young forage and breeding to improve quality offer the greatest opportunity of meeting the nutrient requirements of beef cattle with forage.

Research Needs

1. More detailed information on seasonal forage quality patterns on similar age material of important species, as well as forage quality pattern of available forage in pasture grazing studies.

2. Development of grass-legume mixtures and evaluation for quality as well as production in comparison with the grass alone as a means of improving forage quality.

3. Breeding of legumes for adaptation to the Southern Region specifically for use in mixtures with tropical grasses.

4. Breeding tropical grasses with improved forage quality while retaining high productivity and sustained vigor.

5. More information is required on the influence of specific environmental factors, especially temperature, on forage quality to improve the specificity of breeding objectives for forage quality.

6. Identification of specific components of nutritive quality and quantification of the effects of such components as a basis for selection in forage breeding programs.

7. Development of animal management and/or production systems to optimize the utilization of available forage nutrients.

Acknowledgements

The assistance of the following individuals particularly in making available unpublished data is gratefully acknowledged: Dr. F. M. Rouquette, Jr. and Dr. M. M. McCartor, Texas A&M University Agricultural Research and Extension Center, Overton; Mr. M. E. Riewe and Dr. Hagen Lippke, Texas A&M University Research Station at Angleton; Dr. Paul Mislevy, Florida Agricultural Experiment Station, Ona; Dr. S. C. Shank, Agronomy Department, University of Florida, Gainesville; Dr. Vance R. Watson, Agronomy Department, Mississippi State University, Mississippi State; Dr. J. C. Burns, ARS, USDA and Dr. D. S. Chamblee, Agronomy Department, North Carolina State University, Raleigh; and Mr. R. L. Dalrymple, The Noble Foundation, Ardmore, Oklahoma.

LITERATURE CITED

1. Allen, Marvin, H. D. Ellzey, B. D. Nelson, C. R. Montgomery and P. E. Schilling. 1974. The response of an oat-ryegrass mixture to applied nitrogen, phosphorous and potassium. La. Agr. Exp. Sta. Bul. 680, 63 pp.

2. Barth, K. M., J. B. McLaren and C. D. Lane. 1972. Monthly changes in chemical composition and digestibility of orchardgrass-clover and fescue-lespedeza pasture forage. Tenn. Agr. Exp. Sta. Bul. 500, 15 pp.

3. Blaser, R. E. 1964. Symposium on forage utilization: Effects of fertility level and stage of maturity on forage nutritive value. J. Anim. Sci. 64:246-253.

4. Brannon, W. F., J. T. Reid and J. L. Miller. 1954. The influence of certain factors upon the digestibility and intake of pasture herbage by beef steers. J. Anim. Sci. 13:535-542.

5. Bratzler, J. W., E. Keck, Jr., L. F. Mariott and J. E. Washko. 1959. Nutritive value of orchardgrass as affected by level of nitrogen fertilization and stage of maturity. Paper presented at annual meeting of American Dairy Science Association.

6. Colovos, N. F. and H. A. Keener. 1961. II. The effect of nitrogen fertilization and date of harvest on the nutritive value of bromegrass hay. N. H. Agr. Exp. Sta. Bul. 472.

7. Conrad, B. E. 1971. The influence of season, chronological age, and management on selected forage plant components related to digestibility. Ph.D. Dissertation, Texas A&M University.

8. Decker, A. M., R. W. Hemkin, J. R. Miller, N. A. Clark and A. V. Okorie. 1971. Nitrogen fertilization, harvest management, and utilization of Midland bermudagrass (Cynodon dactylon [L.] Pers). Md. Agr. Exp. Sta. Bul. 487, 71 pp.

9. Deinum, B. and J. B. P. Dirven. Climate, nitrogen and grass. 4. 1971. The influence of age on chemical composition on in vitro digestibility of maize (Zea mays L.) and tall fescue (Festuca arundinacea Schreb.) Neth. J. Agri. Sci. 19:264-272.

10. Deinum, B., A. J. H. Van Es and P. J. Van Soest. 1968. Climate, nitrogen and grass. II. The influence of light intensity, temperature and nitrogen on in vivo digestibility of grass and the prediction of these effects from some chemical procedures. Neth. J. Agri. Sci. 16:217-223.

11. Downes, R. W., K. R. Christian and M. Freer. 1974. Nutritive value of oats and sudangrass grown at controlled temperatures. Aust. J. Agri. Sci. 25:89-97.

12. Gordon, John, Leon Knori, Mike Gould and Robert Totusek. 1975. Three levels of nitrogen for bermudagrass grazed by cows and calves, pp. 41-46. In Animal Sciences and Industry Research Report. MP-94. Okla. Agri. Exp. Sta. and USDA.

13. Hacker, J. B. and D. J. Minson. 1972. Varietal differences in in vitro digestibility in Setaria and the effects of site, age and season. Aust. J. Agri. Res. 23:959-967.

14. Harris, R. R., C. S. Hoveland, J. K. Boseck and W. B. Webster. 1972. Wheat, oats, or rye with ryegrass and Yuchi arrowleaf clover as grazing for stocker calves. Ala. Agri. Exp. Sta. Circ. 197, 13 pp.

15. High, T. W., Jr., H. R. Duncan, J. H. Felts and J. W. High Jr. 1965. Producing yearling steers on irrigated bluegrass-clover and orchardgrass-clover pastures. Tenn. Agri. Exp. Sta. Bul. 387, 19 pp.

16. Holt, E. C. and J. A. Lancaster. 1968. Bermudagrass production and management in East Texas. Tex. Agri. Exp. Sta. Bul. 1073, 13 pp.

17. Hoveland, C. S., W. B. Anthony, E. L. Mayton and H. E. Burgess. 1972. Pastures for beef cattle in the Piedmont. Ala. Agri. Exp. Sta. Circ. 196, 11 pp.

18. Hoveland, C. S., E. L. Carden, W. B. Anthony and J. P. Cunningham. 1970. Management effects on forage production and digestibility of Yuchi arrowleaf clover. Agron. J. 62:115-116.

19. Hoveland, C. S., E. M. Evans and D. A. Mays. 1970. Cool season perennial grass species for forage in Alabama. Ala. Agri. Exp. Sta. Bul. 397, 20 pp.

20. Hoveland, C. S., R. F. McCormick and W. B. Anthony. 1972. Productivity and forage quality of Yuchi arrowleaf clover. Agron. J. 64:552-555.

21. Johnson, William L. and Danilo Pezo. 1975. Cell-wall fractions and in vitro digestibility of Peruvian feedstuffs. J. Anim. Sci. 41:185-197.

22. Minson, D. J. and M. N. McCloud. 1970. The digestibility of temperate and tropical grasses. Proc. 11th Int. Grassld. Congr. 719-722.

23. Oliver, W. M. 1972. Coastal bermudagrass pastures for grazing calves and yearlings in Louisiana. La. Agr. Exp. Sta. Bul. 667.

24. Reid, R. L., G. A. Jung and S. J. Murray. 1966. Nitrogen fertilization in relation to palatibility and nutritive value of orchardgrass. J. Anim. Sci. 25:636-645.

25. Siewerdt, Lotar and E. C. Holt. 1974. Yield components and quality of Siratro-Kleingrass association. Agron. J. 66:65-67.

26. Siewerdt, Lotar, and E. C. Holt. 1975. Changes in nutritive value of Siratro forage with age. Agron. J. 67:544-546.

27. Taliaferro, C. M., F. P. Horn, B. B. Tucker, R. Totusek and R. D. Morrison. 1975. Performance of three warm-season grasses and native range mixture as influenced by N and P fertilization. Agron. J. 67:289-292.

28. Ventura, M., J. E. Moore, O. C. Ruelke and D. E. Franke. 1975. Effect of maturity and protein supplementation on voluntary intake and nutrient digestibility of pangolagrass hays. J. Anim. Sci. 40:769-774.

29. Villanueva, Marianito R. 1974. Growth and nutritive quality of Coastal bermudagrass (Cynodon dactylon [L.] Pers.) as influenced by nitrogen fertilization, defoliation and water management. Ph.D. Dissertation, Texas A&M University.

30. Wilson, J. R. and C. W. Ford. 1971. Temperature influences on the growth, digestibility and carbohydrate composition of two tropical grasses, Panicum maximum var. trichoglume and Setaria sphacelata, and two cultivars of the temperate grass Lolium perenne. Aust. J. Agric. Res. 22:563-571.

31. Wilson, J. R. and C. W. Ford. 1973. Temperature influences on the in vitro digestibility and soluble carbohydrate accumulation of tropical and temperate grasses. Aust. J. Agric. Res. 24:187-198.

DISCUSSION

FUNDAMENTAL ASPECTS OF FORAGE AND BEEF PRODUCTION

Discussion of the papers by:
W. C. Ellis and E. C. Holt

MODERATOR: R. R. Johnson, University of Tennessee

QUESTION: R. R. Johnson, Moderator, Tennessee. Given that tropical plants have a high photosynthetic efficiency, but, yet have a propensity for an unfavorable cell wall:cell solubles ratio, is it possible to select among the tropical grasses for photosynthetic efficiency and still try to maintain a favorable ratio of cell wall to cell solubles?

ANSWER: E. C. Holt, Texas A&M University. I think the paper by Dr. Wayne Hanna that follows will deal with that subject more fully. One of the problems with the selection procedure that we are using is primarily that of the in vitro digestibility technique. We are selecting on a gross basis without identification of the specific factors influencing digestibility. I think we can make far more progress if we can identify these components. So far we have not been able to do this with tropical plants. It has been done a little better with temperate plants. We have not come up with any indices, you might say, or specific components that account for the increased digestibility. I think Dr. Hanna will report that there is progress in selecting for increased digestibility, but not necessarily for increased cell contents:cell wall ratio. I don't know if that answers the question or not, but I feel that one of our weaknesses in breeding programs to date is that we are not identifying specific factors contributing to increased dry matter digestibility.

COMMENT: Wayne Hanna, ARS, USDA, Tifton, Georgia. Increasing photosynthetic efficiency and producing forages with a higher energy that can be used by the animal have been my concern and interest. Very little work has been done in this area, i.e., simultaneously increasing photosynthetic efficiency and disgestible energy content. It seems to me that it would be possible. But if you talk to physiologists, they discourage it. They say that photosynthetic efficiency and digestible energy content are inversely related. Their opinions, however, are based on one or two species within a single group of plants. I don't think we have given this a fair chance and I really think it needs to be looked at.

QUESTION: J. P. Fontenot, Virginia Polytechnic Institute and State University. What is known about the intake of highly digestible forages? Is it sufficiently high to give the animal performance that would be expected from diets of such high digestiblity?

ANSWER: W. C. Ellis, Texas A&M University. It is my impression that you do get the performance that you would expect. However, I can't think of specific documentation for it.

QUESTION: Ray F. Brokken, ERS, USDA, Corvallis, Oregon. Does succulence increase or decrease dry matter intake?

ANSWER: W. C. Ellis, Texas. In my experience, primarily based upon dairy cows, there is a very common misconception that forages high in moisture content are usually limited in their intake. The implication is that the high moisture content limits intake. I can't find documentation for it; my feeling is that it is not true. It is probably a reflection that when animals are placed on forages of high moisture content, there is a concomitant large change in gastrointestinal fill which gives apparent lower weight or weight gain. Probably the most responsive animal to this would be the dairy cow. It can sustain very high levels of milk production, something that can more accurately measure as a productive output, on forages of 85 percent moisture. It is my personal feeling that moisture content does not impair intake.

COMMENT: M. J. Montgomery, University of Tennessee. So far as cows are concerned, we may encounter intake in excess of 100 to 200 pounds of high moisture forage. This represents an amount of dry matter which, for fairly high producing cows, could be very limiting as far as total energy intake is concerned. When calculating the amount of dry matter required by a cow producing 60 pounds of milk or more, you will find that it would be almost physically impossible for that cow to consume enough green forage or green chop of 15 percent dry matter.

COMMENT: G. O. Mott, University of Florida. I think we have some very good examples of this high digestibility forage and also rather high rates of intake from the work that has been done in South Chile, New Zealand, and Great Britain on ryegrass. It is not uncommon to receive 2.25 pounds of gain per day for 200 days with steers. I think there are forages that will give us that kind of gain. I have told my students many times, "What we are looking for is tropical ryegrass."

COMMENT: Roy Blaser, Virginia Polytechnic Institute and State University. I think it is interesting to note that in the spring, when these grasses are around 80 to 85 percent water, steers gain the best, cows produce the most milk, and the digestible energy value is in the realm of 75 percent. The water is there; yet, that is when the animal performs the best. The intake must be good.

COMMENT: W. C. Ellis, Texas. There are controlled experiments with harvested forages and other feedstuffs in which added water doesn't affect feed intake. That doesn't simulate what we are trying to answer. It is my impression that the animal has the capacity to absorb and and transport very large amounts of water without inhibiting intake.

COMMENT: Philip Utley, Coastal Plain Experiment Station, Tifton, Georgia. I think there is also a matter of animal selectivity involved here when we are comparing harvested forage and grazed forage. As an example, in a five-year study with Coastal bermudagrass and Pensacola bahiagrass at Tifton, Georgia, we have found that when we graze these two grasses, Coastal is superior to Pensacola bahiagrass. When we harvest them, Pensacola bahiagrass is much superior to Coastal. These apparent responses may be due to animal selectivity or the fact that the clippings which we analyze in the laboratory are not representative of what the animal grazes. Our failure to understand this disparity stems from the difficulty in measuring intake.

COMMENT: W. C. Ellis, Texas. Disparity exists in measuring the plant components of that intake which are differently processed and have a different nutrient value from the intake standpoint.

QUESTION: John Moore, University of Florida. Dr. Ellis, for the purpose of modeling, is a knowledge of digestible energy intake sufficient to predict animal response or do we also need some of the other rate constants that you showed in the slide?

ANSWER: W. C. Ellis, Texas. It depends upon your philosophy in expressing requirements. I personally favor expressing nutritive value of feeds as digestible energy or metabolizable energy and then expressing the efficiency with which digestible or metabolizable energy is used for different functions in the requirement of the animal because this is primarily a function of the animal. I favor expressions of digestible or metabolizable energy because these imply the value of that feed is fairly constant in itself.

QUESTION: John Moore, Florida. Can you predict gain of steers from digestible energy intake?

ANSWER: W. C. Ellis, Texas. I don't think it makes any difference. I think you can predict the gain as efficiently or as accurately whether you use digestible or metabolizable or net energy as long as one accounts for the functional efficiency terms either in the requirements or in the composition of the feed. As long as they are accounted for, it doesn't make any difference.

QUESTION: Roy Blaser, Virginia. If intake is so important, shouldn't we spend more time studying it?

ANSWER: W. C. Ellis, Texas. I couldn't agree with you more. It is simply a matter of time and resources to do that because of the many variables that influence intake, such as grazing pressure and production rates of forage which are constantly changing.

QUESTION: Roy Blaser, Virginia. Why can't we do it within a given controlled grazing pressure?

ANSWER: W. C. Ellis, Texas. I would think that there is much useful information that could be gained to project systems such as the

gentleman from Virginia frequently advocates; that is, of ordering animals in terms of their requirements, for example, rotational types of grazing, or sequencing animals according to their requirements. To do this requires a better knowledge of what is selected, or grazed as a function of grazing pressure.

QUESTION: M. E. McCullough, University of Georgia. Aren't we ignoring the fact that with a forage of 70 percent digestibility versus a ration that has been built to 70 percent digestibility with grain and forage, we may have completely different situations due to end products of fermentation? Aren't we somewhat mistaken in expecting that just because a forage, by itself is 70 percent digestible, we are going to get the same performance that we get from another ration of 70 percent digestibility made up of different ingredients?

ANSWER: W. C. Ellis, Texas. I think that is possible. We might very well conceive a situation that we would desire to have lesser digestibility, if that lesser digestibility was associated with more rapid rate of passage, a higher level of intake, and a higher level of productive energy consumption. In work done at Ohio State, in vitro measures showed soybean hulls to have a very high digestibility. But when fed to the animal, they were very poorly digested, apparently due to a very rapid rate of passage through the site of fermentative digestion. This brings to mind the question originally asked about cell walls. It may very well be that we could conceive a situation where cell walls wouldn't be bad if they didn't impede fragmentation of the fibers of the forage and were not detrimental to feed intake. For as long as the increased level of intake more than compensates for any reduction in digestibility, one would get over compensation and improved productive energy intake.

COMMENT: R. R. Johnson, Moderator, Tennessee. We have talked about two factors. We talked a lot about digestibility because we know a lot about it. But for about 20 years we have been "beating around the bush" with the intake factor(s), and we still don't know much about it. I would submit that whoever suggested intake as an area where we should concentrate might well be correct. The difference between a harvested forage and the things the animal is selecting out there is still an enigma that none of us has solved.

QUESTION: E. H. McIlvain, ARS, USDA, Woodward, Oklahoma. Has anyone done work on the heat of digestion in relation to digestible dry matter of succulent forages versus dryer roughages?

ANSWER: W. C. Ellis, Texas. I would not expect that it would have much importance because various theoretical estimates indicate that less than 8 percent of the total heat increment of the feed is from heat of fermentation. So with that small magnitude, there would not be much opportunity for change in a very favorable fashion.

COMMENT: R. R. Johnson, Moderator, Tennessee. If you look at the proportion of the cell wall material, you ought to be able to come pretty close to predicting the heat of fermentation because the

difference between the succulent and the dried forages might well dwell in that factor alone.

QUESTION: E. H. McIlvain, ARS. Where we have high temperature and humidity conditions I am wondering if we are bordering somewhat on increased heat of digestion being a limiting factor in the utilization of our forages?

ANSWER: W. C. Ellis, Texas. I think you are referring to the total heat production by the animal, including the total heat increment of feeding. I would like to answer by relating to the California net energy system which provides a pretty good prediction under the conditions from which it was derived, i.e., the arid Southwest during the summer months. But it underestimates performance during the winter months. An explanation of this is that what was contrived as efficiency of energy utilization for maintenance in a warm environment is different in a cold environment. Feed net energy for maintenance is used more efficiently in a cool environment than a warm one. To answer your question, yes, roughages would be generally more efficiently used in a cool environment than in a warm environment in the Southwest.

difference between the succulent and the dried forages might well dwell in that factor alone.

QUESTION: E. H. McIlvain, ARS. Where we have high temperature and humidity conditions I am wondering if we are bordering somewhat on increased heat of digestion being a limiting factor in the utilization of our forages?

ANSWER: W. C. Ellis, Texas. I think you are referring to the total heat production by the animal, including the total heat increment of feeding. I would like to answer by relating to the California net energy system which provides a pretty good prediction under the conditions from which it was derived, i.e., the arid Southwest during the summer months. But it underestimates performance during the winter months. An explanation of this is that what was contrived as efficiency of energy utilization for maintenance in a warm environment is different in a cold environment. Feed net energy for maintenance is used more efficiently in a cool environment than a warm one. To answer your question, yes, roughages would be generally more efficiently used in a cool environment than in a warm environment in the Southwest.

BREEDING BETTER FORAGES*

Wayne W. Hanna**

Forage is big business in America with a 1970 farm value of $9.2 billion. In 1970, forages provided 75 percent of the feed units consumed by beef cattle (20). Due to economics, it appears that the amount of forage consumed by ruminants will increase because we will not be able to afford the expensive food grains for beef animals. This means that forages will be called upon to put some of the finish on slaughter animals. Can we develop forages with the necessary quality and energy to finish beef? The answer is, we can and will with support, dedicated scientists, team effort and hard work.

The job of developing superior forages is expensive, complex and time-consuming. Breeding is complicated by genetic and chromosomal incompatibilities. The procedure is further complicated because plants are either cool- or warm-season and annual or perennial. Many improved forage varieties and hybrids have been developed but more outstanding ones are needed.

Yield has always been an important consideration in a breeding program. As land available for growing forages diminishes, this consideration must be intensified in order to meet demands for meat production. The advent of rapid and efficient in vitro digestibility techniques has brought about a growing awareness of forage quality, especially in the grasses. In addition to yield and quality, pest resistance, weed potential, ease of management and establishment, and seed production are important considerations.

More superior grasses and legumes are needed. It is estimated it cost approximately $1 million to develop and learn how to use "Coastal" bermudagrass, but farmers who use it each year across the South realize $300 million more than if they had planted the same acres to common bermudagrass. We need more forages that produce returns on investments like Coastal. "Coastcross-1" bermudagrass bred to be more digestible than Coastal increased average daily gain and

* Cooperative investigations of the Agricultural Research Service, USDA and the University of Georgia, College of Agriculture Experiment Stations, Coastal Plain Station, Tifton, GA.

** Research Geneticist, Agricultural Research Service, USDA and the University of Georgia, College of Agriculture Experiment Stations, Coastal Plain Station, Tifton, GA.

liveweight gains per hectare by 30 percent over Coastal. Both bermudagrasses yield about the same amount of dry matter (4).

The need for forage legumes in the forage system is recognized for a number of reasons. Legumes provide protein, a component of the animal finishing ration that is becoming extremely expensive when purchased as protein supplements. They add quality to grass-legume mixtures, result in higher intake, extend forage production through a longer period of the year, increase daily gains and fix nitrogen available for a companion grass (7). There are other benefits.

In the past twenty years, a number of improved forage legumes have been released in the South. However, cheap nitrogen fertilizer has prevented widespread use and acceptance of these cultivars. Significant increase in the cost of nitrogen has brought about a renewed awareness of the need for legumes.

A major problem encountered in growing legumes is persistence. Improved reseeding ability in winter annuals and seedling vigor are also needed (11). These problems are related to a large extent to pest resistance. Significant progress is being made by forage legume scientists in overcoming many of these problems. Improved and more reliable nitrogen fixation is needed for all forage legumes.

Improved forage varieties have been released with one or more of the needed characteristics of pest resistance, persistence, increased yield, improved reseeding ability, increased seed production, etc. But more needs to be done in order to produce forage that will finish beef. The job has been too large for the small number of scientists with limited support.

Superior forage varieties will be developed as a result of a working team effort between breeders, cytogeneticists, pestologists, agronomists, geneticists, soil scientists, animal scientists, engineers, physiologists, biochemists, economists and administrators.

Plant breeders need to use male sterility, incompatibility systems, natural crossing ability and apomixis to take advantage of hybrid vigor. In addition to conventional breeding methods, they need to develop and use new methods such as recurrent restricted phenotypic selection which will greatly speed up genetic progress (3). Since the germplasm available to the breeder, to a large degree determines his success, he should develop his own "world" collection. Germplasm collection trips need to be made by the breeder to areas most likely to furnish needed germplasm (4).

The plant breeder needs to consider a number of factors in a breeding program. Some are general such as dependability, efficient production, and uniform production. Others such as pest resistance, winterhardiness, and digestibility are more specific.

The purpose of this paper is not to review all forage breeding work or to discuss all possible breeding procedures for improving

forage but to present examples of some aspects of breeding where there is a potential for rapid advances in producing high quality forages.

One of the most exciting areas for rapid forage improvement is increasing the digestibility and intake of forages by using relatively simply inherited genetic characters which can be found in a number of species. These characteristics are easy to transfer into an existing variety by a backcrossing procedure.

A simple inherited dwarf (d_2) gene in pearl millet, Pennisetum americanum, reduced height of plants by one-half, increased the amount of leaf by 50 percent and resulted in only 78 percent as much dry matter per hectare as its near isogenic tall counterpart. Although the dwarf produced only 85 percent as many steer days of grazing as the tall, animals on the dwarf millet made 20 percent better daily gains and steer gains per hectare were equal for both millets (6). The d_2 gene in pearl millet places a higher quality product in a smaller package; it simplifies management and production, and could make harvesting more economical. Other genes can probably be found that reduce height but not dry matter production as much. Preliminary grazing data from an experiment conducted by Drs. Joe Johnson and G. W. Burton, Coastal Plain Experiment Station, Tifton, Georgia, using an improved hybrid with the d_2 gene indicates that 318 kg dairy heifers gained over .84 kg per day for 56 days at a stocking rate of 7.5 animals per hectare.

The brown midrib mutant in sorghum has exciting possibilities for improving the forage sorghums and sorghum-sudan hybrids, since this mutant can reduce lignin by up to 45 percent, increase in vitro dry matter digestibility (IVDMD) by 12 percent, and increase digestibility of fibers by 17 percentage units (26).

These and similar types of mutants could be found in many of the forage species in our breeding material, world gene pools, related species and plant introductions. If, after a thorough search, these mutants are not found, they might be induced with mutagens.

Photoperiodism in plants is a flowering response to specific light and dark periods. "Short day" or "day length sensitive" plants do not flower until days reach a certain minimum length. For most of the "short day" pearl millets, the days need to be 12 hours or less before they will flower. Photoperiod response has been reported for both legumes and grasses (2, 13, 19). This flowering response to day length can be a tremendous asset in forages that do not rely on natural reseeding because the forage remains vegetative and maintains high quality for a longer period of time. The mechanism is usually under genetic control and intermediates can be developed from "day length sensitive" x "day neutral" crosses.

Interspecific and intergeneric crosses may be a way of producing quality forage or improving the quality of widely used forages. Lolium sp. x Festuca sp. crosses are being made to develop lines with lower alkaloid and higher quality (1, 8). Pearl millet, P. americanum x

napier, P. purpureum, hybrids are sterile and remain vegetative until frost. They produce high quality forage through the summer and as late as November. Hybrid seed can easily be produced; the hybrid acts as a perennial and can be vegetatively propagated. Interspecific crosses between Trifolium repens, T. uniflorum and T. accidentale are being used to improve the pest resistance and persistence of T. repens, white clover (12).

The most practical and economical control of pests in forage is by genetic resistance because it provides stable resistance until the pest or plant undergoes a change. Examples of available genetic resistance can be found in both grasses and legumes (13, 21, 22, 30, 31). The sources of resistance genes can be naturally occurring mutants or induced within the species or related species. Pest resistance imparts many plus factors to the plant such as longevity, drought tolerance, dependability, palatability, etc. and might even make the difference as to whether a plant will survive in an area. Nematodes limit the growth of a number of legumes and grasses in the South. Preliminary findings indicate that they are one of the major factors limiting survival of fescue on the sandy soils of the South and significant increases in forage yields in response to nematicides have been obtained for fescue, Phalaris and a number of the Trifolium species (15). A special effort is needed to breed for resistance. However, before this can be done efficiently, nematologists need to develop ways of culturing the major nematode species under controlled conditions so that large populations of plants can be screened for resistance. In addition to nematodes, viruses that are a major problem in the legumes and insects and diseases cause problems in both grasses and legumes. When one considers the number of different pests and the number of crops where pest resistance is needed, the job becomes large but with adequate personnel and support it can be done. Will genetic pest resistance affect quality, intake or palatability? In general, these factors will be improved because of less damage from insect feeding.

Cuticle has been shown to impede penetration of rumen microbes through the leaf surface (23, 24). Research indicates that the waxy (bloom) covering on sorghum leaves and stems slows down penetration of the rumen microbes through the leaf surface (17). Ten-cm long leaf sections of bloomless sorghum lost 31 percent more dry matter per unit time than comparable sections from near isogenic bloomed counterparts. In a study where 205 kg steers were fed bloom and bloomless silage, the animals made significantly higher gains on the bloomless type (10). The increased rate of digestion probably results in higher intake. Studies on in vitro dry matter disappearance (IVDMD) of ground samples of these two lines indicated no difference in dry matter loss. This emphasizes the need to search continually for new and better evaluation methods for determining the value and potential of a forage.

Palatability studies at Tifton, Georgia showed that cattle, when given a choice, repeatedly preferred the trichomeless (tr) pearl millet. Studies indicate that trichomeless pearl millet is digested more slowly than the trichomed counterpart but that it is more drought tolerant due to a more waxy surface (17). Additional research is needed to

determine if its reduced digestion rate is offset by its increased palatability and drought tolerance, and whether the leaf surface may be genetically altered to increase penetration by the rumen microbes. Preliminary unpublished results from our laboratory at Tifton, Georgia indicate that genotypic differences occur in Cynodon, Pennisetum, Paspalum, Sorghum, Avena, Triticum, Hordeum, and Secale which affect the ability of rumen microbes to penetrate the leaf surface. The leaf surface mutants offer one of the most rapid and easy ways to significantly increase the digestion (quality) and intake of forage.

Histological studies on stems of grasses and legumes have shown that greater sylem cell percentages (28), increased vascular bundle areas (27), and formation of lignified bands in stems (18) are inversely related to dry matter disappearance. Research also indicates that larger cells and less compact cell arrangements are related to more rapid digestion (16). These anatomical components may contribute significantly toward improving the digestibility and intake of forage since genotypic variation has been observed for these characteristics. However, a better understanding of the genetic control of cell types and arrangements is needed. There is a need for more histological studies on plant structure and on structural degredation by rumen microbes (25). Studies on both grasses (18) and legumes (28) have shown that stems are one of the most limiting components of forage quality. Therefore, a major portion of a breeding program should be directed toward developing varieties with a higher percentage of leaf and a more digestible stem.

Genetic variability for in vitro digestibility has been reported for bermudagrass (5), alfalfa (14) and orchardgrass (9). Heritability estimates for genetic variability are relatively high indicating that forage varieties with higher digestibility can be developed through breeding.

Nitrogen fixation by grass is another new discovery (29). If developed to a workable stage on a field basis, this phenomenon could do much to improve the quality of forage grasses.

Genetic variability for photosynthetic efficiency and energy storage are other areas that need to be investigated. These considerations are becoming more important as production costs increase and there is a need for higher energy forages.

Tremendous genetic improvement is possible in any species. Our job will be to select the species with the most potential for producing the quality forage needed, decide on the most important quality components, evaluate the germplasm pools, combine the components through breeding, evaluate the package, and teach the farmer how to use it. The job of producing forages with the yield and quality required to finish beef will not be easy, but it can be done. We have a few such forages but we need more. These forages will be produced as a result of a close multi-disciplinary approach involving motivated scientists who are well supported.

LITERATURE CITED

1. Buckner, R. C., L. P. Bush, and P. B. Burris, II. 1973. Variability and heritability of Perloline in Festuca sp. Crop Sci. 13:666-669.

2. Burton, Glenn W. 1965. Photoperiodism in pearl millet, Pennisetum typhoides. Crop Sci. 5:333-335.

3. Burton, Glenn W. 1974. Recurrent restricted phenotypic selection increases forage yields of Pensacola bahiagrass. Crop. Sci. 14: 831-835.

4. Burton, Glenn W. 1975. Breeding superior forages. Forage Res. Jour. 1:23-30.

5. Burton, Glenn W. and Warren G. Monson. 1972. Inheritance of dry matter digestibility in bermudagrass, Cynodon dactylon (L.) Pers. Crop Sci. 12:375-378.

6. Burton, Glenn W., W. G. Monson, J. C. Johnson, Jr., R. S. Lowrey, Hollis D. Chapman and W. H. Marchant. 1969. Effect of the d_2 dwarf gene on the forage yield and quality of pearl millet. Agron. J. 61:607-612.

7. Busbice, T. H. 1975. Personal communication.

8. Bush, L. P., R. C. Buckner, and P. B. Burris, II. 1975. Quality estimates of the ryegrass x tall fescue hybrid derivative, Kenhy tall fescue. Agron. Abstracts, p. 105.

9. Christie, B. R. and D. N. Mowat. 1967. Variability in in vitro digestibility among clones of bromegrass and orchardgrass. Can. J. Plant Sci. 48:67-73.

10. Cummins, D. G. and E. M. Sudweeks. 1975. Comparative quality of bloom and bloomless sorghum silage determined by steer feeding trials. Agron. Abstracts, p. 105.

11. Forbes, Ian. 1975. Personal communication.

12. Gibson, Pryce B., Chi-Chang Chen, J. T. Gillingham and O. W. Barnett. 1971. Interspecific hybridization of Trifolium uniflorum L. Crop Sci. 11:895-899.

13. Gibson, Pryce B. and E. A. Hollowell. 1966. White Clover. Agriculture Handbook No. 314.

14. Gil, H. C., R. L. Davis and R. F. Barnes. 1967. Inheritance of in vitro digestibility and associated characteristics in Medicago sativa L. Crop Sci. 7:19-21.

15. Haaland, Ron and Carl Hoveland. 1976. Personal communication.

16. Hanna, W. W., W. G. Monson and G. W. Burton. 1973. Histological examination of fresh forage leaves after in vitro digestion. Crop Sci. 13:98-102.

17. Hanna, Wayne W., Warren G. Monson and Glenn W. Burton. 1974. Leaf surface effects on in vitro digestion and transpiration in isogenic lines of sorghum and pearl millet. Crop Sci. 14:837-838.

18. Hanna, Wayne W., Warren G. Monson and Glenn W. Burton. 1976. Histological and in vitro digestion study of 1- and 4-week stem and leaves from high and low quality bermudagrass genotypes. Agron. J. 68:219-222.

19. Hanson, A. A. and V. G. Sprague. 1953. Heading of perennial grasses under greenhouse conditions. Agron. J. 45:248-251.

20. Hodgson, H. J. 1972. Forage and Grassland Progress, Vol. 12. Spring Pub. by Amer. For. and Grass. Council., State College, Pa.

21. Leuck, D. B., C. M. Taliaferro, R. L. Burton, G. W. Burton and M. C. Bowman. 1968. Fall armyworm resistance in pearl millet. Jour. of Economic Ent. 61:693-695.

22. Leuck, D. B., C. M. Taliaferro, R. L. Burton, G. W. Burton and M. C. Bowman. 1968. Resistance in bermudagrass to the fall armyworm. Jour. of Economic Ent. 61:1321-1322.

23. Monson, W. G., J. B. Powell and G. W. Burton. 1972. Digestion of fresh forage in rumen fluid. Agron. J. 64:231.

24. Monson, Warren G., and Wayne W. Hanna. 1972. Barriers to improving forage digestibility. Proc. of 29th Sou. Pasture and Forage Crop Imp. Conf., Clemson, SC, pp. 94-99.

25. Moore, John E. and Gerald O. Mott. 1972. Structural inhibitors of quality in tropical grasses. Anti-Quality Components of Forages. CSSA Special Publications No. 4.

26. Porter, K. S., V. L. Lechtenberg and J. D. Axtell. 1975. Laboratory and in vitro evaluation of forage from chemically induced brown midrib mutants of Sorghum bicolor (L.)Moench. Agron. Abstracts, p. 109.

27. Schank, S. C., M. A. Klock, and J. E. Moore. 1973. Laboratory evaluation of quality in subtropical grasses. II. Genetic variation among Hemarthicas in in vitro digestion and stem morphology. Agron. J. 65:256-258.

28. Shenk, John S., and Fred C. Elliott. 1971. Plant compositional changes resulting from two cycles of directional selection for nutritive value in alfalfa. Crop Sci. 11:521-524.

29. Smith, Rex L., S. C. Schank, M. H. Gaskins and D. H. Hubbell. 1975. Nitrogen fixation by grass associations in Florida--a progress report. Agron. Abstracts, p. 133.

30. Sorensen, E. L., M. C. Wilson and G. R. Manglitz. 1972. Breeding for insect resistance. Alfalfa Sci. and Tech. Published by the American Society of Agronomy. No. 15:371-390.

31. Taliaferro, C. M., D. B. Leuch and M. W. Stimman. 1969. Tolerance of Cynodon clones to phytotoxemia caused by the two lined spittlebug. Crop. Sci. 9:765-766.

DISCUSSION

FUNDAMENTAL ASPECTS OF FORAGE AND BEEF PRODUCTION*

Discussion of paper by:
Wayne W. Hanna

MODERATOR: R. R. Johnson, University of Tennessee

QUESTION: *Charles M. Taliaferro, Oklahoma State University.* Does removal of bloom from sorghum influence any other agronomic characteristics?

ANSWER: *Wayne Hanna, ARS, USDA, Tifton, Georgia.* It reduces yield when water is a limiting factor for growth. We feel that this will not be a problem in most of the South and Southeast where rainfall is relatively high.

QUESTION: *E. C. Holt, Texas A&M University.* Have you observed differences in the vascular arrangement of bermudas and related them to digestibility?

ANSWER: *Wayne Hanna, ARS.* We have observed no differences in vascular arrangements in bermudas. However, there are differences in cell wall thickness and ease of degradation. For example, Coastcross-1 bundle sheath cells are degraded to some extent by rumen microbes whereas those of Coastal are quite resistant. It appears that the digestible cell wall component accounts for a major part of the differences in digestibility of the bermudagrasses.

QUESTION: *John Moore, University of Florida.* Is this true for both leaves and stems?

ANSWER: *Wayne Hanna, ARS.* Yes.

QUESTION: *E. C. Holt, Texas.* What are the limits on improvement through cross breeding?

ANSWER: *Wayne Hanna, ARS.* If the quality components are genetically controlled and have relatively high heritability values, then improvement can be made through breeding.

---

*Technical difficulties resulted in incomplete recording of the discussion session following the paper presented by Wayne W. Hanna.

QUESTION: *E. C. Holt, Texas.* To what extent may the necessity for plant structural components limit digestibility?

ANSWER: *Wayne Hanna, ARS.* There is a limit to how much we can reduce structural components depending on the species and its growth characteristics. The are ways of offsetting the detrimental effects of reducing structural components. A way to reduce lodging in sorghum or pearl millet, if the lignified or fibrous components are reduced, would be to introduce the dwarf genes. There are other examples.

INCREASING DIGESTIBILITY AND INTAKE THROUGH MANAGEMENT OF GRAZING SYSTEMS

R. E. Blaser, W. C. Stringer, E. B. Rayburn,
J. P. Fontenot, R. C. Hammes, Jr., and H. T. Bryant*

I. Introduction

Ruminants have a permanent place in the agricultural economy and with consumers because all or most of the required feed nutrients can be furnished by forages grown on soils not suitable for growing crops and from by-product feeds not fit for human consumption. Land suited for intensive tillage has first priority for producing crops for food and clothing for direct human utilization. With minimum or no tillage practices, many soils may be managed to produce one-to-three crops annually. However, because of erosion, leaching, and structural problems with soils and other problems such as weeds, insects, and diseases, many land areas must be rotated with sod crops. Other soils are suited only for sod crops since topography, erodibility and stoniness make them unsuitable for crops. Temporary annual grazing and silage crops (millet, sudangrass, corn, and sorghum) compete for land with crops for direct human consumption.

Forage-animal systems managed for high digestibility and voluntary intake of forage are influenced by single and interacting factors in the soil-biotic-climate complex. Individual factors and interactions dealing with herbaceous forages will be discussed in the first part of this manuscript and then implemented into practical and theoretical forage-animal management systems to maximize intake and digestibility for finishing cattle for suitable carcass grades. Abundant data are available on digestibility but generally lacking for intake. Most of the animal performance data with grazing regimes do not give intake and digestibility data to explain animal gains.

II. Digestibility and Intake on Energy Conversion Efficiency

High daily intake of digestible dry matter is related to the efficiency of converting forages to meat (83)(Figure 1). Daily

* University Professor, Graduate Student of Agronomy, Graduate Student of Agronomy, Professor of Animal Science, Assistant Professor of Animal Science, and Associate Professor of Agronomy, respectively, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

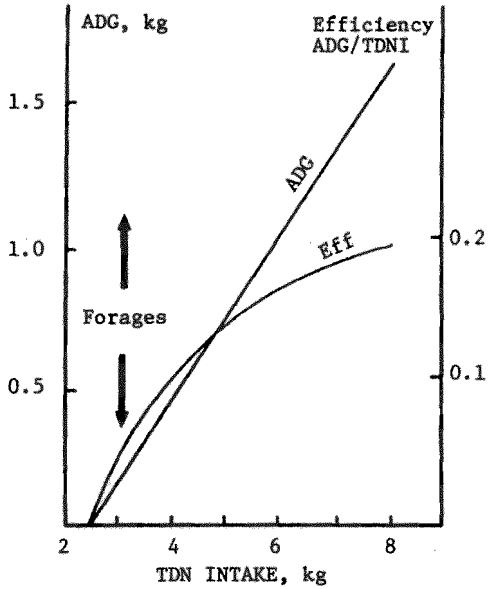


Figure 1. Relationship between TDN intake, daily gains, and efficiency of gains for a growing 300 kg steer. The arrows show a range in quality for forages. Part of the figure adapted from reference (83)

liveweight gains increase linearly and the efficiency of energy utilization curvilinearly with added increments of total digestible nutrients (TDN). Increasing daily gains means that proportionately smaller increments of energy intake are used for body maintenance.

The principles given in Figure 1 apply to TDN intake for forages; however, daily gains of ruminants during entire grazing seasons for well managed perennial forages at medium grazing pressures for cattle are usually less than 1.5 lb (6.8 kg). Such gains are usually attributed to suboptimum energy intake, rather than to digestible protein, minerals, or other nutritional factors. Research with perennial forage diets with various mixtures, species, fertilization, grazing pressures, grazing methods, and methods of conservation shows that performance per ruminant invariably improved when supplemented with energy from ground ear or shelled corn (5, 11, 50, 63, 74, 75, 118).

The low-to-suboptimum energy intake and daily gain of cattle grazing perennial forages are allied with both digestible dry matter and intake; the product of these equals digestible dry matter intake. Data on digestibility of forages as influenced by genetic and environmental factors are voluminous; however, the short-cut diagnostic techniques in most of these experiments were not associated with *in vivo*

digestibility, intake, and/or gains. For a given utilization method, digestibility and intake are often positively correlated for a given species. However, many data show that digestibilities do not accurately predict intake and output per animal (66, 93, 112). With Pensacola bahiagrass (Paspalum notatium Flugge) there was a very high negative correlation between intake and lignin content (88). Voluntary intake has been rather highly associated with rate of digestion (18, 37, 106). Intake is elusive; variances among and within species of plants and ruminants in different environments are large, and short-cut diagnostic techniques to predict intake and output are not available.

III. Factors Influencing Digestibility and Intake

Morphological Stages of Growth and Age

The successive stages of growth of most temperate grasses during spring and most of the temperate legumes and tropical species at all seasons, as canopies change from short young leafy tissues to progressively more stemmy morphology, influence the physiology and chemical composition and quality (intake and digestibility) of herbaceous forages more than any other factor. The decline in forage quality with advancing stages of maturity of herbaceous perennials and annuals is strongly associated with declining leafiness (Figure 2). High values for intake and digestibility within species are generally positively correlated with percentage contents of protein, mineral nutrients, and soluble cell materials, and negatively correlated with cell wall constituents (lignin and cellulose)(11, 23, 65, 77, 78, 92, 111). The changing morphologies are primarily plant responses to changes in temperature and photoperiod, other factors having minor effects.

With increased age of canopy regrowths, when temperate or tropical species grow from leafy to stemmy morphologies, intake and digestibility are negatively correlated with age of growth (91). During spring as temperate grasses and legumes mature, digestible dry matter declines about 0.5 of a percentage unit daily, with an error of prediction of 1.65 (92). However, at a lower latitude, Brown et al. (23) found much lower daily declines in digestibility and the error of estimation was 4.32. The large prediction errors in the latter were associated with large differences in growth stages among cultivars. The longer days in New York (92) than in Virginia (23) narrow the flowering periods within and among cultivars and species. Variations in leafiness among cultivars and species for given growth stages will be allied with digestibility. Matches et al. (72) found Vernal and DuPuit alfalfa cultivars to be of similar quality when harvested at a given stage of maturity; however, the same dates of harvesting over broad latitudes could not be used for producing a standard quality of alfalfa.

Although leafiness is strongly correlated with digestibility, being higher for young than for mature growths, it is often poorly related to intake (23, 66). The importance of leafiness is stressed by the high in vivo digestibility of 75.3 percent of the top leafy half of maturing alfalfa as compared to only 64.9 percent for the

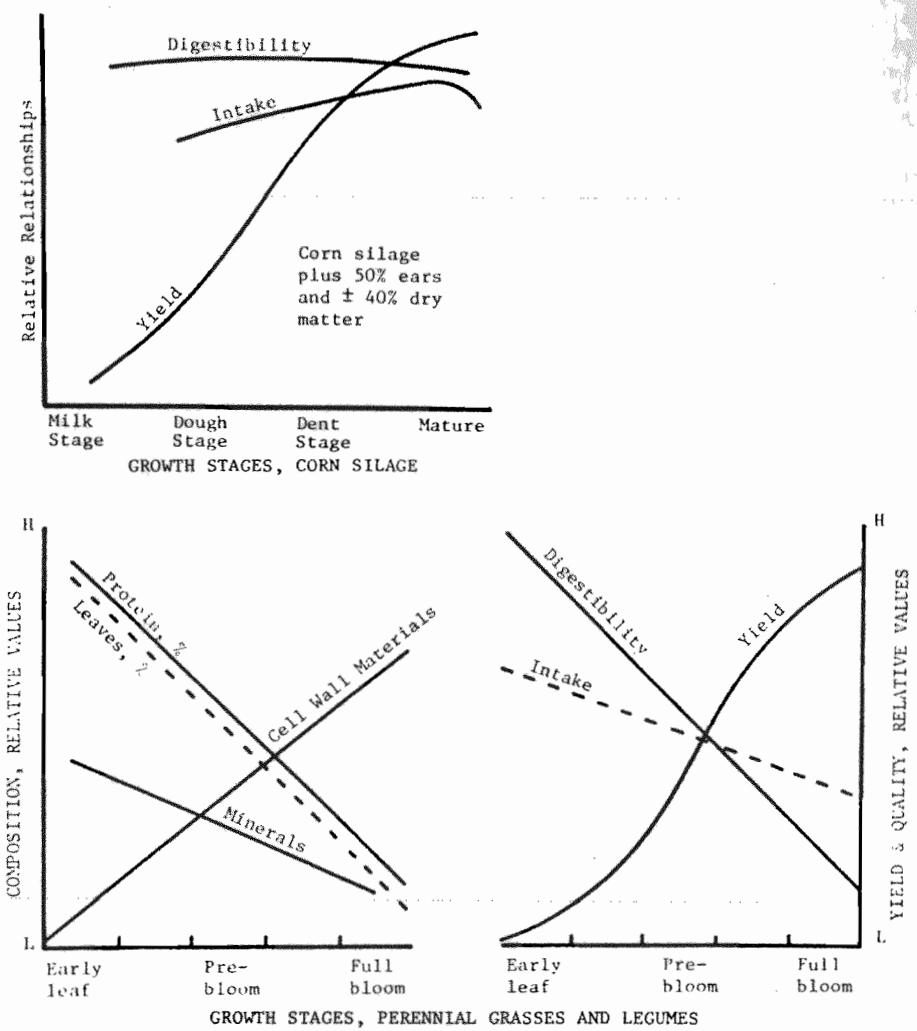


Figure 2. Generalized yield-quality-composition relationships of herbaceous annuals and perennials at various stages of growth (bottom figures) as compared with corn silage high in grain content (top figure).

basal stemmy fraction (Figure 3)(54). The regressions showed that the bottom half of the alfalfa canopy declined 0.6 of a percentage unit digestibility daily; whereas values for the top half changed little. Young stems of grasses were more digestible than leaf blades; however, digestibility of stems declined very rapidly as compared to leaf blades as grasses matured. This is shown for orchardgrass (Figure 4)(90). Leaf sheaths declined more rapidly than blades; thus, sharp declines in digestibilities with maturity are strongly associated with the concurrent increase in stem:leaf ratios and rapid decrease in digestibility of stems.

The yield and quality relationships with stages of maturity for corn and grain sorghum (not bird resistant) for silage are similar, but they differ from herbaceous species as shown for corn in Figure 2. Corn harvested for silage declines very little in digestibility with stages of maturity and intake increases. This is associated with rapid increases in the grain component which nearly maintains a constant digestibility while intake increases, the latter improving with dry matter content of silage (11). Thus, yield, quality, and intake are high at hard dough to hard dent stages of the growth of corn silage. However, with herbaceous forages, intake declines as yields increase with advancing maturities making it impossible to obtain maximum yields and animal performance concurrently; hence, yields of forage must be wisely compromised with quality (intake and digestibility).

The mass of forage present influences selective grazing; however, a large mass of forage with low leaf:stem ratios deters intake as ruminants selectively graze leafy fractions. The presence of old flowering "woody" culms in many grasses, alfalfa, or sericea lespedeza makes leafy high-quality forage less available.

Soil Effects

The alteration of soil environments by liming and fertilization, drainage, and/or irrigation makes it practical to grow introduced forage species with improved quality, growth potential, and herbage distribution over the grazing season. The better nutrition of ruminants from almost all introduced forage as compared to indigenous species in humid regions has improved animal health and productivity. In tropical humid regions, such as some of the Southeastern states and in Queensland, Australia, the indigenous grasses maintain a fair nutritional status during brief periods, after mowing or burning; however, these species are grown on infertile soils and are very low in digestibility, intake, protein and essential mineral nutrients (7, 8, 40, 102). In Florida, cows grazing native grasses without supplements averaged about a 30 percent calf crop; mortalities for raising young cattle for replacements were high, mature cows were small, and cattle fattened only when their growth ceased with age.[1] Forages from improved grasses during the past decades have provided nutrition for cattle that have made Florida an important cattle state.

[1]R. E. Blaser, personal experiences while associated with the University of Florida.

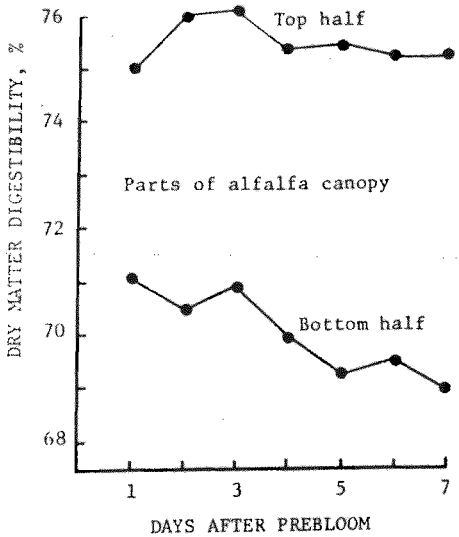


Figure 3. The in vivo (feeding trial) digestibilities of top and bottom halves of alfalfa canopies during seven days after prebloom. Adapted from reference (54)

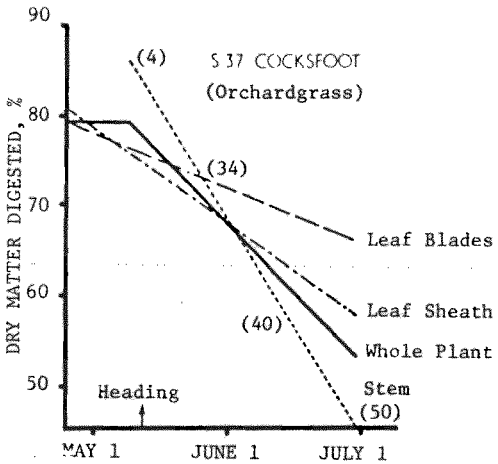


Figure 4. The digestibilities in vitro of the dry matter of top growth and plant parts (leaf blades, leaf sheaths, and in stems) of S 37 orchardgrass during first growth in the spring. Figures in parentheses refer to percent stems at various dates or maturities. Data from reference (90)

For arid regions with fertile soils, the indigenous grasses are of good nutritional value; however, culturing introduced grass-legume mixtures has improved animal production and liveweight gains for finishing because of maintaining a better supply of high forage quality over a long season and an increased use of legumes (109).

Lime and Fertilization. The primary reasons for liming and fertilization are to grow desirable species, maintain desirable botanical components, and obtain economically high yields with good seasonal distribution in planned forage systems. In temperate and tropical humid environments, liming and applying mineral nutrients to grow improved grasses and legumes has given sharp improvements in animal performances compared with grazing native species (12, 102). The improved animal performance with introduced species is attributed to many factors--higher digestibility, intake, protein content, minerals, and better yields and distribution of forage. Thus, it is important to lime and fertilize for high economic yields of high quality improved species or mixtures, if adapted, in forage-animal systems.

After fertilizing and liming to grow a given improved species, the soil availability of some minerals increases absorption and the percent of contents in forage. This is important in the absence of mineral supplements, especially when a mineral nutrient is too low in a forage to supply animal needs. However, for the wide soil nutrient status when a species can be grown, stages of growth when grazed or harvested have a much greater influence on mineral content of herbage than fertilization.[2]

When a soil is high enough in minerals to maintain a given species or mixture, added minerals may improve forage growth but do not usually improve animal performance when controlling stage of growth and grazing pressure (89, 99, 101). Eheart and Pratt (45) found similar digestibilities for fertilized and unfertilized bluegrass pastures. There were no differences in digestibility between control, K, or P fertilized spring and summer tall fescue forages (93). Spring and summer harvests gave insignificant increases and decreases in intake respectively for P fertilization. Likewise, Mg fertilized forage did not improve digestibility of grass and legume forages fed to sheep (96).

N Effects. Nitrogen fertilization influences digestibility and intake in two ways: (1) by changing the botanical components and (2) by changing the chemical constituents or the morphology of a species.

Changes in botanical composition with N fertilization may deter or stimulate animal performance. For example, adding nitrogen to sods with indigenous and introduced grasses often encourages the encroachment of desirable introduced grasses, augmenting digestibility and intake. This is due to species composition of the sod since the N fertilization does not usually improve digestibility or intake for a given species (93, 95). Conversely, added increments of N to

[2]R. E. Blaser, unpublished data, VPI and SU.

grass-legume mixtures depress the leguminous component and animal performance (see section on Legumes versus Grasses).

A review on nitrogen fertilization on forage quality and animal performance (9) shows that added increments of nitrogen cause pronounced changes in chemical composition. However, for a given species when growth stage and grazing pressure are controlled, rates of N do not usually influence the output per animal. In reviewing literature for cool- and warm-season grasses, added rates of N did not generally improve output per ruminant because digestibility was not usually altered. Added increments of N increase the crude protein content and its digestibility, but cellulose or crude fiber contents and digestibility are not usually altered. Also, lignification and leafiness for given stages of growth are similar with low and high N.

Low and high rates of N cause large differences in physiology and composition of herbaceous forages (9, 10, 19, 20). Forages grown with low N regimes are comparatively high in soluble carbohydrates (TNC, total nonstructural carbohydrates) and low in crude protein; a rapid growth stimulated by high N causes steep declines in TNC and inclines in protein as diagrammed in Figure 5. The proteins and TNC make up most of the soluble cell materials that are highly digestible (111, 112). Thus, shifting low protein-high TNC contents with low rates of N to high protein-low TNC in herbage with high N generally nullifies changes in digestibility of "soluble" cell materials with varying rates of N under environments favorable for rapid growth (see section on Climatic Factors). Thus, insignificant changes in the percentage of cell wall components of forages with high and low N suggest insignificant differences in digestibility when stage of growth is controlled.

Stobbs (103,104) postulated that the key principle to intake of herbage by ruminants is the grazing period and rate of grazing, components of the latter being rate and size of bites. For a tropical grass Setaria, using an esophageal fistula, the bite sizes were threefold larger when grazing N versus no N fertilized grass. However, these results are confounded with grazing pressure as the available dry matter was 3120 and 650 kg/ha respectively for N and no N. Data on intake and animal performance were not given. In a cafeteria grazing trial with variable canopy sizes caused by rate of N, cattle showed a grazing preference of 200 to 500 percent more for high N than for low N plots; however, there were no differences in forage digestibility, and data on animal performance were not obtained (113). Intake of first cutting orchardgrass hay was not influenced by source nor rate of nitrogen fertilization (95). Rates of N fertilization with winter annuals did not improve daily gains; intake and digestibility data were not given (29).

The fact that large yield increases occur with N fertilization confounds grazing pressure (84). With several stocking rates with Pennisetum clandestinium, animal gains at a given stocking rate increased as rate of N increased; however, at stocking rates where grazing pressures were similar for different rates of N, the animal gains did not vary. Responses of steers to N rates were attributed to pasture growth and availability rather than to pasture quality.

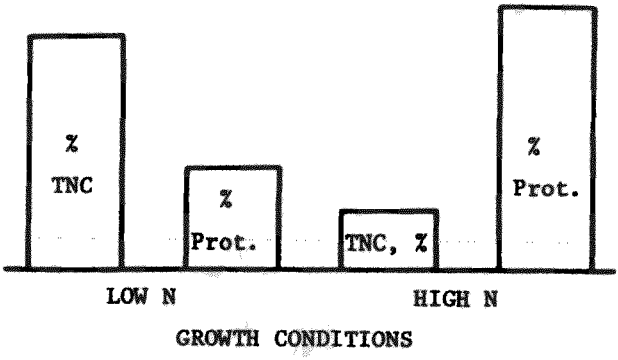


Figure 5. Diagram showing the principle of N fertilization on protein with soluble carbohydrates in forage. Herbaceous forages with low N are relatively high in total nonstructural carbohydrates (TNC percent) and low in protein percent; high N reverses these components, nullifying the effects on digestibility

Because N fertilization increases the crude protein in grasses, it may improve animal performance, intake and digestibility when a low protein status of a forage is a nutritional problem (83). This could be of much importance in tropical environments in the absence of legumes.

Irrigation. Irrigation of forages is not likely to improve the gains per ruminant for a given species or mixture where botanical components are similar and grazing pressure is controlled (Figure 6) (4, 60, 61, 67). However, irrigation improved animal gains grazing sudangrass, but no data were given on grazing pressure, digestibility, or intake (86).

Irrigation may influence digestibility and intake by shifting the botanical components to more nutritious desirable species. For example, in arid regions, the native species grown with irrigation usually have lower values for intake, digestibility, and maintenance of quality over long seasons than desirable introduced species grown with irrigation, especially legumes. Herbaceous annuals and perennials, with sustained fast growth when irrigated, are usually lower in TNC than those with a slower growth. The increased shading of basal portions of the fast developing and larger canopies with irrigation may reduce leafiness (47) and TNC because of reductions in photosynthesis per leaf unit. High rates of cell division and expansion with adequate moisture depress TNC. Blaser et al. and Brown and Blaser (10, 20) showed that the TNC was higher in leaves and stubble tissues of tropical and temperate grasses during moisture stress than with favorable moisture.

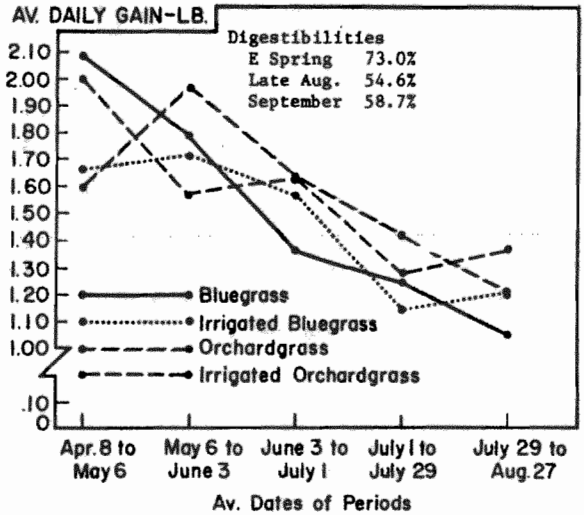


Figure 6. Distribution of animal gains by 28-day periods for irrigated and nonirrigated bluegrass-white clover and orchardgrass-Ladino clover pastures (61). Digestibility data from reference (94).

Generalized respiration-photosynthesis-TNC relationships as affected by moisture, temperature and N fertilization are given in Table 1.

Climatic Factors

Production and health of animals on grasslands appear to be most successful without supplements in countries with moderate temperatures, where ryegrasses or ryegrass-clover mixtures dominate. This temperature-plant species-climate complex is not well understood and is confounded by the effects of cool temperatures on physiology and quality of forage and on animal performance. In southeastern United States, steers at a moderate grazing pressure may gain about 1.3 pounds (.6 kg) daily for the spring-fall season on grass-legume mixtures as compared with about 2 pounds (.9 kg) during the winter on ryegrass or ryegrass-small grain mixtures (5, 11, 57, 58, 60).

Temperature. Although exact values are unknown, physiological processes such as photosynthesis and cell division and expansion have different optimum temperatures. Photosynthesis occurs at much lower temperatures than cell division and expansion (19). At high as compared to cool temperatures, lignin and cellulose percentages increased in ryegrasses while TNC declined in plant tissues (105).

Table 1. The shifting TNC content in herbage is influenced by the relative changes in respiration and photosynthesis caused by a varying status of nitrogen, temperature, water, and their interactions. These principles are based on data in references (10, 19, 20)

Factors			Photosynthesis	Respiration, mainly cell division and expansion	Δ TNC in herbage
Nitrogen	Water	Temperature			
		Favorable environment, nitrogen a variable			
H	F*	F	H	VH	Decrease
L	F	F	M	L	Increase
		Favorable environment, water a variable			
F	H	F	H	VH	Decrease
F	L	F	M-	VL	Increase
		Favorable environment, temperature a variable			
F	F	H	H	VH	Decrease
F	F	L	M+	VL	Increase

*Favorable for growth and photosynthesis, other letters give relative changes from VH (very high) to VL (very low).

Data for 11 temperate species show TNC ranges from 3 to 24 percent at cool temperatures and ranges from 3 to 8 percent at higher temperatures. Digestibilities were highest at the cool temperatures (116). With temperate species, high summer temperatures cause high respiration whereas photosynthesis tends to be low due to photorespiration causing sharp reductions in TNC percentage contents; with cool temperatures, as in spring and fall, photosynthesis exceeds respiration, causing TNC to increase (Table 1). Thus, the decline in animal liveweight gains, commonly experienced during the spring-summer transition months, when grazing temperature perennial species (6, 14, 58, 60, 61, 66), appear to be associated with declining digestibilities during the season (13, 94). In the Virginias, the dry matter digestibility of vegetative growth was: for bluegrass, 73 percent in May, 54.6 percent in late August, and 58.7 percent in mid-September; for orchardgrass, 70 to 75 percent in early April, 58.8 to 66.2 percent for the June to September period. Data in Figure 6 show sharply decreased gains during the season even with favorable moisture. Thus, these declines may be related to temperature-depressed forage quality. Such declines in digestibility are apparently allied with declines in TNC and increases in lignin and cellulose (Table 1).

When grazing temperate species during the late summer-early autumn season, the increasing rates of gain per animal appear to be associated with increases in digestibility of the pasturage allied with TNC increases at cool temperatures. Strong evidence for the contention is given in Figure 7.

During the autumn season with short days and decline in net radiation, the cool temperatures cause digestibility of Kentucky 31 fescue to increase with age, plateau, and finally decline (Figure 7). Note that TNC increased up to 29 percent of the dry matter by the 11th week (October 31) and then declined two weeks later because of freezing temperatures which apparently ruptured tissue and leaching of TNC. The percent of cellulose and lignin declined with age of plant tissue because TNC accumulation at a rapid rate had a diluting influence.

At a given age, the higher dry matter digestibility of Kentucky 31 fescue in 1960 than in 1961 may be attributed to cooler temperatures while canopies accumulated. The date of cutting before accumulating the growth was 19 days later in 1960 than in 1961; however, temperatures during autumn of 1960 were also lower than in 1961.

The high digestibility of autumn accumulated growth and the low incidence of freezing injury to Kentucky 31 fescue canopies, makes this species especially suitable for winter grazing (108).

Temperatures apparently have minor influences on TNC of species of warm season origin. Data for 13 grasses show TNC values ranging from 2 to 3 percent at low as compared with 2 to 5 percent at high temperatures (116). They reported higher digestibility for temperate than for tropical grasses at cool temperatures but the species did not differ at high temperatures.

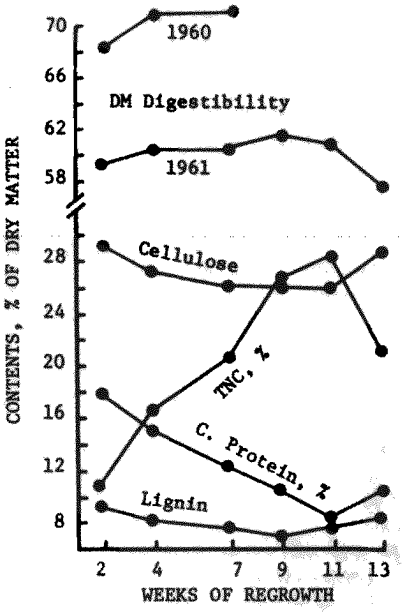


Figure 7. The Ky-31 fescue was cut and accumulated after September 2 in 1960 and after August 14 in 1961. The higher in vivo digestibilities for 1960 than for 1961 may be attributed to the cooler temperatures while top growth accumulated. Chemical constituents are shown for 1961 only. From reference (22)

In generalizing for temperate species, the low lignin and cellulose and high TNC contents (high digestibility) at cool temperatures and high lignin and cellulose and low TNC (low digestibility) at high temperatures for given stages of growth partially explains the variation in animal performance within a grazing season and for widely different temperature environments.

Radiant Energy and Photoperiod

The net daily radiation (intensity and hours of sunlight) influences species adaptation and yield. Photosynthesis of unshaded leaves reach maximum rates at about one-third of the light intensity on a cloudless day for temperate species but most tropical species do not become light saturated (21). However, yields of temperate species increase with light intensity because more of the shaded leaves within accumulating canopies become photosynthetically active. Reductions in light intensity depress TNC in the foliage of canopies (27) which depresses digestibility. Poor animal gains during prolonged rainy periods may be associated with low TNC because of low light intensity and comparatively high respiration:photosynthesis ratios.

Photoperiod (night:day relationships) cause large changes in forage quality in two ways: (a) shifts in botanical components and (b) altering the leaf:stem ratios of forages.

Many areas in the Southern Region grow mixtures of temperate annual and tropical perennial species. Abrupt shifts in botanical components occur with shifts in day:night ratios along with radiant energy and evapotranspiration to alter forage quality and animal performance. Temperate-climate winter annual grasses and legumes become dominant during the late autumn-spring season. As nights become shorter the temperate species mature and cease growing; the progressively longer days and warmer temperatures cause a shift to grasses of warm season origin. Highest rates of daily gain are associated with seasons when temperate legumes and annual grasses dominate (5); rates of gain de decline when tropical species dominate (see section on Morphological Stages of Growth and Age). The shifting to longer days with shorter nights as the spring season advances and with long warm days during summer triggers stemmy morphologies which depress intake and digestibility. Most temperate grasses seed only once yearly in spring as days lengthen because flower primordia develop in the long night-cool temperature periods in fall (49, 87). Temperate legumes such as alfalfa and red clover and tropical grasses and legumes require only long days with warm temperatures for flowering; hence, all summer regrowths become stemmy. However, with alfalfa, the long days per se depress leafiness (35). Leafiness is very important as digestibility and leaf:stem ratios are strongly correlated (23, 34).

Species and Mixtures

Legumes versus Grasses. Almost all temperate and many tropical legumes in grass mixtures give substantial improvements in liveweight gains over vigorous nitrogen fertilized grasses at controlled grazing pressures (12, 14, 24, 58, 59, 60, 62, 64, 109). However, legumes vary in nutritional value, some legumes such as sericea lespedeza give low values for daily gains, digestibility, and intake, possibly because of tannin and phenol compounds (26, 43).

The higher animal performance for most legume-grass mixtures than for grasses alone is attributed to the more rapid digestion of the legume component, thereby stimulating intake (106). Data for sheep with 8 tropical grasses and 6 legumes showed a 28 percent higher intake for legumes than for grasses at equal digestibilities. With similar digestibilities of grasses and legumes, the retention period was longer for grasses. Van Keuren and Heinemann (110) found that with nylon bags, the dry matter digestibility of two cool season legumes was about twice that of orchardgrass in 24 hours; the digestibility of legumes plateaued at 48 hours while that of orchardgrass increased up to 96 hours. Lowrey et al. (70) also showed faster digestibility of alfalfa than for Coastal bermudagrass (Figure 8). Intake of alfalfa by steers was much higher than for Coastal bermudagrass hay, 2.2 versus 1.5 percent of liveweight; however, digestibilities were similar, 57.8 percent for alfalfa and 55 percent digestible dry matter for Coastal bermudagrass (51).

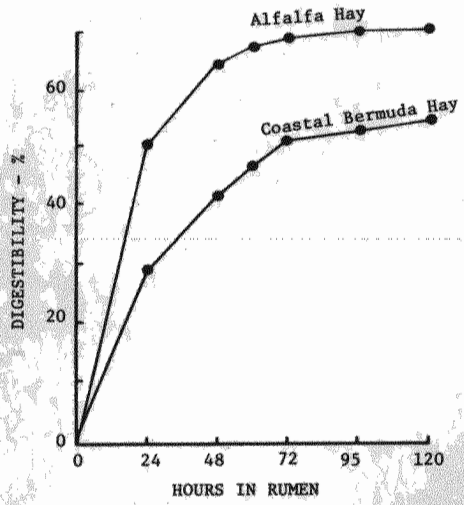


Figure 8. Nylon bag dry matter digestibility of Coastal bermudagrass and alfalfa hays. From reference (70)

The leaf morphology of grasses versus legumes may play an important part in decreased rates of digestion. The parallel veins of grass species may give the grass leaf more strength and resistance to mastication than for the more diffuse veins of legumes and broad-leaves. The structural strength of leaves as measured by fibrousness and artificial mastication were related to intake and digestibility. Fibrousness index (energy requirement to pulverize a sample) was correlated with digestibility ($r = -.93$) and intake ($r = -.90$)(33). Particle size index (small particles associated with digestion rate) after artificial mastication was correlated ($r = .94$) with forage intake (107).

With sheep, digestibility was strongly correlated and intake weakly related to the neutral detergent fiber contents of three species--white clover, perennial ryegrass, and orchardgrass (79). On the other hand, Coleman and Barth (36) found variable responses when grazing two legumes. The correlation between the digestibility of selectively grazed forage with height and percent legumes in two mixtures was positive for Ladino clover in orchardgrass and negative for lespedeza (L. stipulacea)--tall fescue.

From the viewpoint of nutrition for finishing cattle in grazing systems without grain supplements, adapted legumes that can be economically cultured in grass association are vitally important. With Yuchi arrowleaf clover in a winter annual grass mixture, steers with DES implants gained 1.89 to 2.39 pounds daily during a 4-year trial (5). Steers slaughtered directly off pasture graded USDA Good carcass grades or better.

Temperate versus Tropical Grasses

When considering factors already discussed, the variable liveweight gains of ruminants grazing various grasses that are available at different seasons are difficult to explain because the animal gains are often confounded with uncontrolled grazing pressures and sharply different environments during different grazing seasons. The uncontrolled animal condition (liveweight gains before starting a grazing trial) and age also strongly influence the rate of gain, thereby confounding the magnitude of gains (68). However, with moderate stocking (grazing pressure unknown) and with ruminants in good condition when grazing is initiated, the highest and lowest liveweight gains generally occur with winter annual and tropical perennial species, respectively; gains with temperate grasses are high during spring, low during summer, and medium during autumn; and steers grazing well managed leafy summer annuals make moderately high liveweight gains (3, 4, 5, 6, 14, 25, 57, 58, 60, 62, 66, 73, 80, 85, 88). Some data disagree with these generalizations; e.g., liveweight gains per head were low with summer annuals (63, 86) and high with Napier grass (16).

High daily gains (1.70 pounds or more), as with winter annuals, over prolonged periods when weather conditions are favorable make it possible to sell yearlings from such pastures at desirable High Standard to Choice slaughter grades (5, 57). Similar young cattle grazing perennial temperate or tropical species for entire seasons require feedlot feeding at the end of the season to reach suitable carcass grades (5, 60, 62). Although winter annual small grains produce excellent forage quality, the low yields and short grazing seasons because of autumn droughts and cold temperatures sometimes make it impractical to depend on winter grazing unless other feeds are available (29).

The ranges of low to high animal gains among the grasses are strongly associated with digestibility and intake. Rate of digestion, which influences intake as discussed previously varies with grass species (52). Digestible components of 2 cm lengths of leaf tissue were essentially degraded in 24, 48, and 96 hours, respectively, for temperate winter annuals or perennials, pearl millet, and bermudagrass.

High intakes, 4.45 to 5.86 kg (9.8 to 12.9 pounds) TDN per 455 kg (1,000 pounds), liveweight and high digestiblities, 61 to 68 percent, occurred with green chopped perennial legumes and annual grasses fed alone and in mixtures (117). Digestibility of early spring growth of temperate perennial grasses ranged from 73 to 75 percent and declined rapidly for later seasonal growths (13, 94).

Steers grazing Pensacola bahiagrass (Paspalum notatum Flugge) made high daily gains during May; gains declined to (-) .52 kg by September (88). Forage availability was high, more than 2,000 kg/ha of dry matter, during July through October, but estimated intake and digestibility declined with season; the correlation between daily gain and estimated intake was 0.89. Similar declines in daily gain occurred with three tropical grasses in Georgia (Figure 9)(32). The decline in gain may be associated with adverse effects of high temperatures on

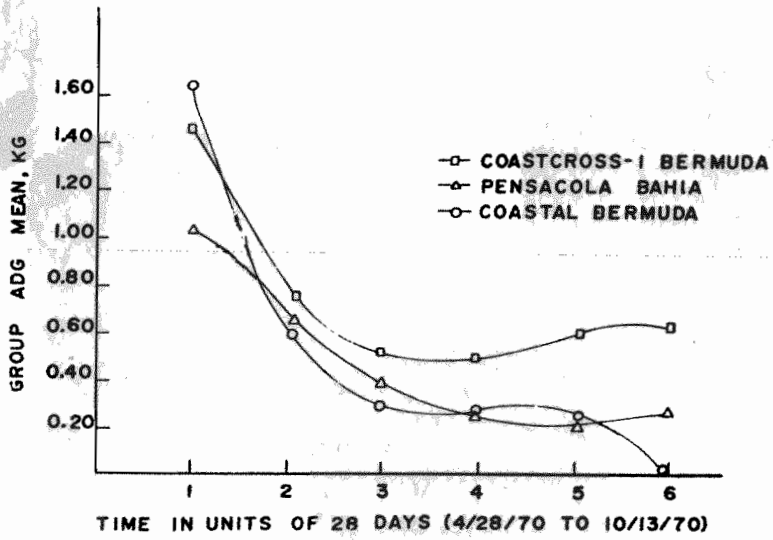


Figure 9. Seasonal daily liveweight gains of steers grazing three tropical grasses in Georgia for 28-day periods beginning with April 28 and ending on October 13, 1970. From reference (32)

quality. Low liveweight gains of ruminants that often occur with Coastal bermudagrass (58, 66, 101) may be attributed to low intake and digestibility. Lowrey et al. (70) obtained lower liveweight gains for Coastal than for Coastcross-1 bermudagrass; the latter gave higher values for digestibility and intake than Coastal bermudagrass.

With cool season grasses, the high daily liveweight gains in spring and declining gains as the season progresses may be associated with the shifting from high to low digestibilities as the season advances (11). When grazing temperate perennials, liveweight gains declined with advance of the grazing season, but after shifting heifers to Coastal bermudagrass there were abrupt declines in gains (66). Dry matter intake per heifer grazing Coastal bermudagrass dropped from 11.1 kg in July to 6.4 kg in September, even though there was an adequacy of short succulent forage. Chemical analyses showed that nutritional components were in excess of NRC standards.

The variable high-to-low liveweight gains for ruminants grazing summer annuals (pearl millet, sudan, and sudan sorghum hybrids) could be attributed to inadequate leafy growth caused by management, cultivar, leaf diseases, or grazing pressures. Higher intakes for leafy than stemmy tissues for tropical grasses were reported by Loredo and Minson (69). The rather low digestibility of tropical species may be improved by managements that suppress stems (41). Intermixed stems and leaves make it difficult for cattle to select leaves. Separating

the leaves and stems of tropical grasses by specific gravity showed higher intake of leaves than for entire plants (69). For most tropical species, such as bermudagrass, regrowths tend to be stemmy; even short young growths have some stems. Most cool season species develop progressively more stemmy morphologies only during spring; with heavy grazing, ruminants bite below floral buds, causing these shoots to die. The growth from new tillers remains leafy. Thus, temperate as compared with tropical grasses remain relatively leafy thereby improving intake. With tropical grasses, the leafy growth of special pearl millet cultivars (28) and Napier and Guinea grasses managed for leafiness may explain good animal performance (14, 89).

However, intake of leafy growths of species vary independent of digestibility.[3] Using leafy tissues of two temperate grasses in similar growth stages, the digestibilities were high and similar but intake was much higher for orchardgrass than for tall fescue. When grazing similar leafy tissue of these two grasses during the growing season, liveweight gains were higher for orchardgrass than for tall fescue (11, 60, 62). Also, two varieties of bermudagrass, Coastal and Coastcross-1, are similar in leafiness, but intake and digestibility are substantially higher for the latter (70).

Microstructure is related to the variable digestibility among tropical and temperate grasses (52, 80). Structural carbohydrates are digested by endoenzymes of rumen microbes, cellulases are not secreted into the rumen by microbes. Thus, digestion only proceeds when rumen bacteria are in intimate contact with forage; when filtering microorganisms out of fresh rumen fluid, degradation of forage did not occur.

The digestibility and intake of a forage appears associated with the types and relative proportions of different cells. Leaves are composed of cutinized epidermal cell layers, mesophyll cells, and vascular tissues enclosed by 1 to 2 bundle sheath cell layers. The cells vary in cell soluble content, cell wall percentages, and lignification of cell wall materials. Digestion of epidermal cells is inhibited by waxy cuticles; a waxy bloom on sorghum leaves strongly restricted digestion through blade surfaces (39, 53). Such cutinized epidermal cells of many grasses are among the last tissues to digest (1). An intact cuticle forces digestive microorganisms to attack through cut ends and surface breaks.

The interior mesophyll cells of blades are generally thin walled, mildly lignified, and digested rapidly. In most temperate grasses much of the mesophyll tissue is loosely arranged with large air spaces; the remaining tissue is in a dense arrangement around the vascular bundles. However, with many tropical species (particularly C_4 photosynthesizers) the mesophyll tissues are in a dense radial arrangement around the vascular tissues. Digestion in temperate species is facilitated by the free movement of microbes into tissues with air spaces

[3] W. E. Hardison, C. Y. Ward and R. E. Blaser, unpublished data, VPI and SU.

(52). Thus, dense mesophyll tissues of tropical C_4 species digest slowly as compared to temperate species.

Bundle sheath cells and vascular tissues are usually high in lignin, and schlerenchyma fibers usually associated with vascular bundles account for restricted digestibility of such tissue (2).

Because vascular tissues generally digest slowly, plants with a smaller proportion of vascular tissue should digest more rapidly. Many C_4 tropical species are threefold higher in vascular bundles than C_3 temperate species (38) and have larger total vascular areas per leaf width (48). Crookston et al. (38) showed that C_3 species have 3 to 7 times more mesophyll cells as compared to C_4 species. Many of the temperate as compared with tropical species digest more rapidly which augments intake or digestibility or both. The cell structures in leaves of C_4 plants, associated with photosynthetic efficiency (38, 48), may make portions of the increased production of less use to ruminants.

Alkaloids and Tannins

Certain chemical compounds lower digestibility and/or intake of forages and animal performance. Alkaloids such as perloline in some species and other similar compounds in tall fescue have been suspected to cause the mediocre performance of animals (30). In vitro ruminal digestion of cellulose was depressed by up to 80 percent by .0001 M. perloline (30).

The highest concentration of alkaloids occurred in young tissue and in leaf blades and nitrogen stimulated alkaloid production in reed canarygrass (71). Alkaloids in this grass were associated with reduced palatability (intake data not given), but effects on digestibility were inconsistent. However, a 35 percent reduction in intake occurred with high alkaloid (unpalatable) canarygrass strains (99).

Tannins in various forage species also affect intake and digestibility. Sericea lespedeza cultivars contain varying amounts of tannins which depress intake and digestibility, particularly of proteins. Differences of 20 percentage units occurred between low and high tannin sericeas (42, 43). Sericea and alfalfa were similar in cell walls, lignin, and other components; the poorer intake, digestibility, and animal performance for sericea was attributed to tannin (26).

Grazing Pressure, Stocking Rates and Selective Grazing

The liveweight gains per ruminant and per hectare for a given mixture with different grazing evaluations are strongly influenced by grazing pressure-stocking rate-selective grazing interactions (15, 32, 44, 73, 76, 81, 82, 97, 98, 115).

In defining terms, grazing pressure refers to the animals per unit of available pasture in kg/ha of dry matter, stocking rate refers to reminants per hectare and selective grazing refers to characteristics of ingested herbage. As long as there is

excess pasturage, ruminants select species and plant parts that are higher in crude protein, digestibility, and ether extract and lower in crude fiber than that of the forage not being grazed (11, 13, 32, 46, 55, 114). Some reports also show an increase in intake as more selective grazing is allowed. With more selective grazing, improved digestibility and intake of pasturage results in higher gains per ruminant.

The model in Figure 10 by Mott (81, 82) shows declining rates in liveweight gains per head as grazing pressures are increased. The shift from high to low selective grazing with increases in grazing pressure causes concurrent high-to-low intake of digestible forage. Thus, liveweight gains per hectare increase as grazing pressure increases from a low to a medium level. This is attributed to more animals per hectare, a sacrifice in gain per head and less wasted pasture. At high grazing pressures, the low gains per head depress hectare yields of animal products. A literature review (15) shows that stocking rates are indicative of grazing pressures, but there are large deviations. With constant stocking rates, there are large changes in grazing pressure during the season because of normal large differences in forage growth at various seasons (Figure 11). Also, increases in the weight of ruminants with seasons increase forage consumption and grazing pressures at constant stocking rates and growth rates of forage.

Rates of nitrogen fertilization and the large differences in pasture growth and availability bias data on animal gains at a given stocking rate because of lighter grazing pressures with high rates of nitrogen. In evaluating two cultivars, where A yields 15 percent more than B, a given stocking rate would bias gains per ruminant in favor of A because of a lighter grazing pressure than for B. With one stocking rate in pastures to ascertain liveweight gains with and without grain supplements, liveweight gains with grain supplements would be inflated because of a lighter grazing pressure as compared with no grain feeding.

Much of the published data on outputs per head and per hectare for treatment comparisons are difficult to interpret or implement into practice because the variable grazing pressures are confounded with treatments. Even for most stocking rate experiments, data on grazing pressure were ignored. Dry matter yields of ungrazed residues for different stocking rates would establish grazing pressures.

Grazing pressures have been controlled by using variable stocking with put-and-take animals for obtaining data with similar grazing pressures (12, 14, 15, 81). Also, when ascertaining the grazing value as for a new cultivar, reliable results at low costs may be obtained with controlled grazing pressures by varying the stocking rate with put-and-take animals.

Grazing pressures as related to high animal gains (high intake and digestibility) and forage control (high yields and controlling growth stage and species balance) vary with species and mixtures (17).

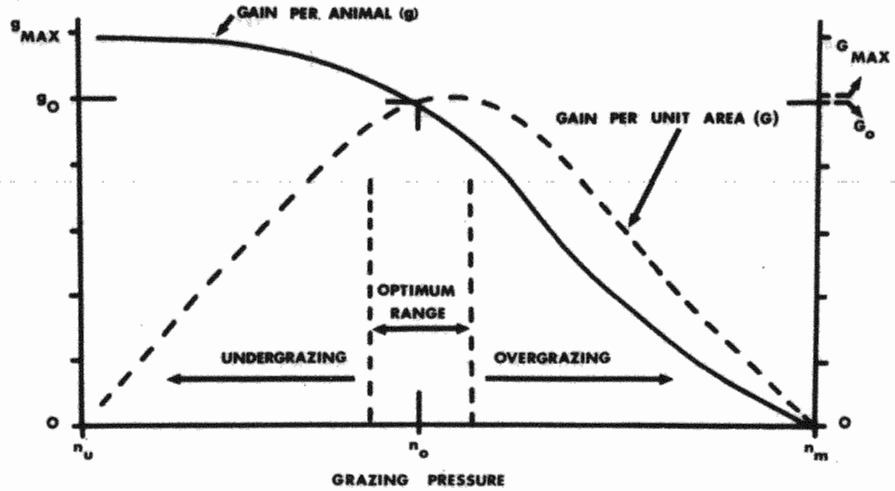


Figure 10. Influence of grazing pressures (n) upon gain per animal (g) and gain per unit area (G). From reference (82).

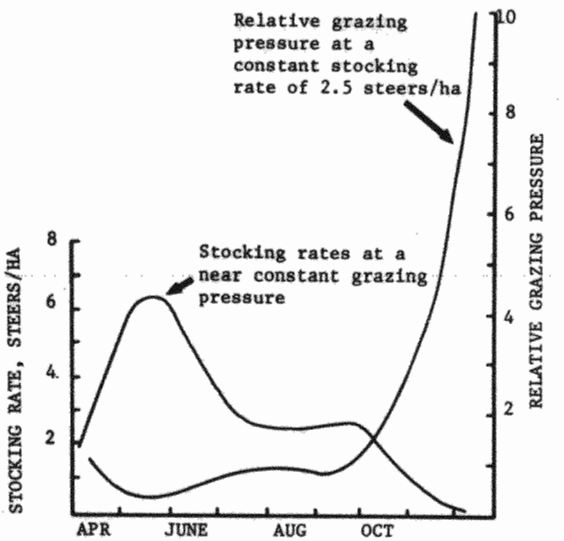


Figure 11. Seasonal stocking rates at a near constant grazing pressure with bluegrass-white clover pastures and relative grazing pressures at a near constant stocking rate of 2.5 318 kg steers per hectare. Based on data in reference (11).

Using variable stocking rates for seasons with put-and-take animals occasionally to control grazing pressure should not be associated with changing animal numbers on a farm. Put-and-take in research applies to shifting hectares of pasture to supply forage for ruminants at different seasons during the year within a farm. It is common for farmers to alter areas for grazing as for "shutting off" fields for harvesting the excess growth, rather than allowing pasturage to grow to maturity or be wasted. Put-and-take management for controlling grazing pressure, stage of growth, and botanical composition can cause large differences in intake and digestibility of test animals if wrongly used; also, adding and withdrawing ruminants should be infrequent (15).

Grazing and Utilization Methods

The utilization methods may be classified as follows:

1. Grazing

   a. Continuous--ruminants remain on a pasture all season or year.
   b. Rotational--accumulation and grazing of canopies.

      1) Ordinary rotational grazing, one group of ruminants.
      2) Two animal groups--first and last grazers or creep grazers followed by other ruminants.
      3) Strip or ration grazing.
      4) Stockpiling--canopies accumulated during favorable growth periods, grazed when there is little or no growth.

2. Green chop

3. Hay or silage (includes low moisture silage) conservation.

The methods of utilization as related to managing species and mixtures to compromise between yield and quality of forage, controlling botanical components, and making compromises between outputs per head and per land area were discussed in detail (17).

This discussion will be restricted to gains per head as related to intake and digestibility and utilization methods. It should be evident that gains per head can be "manipulated" to obtain best results for any utilization plan by biasing stage of growth, botanical species or grazing pressure to augment or deter gains per head. For example, in a theoretical experiment (Table 2) two cultivars of alfalfa are presumed to differ substantially in yield. Based on earlier discussions, the variable results for intake and digestibility with green chop and rotational grazing for the cultivars are associated with uncontrolled stubble residues, stages of growth, and percent of forage above ad lib feeding or grazing pressure. The theoretical situations and data in Table 1 are self-explanatory. In practice, it is likely that the highest yielding alfalfa may give lowest output per animal when harvested, if morphological characteristics for the

Using variable stocking rates for seasons with put-and-take animals occasionally to control grazing pressure should not be associated with changing animal numbers on a farm. Put-and-take in research applies to shifting hectares of pasture to supply forage for ruminants at different seasons during the year within a farm. It is common for farmers to alter areas for grazing as for "shutting off" fields for harvesting the excess growth, rather than allowing pasturage to grow to maturity or be wasted. Put-and-take management for controlling grazing pressure, stage of growth, and botanical composition can cause large differences in intake and digestibility of test animals if wrongly used; also, adding and withdrawing ruminants should be infrequent (15).

Grazing and Utilization Methods

The utilization methods may be classified as follows:

1. Grazing
   a. Continuous--ruminants remain on a pasture all season or year.
   b. Rotational--accumulation and grazing of canopies.
      1) Ordinary rotational grazing, one group of ruminants.
      2) Two animal groups--first and last grazers or creep grazers followed by other ruminants.
      3) Strip or ration grazing.
      4) Stockpiling--canopies accumulated during favorable growth periods, grazed when there is little or no growth.
2. Green chop
3. Hay or silage (includes low moisture silage) conservation.

The methods of utilization as related to managing species and mixtures to compromise between yield and quality of forage, controlling botanical components, and making compromises between outputs per head and per land area were discussed in detail (17).

This discussion will be restricted to gains per head as related to intake and digestibility and utilization methods. It should be evident that gains per head can be "manipulated" to obtain best results for any utilization plan by biasing stage of growth, botanical species or grazing pressure to augment or deter gains per head. For example, in a theoretical experiment (Table 2) two cultivars of alfalfa are presumed to differ substantially in yield. Based on earlier discussions, the variable results for intake and digestibility with green chop and rotational grazing for the cultivars are associated with uncontrolled stubble residues, stages of growth, and percent of forage above ad lib feeding or grazing pressure. The theoretical situations and data in Table 1 are self-explanatory. In practice, it is likely that the highest yielding alfalfa may give lowest output per animal when harvested, if morphological characteristics for the

Table 2. A theoretical experiment showing how some uncontrolled variables may bias results on intake, digestibility and animal performance when evaluating two cultivars with green chop and rotational grazing. It is assumed that cultivars differ only in yield, A being highest.

Hypothetical factors				Estimated[a] relative intake and digestibility
Alfalfa cultivars	Stubble residue cm	Stage of Growth	Excess of ad lib, percent, or grazing pressure	
		Feeding Green Chop		
A	7.5	E Bl	5%	95
B	7.5	E Bl	5%	100
A	7.5	E Bl	5%	95
B	7.5	E Bl	15%	110
A	15[b]	E Bl	5%	120
B	7.5	E Bl	5%	100
A	7.5	E Bl	5%	100
B	7.5	Bud	5%	120
		Rotational Grazing		
A	7.5	E Bl	High	95
B	7.5	E Bl	High	100
A	7.5	E Bl	High	95
B	7.5	Bud	High	120
A	15	E Bl	Low	130
B	7.5	E Bl	High	100

[a]Based on principles in Section III.

[b]As with lodging with taller cultivars.

cultivars are similar. For a given period of canopy growth the higher yielding alfalfa could be either taller or in a more advanced stage of growth; hence, lower in leafiness because less light penetrates into taller canopies or a more advanced stage of growth.

Grazing Methods: The performance of ruminants with rotational as compared with continuous grazing is debatable because of inadvertent grazing pressure biases (15). Schematic rotational grazing experiments with fixed stocking rates and specific grazing and resting periods cause severe grazing pressure differences. Judicious rotational grazing should be based on canopy morphology, when grazing is started in a fresh pasture and on the ungrazed residues when removing cattle, to control grazing pressure.

Expected animal performances with rotational and continuous grazing are summarized by Blaser et al. (17) as follows:

> When comparing ordinary rotational (one group of animals) with continuous grazing under similar grazing pressures and forage maturities, the output (milk or meat) per animal did not usually differ significantly--By biasing selective grazing and maturity control either method can give highest production per animal; however, continuous grazing is likely to give best animal outputs because more selective grazing is inadvertently allowed than for rotational grazing. Continuous grazing is very likely to give better outputs per animal than rotational grazing during flush growth when pressure is apt to be low for continuous grazing; the short sod residues at the end of rotational grazing in each lot with good utilization depress output per animal. After the flush growth, it is common to obtain higher output per animal from rotational than continuous grazing because of better growth stage control, a more uniform leafy canopy is obtained with rotational grazing. With continuous grazing extreme overgrazing and undergrazing and wide ranges in forage maturity occur as the season advances. This suggests continuous grazing be used during early season followed with rotational grazing (Figure (53.8).

(See Figure 12.)

Well managed rotationally grazed pastures give a false impression; the pleasing appearance does not relate to a nutritional advantage (Figure 13). While steers utilize the forage within a rotationally grazed pasture with moderately good forage utilization (medium grazing pressure) they encounter extremes in intake of digestible forage and nutrition. As steers start grazing in a fresh rotation pasture, the low grazing pressure-high selective grazing- high digestible herbage-high intake relationships give high nutrition and gains per head. At the end of a grazing cycle within the same pasture the high grazing pressure-low selective grazing-low digestibility-low intake relationships sharply depress nutrition and output per head (Figure 13 and

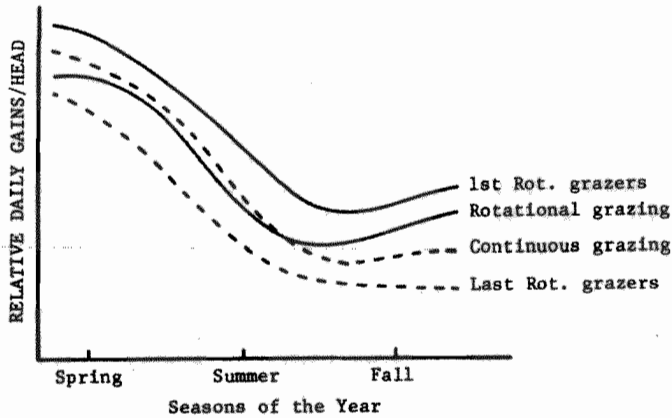


Figure 12. Animal gains with grazing methods vary with season because of selective grazing, grazing pressure, forage quality, and condition of animals. From reference (17)

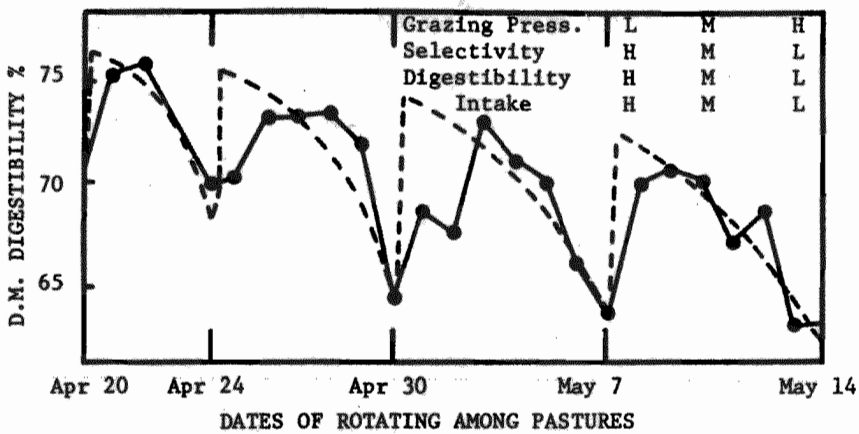


Figure 13. The dry matter digestibility of ingested orchardgrass pasturage under rotational grazing of nitrogen fertilized orchardgrass pastures, 1959. The lag in digestibilities after moving to a fresh pasture occurred because of mixing freshly grazed selected forage with last grazed forage from the previous pasture. The broken lines approximate digestibility changes as pasturage was consumed. The changes from low (L) to high (H) or the inverse for grazing pressure, selective grazing, digestibility and intake while utilizing the forage in a pasture are approximated. Based on data from references (11, 13).

Table 3). As the forage is consumed within a rotationally grazed pasture, the ungrazed residues progressively decline in protein and increase in fiber; hence, animals select leafy fractions that are high in digestibility.

The good pasture utilization usually practiced with rotational grazing causes grazing pressures to average higher for rotational than continuous grazing. Conversely, rather high selective grazing is linked with continuous grazing as there must be some excess forage, as otherwise the risks of inadequate pasture would be encountered.

The use of constant stocking rates for the year or season account for considerably higher grazing pressures with rotational than with continuous grazing (15). During the flush season good utilization (medium grazing pressures) is enforced with rotational grazing, there being excess herbage with continuous grazing.

Strip grazing gives even nutrition as the pasturage is consumed in one day. However, outputs per animal for strip and rotational grazing are similar if stages of growth, botanical components, and ungrazed residues are similar.

Green chop usually gives slightly lower intake and digestibility than strip or rotational grazing when growth stage and animal comfort are controlled. This is attributed to little selection for leaves and heating of green chop forage as compared with grazing. However, any of these systems can give the best gains per head, pending growth stage, botanical components, and grazing pressure.

Intake and digestibilities from conserved forages (hay, silage, or herbage) are usually inferior for animal performance as compared to similar species utilized by grazing (11). With conservation, the more advanced stages of growth, respiration and leaf losses cause lower digestibility and intake as compared with grazing utilization.

Stockpiling refers to accumulating canopies for later grazing; stockpiling tall fescue during August-November for winter grazing is a common practice. It is difficult to diagnose the quality of stockpiled forage as data on intake and digestibility and animal performance with various species and associations are not adequate. Tall fescue stockpiled during summer is known for its unpalatability as ruminants refuse it; however, autumn stockpiled fescue has given good gains of steers (118). For temperate grasses, spring stockpiling causes poor digestibility because of mature stemmy growth; the same would apply for summer stockpiling of tropical species.

By using two animal groups in rotational grazing, high nutrition was obtained for the first grazers by allowing last grazers to consume the residue. For five mixtures, where first grazers consumed 50 percent of the forage, gains were 0.60 kg (1.33 lb) as compared with .40 kg (0.89 lb) per head for last grazers (Table 4). With the two best grass-clover mixtures, the gains averaged .69 kg (1.51 lb) and .49 kg (1.07 lb) per head for first and last grazers, respectively. The

Table 3. General and relative associations among parameters for a given pasture-animal complex at various grazing pressures. From reference (15)

Stocking[a] rates	Grazing pressures	Herbage per head	Selective grazing	Ungrazed wasted herbage	Nutritional status per head[b]	Yield of animal products		Potential pasture yield
						per head	per hectare	
			Continuous grazing					
low	low	high	high	high	high	high	low	low
medium	medium	medium	medium	medium	medium	medium	high	high
high	high	low	low	low	low	low	medium	high (-)
		Rotational grazing - high-to-low nutrition while grazing a lot when starting grazing in a fresh pasture						
medium	low	high	high	high	high	high	v. high	-
		when finishing grazing in a rotated pasture						
medium	high	low	low	low	low	low	v. low	-
mean values	medium	medium	medium	medium	medium	medium	high	high

[a] Stocking rates are not necessarily allied with grazing pressures and constant stocking rates cause sharp changes in grazing pressure (Figure 6).

[b] Intake of digestible energy and protein and minerals.

Table 4. The daily liveweight gains of steers and dry matter digestibility as influenced by two-animal groups (first and last grazers) and ordinary whole canopy rotational grazing. From reference (13).

Pasture mixtures	Kind of rotational grazing - two-animal groups					
	First (Daily gains)		Last (Daily gains)		Whole canopy (Daily gains)	
	kg	lb	kg	lb	kg	lb
Orchardgrass-nitrogen	.56	(1.23)	.36	(0.80)	.44	(0.96)
Tall fescue-nitrogen	.50	(1.09)	.34	(0.75)	.40	(0.89)
Orchardgrass/Ladino clover	.70	(1.53)	.52	(1.14)	.60	(1.31)
Tall fescue/Ladino clover	.60	(1.31)	.35	(0.77)	.54	(1.18)
Bluegrass/white clover	.68	(1.49)	.45	(1.00)	.59	(1.29)
Average 1958 and 1959	.61	(1.33)	.40	(0.89)	.51	(1.13)

Season[a]	Dry matter digestibility percent		
	Orchardgrass-N-fertilized pastures		
April-May	71.7	65.6	68.0
June-July	70.5	65.8	66.2
Aug.-Sept.	60.6	54.4	58.8
	Tall fescue-N-fertilized pastures		
April-May	70.0	62.0	68.2
June-July	68.3	64.9	63.1
Aug.-Sept.	60.7	55.7	58.0

[a]Data by the Chromogen technique.

digestibilities for the whole grazing season for two grasses were substantially higher for first grazers (67.0 percent) than for last grazers (61.4 percent), and the results were consistent among seasons (Table 4).

Allowing first grazers to consume only 25 percent of the forage and using implants to stimulate gains would have given substantial increases in gains. In practice fattening steers could be used as first grazers and cow-calf herds or cows as second grazers. Calves could be allowed to creep with steers for higher nutrition.

IV. Animal-Forage Management Systems

The principles and managements to attain high TDN ingestion to improve output per head and efficiency of converting forages to meat discussed in Section III should be considered in designing animal-forage grazing systems. Such systems must be carefully designed by a research team so findings will be implementable and of economic relevance on farms.

Two concurrent tasks are: (1) to establish and attain finishing goals, including age and carcass grade of cattle and (2) to establish 12-month forage systems that supply the quantity and quality of needed forage. Liveweight gains per head and per hectare are both important and must be wisely compromised; quality and marketability of carcasses supercedes gains per hectare. Unfortunately, when stocking rates are increased to utilize most of the herbage (high grazing pressure) for high gains per hectare, the liveweight gains per ruminant decline because selectivity for the most nutritious plant parts is restricted.

Some of the principles to be embodied into animal-forage management systems are:

1. Plan the best animal forage grazing systems, giving high quality and yields of good seasonal distribution of forage for various environments. Harvesting should be minimized. The systems should be simple; several fields in different species or mixtures will usually be needed. Soil amendments to grow high yields of desired species are basic; high intake of TDN is associated with management. Species should be persistent, dependable, easy to grow and manage, and include desirable legumes. Mowing to control weeds or stages of growth should generally be accomplished with grazing management. Adapted species with management should minimize weed and pest problems.

2. The animal-forage systems should complete finishing cycles by controlling the ingested TDN through grazing pressure. Grazing pressures to maintain desired gains vary with species, mixtures, and seasons. Along with furnishing the needed nutrition, grazing pressures should control stage of growth (leafiness being very important) and maintain a balance of wanted species.

3. Any method of grazing can be "manipulated" to give higher gains than another method. Continuous as compared with rotational

grazing generally gives better gains per head during flush growth because selectivity is linked with it. Rotational grazing is required for maintaining certain species as alfalfa. It is a practical plan when using a sequence of mixtures or species for grazing and harvesting to furnish more land area during periods of slow growth for controlling grazing pressures. Rotational grazing is apt to give adverse results when used with stocking rates, imposing grazing and rest periods on specific dates and using it when forage is scarce (15). With little forage *in situ* continuous grazing lightens the grazing pressure as compared with rotational grazing.

4. Two animal groups, first and last grazers, in rotational grazing allow low grazing pressures and high gains for first grazers; second grazers achieve good utilization to avoid accumulating stemmy dead material and replace mowing. Dry cows with low nutritional requirements might be used as second grazers. This method is likely most practical for use in conjunction with continuous grazing. The plan is complex because several fenced fields or electric fence control of cattle is needed.

5. The concurrent control of animals and forages to achieve desired outputs requires flexibility in management. All areas, seasons, and species are not equally suitable for fattening. Thus, periods of finishing for slaughter should be cycled to the potential nutrition of the forage system. Simultaneously, plants must be managed flexibly as with red clover. An extended grazing season of quality forage can be obtained from this legume during summer-autumn without depressing yields and persistence. Alfalfa, managed flexibly, also furnishes quality of grazable forage during sparse growth.

6. Grain supplements should be restricted and started at seasons when forage quality is depressed. Higher grazing pressures and better utilization can be imposed with grain as compared with no grain supplements.

7. Salable fat cattle should occur at all seasons for orderly marketing to supply consumers' needs and avoid price depressions.

8. Legumes should have a prominent function in forage-cattle systems.

The best quality and intake of forage from temperate annual and perennial plants and animal performance usually occurs during the autumn-spring season and lowest quality forage from tropical and temperate perennials and animal performance occurs during summer.

Based upon this review paper, several animal-forage management systems that associate finishing cycles with nutritious species, season when species are most nutritious, nutritious legumes, and light grazing pressures for high intake of TDN are proposed. Grain supplements are generally proposed when ingested TDN from forages are inadequate. Some systems, with variable stocking rates, also provide for utilizing the flush growth during the spring season.

A. Upper South, Temperate Perennials, No Grain Supplements

Graze bluegrass-white clover or other grass-clover mixtures continuously (exclude tall fescue as it is inferior for finishing).

1. Stock at double rate April-June

   a. Remove half of the steers in June or July and sell as finished steers, or

   b. If not finished, graze red clover or alfalfa-grass mixture, sell when finished in summer.

   c. Steers on bluegrass all season, sell fat in October, or

   d. If not finished, graze red clover-grass mixtures from September to November and sell, or

   e. Finish on corn or a grain sorghum silage with protein supplement and sell during winter.

B. Upper South (same as A above)

1. Stock at double rate April-June

   a. Switch all steers to first grazers by June using the regrowths of red clover and/or alfalfa cut for hay in spring. Steer gains increase as more selectivity is allowed. Steers are sold as they become finished during the season.

   b. Dry cows or dry cows with calves serve as last grazers after steers. Calves may creep graze with steers for better nutrition.

2. Best possible gains for fattening are obtainable by first grazing all season, where 25 to 50 percent of forage is utilized by first grazers. The residues must be grazed by other cattle or quality declines because of "woody" dead forage and/or depressed legumes.

C. Upper South (same as A)

1. Stock at double rate during April-June

   a. Self-feed grain at 1 percent of liveweight after June to reduce grazing pressure and increase TDN intake as forage quality declines. Sell cattle as they fatten to reduce grazing pressure. All cattle should be finished by end of the grazing season.

   b. Self-feed grain at 1 percent of liveweight all season, sell some finished by mid-summer to reduce grazing pressure.

2. Graze bluegrass-clover in sequence with other grass-legume mixtures with 0.5 percent grain self-fed. Sell finished cattle in summer to November.

D. Upper South, Experiment Started at Two Locations in Virginia

1. Use stockpiled Ky-31 fescue-red clover November-March, with and without grain.

   a. Sell some older steers fed grain in April and June.

2. Switch steers on (1) to each of the following:

   a. Grass-legume sequence in rotational grazing with and without grain.

   b. Grass-legume sequence, first grazers all season, with and without grain, cows as last grazers.

   c. No grain steers in (1) and (2) to be finished on corn silage.

Winter and fall born calves (June and October weaning) are to be sold all seasons of the year. Grain supplements vary from .05 to 1 percent of liveweight.

E. Lower South, No Grain Supplements

Winter annual grasses and legumes and tropical perennial grasses are used in these systems.

1. Winter annual cereals and ryegrass--good slaughter grades by Match.

2. Winter annual grasses and legumes--good slaughter grades attained by April.

3. Use combination of (1) and (2) above; also overseed tropical grasses with species in (1) and (2).

4. Hay and winter annuals during dry or cold seasons and central South.

   a. Switch to clover-grass mixtures, slaughter in May, or

   b. Switch to tropical perennial grasses then fatten on corn silage, or

   c. Switch to tropical perennials until June, then finish on summer annuals.

5. Use steers as first grazers on mixtures of perennial temperate and tropical grasses and legumes.

6. Supplement grain or other energy feed at 1 percent of liveweight, except with winter annual grasses and legumes.

V. Conclusions, Including Needed Research

It is easiest to pursue conventional procedures in grazing experiments where schematic controls are set forth and to accept the results, regardless of the magnitude of the outputs per animal or per acre. Such data with replicated treatments have been condoned by scientific publications with strict review committees. Such research was justified during the past years as relatively little was known about the broad nature and the complexity of biotic, climatic, and soil interactions in grazing management that simultaneously influence plant and animal production.

We are of the opinion that the "time" is right for conducting managed animal-forage experiments directed toward economic relevance so as to provide data that are more directly implementable into farm practices for finishing cattle on forages. Instead of accepting results from predetermined schematic treatments, we suggest that experiments be managed to achieve relevant economic goals of animal production. For example, it is senseless to conduct an experiment where an animal averages .3 kg liveweight gain daily when potentials of the forage are .7 kg with a managed system. Thus, it is proposed that goals be established on animal production; for example, (1) produce a steer with a slaughter grade of Good at the age of 18 months with no grain or energy silage feeding, and (2) obtain economically practical returns per hectare. When feeding grains or energy silages, the length of the production cycle can be shortened.

To achieve goals of animal production depends on designing potential forage systems to fulfill the objectives with concurrent pasture and animal management. It is suggested that many systems of management be investigated at the sacrifice of replications, if necessary, as exploratory data on a wide area of forage-animal systems are needed. Then replications of more promising systems can be tested for output per animal and per hectare at a later date. Such experiments with many systems to achieve production goals should be given a high priority.

In most grazing experiments conducted during the past years where efforts of obtaining animal production data have been the major objective, data on plant response and grazing pressure have been largely ignored. Animal-plant relationships should be thoroughly exploited by studying the ecology of yield, regeneration, and maintenance of desirable species, a desirable percentage of legumes as related to grazing pressure.

The utilization of a grazing sequence of perennial grass-legume mixtures as compared with continuous grazing of one mixture should be investigated. Research should be directed toward obtaining higher intakes of highly digestible herbage to shorten the production cycles when producing fat cattle without grain feeding. It would appear

desirable to conduct short-term experiments to evaluate many different treatment comparisons where the major objective is to measure intake rather than animal output.

In conclusion, the success with finishing cattle by obtaining high intakes and digestibilities from forages with little or no grain feeding depends on the concurrent animal-plant management with economic relevance. This task demands an "open" and wanted cooperation among a team of specialists in the biotic-soil-climatic-economic arenas. "Enforced" cooperation with a director chairing a research team or with a one-man dominance is not wanted. The research endeavors and implementation plans must embody a total completed pursuit, the end products being a profit for producers and beef on the consumer's table each day. We must do better per dollar spent for research. To achieve desired goals for all concerned, we must now dedicate ourselves to work in total finishing programs in various regions under the title of Animal-Forage Management Systems for Economic Beef Production.

Writing this research review has been a challenging and difficult task. It was difficult for two reasons: (1) the complex and broad scope of the problem, and (2) making sense out of data that were often incomplete or hopelessly confounded. Team efforts would likely have avoided or acknowledged the confounded results.

Some future needs in research are listed below without giving priorities.

1. Relate grazing pressure to average daily gains over seasons.

2. Control grazing pressure to avoid confounding other factors or variables being investigated.

3. Research areas for increasing digestibility and intake:

   a. Species and mixtures in pastures

   b. Establish principles to make plant breeding more objective

   c. Effect of grazing pressure on selectivity and intake

   d. First and last grazing technique, disclose animal outputs for species and season when 25 and 50 percent of herbage is consumed by first grazers.

4. Efficiency and use of nitrogen fertilization in animal-forage management systems.

5. Animal breeding to improve liveweight gains and carcass grades when grazing forages:

   a. Bull testing on forages

   b. Most efficient milk production level for cow herd

c. Most efficient animal size for production on forage

6. Feeding energy supplements:

   a. Improve the controlling of supplement intake

   b. Relate supplementation to grazing pressure for species and mixtures.

7. Development of management systems to provide continuous supplies of forage of potentially high intake and digestibility over the entire fattening period.

   a. Flexibility of management of species now used

   b. Potential use of species not now used in the region

8. Data should be obtained for computer programming in an integrated economic-biotic systems approach.

9. Develop the management concept of grazing pressure as related to nutrition as a tool for livestock producers to apply biological principles in the field.

   a. Easy determination of grazing pressure

   b. Timing rotational grazing on basis of grazing pressures

VI. Summary

This review summary gives principles for increasing intake and digestibility from herbaceous forages to improve liveweight gains and finishing of cattle without or with low grain supplements. Factors discussed are morphology and physiology as related to stages of growth or age, grass-legume mixtures as compared to nitrogen fertilized grasses, tropical and temperate grasses, grazing pressure, and methods of grazing. All of these principles are fundamental for planning and managing forage-animal systems.

Animal-forage systems of management must provide continuously high nutrition for finishing cattle. A problem with all herbaceous forages is inadequate TDN ingestion caused by digestibility and intake or both, thereby depressing animal gains, efficiency of forage conversion, and lengthening production cycles. Supplementing of energy concentrates increases liveweight gains and biological efficiency of production. However, economics may make this unprofitable.

Low grazing pressures on pastures allow high selectivity (intake and digestibility) and thereby high rates of animal gains at the expense of good forage utilization. A proper economic compromise between animal gains/head and production per hectare must be made for the finishing enterprise; however, a first grazer technique allows high

selectivity and gains/head; cows serve as second grazers to consume residues.

Adapted species must be used alone or flexibly in a grazing sequence to have high quality forage over long seasons to supply needed nutrition of animals. Management for high yields makes possible higher stocking rates without increasing grazing pressure.

It is especially important to use desirable legumes since they increase liveweight gains and the efficiency of forage utilization as well as economy of production. Winter annual grasses and legumes are best for finishing cattle, many tropical perennial grasses generally being least desirable. The temperate perennial grasses give best liveweight gains during the cool spring season. Tropical annual grasses managed to maintain leafiness are similar in quality to temperate perennial grasses.

Animal-forage management systems are proposed for finishing cattle with and without grain supplements for various regions in the Southeast and for marketing fat cattle during various months of the year to provide needed meat supplies.

It is suggested that goals for finishing animals be set forth and that forage systems be planned to achieve the production goals through the concurrent management of animals and forages. We have listed some research needs.

LITERATURE CITED

1. Akin, D. E., H. E. Amos, F. E. Barton and D. Burdick. 1973. Rumen microbial degradation of grass tissue revealed by scanning electron microscopy. Agron. J. 65:825-828.

2. Akin, D. E. and Donald Burdick. 1973. Micro anatomical differences of warm season grasses revealed by light and electron microscopy. Agron. J. 65:533-537.

3. Anthony, W. B. 1954. Annual Report. Auburn University, Auburn, Alabama.

4. Anthony, W. B. 1958. Annual Report. Auburn University, Auburn, Alabama.

5. Anthony, W. B., C. S. Hoveland, G. L. Mayton and H. G. Burgess. 1971. Rye-ryegrass-Yuchi arrowleaf clover for production of slaughter cattle. Agric. Exp. Sta., Auburn University Circular 182, 13 pp.

6. Baker, K. G. and E. L. Mayton. 1944. A year-round grazing program for the alkaline soils of the blackbelt of Alabama. J. Amer. Soc. of Agron. 36:740-748.

7. Becker, R. B., W. M. Neal and A. L. Shealy. 1933a. Effect of calcium-deficient roughages upon milk production and welfare of dairy cows. Fla. Agric. Exp. Sta. Bull. 262.

8. Becker, R. B., W. M. Neal and A. L. Shealy. 1933b. Stiffs or sweeny (phosphorus deficiency) in cattle. Fla. Agric. Exp. Sta. Bull. 264.

9. Blaser, R. E. 1964. Symposium on forage utilization: Effects of fertility levels and stage of maturity on forage nutritive value. J. Ani. Sci., pp. 243-253.

10. Blaser, R. E., R. H. Brown and H. T. Bryant. 1966. The relationship between carbohydrate accumulation and growth of grasses under different microclimates. Proc. of X Internat. Grassld. Cong., Printed in Finland.

11. Blaser, R. E., H. T. Bryant, R. C. Hammes, Jr., R. L. Boman, J. P. Fontenot and C. E. Polan. 1969. Managing forages for animal production. VPI and SU Res. Bull. 45.

12. Blaser, R. E., R. S. Glasscock, G. B. Killinger and W. E. Stokes. 1948. Carpetgrass and legume pastures in Florida. Univ. of Fla. Agric. Exp. Sta. Bull. 453, 36 pp.

13. Blaser, R. E., R. C. Hammes, Jr., H. T. Bryant, W. A. Hardison, J. P. Fontenot and R. W. Engel. 1960. The effect of selective grazing on animal output. Proc. of 8th Internat. Grassld. Cong., Printed in Great Britain, pp. 601-606.

14. Blaser, R. E., R. C. Hammes, Jr., H. T. Bryant, C. M. Kincaid, W. A. Skrdla, T. H. Taylor and W. L. Griffeth. 1956. The value of forage species and mixtures for fattening steers. Agron. J. 48: 508-516.

15. Blaser, R. E., E. Jahn and R. C. Hammes, Jr. 1974. Systems analyses of forages in forage production and utilization: Evaluation of forage and animal research. Amer. Soc. of Agron. Spec. Pub. No. 6, pp. 1-26.

16. Blaser, R. E., G. E. Ritchey, W. G. Kirk and P. T. Dix Arnold. 1955. Experiments with Napier grass. Univ. of Fla. Agric. Exp. Sta. Bull. 568, 32 pp.

17. Blaser, R. E., D. D. Wolf and H. T. Bryant. 1973. Systems of grazing management. Forages.Iowa State Univ. Press, Chapter 53.

18. Blaxter, K. L., F. W. Wainman and R. S. Wilson. 1961. The regulation of food intake by sheep. Ani. Prod. 3:51.

19. Brown, R. H. and R. E. Blaser. 1965. Relationships between reserve carbohydrate accumulation and growth rate in orchardgrass and tall fescue. Crop Sci. 5:577-582.

20. Brown, R. H. and R. E. Blaser. 1970. Soil moisture and temperature effects on growth and soluble carbohydrates of orchardgrass (Dactylis glomerata). Crop Sci. 10:213-216.

21. Brown, R. H., R. E. Blaser and H. L. Dunton. 1966. Leaf-area index and apparent photosynthesis under various microclimates for different pasture species. Proc. 10th Internat. Grassld. Cong., pp. 108-113.

22. Brown, R. H., R. E. Blaser and J. P. Fontenot. 1963. Digestibility of fall grown Ky 31 fescue. Agron. J. 55:321-324.

23. Brown, R. H., R. E. Blaser and J. P. Fontenot. 1968. The effect of spring harvest dates on nutritive value of orchardgrass and timothy. J. Ani. Sci. 27:562-567.

24. Burns, J. C., L. Good, H. D. Gross and A. C. Linnerud. 1973. Cow and calf gains on Ladino clover-tall fescue and tall fescue grazed alone and with Coastal bermudagrass. Agron. J. 65:877-880.

25. Burns, J. C., H. D. Gross, W. B. Gilbert, R. W. Harvey, M. W. Wise, D. F. Tugman and J. W. Bentley. 1970. Pastures and grazing systems in the mountains of North Carolina. N. C. State Univ. Agric. Exp. Sta. Bull. 437, 49 pp.

26. Burns, J. C., R. D. Mochrie and W. A. Cope. 1972. Responses of dairy heifers to crownvetch, sericea lespedeza, and alfalfa forages. Agron. J. 64:193-195.

27. Burton, G. W., J. E. Jackson and F. E. Knox. 1959. The influence of light reduction upon the production, persistence, and chemical composition of Coastal bermudagrass, Cynodon dactylon. Agron. J. 51:537.

28. Burton, G. W., W. G. Monson, J. C. Johnson, Jr., R. S. Lowrey, H. D. Chapman and W. H. Marchant. 1969. Effect of the d_2 dwarf gene on the forage yield and quality of pearl millet. Agron. J. 61:607-612.

29. Burton, Glenn W., S. A. Parham, B. L. Southwell and J. L. Stephens. 1952. Winter grazing in Georgia Coastal Plains. Univ. of Ga. College of Agric. Exp. Sta. Bull. 47, 41 pp.

30. Bush, L. P., J. A. Boling, G. Allen and R. C. Buckner. 1972. Inhibitory effects of perloline to rumen fermentation in vitro. Crop. Sci. 12:277-279.

31. Bush, L. P. and R. C. Buckner. 1973. Tall fescue toxicity. Chapter 5 of Anti-quality components of forages. CSSA Spec. Pub., A. G. Matches, Editor.

32. Chapman, Hollis D., W. H. Marchant, P. R. Utley, R. E. Hellwig and W. G. Monson. 1972. Performance of steers on Pensacola

bahiagrass, Coastal bermudagrass and Coastcross-1 bermudagrass pastures and pellets. J. Ani. Sci. 34:373-378.

33. Chenost, M. 1966. Fibrousness of forage, its determination and its relation to feeding value. Proc. 10th Internat. Grassld. Cong., p. 406.

34. Christian, K. R., D. B. Jones and M. Freer. 1970. Digestibility and chemical composition of fractions of lucerne during spring and summer. J. of Agric. Sci. 75:213-222.

35. Coffindaffer, B. L. and O. J. Burger. 1958. Response of alfalfa varieties to day length. Agron. J. 50:389-392.

36. Coleman, Samuel W. and Karl M. Barth. 1973. Quality of diets selected by grazing animals and its relation to quality of available forage and species composition of pastures. J. Ani. Sci. 36(4):754-761.

37. Crampton, E. W. 1957. Interrelations between digestible nutrient and energy content, voluntary dry matter intake, and overall feeding value of forages. J. Ani. Sci. 16:564.

38. Crookston, R. K. and D. M. Moss. 1974. Interveinal distance for carbohydrate transport in leaves of C_3 and C_4 grasses. Crop Sci. 14:123-125.

39. Cummins, D. G. and J. W. Dobson, Jr. 1972. Digestibility of bloom and bloomless sorghum leaves as determined by a modified in vitro technique. Agron. J. 64:682-683.

40. Davis, G. K. 1950. Symposium on copper metabolism (W. D. McElroy and B. Glass, ed.). Johns Hopkins Press, Baltimore, Maryland.

41. Deinum, B. and J. G. P. Driven. 1974. Climate, nitrogen, and grass: VI. Comparison of yield and chemical composition of some temperate and tropical grass species grown at different temperatures. Neth. J. Agric. Sci. 23:69-82.

42. Donnelly, E. D. and W. B. Anthony. 1970. Effect of genotype and tannin on dry matter digestibility in sericea lespedeza. Crop Sci. 10:200-203.

43. Donnelly, E. D. and W. B. Anthony. 1973. The relationships with sericea lespedeza leaf and stem tannin to forage quality. Agron. J. 65:993-994.

44. Duble, R. L., J. A. Lancaster and E. C. Holt. 1971. Forage characteristics limiting animal performance on warm season perennial grasses. Agron. J. 63:795-798.

45. Eheart, James F. and Avery D. Pratt. 1942. The digestibility and utilization by dairy cows of nutrients from fertilized and unfertilized bluegrass pasture. Va. Agric. Exp. Sta. Bull. 81.

46. Fontenot, J. P. and R. E. Blaser. 1965. Symposium on factors influencing the voluntary intake of herbage by ruminants: Selection and intake by grazing animals. J. Ani. Sci. 24:1202-1208.

47. Fuess, Frederick W. and Milo B. Tesar. 1968. Photosynthetic efficiency, yields, and leaf loss in alfalfa. Crop. Sci. 8:159-163.

48. Gallaher, R. N., D. A. Ashley and R. H. Brown. 1975. ^{14}C photosynthate translocation in C_3 and C_4 plants as related to leaf anatomy. Crop Sci. 15:55-59.

49. Gardner, F. P. and W. E. Loomis. 1953. Floral induction and development in orchardgrass. Plant Phys. 28:201-217.

50. Haines, C. E., H. L. Chapman, Jr., R. W. Kidder, and R. E. L. Greene. 1965. Effects of feeding limited amounts of concentrate to stocker steers on pasture. Univ. of Fla. Agric. Exp. Sta. Bull. 693, 17 pp.

51. Hammes, R. C., Jr., R. E. Blaser, H. T. Bryant and R. W. Engel. 1962. Palatability and digestiblity of Coastal bermudagrass and alfalfa hays. VPI Res. Bull. 533.

52. Hanna, W. W., W. G. Monson and G. W. Burton. 1973. Histological examination of fresh forage leaves after in vitro digestion. Crop Sci. 13:98-102.

53. Hanna, W. W., W. G. Monson and G. W. Burton. 1974. Leaf surface effects on IVD and transpiration in isogenic lines of sorghum and pearl millet. Crop Sci. 14:837-838.

54. Hardison, W. A., W. N. Linkous and C. Y. Ward. 1957. Digestibility of the top and bottom portions of the alfalfa plant, as estimated from small, randomly collected samples of feces. J. Dai. Sci. 40:768-773.

55. Hardison, W. A., J. T. Reid, C. M. Martin and P. G. Woolfolk. 1954. Degree of herbage selections by grazing cattle. J. Dai. Sci. 37:89-102.

56. Hardison, W. A., C. Y. Ward and R. E. Blaser. 1957. Unpublished data. VPI and SU.

57. Harris, R. R., W. B. Anthony, V. L. Brown, J. K. Boseck, H. F. Yates, W. B. Webster and J. E. Barrett, Jr. 1971. Cool season annual grazing crops for stocker calves. Agric. Exp. Sta., Auburn Univ. Bull. 416.

58. Harris, R. R., E. M. Evans, J. K. Boseck and W. B. Webster. 1972. Fescue, orchardgrass and Coastal bermudagrass grazing for yearling beef steers. Agric. Exp. Sta., Auburn Univ. Bull. 432.

59. High, Joe W., Jr., L. M. Safley, O. H. Long, H. R. Duncan and T. W. High, Jr. 1965. Combinations of orchardgrass, fescue, and Ladino clover pastures for producing yearling steers. Univ. of Tenn. Agric. Exp. Sta. Bull. 388, 26 pp.

60. High, T. W., Jr., D. J. Chapman, B. L. Whittenberg and J. W. High, Jr. 1965. Fescue pastures under different management systems and orchardgrass-clover for yearling slaughter steer production. Univ. of Tenn. Agric. Exp. Sta. Bull. 385, 19 pp.

61. High, T. W., Jr., H. R. Duncan, H. J. Felts and J. W. High, Jr. 1966. Producing yearling steers on irrigated bluegrass-clover and orchardgrass-clover pastures. Univ. of Tenn. Agric. Exp. Sta. Bull. 387.

62. Hobbs, C. S., J. W. High, Jr. and Ira Dyer, Jr. 1965. Orchardgrass and fescue pastures for producing yearling slaughter steers. Univ. of Tenn. Agric. Exp. Sta. Bull. 386, 22 pp.

63. Hoveland, C. S., R. R. Harris, J. K. Boseck and W. B. Webster. 1971. Supplementation of steers grazing sorghum-sudan pasture. Auburn Univ. Agric. Exp. Sta. Cir. 188, 8 pp.

64. Jones, R. J. 1974. The relation of animal and pasture production to stocking rate on legume based and nitrogen fertilized subtropical pastures. Proc. of Australian Sci. of Ani. Prod. 10:340-343.

65. Joyce, J. P. and L. F. C. Brunswick. 1973. Nutritive value of lucerne for land. Proc. Ruakura Farmer's Conf., pp. 13-20.

66. Jutras, N. W., B. C. Morton, R. L. Edwards and J. W. Hubbard. 1975. Grazing systems for growth of replacement beef heifers in the Southern Piedmont. Submitted to Agron. J.

67. Kincaid, C. M., R. C. Carter, J. S. Copenhaver, F. S. McClaugherty, J. H. Lillard, J. Nick Jones, J. E. Moody and R. E. Blaser. 1960. Supplemental irrigation of permanent pastures for beef cattle. VPI Res. Bull. 513.

68. Kinciad, C. M., R. E. Hunt and G. W. Litton. 1958. Age, winter gain, and grazing methods as factors in fat steer production from pasture. Va. Agric. Exp. Sta., VPI Tech. Bull. 135, 22 pp.

69. Loredo, M. A. and D. J. Minson. 1973. The voluntary intake, digestibility, and retention time of leaf and stem fractions of 5 grasses. Aust. J. Agric. Res. 24:875-888.

70. Lowrey, R. S., G. W. Burton, J. C. Johnson, Jr., W. H. Marchant, and W. C. McCormick. 1968. In vivo studies with Coastcross-1 and other bermudas. Univ. of Ga. College of Agric. Exp. Sta. Res. Bull. 55, 22 pp.

71. Marten, G. C. 1973. Alkaloids and Reed canarygrass. Chapter 2 of Antiquality components of forages. CSSA Spec. Pub.

72. Matches, A. G., W. F. Wedin, G. C. Marten, Dale Smith and B. R. Baumgardt. 1973. Forage quality of Vernal DuPuits alfalfa harvested by calendar dates and plant maturity schedules in Missouri, Iowa, Wisconsin and Minnesota. Univ. of Wis. Res. Rep. 73, 20 pp.

73. McCartor, M. M. and F. M. Rouquette, Jr. 1975. Pearl millet: I. Effect of grazing pressure on performance and economy of weaning beef cattle (in press).

74. McClaugherty, F. S. and R. C. Carter. 1961. Producing yearling slaughter steers from pasture. Va. Agric. Exp. Sta. Bull. 531, 25 pp.

75. McClaugherty, F. S., J. P. Fontenot, R. F. Kelly, M. B. Wise, and R. C. Carter. 1975. Systems of fattening cattle in southwest Virginia, VPI and SU Res. Div. Rep. 163:18-22.

76. McMeekan, C. P. 1953. The utilization of grassland. New Zealand Sci. Rev. 11:115-121.

77. Minson, D. J. and R. Milford. 1966. The energy values and nutritive value indices of Digitaria decumbens, Sorghum alum, and Phaseolus atropurpureus. Aust. J. Agric. Res. 17:411-423.

78. Minson, D. J., W. F. Raymond and C. E. Harris. 1960. Studies in digestibility of herbage: VIII. The digestibility of S-37 cocksfoot, S-23 ryegrass and S-24 ryegrass. J. British Grassld. Soc. 15:1974.

79. Mitchell, E. 1973. Relations between fiber and water soluble carbohydrate content of pasture species and digestibility and voluntary intake by sheep. Aust. J. of Exp. Agric. and Ani. Husbandry. 13:165-170.

80. Moore, John E. and Gerald O. Mott. 1973. Structural inhibitors of quality in tropical grasses. Reprinted from A. G. Matches (Ed.). Antiquality components of forages, pp. 53-98. CSSA Special Pub. 4, Crop Sci. Soc. of Amer., Madison, Wisconsin 53711.

81. Mott, G. O. 1960. Grazing pressure and the measurement of pasture production. Proc. 8th Internat. Grassld. Cong., pp. 606-611.

82. Mott, G. O. 1973. Evaluation of forage production. Forages. Iowa State Univ. Press, Chapter 12.

83. N. R. C. 1970. Nutrient requirements of domestic animals, No. 4. Nutrient requirements of beef cattle. National Academy of Sciences, Washington, D. C.

84. Nears, P. T. and L. R. Humphreys. 1974. Nitrogen response and stocking rate of Pennisetum clandestinum pastures. J. Agric. Sci., Camb. 83:469-478.

85. Patterson, R. M., W. B. Anthony and V. L. Brown. 1959. Pasture know-how from winter grazing trials. Highlights of Agric. Res. Published by Agric. Exp. Sta. of the Ala. Poly. Inst., Auburn, Ala. 6(3).

86. Patterson, R. M., W. B. Anthony and V. L. Brown. 1961. Summer pastures for grazing steers. Highlights of Agric. Res. Published by Agric. Exp. Sta. of Auburn Univ., Auburn, Ala. 8(1).

87. Peterson, Maurice L. and W. E. Loomis. 1948. Effects of photoperiod and temperature on growth and flowering of Kentucky bluegrass. Plant Phys. 24:31-43.

88. Prates, E. R., H. L. Chapman, Jr., E. M. Hodges and J. E. Moore. 1974. Animal performance by steers grazing Pensacola bahiagrass pasture in relation to forage production, forage composition and estimated intake. Proc. Soil and Crop Sci. Soc. Fla. (in press).

89. Quinn, L. R., G. O. Mott, W. B. A. Bisschoff and G. L. daRocha. 1962. Beef production of six tropical grasses. Bolgtim Da Induscria Animal DDA, 35 pp.

90. Raymond, W. F. 1969. The nutritive value of forage crops. Advances in Agron. 21:2-108.

91. Reid, J. T. 1959. Evaluation of energy in forage. Grassld. Pub. 53. Amer. Assn. Adv. of Sci., Washington, D. C., p. 213.

92. Reid, J. T., W. K. Kennedy, K. L. Turk, S. L. Slack, G. W. Trimberger and R. P. Murphy. 1959. Symposium on forage evaluation: I. What is forage quality from an animal standpoint? Agron. J. 51:213.

93. Reid, R. L. and G. A. Jung. 1965. Influence of fertilizer treatment on the intake, digestibility, and palatability of tall fescue hay. J. Ani. Sci. 24:615-625.

94. Reid, R. L., G. A. Jung and S. Murray. 1964. The measurement of nutritive quality in a bluegrass pasture using in vivo and in vitro techniques. J. Ani. Sci. 23:700-710.

95. Reid, R. L., G. A. Jung and S. J. Murray. 1966. Nitrogen fertilization in relation to the palatability and nutritive value of orchardgrass. J. Ani. Sci. 25:636-645.

96. Reid, R. L., G. A. Jung, J. Roemig and R. E. Kocher. 1975. Magnesium utilization by growing lambs fed magnesium fertilized grass and legume hays. Agron. Abst. 109.

97. Riewe, Marvin E. 1969. The relationship of amount of available forage to gain per animal and gain per hectare. Agron. Abst. 45.

98. Rivadeneira, H. and F. Morel. 1974. Istensidad de pastoreo en alfalfa con novillos (Grazing intensity in alfalfa with steers). Asociacion Latino-Americana de Produccion Animal, pp. 136-137.

99. Roe, R. and B. E. Mottershead. 1962. Palatability of Phalaris crundinacea L. Nature. 193:255-256.

100. Spooner, A. E. and Maurice L. Ray. 1966. Steer gains on bermudagrass pastures in eastern Arkansas. Univ. of Ark. Agric. Exp. Sta. Rep. Ser. 150, 12 pp.

101. Spooner, A. E. and Maurice L. Ray. 1969. Pasture fertilization and grazing management studies in southwest Arkansas. Univ. of Ark. Agric. Exp. Sta. Bull. 741, 22 pp.

102. Staff of the Cunningham Laboratory, C.S.I.R.O. 1964. Commonwealth Bureau of Pasture and Field Crop, Hurley, Berkshire, Bull. 47.

103. Stobbs, T. H. 1973a. The effect of plant structure on the intake with tropical pastures: I. Variation of the bite size of grazing cattle. Aust. J. Agric. Res. 24:808-819.

104. Stobbs, T. H. 1973b. The effect of plant structure on the intake of tropical pastures: II. Differences in sward structure, nutritive value, and bite size of animals grazing Setaria anceps and Chloris gayana at various stages of growth. Aust. J. Agric. Res. 24:821-829.

105. Sullivan, J. T. and V. G. Sprague. 1943. Composition of the roots and stubble of perennial ryegrass following partial defoliation. Plant Phys. 18:656-670.

106. Thornton, R. F. and D. J. Minson. 1973. The relationship between apparent retention time in the rumen, voluntary intake, and apparent digestibility of legume and grass diets in sheep. Aust. J. Agric. Res. 24:889-898.

107. Troelsen, J. E. and F. W. Bigsby. 1964. Artificial mastication--a new approach for predicting voluntary forage consumption by ruminants. J. Ani. Sci. 23:1139-1147.

108. Van Keuren, R. W. 1970. Symposium on pasture methods for maximum production in beef cattle: Pasture methods for maximum beef production in Ohio. J. Ani. Sci. 30:138-142.

109. Van Keuren, R. W. and W. W. Heinemann. 1958. A comparison of grass-legume mixtures and grass under irrigation as pastures for yearling steers. Agron. J. 50:85-88.

110. Van Keuren, R. W. and W. W. Heinemann. 1962. Study of a nylon bag technique for in vivo estimation of forage digestibility. J. Ani. Sci. 21:340.

111. Van Soest, P. J. 1965. Symposium of factors influencing the voluntary intake of herbage by ruminants: Voluntary intake in relation to chemical composition and digestibility. J. Ani. Sci. 24:834-843.

112. Van Soest, P. J. 1968. Structural and chemical characteristics which limit the nutritive value of forages. In Forage Economics-Quality. ASA Spec. Pub. No. 13, pp. 63-76.

113. Ward, W. W. and Vance Watson. 1970. Annual Report. Mississippi State Univ.

114. Weir, W. C., J. H. Meyer and G. P. Lofgreen. 1959. Symposium on forage evaluation: VI. The use of the esophageal fistula, lignin, and chromogen techniques for studying selective grazing and digestibility of range and pasture by sheep and cattle. Agron. J. 51:235-237.

115. Wheeler, J. L., J. C. Burns, R. D. Mochrie and H. R. Gross. 1973. The choice of fixed or variable stocking rates in grazing experiments. Exp. Agric. 9:289-302.

116. Wilson, J. R. and C. W. Ford. 1973. Temperature influences on the in vitro digestibility and soluble carbohydrate accumulation of tropical and temperate grasses. Aust. J. Agric. Res. 24:187-198.

117. Wing, J. M. 1965. Production, voluntary consumption and digestibility of forages when used as feeds for dairy cattle in Florida. Univ. of Fla. Exp. Sta. Bull. 688, 14 pp.

118. Wise, M. B., E. R. Barrick and T. N. Blumer. 1967. Finishing steers with grain on pasture. N. C. State Univ. Agric. Exp. Sta. Bull. 425.

DISCUSSION

FUNDAMENTAL ASPECTS OF FORAGE AND BEEF PRODUCTION*

Discussion of paper by:
R. E. Blaser, W. C. Stringer, E. B. Rayburn,
J. P. Fontenot, R. C. Hammes, Jr., and H. T. Bryant

MODERATOR: R. R. Johnson, University of Tennessee

QUESTION: Carl S. Hoveland, Auburn University. From the standpoint of economics, what is your opinion of tying up land for a relatively short period for growing pearl millet?

ANSWER: Roy E. Blaser, Virginia Polytechnic Institute and State University. It would be most practical to grow corn if adapted, grain sorghums being next in priority. Yield potentials and value of pearl millet are low as compared to the other crops.

QUESTION: R. W. Harvey, North Carolina State University. Have you made an economic evaluation of your system where steers graze the higher quality forage and cows the lower quality forage (i.e., first and second grazers) versus the program of steers in drylot on grain and cows on pasture?

ANSWER: Roy E. Blaser, Virginia. We do not have economic evaluations on this; such a system of management is now being initiated and economic data will become available as results are obtained during a three-year period.

QUESTION: H. L. Lucas, North Carolina State University. In your grazing studies, which of the infinite number of systems are you going to use?

ANSWER: Roy E. Blaser, Virginia. We do not have an infinite number of systems; there are only eleven. The design of the experiments will give good nutritional and economic information on the performance of the animal but there is no measure of the reliability of the output per acre. It appears that the systems with stockpiled fescue and red clover during the summer will eliminate themselves because of inferior animal performance as compared with other systems. Stockpiled fescue

*Technical difficulties resulted in incomplete recording of the discussion session following the paper presented by Roy E. Blaser.

for winter grazing with bluegrass-white clover pastures are giving very satisfactory animal responses.

COMMENT: H. L. Lucas, North Carolina. Studying systems without a methodical approach will not yield data that can be extrapolated to variations of the specific systems used.

THE ROLE OF HARVESTED OR PROCESSED FORAGE IN BEEF FEEDING

M. E. McCullough*

The development of a stable, permanent and profitable forage-fed beef industry in the Southeast will necessitate the production of a year-round supply of slaughter cattle to insure markets, the provision of dependable feed supplies, and flexibility for producers to change feeding programs to meet changing economic conditions. These conditions must be met against a probable background of increasing land values, higher taxes and competition with other enterprises for land use. Within this situation, harvested forages offer several advantages for the development of either all stored forage feeding programs or programs designed to make maximum use of the several soil and topography conditions on a given farm.

From a nutritional point of view, stored forages offer several advantages:

1. A known quantity and quality of feed is available.
2. Based on known or predicted economic factors, decisions can be made relating cattle weight, rate of gain, and selling practices prior to the feeding season.
3. Maximum use of proven nutritional knowledge can be made to optimize feed utilization.

The antiquated procedure of attempting to evaluate forages by trying to set a quantity of beef or rate of gain that can be expected (so many pounds of beef per acre of corn silage) is no longer a useful system. We have advanced to the position that we must talk in terms of quantity and quality of forage when combined with other feedstuffs to provide balanced rations.

To realize the maximum benefit from stored forages, it would appear useful to review the major factors in forage utilization.

Feed Intake

Feed intake in ruminants has been reviewed by Jones (3) who concluded that "the primary determinant controlling intake of roughages

* Professor and Head, Animal Science Department, Georgia Station, Experiment 30212.

and feedstuffs, whose digestibility or energy level is less than 55-65 percent, or 2.5-3.0 kcal DE/g (digestible energy), would be digestion in the reticulorumen." Montgomery and Baumgardt (8) proposed a general relationship to describe feed intake regulation where intake of feed and, hence, energy are restricted by physical means for feeds of low nutritive value, and by chemical or thermal mechanisms for feeds of higher nutritive values. For rations containing maximum forage, the primary factors influencing intake probably are dry matter or energy digestibility and density of the feedstuffs. These two factors were combined by McCullough (5) into a single value by multiplying the density (volume per 100 g of feed) times the digestibility (TDN) of the feedstuff. The values are relative and illustrate the principle. Intake is maximized when feedstuffs (Figure 1) with high density values are combined with other feedstuffs having low density values. The data (Figure 1) indicate that intake would be maximized when rations contain grain to forage ratios between 40:60 and 60:40. It is important to recognize that individual feedstuffs must be considered and not vague classifications such as forages or grains or concentrates. This factor is illustrated by the data in Table 1. The data are from an intake trial with dairy-type heifers fed wheat and ryegrass silage with either ground corn or beet pulp at three forage to grain ratios. The rations containing corn or beet pulp at a silage to grain ratio of 80:20 permitted a significant increase in intake above silage alone. Increasing the ratio of corn to forage was without significant effects on intake but a silage to grain ratio of 40:60 with beet pulp lowered intake. The data clearly indicate an area for future research. Maximum intake cannot be predicted on the basis of current knowledge and available values for describing the inter-relationships between the physical densities of combinations of feedstuffs are inadequate for computer feed formulation.

Assuming the use of good nutritional judgment in ration formulation, the calculated average and maximum intake values prepared by Preston (9) and shown in Table 2, are adequate for most decision making in cattle feeding programs. These values assume an average intake of 95 g DM/Wkg$^{0.75}$ and a maximum of 105 g DM/kg$^{0.75}$.

Feedstuff Digestibility

Within forage production and feeding programs, the factor most under control of the producer is the digestibility of his harvested forage. In most forage crops, digestibility is a function of stage of maturity at harvest. The data in Figure 2 compare the intake of two varieties of alfalfa and four grass species, each harvested at six stages of growth. The research was reported by Trollsen and Campbell (10). In the regression equation $Y = a + b_1X + b_2X^2$, Y is intake and X is dry matter digestibility. The equation for the alfalfas (0-0) was $Y = -85.3 + 3.58X - 0.017Y2$ and for the grasses (0-0) it was $Y = 2.37 + 0.348X + 0.010X^2$. In general, the alfalfa was consumed somewhat better than the grasses at a given digestibility and other factors such as density are indicated for the standard deviations of Y from the regression lines of ± 7.3 for alfalfa and ± 8.5 for grass.

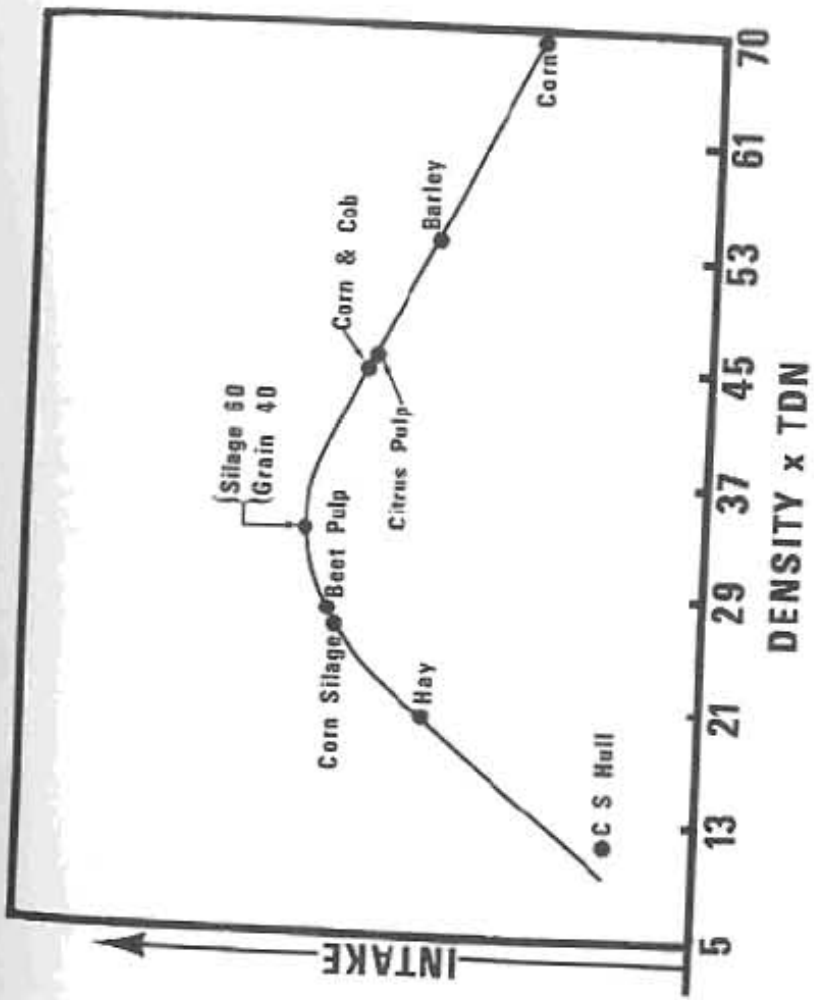


Figure 1. Influence of density x TDN on feed intake

Table 1. Influence of corn or beet pulp and ratio of silage to grain on dry matter intake (5)

Ration	Weight of animals (kg)	($W_{kg}^{.75}$)	Dry matter intake (g/kg)	($gW_{kg}^{.75}$)
Silage alone	254	56	2.34	106[a]
80% silage + 20% corn	253	56	28.3	128[b]
60% silage + 40% corn	254	56	28.4	129[b]
40% silage + 60% corn	254	56	28.0	127[b]
80% silage + 20% beet pulp	258	58	27.8	124[b]
60% silage + 40% beet pulp	258	58	27.8	124[b]
40% silage + 60% beet pulp	258	58	25.2	113[a]

[a,b]Means with different letters are significantly different ($P < .01$) (Duncan's test).

Table 2. Estimated average and maximum levels of dry matter intake (9)

Body weight	$W^{0.75}$	Air-dry feed	
		Avg[a]	Max[b]
kg	kg	kg	kg
18.2	8.8	0.93	1.01
27.2	11.9	1.26	1.37
36.3	14.8	1.56	1.70
45.4	17.5	1.85	2.01
68.0	23.7	2.20	2.72
90.8	29.7	3.13	3.40
136	39.8	4.20	4.57
182	49.6	5.23	5.68
227	58.5	6.17	6.71
272	67.0	7.07	7.68
318	75.3	7.95	8.64
363	83.2	8.78	9.54
410	91.0	9.61	10.4
454	98.4	10.4	11.3
499	105.6	11.1	12.1
545	112.8	11.9	12.9

[a]Based on 95 g DM intake/$W_{kg}^{0.75}$.

[b]Based on 103 g DM intake/$W_{kg}^{0.75}$.

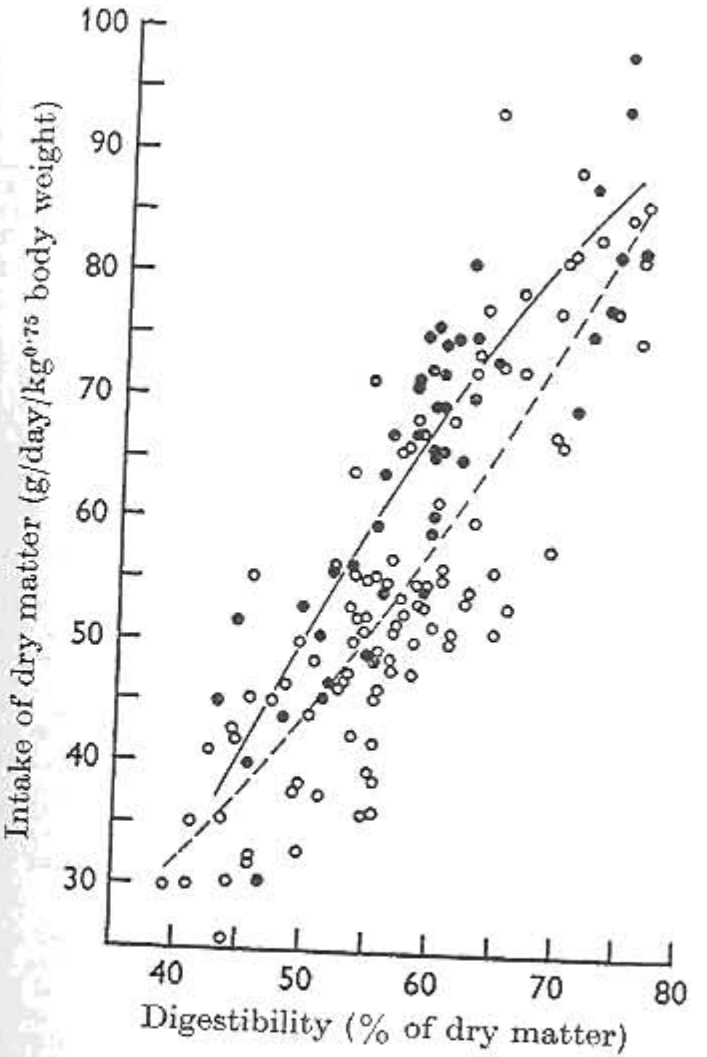


Figure 2. Relationship between forage dry matter digestibility and dry matter intake

The relationships between the dry matter digestibility of silage and average daily gains of dairy-type heifers are illustrated in Figure 3. The data are from work by the author at the Georgia Station.

The general influence of intake, digestibility and forage:grain ratio on animal performance can be seen in an experiment reported by Marsh (4) in Table 3. The grain portion of the ration was primarily barley, which has a relatively low density. Thus, increasing the ratio of grain to hay in the ration had little effect on the intake of dry matter. The relationships between hay to grain ratio and daily gain were typical of the known influences of ration on animal performance. An important point was the fact that the digestibility of the rations was essentially additive with no apparent associative effects. This general observation in response to changing ratios of forage and grain is of considerable importance in ration formulation.

Efficiency of Feed Utilization

Once rations have been formulated to provide a desired intake of energy and balanced for protein, minerals, etc., the next factor in animal performance is the effect of the ration on the efficiency of feed utilization. Since energy retention is the primary goal of cattle feeding, this factor can be considered in relation to forage-to-grain ratios and energy concentration of the ration. Greenhalgh (2) summarized data from energy retention trials with sheep fed on forage alone (Figure 4). Using 50 kg sheep with daily intakes of 3000 kcal ME (metabolizable energy), 1125 g digestible organic matter, and a fasting metabolism of 1100 kcal/day, the influence of concentration of energy on energy retention was calculated for several forages. The solid line is a prediction value based on the Agricultural Research Council system for evaluating feeds in terms of energy (1). The data clearly indicate the tendency for energy retention to fall as the ME concentration of the feed falls, even where the quantity of ME remains constant. The forages (represented by individual lines) exhibited considerable variation at the same concentration of energy. These variations are undoubtedly exaggerated by the feeding of forage alone. A primary improvement that would be expected from balancing rations for protein, minerals, etc., would be the reduction or elimination of such variations.

Similar data for cattle fed forage and grain in balanced rations were prepared by Preston in Figure 5 (9). The data illustrate the influence of weight of animals (maintenance requirements) and concentration of ration energy on the feed required for a unit of gain. The deviation from a linear response due to reduced intake at high levels of grain feeding is also apparent.

Predicting Animal Performance

Since a major nutritional advantage of harvested forage is the ability to prepare a variety of rations, it would be useful to know how well our current technology can be used to obtain a predicted response in animal performance. The data in Table 4 represent one

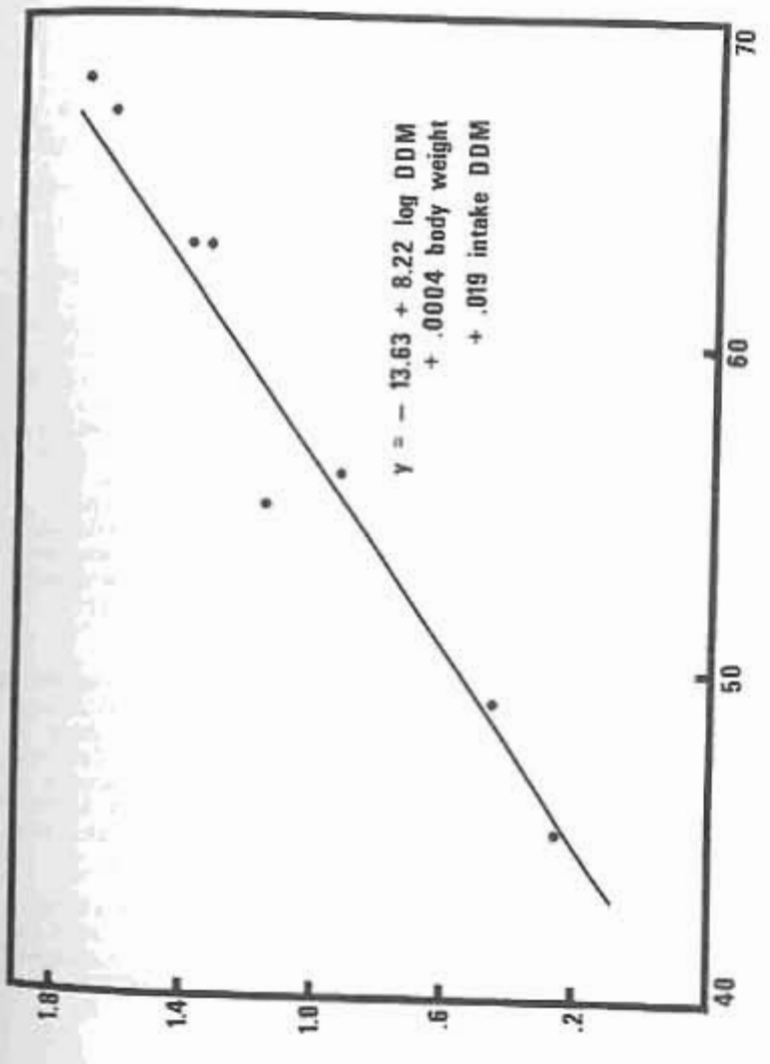


Figure 3. Relationships between body weight, silage digestibility, dry matter intake and average daily

Table 3. Influence of hay:grain ratio on dry matter intake and average daily gain (4)

Item	Hay:grain ratio				
	0:100	25:75	50:50	75:25	100:0
DM digestibility (percent)	76.7	71.3	66.7	62.0	55.1
DM intake (kg)	2.36	2.38	2.38	2.39	2.38
Daily gain (kg)	0.97	1.08	1.01	0.73	0.75

controlled experiment to compare actual animal performance to the performance predicted from American and British feeding standards (6). Corn silage was preserved with either formic acid or dried steep liquor concentrate (DSLC) to provide three feeding conditions with a similar silage. The rations were fed to weaned Hereford steers. Ration 1 consisted of 87 percent silage + 13 percent grain (dry matter basis), Ration 2 consisted of 60 percent silage + 40 percent grain and Ration 3, 33 percent silage and 67 percent grain. The rations were fed free choice. Total collection digestion trials were used to evaluate the diets. Average daily gains ranged from 0.52 kg to 1.15 kg. Within this range of production, the calculated requirements for metabolizable energy were quite close to the actual intake. The British system overestimated intake by 5 percent, while the American system underestimated intake by 2 percent. The two systems were obviously sufficiently accurate to permit feed programming with considerable precision.

As a result of this and other studies, the Georgia Feed Programming System was developed (7). The system combined forage testing with computer programming to formulate least-cost balanced rations for three rates of average daily gains within weight classes of cattle. In seven controlled feeding trials with a total of 369 head of cattle, actual daily gains varied from calculated daily gains from a minus .09 kg to a plus .15 kg. The actual variation may have been more representative of differences between cattle than errors in ration programming.

At our present state of technology it seems obvious that stored forages can be programmed to meet the level of performance dictated on individual farms within existing feed supplies and economic conditions. The data also permit some relative comparisons between forages that are produced in the Southeast.

Conclusions

Maximum use of harvested forages for forage fed beef involves such nutritional considerations as digestibility, density, efficiency of feed utilization and total ration balance. Outside of economic considerations which play a major role in deciding between grazing and

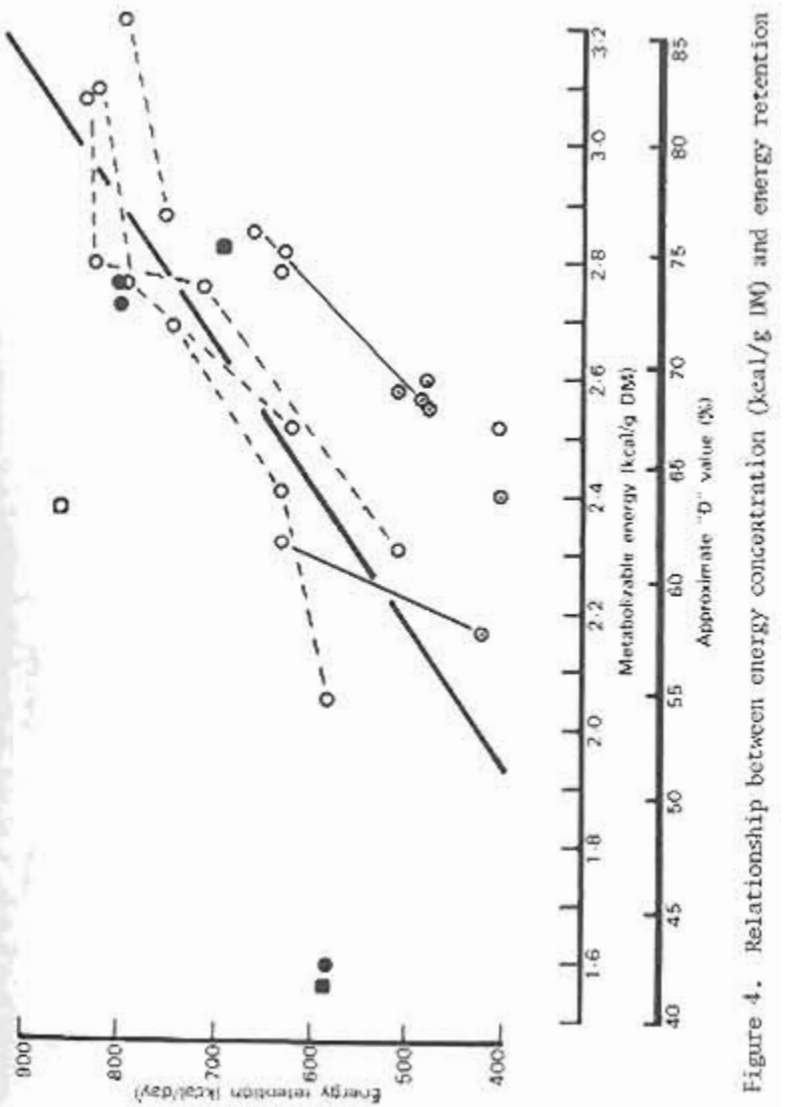


Figure 4. Relationship between energy concentration (kcal/g DM) and energy retention

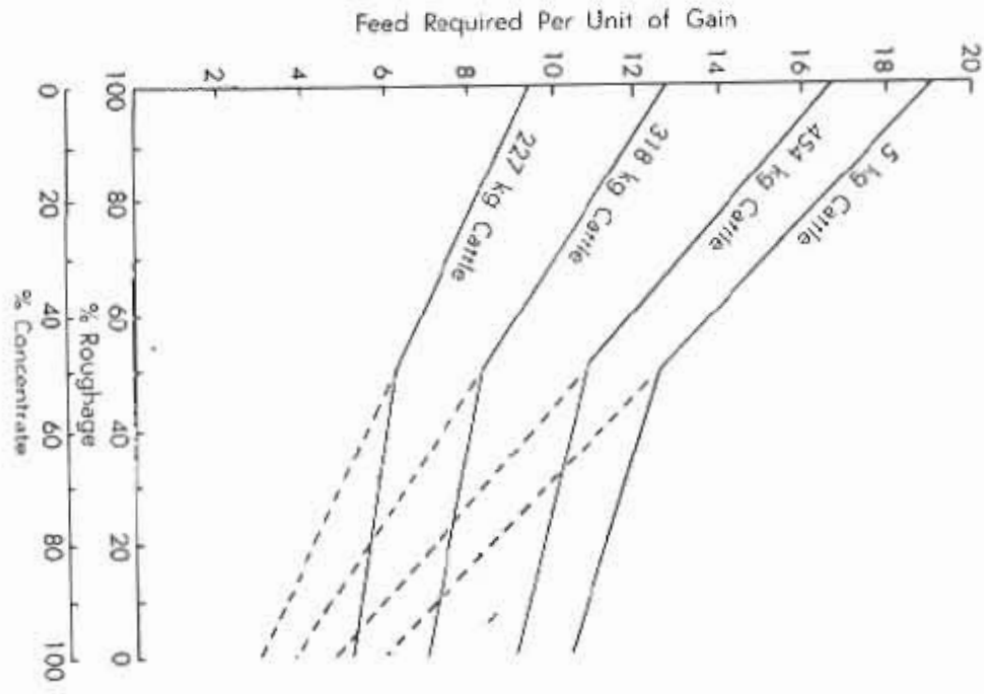


Figure 5. Influence of roughage to concentrate ratio and weight of cattle on feed required per unit of gain

Table 4. Influence of type of silage and ratio of silage to grain on animal performance

Silage	Ration	Mean body weight	Average daily gain	Intake of		Calculated daily requirement of ME	
				Dry matter	Metab. energy[a]	ARC[b]	NRC
		kg	kg	kg	Mcal	Mcal	Mcal
Control	1	231	0.52	6.0	11.9	12.3	12.5
	2	256	0.74	6.7	15.0	14.2	15.9
	3	293	1.08	7.6	18.3	18.1	18.6
	Mean	260	0.78	6.8	15.1	14.9	15.7
Formic acid	1	234	0.67	6.1	12.6	13.5	13.6
	2	258	0.76	6.7	16.2	14.0	16.1
	3	292	1.15	7.6	19.9	17.6	18.7
	Mean	261	0.86	6.8	16.2	15.0	16.1
USLC	1	247	0.66	6.4	13.6	13.7	14.4
	2	278	0.91	7.2	16.5	16.0	17.1
	3	318	1.07	8.2	20.7	17.7	19.4
	Mean	281	0.88	7.3	16.9	15.8	16.9

[a]Metabolizable energy of rations was determined at maintenance and corrected for level of intake by method of Blaxter in A.R.C. (1965).

[b]Calculated from standards of British Agricultural Research Council using the formula:

$$Y = 8.719 - 2.92X_1 + .026X_2 + 8.483X_3$$

where Y = intake of ME (Mcal); X_1 = ration concentration (Mcal/kg); X_2 = body weight (kg); and X_3 = daily gain (kg).

harvesting forage, it is apparent that the major advantage of harvested forages is the ability to establish feeding programs to maximize feed resources under existing farm conditions.

LITERATURE CITED

1. Agricultural Research Council. 1965. Nutrient requirements of farm livestoc. No. 2. Ruminants. H.M.S.O., London.

2. Greenhalgh, J. F. D. 1975. Factors limiting animal production from grazed pasture. J. British Grassland Soc. 30:153-159.

3. Jones, G. M. 1972. Chemical factors and their relation to feed intake regulation in ruminants: A review. Can. J. Anim. Sci. 52: 207-239.

4. Marsh, R. 1975. Intake and live-weight gain by British Friesian calves offered different ratios of dried grass and concentrates. Anim. Prod. 20:345-353.

5. McCullough, M. E. 1973. Optimum feeding of dairy animals. 2nd edition. Univ. of Georgia Press, Athens.

6. McCullough, M. E. 1972. Effects of formic acid and dried steep liquor concentrate on digestibility and steer growth from corn silage. J. Anim. Sci. 34:127-131.

7. McCullough, M. E. 1974. Feed programming for beef feeding. Ga. Agr. Res. 16:9-11.

8. Montgomery, M. J. and B. R. Baumgardt. 1965. Regulation of food intake in ruminants. 1. Pelleted rations varying in energy concentration. J. Dairy Sci. 48:569-574.

9. Preston, R. L. 1972. Nutritional implications in economy of gain of feedlot cattle. J. Anim. Sci. 35:153-159.

10. Trollsen, J. E. and J. B. Campbell. 1969. The effect of maturity and leafiness on the intake and digestibility of alfalfas and grasses fed to sheep. J. Agric. Sci. 73:145-154.

DISCUSSION

FUNDAMENTAL ASPECTS OF FORAGE AND BEEF PRODUCTION*

Discussion of paper by:
M. E. McCullough

MODERATOR: R. R. Johnson, University of Tennessee

QUESTION: Roy Blaser, Virginia Polytechnic Institute and State University. Have you attained the levels of digestible dry matter with small grain silages that you have for corn silage?

ANSWER: M. E. McCullough, University of Georgia. No. We can produc[illegible] small grain silages with 63 to 66 percent dry matter digestibility compared to 68 to 70 percent with corn. Small grain silages can be very useful, but they do not contain the high grain level of corn silage.

*Technical difficulties resulted in incomplete recording of the discussion session following the paper presented by M. E. McCullough.

CAPABILITIES OF VARIOUS PHYSIOGRAPHIC REGIONS

EXISTING AND POTENTIAL SYSTEMS OF FINISHING CATTLE ON FORAGES OR LIMITED GRAIN RATIONS IN THE UPPER SOUTH

A. E. Spooner and Maurice L. Ray*

The Upper South as it relates to this paper includes eastern Oklahoma, Arkansas, Kentucky, Tennessee, Virginia (except the Piedmont area) and the mountain areas of the adjoining states to the south. There are major differences in soil types in this area; however, a large part of the soils were derived from a limestone base. These soils provide adequate minerals, especially calcium, for good forage and livestock production. It is commonly known among livestock feeders that cattle produced in these mountain regions have excellent bone structure and feed-out extremely well. Most of the soils in the mountain areas are well drained internally and externally.

The Upper South is characterized by diverse climatic conditions. There are tremendous differences in the amount and distribution of rainfall among the different areas. The annual rainfall will range from around 76 cm in the western section of eastern Oklahoma to 130 cm in most of the other states. Most of the rainfall received in Oklahoma comes in the winter and early spring as contrasted to fall, winter, spring and early summer in the other areas. Winter low temperatures range from around 0° C in the lower part of the area to -20°C in the northern areas and summer high temperatures range around 40°C in the extreme western area to 35°C in the central and eastern areas. The length of growing season may vary as much as 30-45 days from the southern to northern boundaries of the Upper South.

The topography is extremely variable ranging from flat to steep in the Upper South. Much of this area is characterized by mountains and some of the land is too steep and rocky for successful use of farm equipment. This type of land can provide good forage production when the timber canopy is removed and the area seeded to tall fescue. The livestock farms in the Upper South are, in general, small, one-family operations. Most of these farms will range from 30 to 100 hectares in size. There are some large livestock operations, but these make up only a small percentage (estimated 5-7 percent) of the total farms and total hectares used for beef cattle production.

The Upper South has a number of available and potential systems of forage production that lend themselves to finishing beef cattle on

*Professors, Departments of Agronomy and Animal Science, respectively, University of Arkansas, Fayetteville, Arkansas 72701

forages. There are a number of forage species and mixtures of species that are relatively high in quality and may be grown to background and finish beef cattle. These species include both warm and cool season perennial and annual grasses and legumes.

There are basically two types of systems used to background and finish beef animals in this area. The first is accomplished by the use of high quality forages without grain, and the second uses varying lengths of time in which grain is fed to obtain the finish desired for slaughter. The annual species of grasses and legumes are used more throughout the Upper South for the production of slaughter beef animals without the feeding of grain. The cereal grains (oats, rye and wheat) plus ryegrass and one of the annual legumes (arrowleaf clover or crimson clover) are grazed in the late fall through the spring in areas other than Kentucky and Virginia with the expectations of going to slaughter in June. These animals are not fed grain and are usually marketed weighing around 450 kg.

Perennial species (tall fescue, orchardgrass, bromegrass, and bluegrass) are used to a great extent where grain is to be fed near the end of the producing period in the summer. Bermudagrass may be used if summer feeding is desired. Legumes (alfalfa, white clover and red clover) are seeded with the grasses to provide higher quality forage and to decrease the amount of grain needed to finish the animal for slaughter. These animals are usually marketed at a heavier weight (around 500 kg) than the ones marketed from forage without grain.

Research Data

Research data are limited on the finishing of beef animals on various forages in the Upper South. The following review of this work is a summary of the research data available in this area and is presented to show the type of work done and results obtained.

In a three-year study in Oklahoma, Elder (2) found that increased fertilizer level increased the average daily stocking rate (1.75 to 2.25/ha) and steer gains, from 259 to 323 kg per hectare on small grains (Table 1). The average daily gain was not significantly affected. In another study, Elder (2) measured the effect of grain vs. no grain on small grain pastures with steers weighing around 204 kg at the start of the grazing period and grazed for 150 days (Table 2). The steers consumed an average of 2.5 kg of grain daily and gained 0.14 kg daily more than the steers not fed grain. There was approximately 20 percent greater carrying capacity where grain was fed and an increase of 147 kg/ha in gains over the 150-day period.

Feeding of grain free choice for approximately 100 days on bermudagrass and white clover pasture in Arkansas was studied by Spooner and Ray (4). The data are given in Table 3. Two fertilizer levels were used. No differences were obtained in average daily gain, grain fed per steer and grain fed per kg of gain. The increased fertilizer rate significantly increased the carrying capacity (7.41 to 12.35 steers/ha)

Table 1. Performance of steers on winter small grain pasture, averaged over three years, Muskogee, Oklahoma, 1963-65

	Fertilizer levels	
	20-40-20 kg/ha	100-40-20 kg/ha
Average daily stocking rate/ha	1.75	2.25
Average daily gain, kg	0.68	0.70
Steer gains/ha,kg	259	323

Source: Elder, 1967 (2).

Table 2. Performance of steers on winter small grain pasture, with and without grain,[a] averaged over three years, Muskogee, Oklahoma, 1963-65

	Pasture no grain	Pasture grain
Average grain consumed daily, kg	0	2.5
Steer days/ha	459	556
Average daily gain, kg	0.63	0.77
Steer gains/ha,kg	288	435

Source: Elder, 1967 (2).

[a]Steers averaged approximately 204 kg at start of grazing in November.

Table 3. Performance of steers on bermudagrass-white clover pasture with a full feed of grain for approximately 100 days, averaged over three years and 3 replications, Mariana, Arkansas, 1965-67

	Fertilizer rate	
	112-67-67 kg/ha	224-134-134 kg/ha
Steers/ha	7.41	12.35
Average daily gain, kg	1.09	1.07
Steer gains/ha, kg	818	1353
Grain fed/steer, kg	898	887
Grain fed/kg of gain, kg	8.07	8.05

Source: Spooner and Ray, 1972 (4).

and the steer gains per hectare (818 to 1353 kg/ha). Following this study, Spooner and Ray (4) conducted an experiment where three levels of grain were fed to beef steers on bermudagrass and white clover pasture (Table 4). This test was 84 days in length with grain intake limited for the first 42 days for two of the groups while the third group received a full feed of grain. All three groups received a full feed of grain for the second 42 days. Average daily gains increased as amounts of grain were increased by increasing the grain fed from 2.27 kg. to 4.54 kg during the first 42-day period, but there was no significant difference in the 4.54 kg and full-feed treatments. The amount of grain required to produce a kg of gain increased from 5.50 to 7.13 kg as the level of grain feeding was increased.

Spooner and Ray (4) compared performance of steers over a five-year period when fed in the dry lot compared to feeding on tall fescue and white clover pasture (Table 5). The length of feeding period averaged 66 days. There were no significant differences in the rate of gain, total gain per steer or carcass grade for the two systems. The steers fed on pasture consumed less grain per day than those fed in dry lot (9.2 vs. 10.0 kg). These data support the fact that steers can be fed on pasture and gain equally as well as steers fed in dry lot.

Different combinations of orchardgrass, tall fescue and ladino clover were evaluated for backgrounding and finishing beef animals in Tennessee by High et al. (3). The orchardgrass and ladino clover combination produced the highest daily gain (Table 6). All combinations containing fescue were lower in daily gains. Average final grades were higher for the steers that were grazed on orchardgrass pastures. It should be noted that none of these steers reached an acceptable

Table 4. Performance of steers on bermudagrass-white clover pasture when fed different levels of grain over 84 days, averaged over three years and three replications, Marianna, Arkansas 1968-70

	Grain fed per steer per day		
	2.27 kg first 42 days then full feed	4.54 kg first 42 days then full feed	Full feed for 84 days
Average daily gain, kg			
1st 42 days	0.90	1.15	1.38
2nd 42 days	1.00	1.00	0.90
Total season	0.95	1.08	1.14
Steer gains/ha,kg			
1st 42 days	373	479	571
2nd 42 days	416	416	376
Total season	789	895	947
Grain fed/steer, kg	430	552	688
Grain fed/kg of gain, kg	5.50	6.07	7.13

Source: Spooner and Ray, 1972 (4).

grade for slaughter. The lowest grade was obtained from the steers grazing fescue and ladino clover plus extra nitrogen applied each year. This was attributed to the fact that the added nitrogen drastically reduced the stand of the ladino clover in the pasture. Grazing days were highest from the fescue and ladino clover pasture. There were no differences in estimated steer gains per hectare between the orchardgrass and ladino, and the fescue and ladino plus nitrogen pastures. The lowest estimated steer gains per hectare were produced on the fescue and ladino pasture.

Templeton et al. (5) evaluated the performance of steers on three pasture programs in Kentucky (Table 7). There were no differences in daily gain among the three pasture programs. Steer days per hectare were highest from program three and lowest for program one. The same was true for steer gains per hectare (601 to 381 kg). The value of using alfalfa in the pasture program was demonstrated in this study. There were no differences in final grades of the steers among the three pasture programs. None of the steers reached an acceptable grade for evaluation.

Table 5. Performance of steers when fed a full feed of grain in the drylot and on a tall fescue-white clover pasture, averaged over five years, Marianna, Arkansas, 1966-70

	Drylot	Pasture
Days fed	66	66
Initial weight, kg	339	339
Final weight, kg	435	433
Total gain, kg	96	94
Average daily gain, kg	1.45	1.43
Initial grade[a]	12.2	12.2
Final live grade[a]	11.7	11.4
Carcass grade[a]	11.3	11.4
Total feed per head, kg		
Grain	658	607
Cottonseed hulls	254	0
Feed/head daily, kg		
Grain	10.0	9.2
Cottonseed hulls	3.9	0

Source: Spooner and Ray, 1972 (4).

[a]Scale: Prime 16; Choice 13; Good 10.

Burns et al. (1) evaluated different legumes vs. nitrogen on an improved mountain pasture in North Carolina. The pasture treatments and the performance data are presented in Table 8. Alfalfa and birdsfoot trefoil produced significantly higher daily gains than extra nitrogen applied each year (approximately 0.60 vs. 0.46 kg). The greatest number of grazing days (348) and gains per hectare (345) were obtained from the pasture that received the extra nitrogen. Sod seeding of the birdsfoot trefoil produced the second highest gains (304) per hectare.

Table 6. Performance of steers during the winter and summer grazing periods, averaged over four years, Springfield, Tennessee, 1953-56

	Pasture treatment[a]			
	O-C	O-F-C	F-C	F-C-N
Average weight and gain per head, kg				
Initial weight	224	221	221	223
Final weight	388	372	374	368
Total gain	164	151	153	145
Daily gain	0.60	0.55	0.56	0.53
Average animal grades[b]				
Final condition	8.3	8.1	7.9	8.3
Productivity of pastures				
Grazing days/ha	284	312	268	339
Estimated steer gains/ha, kg	414	389	353	415

Source: High et al., 1965 (3)

[a]O = Orchardgrass; C = Ladino clover; F = Tall fescue; N-23 kg ammonium nitrate each 56 days beginning in February and ending in September. No additional nitrogen was applied to the other treatments

[b]7.0 average standard; 8.0 high standard.

In another study in North Carolina, Wise et al. (6) fed different levels of corn to steers grazing a ladino clover pasture and a fescue and ladino clover pasture. They measured average daily gain, corn consumed per head, and carcass grades (Table 9). The average daily gains were the same for both pasture systems where no corn and deferred corn were fed. Higher daily gains were obtained from the pure ladino clover pasture when the steers were fed limited, a medium level and liberal corn. In general, the steers on the fescue and ladino clover pasture consumed more corn per head than those on the pure ladino clover pasture. The overall average carcass grades were about the same for the two pasture systems with the highest grades being obtained from the steers that were fed corn.

Table 7. Performance of steers when grazing on three programs, averaged over five years, Versailles, Kentucky, 1962-66

	Grazing programs[a]		
	1	2	3
Average daily gain, kg	0.56	0.54	0.56
Steer days/ha	129	154	178
Steer gains kg/ha	381	500	601
Initial grades[b]	8.26	8.24	8.18
Final grades[b]	7.73	7.74	7.70

Source: Templeton et al., 1970 (8).

[a]Program 1--Ky bluegrass plus ladino white clover.
Program 2--Half of the allotted area was Ky bluegrass plus ladino clover and one-fourth was seeded to Piper sudangrass and one-fourth to Korean lespedeza each year.
Program 3--Same as Program 2 except the ladino clover was replaced by alfalfa and these pastures received twice as much P and K plus boron.

[b]13 Choice; 10 Good; 7 Standard.

Many of the beef cow-calf farmers in the Upper South in recent years have become interested in keeping their calves beyond weaning age. Some are keeping their calves for around 9 months in a backgrounding program and either contracting with a feed lot to finish them or sell them to someone as long-yearling feeders. This type of a program requires a different pasturing system than is normally used for the cow-calf operation. Higher quality forage is necessary if acceptable daily gains (0.60 - 0.70 kg) are to be obtained over the backgrounding period. This pasture requirement can best be met by seeding combinations of annual species of grasses and legumes. A combination of rye-wheat-ryegrass-arrowleaf clover will normally supply high quality forage from mid-October to June except during the extremely cold periods in winter. A high quality corn or sorghum silage or high quality hay is used during these periods to maintain the desired daily gains. Hybrid sudan or hybrid millets overseeded with annual lespedeza is used during late summer and early fall for the calves that are weaned in July. Pure stands of annual lespedeza are used by some farmers for late summer and early fall grazing. Orchardgrass or bromegrass with alfalfa, white or red clover can also be used for the backgrounding program. This type of forage system requires a much higher level of management than does the use of annual species.

Table 8. Performance of steers in a stocker grazing program, averaged over three years and three replications, Laurel Springs, North Carolina, 1964-66

	IMP[a]	IMP[b] plus A	IMP[c] plus BFT	IMP[d] plus BFT	IMP[e] plus N
Length of grazing season, days	167-179	167-179	167-179	167-179	167-179
Average daily gain, kg	0.56	0.60	0.59	0.61	0.46
Animal days/ha	180	170	162	234	348
Animal gains kg/ha	211	222	207	304	345

Source: Burns et al., 1970 (1).

[a]Improved mountain pasture consisting of bluegrass-white clover mixture with some orchardgrass.

[b]Improved mountain pasture plus rotation to alfalfa after July 1.

[c]Improved mountain pasture plus rotation to birdsfoot trefoil after July 1.

[d]Improved mountain pasture sod-seeded with birdsfoot trefoil.

[e]Improved mountain pasture plus 225-280 kg/ha of nitrogen each year.

Some cow-calf producers in the Upper South are keeping their calves after backgrounding and finishing them for slaughter. This is being accomplished in two ways. First, they continue the yearlings on high quality forage until they reach an acceptable weight for slaughter of around 450 kg or, second, they feed grain on pasture for a short period (around 60-90 days) and sell for slaughter when the animals reach a weight of around 300 kg and grade high good to low choice. The finishing system used is usually determined by the availability and cost of grain.

A third system that is used involves purchase of calves in the fall and backgrounding them on small grains-ryegrass-clover pasture through the winter and spring. Grain may be fed for a short period in late spring and early summer or the animals marketed directly off pasture without any grain being fed. These farmers are usually row

Table 9. Performance of steers fed grain on pasture, North Carolina, 1953

	Average daily gain kg	Corn consumed kg/head	Carcass grade* number C	G	S
Ladino clover pasture					
No corn[a]	0.55	0	0	5	0
Limited corn[b]	0.78	245	4	1	0
Medium level corn[c]	0.91	441	4	1	0
Liberal corn[d]	0.90	587	4	1	0
Deferred corn[e]	0.57	166	2	3	0
Ladino-Fescue pasture					
No corn[a]	0.56	0	2	1	2
Limited corn[b]	0.57	245	2	3	0
Medium level corn[c]	0.84	490	4	1	0
Liberal corn[d]	0.84	651	4	1	0
Deferred corn[e]	0.57	207	2	3	0

Source: Wise et al., 1965 [6].

[a]No corn during the grazing season.

[b]0.5 percent of body weight/day.

[c]1.0 percent of body weight/day.

[d]1.5 percent of body weight/day.

[e]1.5 percent of body weight/day for the last 60 days only.

*C = Choice; G = Good; S = Standard.

crop farmers who use pastures in their rotation. They produce grain which may be used to feed the steers and, in some cases, they produce good quality silage for winter feeding.

One of the major uncertainties in forage production is adequate rainfall properly distributed to maintain even growth throughout the pasture growing period. Many farmers have a source of water, from creeks, wells or impoundments, that can be used to supply the water as irrigation when needed to assure even forage production. The use of irrigation water increases the possibility of the use of more fertilizer which increases the production of forage per hectare. This

increase in production over the pasturing period allows the farmer to carry more animals on a given size pasture.

There is a relatively new twist to an old method of sod seeding that offers promise. The no-till seeders along with the use of a chemical (paraquat) to burn the grass sod back have opened a new system of producting high quality forage over a longer period of time. It is possible to maintain continuous grazing of hybrid sudans or millets and small grains plus ryegrass and arrowleaf clover throughout most of the year by sod seeding and rotational grazing. The use of a chemical to control growth of the existing species is not necessary in this type of program provided you have enough cattle to graze the forage very short immediately before seeding. It is best to have the total grazing area divided into at least three pastures for this type of a seeding program.

The production of forage-finished beef can be increased through the use of irrigation and sod seeding. The increase would come primarily from the extra carrying capacity obtained from the irrigation, increased fertilizer and earlier seeding from the sod seeding. The use of irrigation and sod seeding dictates the need for use of additional fertilizers.

Problems

There are a number of problems associated with forage finishing of beef cattle in the Upper South. It is recognized that all cattle in this area should not attempt to produce finished cattle for slaughter however, there are many producers who can finish beef on forage.

One of the major problems associated with producing forage-finished beef in this area is the seasonality of maximum and high quality production of forage. The producer is limited in the timing that he can market grass finished cattle. Most of his cattle would be ready for market in early summer which would limit the possibility of his keeping the light end of cattle for further finishing because of a lack of high quality forage at this time. Most of the high quality forage production and high carrying capacities are obtained in the spring and early summer. There are periods during this time where the high moisture content of the forage limits the daily dry matter intake to the point that daily gains are drastically reduced.

The problem of matching animals to the forage system is one that causes concern among producers. Certain types of cattle mature more slowly than others. A forage finishing program almost dictates the use of the faster maturing cattle. It is common knowledge among cattle producers that the large type of cattle, including many of the large crossbreeds, require a much longer period of time to reach a given degree of finish than do the smaller English breeds, including those with some dairy cross breeding.

Another problem associated with forage finishing of beef cattle in the Upper South is the lack of managerial expertise to operate such

a program. It takes a special type of manager who knows cattle and pasture forages and one who can fit the two together to finish cattle on pasture. This person must be able to determine the needs of his pasture and provide these needs so that adequate amounts of high quality forage are available throughout the grazing season. He must be able to select cattle that will reach the degree of finish desired within the producing period of his pasture.

Future Needs

There are a number of research needs relative to forage finishing of beef cattle in the Upper South. These will be listed as we see them and not in the order of importance.

(1) There is a need to develop high quality, high producing forage species that can be grown in mixtures to provide a longer grazing season. This would allow the producer to market his finished cattle over a longer period of time and would give more latitude in the type of cattle he could use.

(2) The use of sod seeding and chemicals to surpress growth when desired, needs to be explored as a possibility of extending the grazing periods.

(3) The interseeding of grain sorghum into a cool season perennial pasture sod may give the producer another alternative for producing grain and, at the same time, forage to background his cattle through the winter. The grain could be used in late spring and early summer to finish the background cattle.

(4) There needs to be more research on the storage and cost of storage of high quality pasture forage during periods of excessive production. This type of storage would probably be air tight silos. The forage could be fed during periods of low production to maintain adequate daily gains on the cattle.

(5) The use of irrigation needs to be extensively evaluated for high quality forage production. The amount of water to apply, when to apply it, how much fertilizer to use, and the grazing management required are some of the problems that should be answered.

In summary, it appears that the possiblity of finishing beef cattle on forages in the Upper South has great promise. Many of the questions that we have today will be answered tomorrow which will make finishing beef cattle on forages even more feasible.

LITERATURE CITED

1. Burns, J. C., H. D. Gross, W. B. Gilbert, R. W. Harvey, M. B. Wise and D. F. Tugman. 1970. Pastures and grazing systems for the mountains of North Carolina, N. C. Agri. Exp. Sta. Bull. 437, 49 pp.

2. Elder, W. C. 1967. Winter grazing small grains in Oklahoma, Okl. Agri. Exp. Sta. Bull. B-654, 18 pp.

3. High, Joe W., Jr., L. M. Safley, O. H. Long, H. R. Duncan and T. W. High, Jr. 1965. Tenn. Agri. Exp. Sta. Bull. 388, 26 pp.

4. Spooner, A. E. and Maurice L. Ray. 1972. Finishing yearling steers on pasture with grain. Ark. Agri. Exp. Sta. Bull. 772, 15 pp.

5. Templeton, W. C., Jr., C. F. Buck and N. W. Bradley. 1970. Renovated Kentucky bluegrass and supplementary pastures for steers. Ky. Agri. Exp. Sta. Bull. 709, 19 pp.

6. Wise, M. B., E. R. Barrick and J. N. Blumer. 1965. Finishing steers with grain on pasture, N. C. Agri. Exp. Sta. Bull. 425, 48 pp.

EXISTING AND POTENTIAL SYSTEMS OF FINISHING CATTLE ON FORAGES OR LIMITED GRAIN RATIONS IN THE PIEDMONT REGION OF THE SOUTH

Carl S. Hoveland and W. B. Anthony*

The Piedmont region is the non-mountainous part of the Appalachain Highlands, lying to the east and south of the Blue Ridge (Figure 1). It extends from Virginia through North Carolina, South Carolina, and Georgia to eastern Alabama. The gently rolling landscape has an elevation of 300 to 500 meters, broken by many hills and narrow valleys. Originally, the area was covered with oak-hickory forest but much of the land was cleared and planted to row crops during the 1800s. By the 1940s, severe erosion problems were common and conservation programs resulted in extensive planting of pine forests and pastures on former row crop land. At present, most of the Piedmont is forested with the remainder mainly in pasture.

Beef cattle farms in the Piedmont have been and still are cow-calf operations. Many of these farms are small part-time operations where the owner has a job in a nearby factory. Cows are grazed on perennial grass and wintered on hay. Calves are generally sold in late summer and early fall as stocker-feeder calves, shipped out of the area to the Midwest and Southern Great Plains. In recent years some Peidmont farmers have been carrying calves to heavier weights on pasture. However, few cattle are finished either on pasture or in drylot in the Piedmont at present.

Climate, Soil and Plant Resources

Climate

Climatic conditions differ considerably from north to south within the Pidemont (Table 1). Mean January temepratures are much lower in the northern section of the Piedmont than in South Carolina, Georgia and Alabama. In addition, the autumn and spring temperatures are lower in Virginia and North Carolina than areas further south, so that winter forage production in most years is restricted to the Piedmont of Alabama, Georgia and South Carolina. July mean temperatures throughout the Piedmont region are quite similar. Total annual rainfall increases from north to south. Seasonal distribution of rainfall

* Professor, Agronomy and Soils Department, and Professor, Animal and Dairy Science Department, respectively, Auburn University Agric. Exp. Sta., Auburn, AL 36830

Figure 1. The Piedmont region extends from Virginia to Alabama

Table 1. Temperatures and rainfall at selected locations in the Piedmont

Location	Mean temperature, °C				Annual precipitation
	January	April	July	October	
					cm
Lynchburg, Va.	2.5	13.6	24.3	14.4	97
Raleigh, N.C.	4.7	15.3	25.2	15.6	108
Clemson, S.C.	6.3	16.4	25.8	16.8	131
Athens, Ga.	6.8	16.9	26.1	17.1	125
Camp Hill, Ala.	6.2	16.6	25.5	16.5	144

is fairly uniform in the northern Piedmont while in the southern area there are pronounced peaks in midsummer and again in winter. In the southern Piedmont, late spring and autumn droughts often reduce forage production.

Soil

Soils of the Piedmont area generally fall into two groups--Hapludults and Rhodudults (5). Uneroded Hapludults have a light-colored sandy loam horizon overlying yellow to brown to red loam or clay. However, severe erosion has often removed the sandy upper horizon. Hapludults have relatively low base saturation, are moderately to strongly acid, and may contain substantial amounts of potassium-bearing minerals. Rhodudults have dark brown or reddish-brown loam or clay surface horizons overlying clay. They are moderately acid, contain considerable bases along with iron and manganese, and are quite sticky when wet so are easily puddled. Both groups of soils respond well to fertilization and have better water-holding capacities than sandy soils of the Coastal Plain.

Forage Plants

As in other regions of the southeastern United States, introduced forage grasses and legumes have replaced native species because of superior yield and/or quality. The most widely grown grass in the Piedmont is tall fescue (Festuca arundinacea Schreb.). Other cool-season perennial grasses, found mainly in the nothern part of the Piedmont, are orchardgrass (Dactylis glomerata L.) and Kentucky bluegrass (Poa pratensis L.). Warm-season perennial grasses, restricted to the southern Piedmont are bermuda (Cynodon dactylon (L.) Pers.), bahia (Paspalum notatum Flugge), dallis (Paspalum dilatatum Poir.), carpet (Axonopus affinis Chase), and johnson (Sorghum halapense (L.)

Pers.). Winter annual grasses, grown mainly in the southern part of the Piedmont, include rye (Secale cereale L.), Wheat (Triticum aestivum L.), oats (Avena sativa L.), and Italian ryegrass (Lolium multiflorum Lam.).

White clover (Trifolium repens L.) is the most widely distributed legume in the Piedmont. Other legumes found in the region are sericea lespedeza (Lespedeza cuneata (Dumont) G. Don.), striate or Kobe lespedeza (L. striata (Thunb) H. & A.), Korean lespedeza (L. stipulacea Maxim.), and alfalfa (Medicago sativa L.). Arrowleaf clover (Trifolium vesiculosum Savi) and crimson clover (T. incarnatum L.) are cool-season annuals grown mainly in the southern part of the Piedmont.

Research Results with Forage-Finishing of Beef Cattle in the Piedmont

Pasture Only

Finishing of cattle on pasture without grain supplementation was common in the past when animals were two or more years old and weighed 600 to over 700 kg at slaughter. However, current market demands for smaller carcasses and the cost of carrying animals for long periods of time dictate that cattle must be grown rapidly and marketed at a young age. If this is to be done on pasture alone, the forage species must be moderately high in protein and have a digestible energy concentration sufficient for cattle to reach an acceptable degree of finish. Current market demands are for high Good and low Choice grade carcasses which can be produced mainly on forage.

Cool season annuals such as small grains, ryegrass and clovers have been used to finish cattle on pasture without grain supplements in the Piedmont. In a three-year South Carolina study (7), steers initially averaging 306 kg, gained 1.0 kg/day to reach a final weight of 448 kg during 140 days on ryegrass-crimson clover pasture. Carcasses graded 6 percent Choice, 47 percent Good and 47 percent Standard. In this 1955-58 study, cattle on pasture alone were more profitable than steers fed in dry lot or supplemented on pasture with corn, sorghum, barley or a full-fed mixture of corn, oats and cottonseed meal.

Similar results were obtained from a two-year experiment in the Georgia Piedmont (W.C. Russon, Sr., 1973: Effects of methods of finishing on performance and carcass composition of beef cattle, M. S. Thesis, University of Georgia, Athens). Steers initially weighing 212 kg grazed a mixture of oats, wheat and ryegrass from November 2 to May 15 and gained 0.88 kg daily for a final weight of 385 kg. Carcasses graded 5 percent Choice, 86 percent Good and 9 percent Standard.

In the Alabama Piedmont, finished beef was produced with Angus x Hereford steers on a pasture mixture of rye, ryegrass and Yuchi arrowleaf clover (1). Over a six-year period, steers grazed this pasture mixture from November 16 to June 6, gaining 0.92 kg daily for a total of 182 kg per steer (Anthony, W. B. and C. S. Hoveland,

unpublished data). Carcasses graded 9 percent Choice and 91 percent Good. Carcasses produced on the cool-season annual pasture were compared with carcasses from animals finished on a high-energy ration in the feedlot for 90 days (10). There were no differences between the two groups of cattle in USDA quality grade or yield grade, marbling, backfat thickness, or ribeye area. Pasture-finished cattle had more yellow color in the external fat of carcasses. A sensory panel rated steaks from the two groups of cattle similar in flavor, tenderness, and juiciness.

Perennial grass pastures are commonly grown in the Piedmont because of lower cost and for soil conservation on hilly land. Unfortunately, individual animal performance on these pastures has been poorer than on cool season annuals. This is illustrated by results in the upper Piedmont of Virginia (3). Steers on grass pastures fertilized with 242 kg N/ha had daily gains of only 0.42 on tall fescue and 0.54 kg on orchardgrass. Ladino clover in the pastures increased daily gains to 0.46 on tall fescue and 0.56 kg on orchardgrass. No carcass evaluations were made in this experiment.

Much better animal gains were obtained from a four-year experiment in the North Carolina Piedmont (8). Daily gains of tester steers averaged 0.84 kg for orchardgrass-ladino clover rotationally grazed with alfalfa, and 0.50 kg on a system of tall fescue and Coastal bermuda in separate pastures. The authors stated that the gains obtained with the tester animals on cool season perennial grass-legume pastures were higher than would be expected under farm grazing conditions. A more realistic daily gain was obtained by combining gain data from experimental and reserve pastures. This resulted in daily gains of 0.68 kg for orchardgrass-ladino clover, 0.72 kg for tall fescue-ladino clover, and 0.66 kg for the orchardgrass-ladino clover + alfalfa rotation. Slaughter grade of steers at the end of the grazing seasons averaged high Standard. Cattle grazed on the tall fescue-bermudagrass system graded about one-third of a grade lower than those on the other treatments. The authors concluded that these pastures alone were a satisfactory feed for growing yearling beef cattle but did not produce highly finished slaughter cattle of this age. A period of concentrate feeding either during or after the grazing season was deemed necessary to obtain high Good or Choice cattle.

Coastal bermuda, a commonly-grown warm season perennial grass in the lower Piedmont, is unsatisfactory for finishing steers on unsupplemented pasture. In North Carolina (8), steers gained only 0.41 kg per day while on this pasture. In the Alabama Piedmont, daily steer gains were only 0.34 kg while at other locations gains ranged up to 0.57 kg (9). Slaughter grade was only Utility at the end of summer.

Finishing cattle on pasture with no energy supplements appears to be possible only on cool season annuals in the lower Piedmont where milder winters permit a long grazing season. Yearling steers weighing 275 kg or more are necessary for proper finish during the grazing season from November to June. Neither cool nor warm season perennial grasses provide sufficient energy to finish cattle on pasture without supplementation in the Piedmont.

Supplementation on Pasture

Supplemental feeding of grain on cool season annual pastures has been studied at a number of locations in the Piedmont. Feeding grains to steers with an initial weight of 306 kg on ryegrass-crimson clover pasture in South Carolina had little effect on carcass grades or animal performance (7). In another experiment with lighter weight cattle, animals fed limited grain on ryegrass-crimson clover pasture required only 44 percent as much concentrate per unit of gain as dry lot fed cattle (6). Feeding whole shelled corn ad libitum to steers on rye-ryegrass-Yuchi arrowleaf clover pasture in the Alabama Piedmont increased stocking rate, daily gain and carcass finish but also increased the feed cost of gain (1). Feed cost of gain in this study was lower for steers produced on pasture alone than on pasture + grain or in drylot with silage, protein and full-fed corn. In Georgia, ad libitum feeding of ground corn and oats on oats-wheat-ryegrass pasture increased daily gain from 0.88 kg to 1.01 kg but did not affect carcass grade or marbling (Russom, loc. cit.). However, cattle fed grain on pasture were superior to non-grain fed cattle in ribeye area, flavor, tenderness and juiciness. Feed cost of gain was lowest for steers on grazing alone. Supplemental feeding of silage on cool season annual pasture in mid-winter has been suggested as a way to maintain gains and stocking rate at a high level throughout the season (2). However, no published research results were available from the Piedmont.

Limit feeding of grain at 1 percent of body weight on perennial grass pastures may be profitable in finishing cattle (13). Steers grazing orchardgrass-ladino clover or orchardgrass pasture and fed-grain at 1 percent of body weight in North Carolina resulted in gains of 1.0 to 1.25 kg/day during grazing periods of 150 to 170 days (2). It was concluded that pasture feeding of grain saved 40 to 50 percent of the grain, protein supplement, and harvested roughage that would be required in confinement feeding. Carcasses graded high Good.

In a three-year Virginia study, yearling steers gained 0.64 kg/day on mixed bluegrass-orchardgrass-white clover pastures as compared to 0.83 kg when fed grain to 1 percent of body weight on pasture (4). Both groups of steers graded only high Standard at the end of the 163-day average grazing season. In South Carolina, steers fed grain ad libitum on tall fescue pasture gained 0.75 kg/day as compared to 0.65 kg on one-half ad libitum feeding (6). Carcasses graded high Good in both cases. Grain feeding on tall fescue in this experiment was less profitable than on cool season annual pasture.

Feeding grain ad libitum to steers on Coastal bermuda pasture in South Carolina resulted in daily gains similar to those of steers fed in drylot, but reduced the concentrate consumption per steer by 175 kg annually (11). Production costs were less on pasture than in drylot. Carcasses of both groups graded Good and beef were acceptable to both taste panel and consumer tests.

Supplemental feeding of grain on cool-season annual pasture in the Piedmont may increase daily gain and carcass quality. However,

grain feeding has not been profitable when large yearling cattle were grazed on these high quality pastures. On perennial grass pastures, grain feeding is essential to produce finished cattle. Ideally, legumes should be present with the grass to improve pasture quality. On perennial grass-legume pastures, grain feeding should be restricted to 1 percent of body weight. Satisfactory finish within the grazing season will not be achieved unless animals initially weighing about 300 kg are used.

Post Grazing Short-Term Dry-Lot Finishing

Steers grazed on cool season perennial grass pastures often do not reach slaughter finish. Drylot feeding after the grazing season may be used in the Piedmont to achieve this goal. Research results from Virginia illustrate what can be accomplished (4). Drylot feeding for two to three months after the grazing season added another 73 kg gain and increased carcass grade from Standard to Good. On cool-season annual pasture, steers initially weighing 270 kg are reasonably well finished at the end of the grazing season and may be more profitably sold for slaughter than fed in drylot (2).

Current Forage Systems for Production of Finished Beef

Where adapted, corn grown for silage can produce more energy per unit area of land than any other forage crop. In the upper Piedmont, good corn silage can be grown dependably on many farms. However, in the lower Piedmont several problems limit corn silage production. Late spring and early summer droughts may reduce yields and also lower the percent grain in the silage below the 50 percent desired for good animal growth. Rough topography, and small farms with odd-shaped fields also discourage large scale production of corn silage.

Over much of the Piedmont, any increase in production of finished beef will be based on pasture. A survey of research and/or extension animal scientists in the Piedmont states revealed a variety of mainly pasture-based systems for the production of finished beef (Table 2). In the northern part of the region, grazing on perennial cool-season grass pasture begins in April and continues until October. Further south, cool-season annual pastures permit grazing from November until May or June. Grain feeding is necessary on perennial grass but generally not on cool season annual grass pasture.

Limitations and Problems of Current Forage Utilization Systems

Current forage systems for finishing cattle in the Piedmont are far from satisfactory. There are many problems, most of which are not unique to the Piedmont region but are common to all regions of the southern United States. Some of these problems may be solved with improved management, changed meat grading standards, or further research, but others seem to defy solution.

Table 2. Forage systems available for production of finished beef in the Piedmont[a]

State		Systems	Marketing period
Virginia	(a)	Corn silage + protein supplement	April-May
	(b)	Grain feeding to 1% of body weight on bluegrass-orchardgrass-white clover pasture	October
North Carolina	(a)	Corn silage in winter, orchardgrass-ladino clover in spring	June-July
	(b)	Small grain pasture in winter, orchardgrass-ladino clover in spring	June-July
South Carolina	(a)	Grain feeding to 1% of body weight on small grain clover pasture	May-June
	(b)	Grain feeding on tall fescue pasture	early June
	(c)	Grain feeding to 1% of body weight in Coastal bermuda pasture	late Sept.
Georgia	(a)	Yearling steers weighing 320-340 kg grazed on small grain-ryegrass pasture	late May
	(b)	Weanling steers weighing 200-230 kg grazed on small grain-ryegrass pasture and fed free choice grain	late May
	(c)	Weanling steers weighing 200-230 kg grazed on small grain-ryegrass pasture and fed grain 60 to 90 days post grazing in drylot	August
Alabama		Yearling cattle grazed on rye-ryegrass-Yuchi arrowleaf clover pasture alone or supplemented with corn silage in midwinter	May-June

[a]Information obtained from survey of research and/or extension animal scientists in respective states.

Available energy is the primary limiting factor in the nutritive value of pasture for growing cattle (12). This is reflected in the generally poor performance of growing animals on perennial grasses. Warm season perennial grasses such as bermuda and bahia have especially low digestibility. Average daily gain of young growing animals grazing these pastures is simply too low for satisfactory growth or finish. Young animals going on such pasture in good condition may lose finish during the growing season even though they gain weight.

Cool-season perennial grasses are somewhat better but still do not match the winter annuals in available energy for satisfactory animal performance.

Several physiological stress components in forage such as tannins, bloat and toxicity factors limit finishing cattle on pasture. Fescue toxicity is of particular concern in the Piedmont since tall fescue is the most important grass in the region. Tannins in available cultivars of sericea lespedeza reduce gains and eliminate the use of this well-adapted plant for yearling animals. Bloat can be a serious problem in a white or crimson clover dominant sward but not with arrowleaf clover.

Productive pasture legumes are important in maintaining good animal gains over a long season as well as reducing the need for nitrogen fertilizer. Ladino clover is an excellent legume in combination with tall fescue or orchardgrass. However, it is often difficult to maintain clover dependably in a perennial grass sward for more than two or three years. Dependable, high quality, productive summer legumes are lacking in the Piedmont.

Cool-season annual pastures in the lower Piedmont can be damaged by cattle trampling during periods of heavy rainfall in winter and early spring. Clay soils, common in the Piedmont, become deeply pitted with hoof marks during winter grazing. Soil compaction may result, causing poor aeration, shallow root development, and reduced growth or even stand loss of sensitive pasture plants.

The grazing season of different species in the Piedmont differs considerably (Table 3). In the northern Piedmont, pasture growth ceases for a long winter period. In addition, late summer drought may decrease both quantity and quality of forage in the pasture. In the southern Piedmont, winter production of cool season annuals may be curtailed by sudden freezes. Cool-season perennial grass production is minimal in winter, necessitating supplemental feeding of roughage as well as grain. Warm season perennial grass yields are often erratic, because of cool spring weather or summer droughts.

Uneven seasonal distribution of forage is difficult to cope with when finishing cattle on pasture. A heavy flush of spring growth may result in forage being wasted or reduced in quality. Many of the farms in the Piedmont are too small to afford silage equipment or even hay making machinery.

One of the most serious problems in developing a strong forage-finished beef industry in the Piedmont is the lack of a year-around supply of a single type of slaughter animal. Processing facilities to handle a large influx of finished cattle over a short slaughter season are not available. Currently available forage systems for production of finished beef in the Piedmont would result in marketing the entire annual production of slaughter animals over two to three months in late spring and early summer (Table 2). Obviously, slaughter

Table 3. Grazing season of major pasture species in states of the Piedmont region[a]

State	Tall fescue	Orchardgrass	Small grain-ryegrass-clover	Coastal bermuda
Virginia	early April-early Nov.	mid April-late Oct.	March-May	--
North Carolina	late March-mid Dec.	early April-mid Nov.	mid Oct.-late Dec. Feb.-May	early June-late Aug.
South Carolina	early Oct.-early Jan. March-June	early Nov.-early Jan. March-June	mid Nov.-late May	mid May-mid Sept.
Georgia	late Sept.-early Jan. early March-late June	--	mid Nov.-late May	early May-early Oct.
Alabama	late Sept.-early Jan. early March-mid June	--	mid Nov.-early June	early May-early Oct.

[a]Information obtained from survey of research and/or extension animal scientists in respective states.

animals must be available at all seasons of the year if the Piedmont is to supply the requirements of local processing plants.

Biological Research Needs

Several research areas may offer promise in improving the efficiency and dependability of producing finished beef cattle on pasture in the Piedmont:

(1) Breeding of improved forage plants for disease, insect and nematode resistance, decreased concentration of anti-quality components (tannins, alkaloids, saponins, lignin), greater available energy, more dependable biological nitrogen fixation, increased winter production and better persistence in pastures. Special attention should be given to improved perennial warm-season pasture legumes.

(2) Identifying effect of livestock trampling in wet weather, soil compaction and poor soil aeration upon the yield losses and response of individual pasture species. Investigation of methods to alleviate soil compaction and aeration problem by crop rotation, soil tillage treatment, deferred grazing and tolerant forage species.

(3) Improved methods of establishment and maintenance of legumes in perennial grass pastures.

(4) Improved utilization of surplus spring and summer forage.

(5) Selection of cattle with greater ability to utilize forages for growth.

(6) Development of forage systems that allow production of finished slaughter cattle throughout the year.

(7) Development of practical methods for using new sources of plant nutrients from wastes such as municipal sewage sludge for pasture fertilization.

Summary

The Piedmont, an area of rolling landscape, loam to clay coils and covered mainly with forests and pastureland, extends from Virginia to Alabama. Although most of the beef cattle farms are small in this region and are cow-calf operations, the potential exists for forage-finishing of slaughter cattle.

Finishing cattle on pasture with no supplement is possible on cool season annuals in the lower Piedmont. Daily gains of about 0.9 kg can be obtained on small grain-ryegrass-clover pastures. Cattle on perennial grass or grass-legume pasture will require grain supplements to achieve adequate finish. Satisfactory finish within the grazing season will not be achieved unless animals weigh about 300 kg when put on pasture.

Major problems in developing a forage-finished beef industry in the Piedmont are: (a) perennial grasses too low in available energy, (b) physiological stress components in forages, (c) uncertain legume production and persistence, (d) uneven seasonal distribution of forage, and (e) lack of production systems to give a year-around supply of finished slaughter animals.

LITERATURE CITED

1. Anthony, W. B., C. S. Hoveland, E. L. Mayton and H. E. Burgess. 1971. Rye-ryegrass-Yuchi arrowleaf clover for production of slaughter cattle, Auburn Univ. Agr. Exp. Sta. Circ. 182.

2. Barrick, E. R. and R. W. Harvey. 1974. Use of forage for finishing cattle, North Carolina State Univ. Anim. Sci. Rep. 226.

3. Blaser, R. E., R. C. Hammes, Jr., H. T. Bryant, C. M. Kinkaid, W. H. Skrdla, T. H. Taylor and W. L. Griffeth. 1956. The value of forage species and mixtures for fattening steers. Agron. J. 48: 508-513.

4. Bryant, H. T., R. C. Hammes, Jr., R. E. Blaser and J. P. Fontenot. 1965. Effects of feeding grain to grazing steers to be fattened in drylot, J. Ani. Sci. 24:676-680.

5. Buol, S. W. 1973. Soils of the southern states and Puerto Rico, Southern Coop. Series Bull. 174.

6. Edwards, R. L., G. C. Skelley, Jr., D. W. Eaddy, W. C. Godley, R. F. Wheeler, J. W. Hubbard and H. C. Gilliam, Jr. 1968. A comparison of drylot and supplemented pasture systems for finishing beef cattle, South Carolina Agr. Exp. Sta. Bull. 537, 36 pp.

7. Godbey, E. G., R. F. Wheeler, D. H. Kropf, W. C. Godley and L. V. Starkey. 1959. Winter forage for fattening steers, South Carolina Agr. Exp. Sta. Bull. 469.

8. Gross, H. D., L. Goode, W. B. Gilbert and G. L. Ellis. 1966. Beef grazing systems in Piedmont North Carolina. Agron. J. 58: 307-310.

9. Hoveland, C. S., C. C. King, E. M. Evans, R. R. Harris and W. B. Anthony. 1971. Bermudagrass for forage in Alabama. Auburn Univ. Agr. Exp. Sta. Bull. 328, 27 pp.

10. Huffman, D. L. and W. A. Griffey. 1975. Cattle finished on winter pasture rate high in carcass quality, Auburn Univ. Agr. Exp. Sta. Highlights of Agr. Res. Vol. 22, No. 3.

11. Malphrus, L. D., R. L. Edwards, D. H. Kropf and Mary J. Marbut. 1962. Consumer preference for beef produced on grass and grain

or in drylot: A comparison, South Carolina Agr. Exp. Sta. Bull. 499.

12. Reid, J. T., K. L. Turk, W. A. Hardison, C. M. Martin and P. G. Woolfolk. 1955. The adequacy of some pastures as the sole source of nutrients for growing cattle, J. Dairy Sci. 38:20.

13. Wise, M. B., E. R. Barrick and T. M. Blumer. 1967. Finishing steers on pasture, North Carolina Agr. Exp. Sta. Bull. 425.

EXISTING AND POTENTIAL SYSTEMS OF FINISHING CATTLE ON FORAGES OR LIMITED GRAIN IN THE LOWER SOUTH*

Warren G. Monson and Philip R. Utley**

The lower South to be considered in this presentation generally lies below the 33rd parallel and east of the 100th meridian. It also includes the coastal plain areas of the Carolinas. The area has an average frost-free growing season of 240 or more days with average summer temperatures of 27 to 32C. Average winter temperatures may range from 5 to 18C and killing frosts as low as -15C may be expected annually. Rainfall is reasonably well distributed throughout the year and averages about 120cm but drops considerably below this in the western part of the area. The lower South is not immune to droughts which reduce crop yields, but few areas with available land space have a more dependable annual rainfall.

More than 75 percent of the soils of the area are sandy in nature, a factor which contributes to low fertility and low water-holding capacity. Native vegetation is primarily timber with an understory of shrubs and grass.

The native range on most of this area after removal of timber will produce about 8 kg of liveweight gain (LWG) per ha per year. If cleared, planted to the most efficient forage varieties now available, and heavily fertilized, these soils can produce annually more than 2 metric tons of liveweight gain per ha (2).

Given the generally favorable conditions for optimizing plant growth, just how well are we supplied with forage plants which can capitalize on these resources? It has often been said that one of our problems in the lower South has been the availability of too many forage species and cultivars and that this overly complicates the situation for both the farmer and researcher.

---

* Cooperative investigations of the Agricultural Research Service, U. S. Department of Agriculture, and the University of Georgia, College of Agriculture Experiment Stations, Coastal Plain Station, Tifton, GA.

** Research Agronomist, Agricultural Research Service, U. S. Department of Agriculture, and the University of Georgia, College of Agriculture Experiment Stations, Coastal Plain Station, Tifton, GA; and Animal Scientist, Animal Science Department, Coastal Plain Experiment Station, Tifton, GA.

Plant Resources

If the South is to improve its position as a forage producer, a primary requirement is superior forage plants. To be successful, these plants must be dependable and possess both drought and cold tolerance. These improved forages must be adapted to varied climatic and soil conditions and efficiently utilize all the light, temperature and water characteristic to the area. High yield potential must also be coupled with improved quality. Resistance to pests not easily controlled will enhance dependability. With these ideals in mind, how well do our present forages meet these criteria and how can they be improved?

Perennial Grasses

The summer growing perennial grasses have been and will continue to be the backbone of most forage systems. This is true because perennials obviate the necessity of annual seeding and the short-term vagaries of weather which sometime plague establishment of annual forages. Several summer perennial forages, such as the bermudagrasses have been successfully used.

Coastal bermudagrass (Cynodon dactylon (L.) pers.) (1) has been a major factor in the development of the livestock industry in the South. Recent estimates place this grass on about 10 million acres across the South, with a substantial increase in productivity over the common bermudagrass it replaced. It has shown both disease and drought tolerance and good agronomic characteristics all of which contribute to dependability. However, Coastal bermudagrass has some shortcomings when measured against our ideal forage.

1. Stops growth too early in fall and thus fails to fully utilize the potential growing season. This is characteristic of most of our perennial grasses.
2. Is susceptible to the spittlebug.
3. Quality is less than desired in many instances.

The development of Coastcross-1 is evidence that the quality of Coastal bermudagrass can be improved. This hybrid between Coastal and an introduction from Kenya is 12 percent more digestible and has given 30 percent higher average daily gains (ADG) by cattle grazing it (11). This was achieved with some loss in winterhardiness. Coastcross-1 is a very welcome addition to the arsenal of available grasses. It is not recommended north of Macon, Ga. and may suffer some injury at Tifton in severe winters.

Common bermudagrass also finds considerable usage. There appears to have been some selection for superior strains of this grass which are more responsive to management.

There are additional bermudagrasses on the horizon which may have considerable effect on forage production in the lower South. Hybrids

with improved winter hardiness and quality are being evaluated as are some giant types with as yet undetermined cold tolerance and animal response potential. Certainly research must continue to improve this highly adapted grass.

Pensacola bahiagrass (Paspalum notatum Flugge) probably ranks second to bermudagrass in area occupied by a perennial grass in the lower South. This is a well adapted, widely used grass which is aggressive and forms a dense sod. Under grazing, it has usually given slightly lower animal gains than Coastal bermudagrass at Tifton, Ga. (20). However, this difference is often reversed when feeding conserved forage. Bahiagrass also appears to be more tolerant of shade and wetter soil conditions than Coastal. Under adequate fertilization, Pensacola bahiagrass yields less than Coastal bermudagrass. In a four-year study at Tifton, the dry matter yield from Pensacola bahiagrass was 15.5 MT/ha compared to 16.0 and 22.3 MT/ha from Coastcross-1 and Coastal bermudagrass, respectively (20). In addition, it is a prolific seed producer which can lead to it becoming a weed in lawns or in other areas where it is not desired. Current research (3) shows promise of producing bahiagrasses with improved yield and digestibility.

There are other summer perennial grasses available which are readily used in their areas of adaptation. These include dallisgrass (Paspalum dilatatum Poir), carpetgrass (Axonopus affinis Chase) and johnsongrass (Sorghum halepense L.). A common criticism of the subtropical perennial grasses is one of low quality which is the justification for the current widespread effort to improve the quality of these indispensable forage plants in the lower South.

Cool season perennial grasses are not widely used in the lower South. Tall fescue may find some use but generally rust, nematodes and other pests have restricted its utility. Current work at Auburn (9, 16) shows promise of developing adapted varieties of fescue and Phalaris which could greatly improve the production of quality forage during the cool season.

Annual Forages

Any forage program to be successful in the lower South will demand more than one forage. One could make a case for utilizing only the best perennial grass by grazing during the growing season and conserving enough as hay for the remainder of the year. However, current land values will probably not permit this type of land use. The alternative then becomes one of using another forage species to overseed the perennial sod and increase the productive season. This is not a new concept and is widely practiced. The cereals and ryegrass are increasingly being fall-seeded in summer growing perennial sods. Several winter annual legumes are also utilized in this way, which is a practice given considerable impetus by current economics. These winter annual forage plants all produce high quality forage during a time of the year when it is often scarce. Annual seeding of this forage can be expensive and may suffer from frequent fall droughts which detract from their dependability. Reseeding annual clovers, such as arrowleaf,

crimson, subterranean, and others can reduce or eliminate the annual seeding expense. Judicious use of these winter annuals is imperative in order to maximize their inherent high quality.

Sweet blue lupine (Lupinus angustifolius L.) is another winter annual legume which can fill a special need for high quality forage in late winter or early spring. It supplies a shorter grazing season than reygrass or arrowleaf clover but can be utilized following cereals. It might profitably be used in a double cropping sequence with a summer annual such as pearl millet (Pennisetum americanum (L.) K. Schum).

The legumes have the special advantage of being able to fix atmospheric nitrogen. As important as this is, it cannot be counted on to provide all the N needed by the perennial grasses for maximum production.

Summer annual grasses such as pearl millet, sudangrass, forage sorghum, or sorghum x sudan hybrids all generally provide high quality summer forage. In the absence of a dependable summer growing legume for the area, the summer annual grasses are an important source of high quality feed during the summer months. Studies at Tifton, Ga. (10, 23) have shown the feasibility of getting good animal gains on pearl millet. Steers grazing Gahi 1 pearl millet gained 0.97 kg/day and 525 kg/ha while gains on Coastcross-1 bermudagrass were 0.72 kg/day and 598/ha (23).

The possible combinations of forage and other feed sources which could be assembled in systems are larger. For the most part, this would be an academic exercise. It appears more appropriate to take workable systems and attempt to improve them, with a goal of the simplest forage system to meet the livestock requirements. Research must continue to evaluate new and promising forages as they are developed.

Finishing Systems Which Make Maximum Use of Forages

Throughout the United States, new prospective forage species and varieties are continually being developed. Many of these new, more productive, higher quality forages will replace and supplement the forages available today. In the meantime, better use of the existing forages needs to be made. It has been estimated that in the United States alone there are over a billion acres of forage producing only 22 percent of its known potential. Much of this is due to poor agronomic practices but some of this loss is also due to improper animal management and utilization practices.

Beef cattle are unique in their ability to convert forages into palatable red meat at a low cost per unit of carcass weight. In order to realize the most from our forage crops, the animal production potential of each type of forage grown must be known so that an economical system of utilization can be developed.

Finishing cattle on all-forage diets is a reality. Many Southwestern and Midwestern cattle feeders say "It can't be done," but it

is being done throughout the South and Southeast. With this all-forage finishing program, conventional choice and prime carcasses are not being produced, but finished slaughter animals with slightly lower quality grades and yield grades are being produced. In fact, a strong market has developed recently for beef carcasses which grade high good and have yield grades of one or two. Scruggs (18) and Monfort (13) postulate that the demand for this type of carcass will be the future of the beef industry. With an abundance of sun, water, land and cattle, the lower South has the potential to economically produce lean, tender, beef of this type on its high quality forages.

All Forage Diets

All-forage systems are successful only when high quality forages are available in abundance throughout the finishing period. Perennial grasses are generally of sufficient quality to meet the animals' requirements during the first part of the growing season, but usually decline in quality during the last one-half of the growing season (20). This problem can be solved to some extent by using multiple plantings of high-quality winter and summer annuals as grazing crops and/or with the use of high quality harvested forages.

One example of finishing steers for slaughter on a combination of winter and summer annual pastures is the results (McCormick, unpublished data) obtained during the past 12 years in cooeprative studies with the Georgia State Prison Farm at Reidsville, Georgia. Each year, 50 to 60 steer calves were grazed on high-quality forages, without supplemental feed, until slaughter weights of 432 and 455 kg were reached. Pastures consisted of small grain in the winter and millet in the summer. By making multiple plantings of winter and summer annual grasses, high-quality forage was available to the steers throughout the grazing period.

The steers grazed oat pastures for an average of 168 days and averaged .83 kg/day gain. The millet furnished grazing for an average of 119 days and produced average daily gains of .72 kg/day. As a result, the combined oats and millet crops were grazed for an average of 287 days and produced body weight gains of .78 kg/day. These gains resulted in slaughter steers weighing about 440 kg at 19 months of age. On the average, these steers dressed 54.6 percent, had 1.3 cm of fat covering over the 12th rib and graded low good.

A second example of an all-forage finishing system is the use of winter annual grazing plus high-quality harvested forage (21). Over a four-year period, two finishing systems were compared at the Coastal Plain Experiment Station, Tifton, Georgia. A total of 68 crossbred steers (32 calves and 36 yearlings) was fed either a high-energy diet in drylot or an all-forage diet. The high-energy diet, composed of 72 percent ground shelled corn, 20 percent peanut hulls and 8 percent protein supplement, was fed to calves for 196 days and to yearlings for 161 days. Steers on the all-forage diet were fed dehydrated Coastal or Coastcross-1 pellets in drylot for about 56 days, transferred

to oat and rye pasture for about 120 days, then returned to drylot and were fed pellets until slaughter weights were reached. Calves in the all-forage group were fed and grazed for 240 days and the yearlings were fed and grazed for 205 days.

Animals fed the high-energy diet gained 1.35 kg/day and steers fed the all-forage diet gained 1.06 kg/day. Average daily gains for calves and yearlings were almost identical when fed the all-forage diet. However, the average gain for yearlings was 8 percent faster than for calves when fed the high-energy diet.

Calves fed the high-energy diet consumed an average of 9.3 kg of the grain mixture per day compared with 11.6 kg/day for the yearling steers. As a result, the calves required about 7.2 units of feed/unit of gain and yearling steers required about 8.3 units of the high-energy diet/unit of gain.

Steer calves fed the all-forage diet required a total of 680 kg of pellets and .41 ha of small grain grazing to produce 255 kg of gain. The yearling steers fed the all-forage diet were less efficient and required an average of 1,001 kg of pellets plus .53 ha of grazing to produce 216 kg of body weight gain.

Steers fed the high-energy diet dressed out about 7.5 percent more liveweight as carcass when compared with all-forage fed steers. In addition, all-forage fed steers had less marbling and less fat cover over the 12th rib but more desirable yield grades than steers fed the high-energy diet. Carcasses of steers in all groups averaged grading from medium to high good.

Limited Grain

When maintaining high quality forage crops throughout the finishing period is impractical or uneconomical, it sometimes becomes more desirable to supplement the grazing diet with a limited amount of grain.

In general, there are three basic reasons why grass-grain combinations are more desirable than strictly a grazing program. First, the manipulation of the amount of supplemental feed will reduce problems associated with grazing management. Forage production during the growing season is quite variable. Usually, forage growth is greatest during the vegetative stage and then decreases as the plant matures. With the use of varying amounts of supplemental feed, utilization of available forage can be almost complete. Second, when rapid growing, succulent grasses are consumed without supplemental energy, body fill may prevent the animal from consuming sufficient energy to make maximum gains. Third, when high quality forages are grazed without supplemental feed, a nutrient imbalance exists which results in a waste of valuable protein. Most studies where the crude protein content of summer perennials (20), cool-season annuals (15) and summer annuals (20) has been monitored, show that protein intake greatly exceeds the requirements of the animals (14). Therefore, in order to maximize animal production and profit, some type of supplemental energy should be fed to the grazing animals.

The literature contains numerous examples of the supplemental feeding of grazing animals throughout the lower South. North Carolina investigators (26) showed that one way to increase the returns from a cattle finishing program was to graze high-quality pasture and feed supplemental concentrates. Researchers in Alabama (8), Florida (7), Louisiana (4) and Georgia (17) all confirm the desirability of using grass-grain combinations for finishing cattle for slaughter.

In addition, these and other studies point out the wide variation in possible combinations which can be used to finish cattle on high-quality forages with or without supplemental feed. Carpenter and Klett (5) compared wheat pasture, corn silage and sorghum silage with and without added concentrates and found that wheat pasture and sorghum silage plus concentrates were most desirable. Chapman et al. (6) reported that the use of limited amounts of concentrates on good-quality pasture was more economical than either pasture alone or self-feeding of concentrates on pastures. Suman and Woods (19) compared gains made by yearling steers grazing Coastal bermudagrass with and without concentrate supplements of cottonseed meal, bermudagrass pellets and ground shelled corn. An increase in gain was obtained from all supplements; however, corn fed at 1 percent of body weight resulted in body weight gains of over 591 kg/ha. McCormick et al. (12) reported more economical gains when cattle were limited-fed various concentrates on winter annual pastures. Utley et al. (24) reported that the inclusion of small grain grazing was more desirable than the use of perennial grasses as a grazing crop when included in a finishing system. Utley et al. (22) compared corn silage and corn silage plus small grain pasture for finishing steers and obtained more economical gains for steers grazing small grain pastures when supplemented with corn silage. Utley and McCormick (25) successfully finished steers to slaughter weights by self-feeding whole shelled corn in combination with grazing oats and found this system more economical than feeding in drylot. Baker (North Florida Experiment Station, unpublished data) fed various levels of concentrate to cattle grazing Gahi millet during a four-year study. All treatments utilizing millet grazing were more economical compared to a drylot finishing system.

Conclusion

In conclusion, the key to the utilization of grazed forages is to use plant material that will meet the nutrient requirements of an animal. This means a high quality forage for high production needs such as milk production or finishing beef animals, medium quality forages for growing animals and for maintaining the brood cow herd, and low quality forages to provide the needed filler and roughage effect when used in combination with concentrate feedstuffs.

Forages are now and always will be an important nutrient source for ruminants. However, until we can develop a consistently high-quality forage that will allow an animal to express his full genetic growth potential, we may need to use supplemental feed to assure the intake of a completely balanced diet.

Much has been done to improve the quantity and quality of forages and the production of animals consuming the forages. We believe more can and must be done. Specifically, the following areas need additional attention:

1. Widely diverse germplasm pools need to be assembled and evaluated for their potential in contributing to improved forage varieties.

2. Factors affecting forage digestibility and intake must be identified and if possible modified. These should include both mechanical and chemical factors.

3. Management of forages needs to be refined and new forage varieties must be management responsive so the farmer or rancher can modify his production practices to meet the needs of his livestock.

4. Evaluation of forage utilization practices is essential to the synthesis of the best forage-livestock system for the individual livestock farmer.

LITERATURE CITED

1. Burton, Glenn W. 1951. Coastal bermudagrass. Ga. Coastal Plain Exp. Sta. Bull. N. S. 2, September.

2. Burton, Glenn W. 1970. Can the South become the world's greatest grassland? The Prog. Farmer, March.

3. Burton, Glenn W. 1974. Recurrent restricted phenotypic selection increases forage yields of Pensacola bahiagrass, Crop Sci. 14: 831-835.

4. Carpenter, John C., Jr. and Paul B. Brown. 1966. Feeding beef calves from weaning to market. La. Agr. Exp. Sta. Bull. 612.

5. Carpenter, John C., Jr., and R. H. Klett. 1969. Silage and wheat pasture for wintering and finishing weaning calves. La. Agr. Exp. Sta. Bull. 642.

6. Chapman, H. L., Jr., D. W. Beardsley, T. J. Cunha and W. K. McPherson. 1967. Developing calves and steers on pasture in South and Central Florida, Fla. Agr. Exp. Sta. Bull. 719.

7. Chapman, H. L., Jr., A. Z. Palmer, R. W. Kidder, J. W. Carpenter and C. E. Haines. 1964. Oral and implanted stillbestrol for beef cattle fattened on pasture and in drylot. Fla. Agr. Exp. Sta. Bull. 666.

8. Hoveland, C. S., W. B. Anthony, E. L. Mayton and H. E. Burgess. 1972. Pasture for beef cattle in the Piedmont. Ala. Agr. Exp. Sta. Cir. 196.

9. Hoveland, C. S., R. Rodriguez-Kabana and C. D. Berry. 1974. Phalaris and tall fescue forage production as affected by nematodes in the field. Agron. Abstracts, p. 85.

10. Johnson, J. C., Jr., R. S. Lowrey, W. G. Monson and G. W. Burton. 1968. Influence of the dwarf characteristic on composition and feeding value of near-isogenic pearl millets. J. Dairy Sci. 51: 1423.

11. Lowrey, R. S., G. W. Burton, J. C. Johnson, Jr., W. H. Marchant and W. C. McCormick. 1968. In vivo studies with Coastcross-1 and other bermudas. Univ. of Ga. Res. Bull. 55, pp. 1-22.

12. McCormick, W. C., O. M. Hale and B. L. Southwell. 1958. Fattening steers on small grain pastures. Ga. Agr. Exp. Sta. Bull. N. S. 49.

13. Monfort, Ken. 1974. Address to "Midsummer Conference of the Midwest Association of State Departments of Agriculture." Lincoln, Nebraska, June 19.

14. N. R. C. 1970. Nutrient requirements of domestic animals, N. 4. Nutrient requirements of beef cattle. National Research Council, Washington, D. C.

15. Roark, C. B., H. E. Harris and J. I. Feazel. 1966. Winter pasture for fattening feeder calves in the upland area of West Louisiana. La. Agr. Exp. Sta. Bull. 609.

16. Saibro, J. C. and C. S. Hoveland. 1975. Seasonal forage production and nutritive quality of phalaris aquetice as affected by growth stage and nitrogen fertilization. Agron. Abstracts, p. 109.

17. Saunders, F. B., W. J. Staub, S. J. Banner and A. E. Cullison. 1966. Costs and returns for alternative cattle feeding systems in Georgia. Ga. Agr. Exp. Sta. Bull. N. S. 163.

18. Scruggs, C. G. 1974. The new world of agriculture. Proceedings of the Beef Improvement Federation, Denver, Colorado, April 15-17.

19. Suman, R. F. and S. G. Woods. 1966. Beef production from Coastal bermudagrass. S. C. Agr. Exp. Sta. Bull. 524.

20. Utley, P. R., Hollis D. Chapman, W. G. Monson, W. H. Marchant and W. C. McCormick. 1974. Coastcross-1 bermudagrass, Coastal bermudagrass and Pensacola bahiagrass as summer pasture for steers. J. Anim. Sci. 38:490.

21. Utley, P. R., R. E. Hellwig and W. C. McCormick. 1975. Finishing beef cattle for slaughter on all-forage diets. J. Anim. Sci. 40:1034.

22. Utley, P. R., W. H. Marchant and W. C. McCormick. 1976. Evaluation of annual grass forages in prepared seedbeds and overseeded into perennial sods. J. Anim. Sci. 42:16-20.

23. Utley, P. R., Robert S. Lowrey and William C. McCormick. 1973. Corn Silage and corn silage plus small grain pasture for finishing steers. J. Anim. Sci. 36:423.

24. Utley, P. R., Robert B. Moss and W. C. McCormick. 1972. Systems of management for finishing beef steers. Ga. Agr. Exp. Sta. Res. Rept. 128.

25. Utley, P. R. and W. C. McCormick. 1975. Dry or high-moisture corn for finishing steers in drylot or on oat pasture. J. Anim. Sci. 41:495.

26. Wise, M. B., E. R. Barrick and T. N. Blumer. 1965. Finishing steers with grain on pasture. N. C. Agr. Exp. Sta. Bull. 425.

EXISTING AND POTENTIAL SYSTEMS OF FINISHING CATTLE ON FORAGES OR LIMITED GRAIN RATIONS IN THE SEMI-ARID SOUTHWEST*

F. P. Horn and C. M. Taliaferro**

Introduction

The area studied for this report lies along the western edge of the Southern Region. It is bordered on the north by Kansas and Colorado, on the west by New Mexico and on the South by Mexico. It includes the western halves of Oklahoma and Texas. The Central Great Plains Land Resource Region (3) contains most of the area, but also included are small parts of the Southwest Plateau and Plains Range and Cotton Region and the Western Range and Irrigated Region. In all, there are nine Land Resource Areas represented. To provide a general overview, we will describe only six of these land resource areas because they make up most of the semi-arid parts of Oklahoma and Texas.

The Reddish Prairies Land Resource Area

The Reddish Prairies Land Resource Area occupies a wide belt that crosses Central Oklahoma from north to south and extends into north-central Texas. It contains 3,434,400 ha in Oklahoma and 1,756,320 ha in Texas (1, 17). The Prairies are characterized by smooth to rolling lands scored only by drainageways. Elevations range from 420 m in the west to about 270 m in the southeast. Rainfall varies from 71 to 89 cm, with lesser amounts as one moves west (3). Soils have developed under tall bunch and middle height grass cover over weakly calcareous red shales and sand stones (17). Much of the original grass has been replaced by woody vegetation (3). This problem of woody vegetation increases as one moves south. About one-half of the area is in pasture or range land.

The Rolling Red Plains Land Resource Area

The Rolling Red Plains include much of west-central Oklahoma and west-central Texas. In Oklahoma, these plains include 3,766,800 ha,

* This research was conducted by the USDA-ARS and the Oklahoma Agricultural Experiment Station cooperating.

** Research Animal Husbandman, USDA-ARS Southern Region, Southwestern Livestock and Forage Research Station, El Reno, Oklahoma 73036; Associate Professor, Department of Agronomy, Oklahoma State University, Stillwater 74074.

and in Texas they include 6,814,000 ha (1, 17). The resource area slopes toward the southeast and the elevation ranges from 900 m in the northwest to 300 m. in the southeast. The surface relief is rolling with deep cut valleys and narrow strips of alluvial soils. This Land Resource Area is divided from the Reddish Praries because of drier, less leached soils subject to greater problems from wind erosion and evapotranspiration water losses (17). Plant nutrients, except nitrogen are usually moderately high to high in most area soils. Rainfall in the Rolling Red Plains ranges from 56 cm in the northwest to 71 cm in the southeast. Rainfall is seasonal, however, and predominates in April and September (3). Generally, the vegetation in this resource area is referred to as "mixed grass praries." The gramas and buffalo grasses are dominant on clay soils. Gramas and tall grasses are found on the loams and sandy soils. Heavy grazing has increased the infestation of woody plants tremendously, however, and much of the grassland cover has been lost. About one-third of the area is in pasture and range (1).

The Edwards Plateau Land Resource Area

The Edwards Plateau is located wholly in Texas where it makes up most of west-central Texas. It contains 8,915,200 ha (1). The vegetation and climate are extremely variable. Live oak--shinnery oak--tall grass savannas at the eastern edge change with decreasing annual rainfall to a desert-plains grassland with low shrubs in the western part. The soils are generally loamy sands, bleached and somewhat subject to wind erosion. Annual rainfall ranges from 89 cm on the eastern edge to about 38 cm in the west. With the advent of heavy grazing and cropping, the grass cover has been seriously reduced. Ninety-seven percent of the area is infested with woody brush species, fifty-one percent with dense stands (3).

The Southern High Plains Land Resource Area and the Breaks

The High Plains contains 1,537,600 ha in Oklahoma and 2,593,400 ha in Texas (1, 17). Level plateaus are found in the Oklahoma and Texas "Panhandles," but land slopes from the 1350 m plateau to about 600 m above sea level in the southeast. The soils have developed from outwashed material carried from the high country to the west. Headward erosion along the major rivers and tributaries has cut away great quantities of the soil material, sometimes to the bedrock, forming what is known as the "breaks of the plains." Rainfall ranges from 38 to 56 cm per year, with the lighter rainfall in the northwest and the heavier in the southeast (17). The original vegetation reflected the rainfall limitations; "mixed grass" prevailed on the fine-textured soils, and a mixture of mid and tall grasses with shinnery oak and sage brush covered the deep sands. Agriculture has resulted in the spread of mesquite onto 51 percent of the grasslands. In recent years, irrigation both from deep wells and surface reservoirs has been a major factor increasing crop production. The long-range future of this aspect of management is questionable at best. Ground water levels, dropping in the Ogallala Formation with each growing season, are expected to decrease irrigation markedly.

The Trans-pecos Land Resource Area

The Trans-pecos is unique in many ways. Its 6,704,800 ha make up the more arid part of Texas and for the most part, it is covered by desert or desert-plains grassland (1). Extensive irrigation is impracticable; consequently, there is only limited opportunity for increasing productivity. Isolated locations because of irrigation and superior grass-covered soils have been productive. Rainfall is annually less than 46 cm, but large parts receive less than 25 cm. Creosote bush, tar bush, and cactus are the dominant plants, and their investation, at the expense of the grass vegetation, has increased with grazing (1).

The Rio Grande Plain Land Resource Area

Only the northwestern corner of the Rio Grande Plain is semi-arid. Soils and geological formations of the Nueces and Guadelupe-San Antonio parts of the plain are generally not as permeable and well drained as are soils to the north and west. Rainfall ranges from 46 to 89 cm; the western sections receive the lesser amount. Very dense brush infestation predominates the area, and little grassland agriculture is feasible without extensive brush control (3).

The soils, climax vegetation, invading plant species, water use efficiency and, consequently, the productivity of the entire area described in the preceding pages is tied to the climate of the region. To summarize the introductory section of the paper then, one may generalize about the area studied in terms of "Climatic Provinces." Figure 1 shows the delineation of Climatic Provinces based upon rainfall, evapotranspiration and temperature. In our discussion, we will concentrate on areas 17 and 25 (20).

Existing Systems

The beef industry in the subject area is as varied as the land. Although very few cattle are slaughtered directly off grass, forages are indispensable in the semi-arid production arena. To properly represent systems currently in use and to develop useful generalizations from which to work, we relied heavily on responses to a questionnaire circulated to "key" extension, research and industry personnel operating in the area. Of 20 questionnaires distributed, 19 were returned and provided excellent coverage of the area.

Forages available for use and generalized information on growth habits and current uses are shown in Table 1. Most systems are built around the grazing of small-grains pasture in winter and of native range in summer. By far, the most common use of native range is grazing, but some "prairie hay" is still harvested. Because of the indeterminate flowering characteristics of the collective native grass sward, the quality of prairie hay is seldom high. This low quality, plus the low yield of native pastures (especially those with a history of abuse) and encroachment of woody species, have brought

Table 1. The growth and quality characteristics and uses of forages available in the semi-arid South

Item	Common name	Scientific name	Period of growth[a]	Period of high quality[b]	How consumed:[c] Grazed	Hayed	Processed
Commonly used							
Perennials	Bermudagrass	Cynodon dactylon	May 1-F	May 1-June 15	1	1	3
	Weeping Lovegrass	Eragrostic curvula	April 15-F	Apr. 15-June 15	1	1	3
	Native Range	Mixed	May 1-F	May 1-July 1	1	3	3
	Kleingrass	Panicum coloratum	June 1-F	June 1-July 1	1	1	3
	Alfalfa	Medicago sativia	April 15-F	April 15-F	2	1	1
Annuals	Sudangrass	Sorghum bicolor	July 15-F	July 15-F	2	1	3
	Wheat	Triticum aestivum	Nov. 20-May 1	Nov. 20-May 1	1	3	3
	Sorghum X Sudangrass	Sorghum X Sudan	July 15-F	July 15-F	2	1	3
	Rye	Secale cereale	Nov. 20-June 1	Nov. 20-June 1	1	3	3
Occasionally used							
Perennials	Fescue	Festuca arundinacea	Nov. 1-May 1	Nov. 1-May 15	1	2	3
	Plains Bluestem	Bothriochloa ischaemum	June 1-F	June 1-F	1	1	3
	Caucasian Bluestem	Bothriochloa caucasiacus	June 1-F	June 1-F	1	1	3
	Orchardgrass	Dactylis glomerata	Nov. 1-May 1	Nov. 1-May 1	1	2	3
	Bromegrass	Bromis inermis	Nov. 1-May 1	Nov. 1-May 15	1	2	3
	Ryegrass	Lolium perenne	Nov. 20-June 1	Nov. 20-June 1	1	2	3
	Tall Wheatgrass	Agropyron elongatum	Nov. 1-May 15	Nov. 1-May 15	1	1	3

Table 1 (continued)

Item	Common name	Scientific name	Period of growth[a]	Period of high quality[b]	How consumed:[c] Grazed	Hayed	Processed
Annuals	Hairy Vetch	Vicia cillosa	Nov. 1-June 1	Nov. 1-June 1	1	2	3
	Barley	Haridum vulgare	Nov. 20-May 1	Nov. 20-May 1	1	3	3
	Oats	Avena sativa	Nov. 20-May 1	Nov. 20-May 1	1	3	3
	Corn	Zea mays	Apr. 15-June 1	N/A	3	3	1
	Sorghum				3	3	1

[a] F = Frost

[b] "Period of High Quality" is defined here as that time period when under existing levels of management calves gain 0.8 - 0.9 kg./head/day.

[c] 1 = frequently; 2 = occasionally; 3 = seldom.

about a decrease in the use of prairie hay. Where there has been a need to intensify or where the native grass vegetation has been severely damaged by overgrazing, warm-season perennial grasses have become important. Bermudagrass (Cynodon dactylon (L.) Pers.) on irrigated as well as dry land pastures on the eastern edge of the subject area (area 17 in Figure 1) is highly productive when fertilized. When grazed, bermudagrass forage normally produces good gains on calves for about 6 weeks in the spring, then it becomes more useful as cow feed. Bermudagrass hay is harvested in great quantities, especially from irrigated fields. Not only does this practice result in winter feed for the cow herd, but it also tends to improve quality of the standing forage by keeping the plants vegetative.

Lovegrass replaces bermudagrass in "improved" pastures in much of the northern half of the area designated 25 in Figure 1. Lovegrass is more drought tolerant; hence, in the dry northwest part of the area, it supports beef gains and carrying capacity superior to those of bermudagrass. Yields of weeping lovegrass are also high and this forage is quite often harvested as hay.

In the southern half of area 25, Kleingrass is used nearly as frequently as lovegrass primarily because it is higher in quality. Kleingrass is not as winter hardy as lovegrass but nevertheless it provides an excellent hay crop for use in cow-calf winter feeding.

Particularly in the grazing situation, these grasses must be managed with care to assure high quality. As the stage of maturity increases in these warm-season perennial grasses, quality decreases precipitously.

Annual forage species can provide high-quality forage for much of the year in the area. Wheat is the predominant annual forage in all of the area under discussion except the southernmost areas where wheat grows poorly and is replaced by oats. About 4,800,000 ha of winter wheat were planted in Oklahoma and Texas in 1974 (8, 10). Much of this is not now grazed, but it represents a potential resource of nearly unlimited proportions. That wheat which is grazed is stocked at rates averaging 0.8-1.2 ha per head. Little use is made of wheat in cow-calf operations when grain supplements are readily available, but grain-supplement cost increases could result in return of some cows to wheat. Wheat pasture forage can support calf gains in excess of 1 kg per head daily.

Other small grains are grazed in substantially lesser amounts. Rye, in particular, is used when the producer wants to improve fall and winter grazing. Regardless of the biological potential offered by small grains forage in the spring, it would not be realistic to rely on this forage after March 1-10. The very factors that have brought forage-feeding systems to the forefront of agricultural concern are the factors that encourage increased grain harvest. This condition explains the present (and anticipated) practice of removing calves from small grains pasture March 1-10, before the onset of "jointing." Such a system will allow June-July harvest of grain.

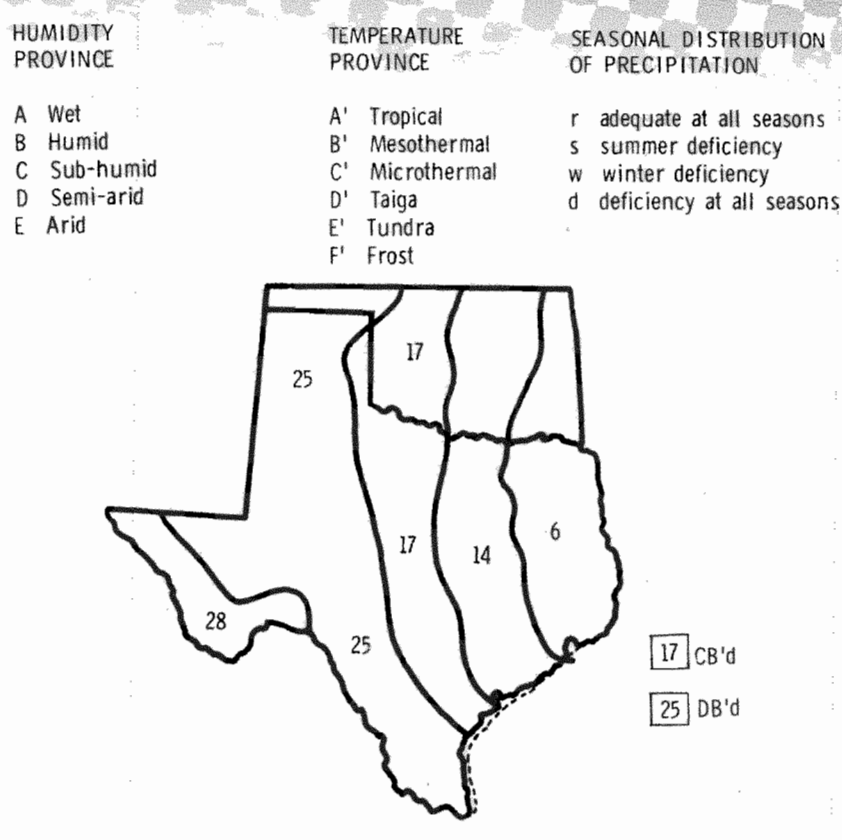


Figure 1. Climatic provinces for climates of Oklahoma and Texas (adapted from C. W. Thornthwaite, Geographical Review v.21: 633-655, 1931).

Summer annual forages, although they are not as high in quality as wheat, are used extensively throughout the area. Where moisture is adequate, they are commonly used in rotation with wheat. Carrying capacity of sudangrass or sorghum x sudangrass pastures is about one head per acre and individual animal gains commonly exceed .7 kg per head daily. These forages are also used extensively for production of hay for winter feeding. The quality of the hay is not high, but it assures winter feed in dry years.

The major hay crop in the area studied is alfalfa. This high quality forage is grown virtually throughout the area, with the exception of parts of the High Plains and Trans-pecos where infestations with mold organisms destroy the stand. Cattle do not graze alfalfa extensively because of the high incidence of bloat on alfalfa pastures. After frost, the bloat diminishes, however, and grazing then becomes common.

The many species of forages shown as "Occasionally Used" in Table 1 are used to "fill the gaps" in the basic wheat-native grass system. Land areas on which these grasses grow are increasing but, to date, are relatively small.

Althought the forage management components of the system across the subject area are not usually consistent, the animal management component is remarkably uniform. Despite the myriad of crossbreeding programs ostensibly designed to increase feed efficiency, growth rate and reproductive performance, Hereford blood and Angus blood still dominate the beef cattle enterprise in the semi-arid area. Few other breeds or breed-crosses were mentioned; and when they were mentioned, it was noted that their incorporation into the breeding program was slow and rare.

Existing systems of forage-beef management are not geared toward production of a finished beef. Rather, they prepare the calf for a period of about 120-140 days in the feedlot on a high-concentrate ration. Most cow-calf operators have gone to spring calving. Notable exceptions are in areas around Amarillo, Texas, and Ardmore, Oklahoma, and in parts of south Texas near San Antonio. In these fall-calving programs, most calves are born in November. In spring calving programs, most calves are born in February and March. In the Trans-pecos Land Resource Area, calving is somewhat later; most calves are born in April and May. Essentially, all calves are sold as stockers at about 178 to 268 kg and 6 to 8 months of age, at the time of weaning. If there is a trend in weaning--sale weight and age, it is an increase as one moves west. However, it is more likely that even as one goes west, the variability rather than the average age changes. In the eastern part of the subject area, reported sale ages are 6 to 9 months; in the western part reported sale ages are 7 to 9½ months. In the Trans-pecos country (except for the Davis Mountain Area), still another exception is found. Calves in most of the Trans-pecos reach 15 months of age and 357 kg before they are sold as "stockers."

Two general forage-stocker systems can be inferred from the information collected. One system is used by most producers in years when

grain prices are high and cattle prices are low. The major consideration is, of course, whether to harvest wheat grain. To do so demands removal of all cattle from the wheat before March 15. Presently, there is no forage available to cattlemen in the area which will support acceptable gains from "pull off" time until perennial warm-season grasses are growing. Most stocker cattle producers, therefore, sell directly to feedlots during this period.

A second popular system is used in years when grain prices are low and cattle prices are high. Futility of producing grain spells success for producing beef. The best gains recorded in the area have been achieved on "graze out" small grains pasture. When a "graze out" program is used, no supplementation with grain is required in the spring months. Both of the general system frameworks currently in use fail to provide adequate forage-based nutrients for rapid animal growth in the fall.

Potential New Systems

The integration of multiple plant species into systems that will provide near year-round grazing of quality forages seems to offer the greatest potential for increasing the role of forages in finished beef production. The utopian goal of such systems is the elimination of the "peaks" and "valleys" of seasonal forage production and the substitution in their place of ample quantities of nutritious forages for grazing animals throughout the year. Unfortunately, the erratic, often harsh climatic conditions of the semi-arid southern great plains make this utopian goal very unrealistic.

On the other hand, forages can play a more important role in the production of marketable beef. Results of recent work at the Southern Great Plans Field Station, Woodward, Oklahoma, clearly show that available forages can be incorporated into grazing systems with the potential of increasing beef production per hectare many fold. McIlvain and Shoop (19) measured the performance of steers on each of three complementary pasture systems and compared these results with performance data of steers continuously grazing native range (Table 2). The three complementary pasture systems were: 1) native range plus weeping lovegrass, 2) native range plus wheat plus sudangrass and 3) weeping lovegrass plus wheat plus sudangrass. Stocker steers were maintained on the respective pasture systems from the time they were weaned in October to the time they were sold as feeder steers one year later. Use on any of the three complementary pasture systems resulted in increased animal carrying capacity and consequent increased animal gains and economic returns per hectare. Gains per steer did not fluctuate as widely between systems; indeed, only the native range plus wheat plus sudangrass system produced greater individual steer gains than did continuous grazing of native range.

More recently, Dewald and McIlvain (14) have incorporated more forage species into complementary pastures systems that they have used for three years to produce calves with an average weaning weight of 318 kg. The forages used in their system included native range,

Table 2. Generalized beef production data and economic returns from four grazing systems, 1966-72. U. S. Southern Great Plains Field Station, Woodward, Oklahoma

Grazing system	Generalized yearlong data					
	Hectares per steer	Gain per steer (kg)	Gain per hectare kg	% of NR	Returns per hectare $	% of NR
Continuous Native Range	3.2	177	55	-	9.51	-
Narive Range + Weeping Lovegrass	2.0	163	82	149	15.81	166
Native Range + Wheat + Sudangrass	1.8	191	106	193	24.71	260
Lovegrass + Wheat + Sudangrass	0.8	168	210	382	33.36	351

Source: After McIlvain and Shoop, 1973 (19).

small grains (wheat, rye) and pearl millet. Fall-born calves (born late September through early October) were given free access to wheat or rye "creep" pastures, or wheat and rye pasture mixtures, from November 1 through May 30. They were given access to pearl millet from June 15 to about mid-August, at which time they were weaned. The small grains and pearl millet pastures were used to complement the moderate use of native range for this October to mid-August period. The mother cows were rotationally grazed on small grains (wheat or rye or wheat and rye mixture) during a "flushing" period from November 1 through 30 and during a 70-day breeding season beginning December 1 and ending February 8. Cows were otherwise pastured on native range. When on dormant native range, each cow received 0.7 to 0.9 kg each of 41 percent crude protein cottonseed cake and cracked sorghum grain daily. The important forage management components of the systems as outlined by Dewald and McIlvain include:

1) Moderate use of native range by the cow-calf pair except for light use during April, May and August.

2) Brush and weed control.

3) Proper livestock distribution and complementary use of native range with a minimum acreage of high quality farmed forages

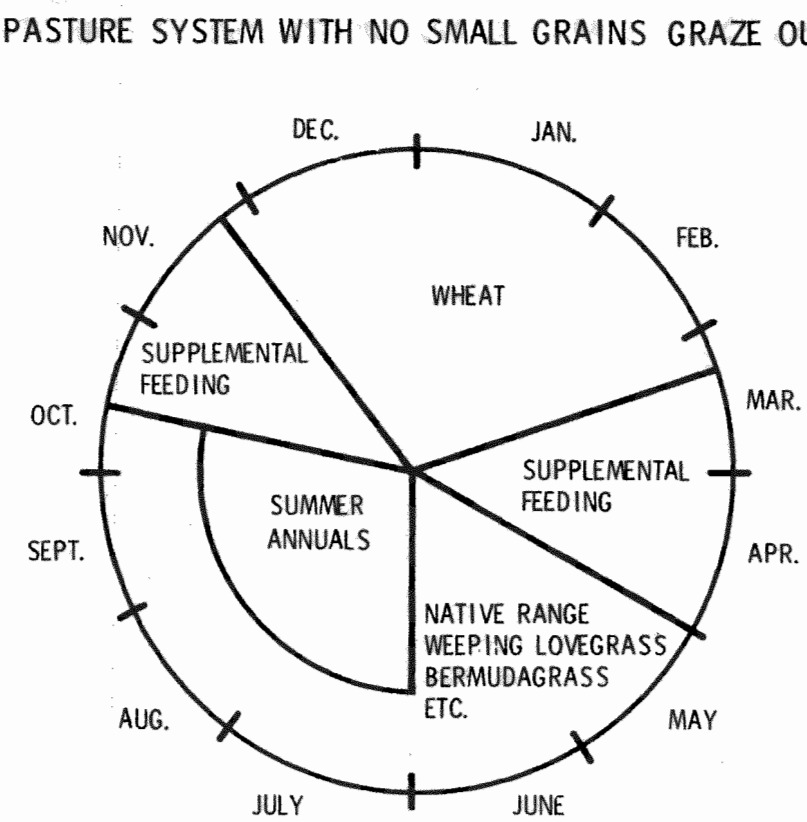


Figure 2. Potential forage-based beef finishing system founded on March "pull-off" os small grains winter pasture

to meet the critical needs of the cow and allow her to recycle promptly and to increase milk production and prolong her lactation period and to provide the calf with a green creep at all times.

Dewald and McIlvain view this accomplishment as a springboard towards producing 454 kg of forage-fed weaner calves in the near future. The experimental grazing systems outlined serve as prototypes for future discussion of potential new systems.

The small grains species (wheat, rye, oats and barley) are unquestionably the highest quality forages available for use in the semi-arid southern plains area. Consequently, potential pasture systems designed to increase individual animal gains must revolve around the expected use of these species. Wheat is by far the most predominant small grains species used and its period of use is dependent upon whether a grain crop is to be produced. Thus, we shall explore the possibilities of two such potential systems, one assuming the dual use of wheat for winter pasture with subsequent harvest of grain and the second assuming the use of small grain species in a "graze out" system.

In addition to the small grains species, other available forages include native range and warm-season perennial species such as weeping lovegrass, bermudagrass and, in the southern part of the area we are concerned with, perhaps kleingrass. Summer annual forages would either be sudangrass, sorghum x sudan hybrids or one of the millets, probably pearl millet. Also, volunteer annual forages such as the cool-season bromes and crabgrass offer highly nutritious grazing during short periods of the year.

System 1. Wheat-No Graze Out

This potential system is schematically presented in Figure 2. Wheat is grazed from November to about March 10. We have indicated the initiation of wheat grazing to begin about November 20, but the date of this occurrence obviously depends upon climatic conditions and planting date. A late August or early September planting of wheat will, under favorable moisture conditions, provide earlier grazing and a consequent extended fall grazing period. The March 10 to 15 grazing deadline is more or less fixed. Any grazing beyond those dates is at the expense of grain yield. Removal of the animals from the wheat pasture will necessitate putting them on dormant warm-season pasture until about May 1 when the warm-season perennial pasture grasses are available. During this March 10 to May 1 period, supplemental feeding of high-quality hay or concentrate, or both will be necessary. Supplementation will also be necessary during harsh climatic periods that occur sporadically from December to "pull-off" time March 10. Beginning about May 1, the warm-season perennial forages, including native range, weeping lovegrass and bermudagrass, usually provide ample amounts of high-quality herbage for about six weeks, or until June 15. Daily individual animal gains in well managed pastures of any of these species will average 0.9 kg or greater. After June 15, forage quality of these species rapidly decreases, and individual daily animal gains

usually decrease accordingly to 0.5 kg or less. The warm-season annual grasses such as sudan or sorghum x sudangrass hybrids or pearl millet can be used advantageously from about July 1 to late summer or early fall. Given adequate moisture, the forages produce high yields of dry matter, but individual daily gains by grazing animals is often disappointing. Elder and Denman (16) reported average daily annual gains of 0.4 to 0.6 kg for 272 kg animals grazing either sudangrass or a sorghum x sudan hybrid in tests at Muskogee and Stillwater, Oklahoma. These grasses can, however, complement native range, lovegrass and bermudagrass, which often are deficient in both quantity and quality during the summer months. From October 1 to the time wheat pasture is ready is characteristically a forage-deficient period requiring supplemental feeding to sustain good animal gains. The sweet sorghums such as the "Sugardrip" variety have been used successfully to provide stockpiled forage during this period. But again, supplemental feeding of high-quality hay or concentrates is required to sustain good animal gains.

System 2. Wheat--Graze Out

A schematic presentation of this potential system is presented in Figure 3. The principal difference between this system and system 1 is that small grains species other than wheat are included and the length of the grazing season on small grains is extended to the time of their maturity in late spring. Again, we have indicated a late November initiation of grazing on small grains, but the actual date is determined by the aforementioned factors. Also, the use of mixtures of small grains, particularly wheat and rye, or the growing of these species in respective pastures will influence available forage at particular periods of the season. The relative merits of small grains species and their management in pasture systems have been discussed by Dalrymple (13) and Elder (15). Use of small grains species mixtures or the planting of separate pastures of different small grains species usually is preferred because of differences in seasonal production and maturity dates. Rye usually is more productive than wheat in the fall months but matures earlier in the spring. Conversely, wheat matures later than rye in the spring and thus extends the length of grazing during this period. To this point, no legume other than alfalfa (for hay) has been mentioned. Hairy vetch (Vicia villosa roth) is the one proven legume species that has been used successfully for grazing in parts of the semi-arid great plans area. When planted as a mixture with wheat or rye or both, it will extend the spring grazing period by two to three weeks. Annual ryegrass is used successfully in central Oklahoma and Texas, but results have not been encouraging in western sections of the two states because of its poor growth until late in the spring.

Small grains species planted specifically for grazing can provide 5 1/2 to 6 months of grazing from November 1 to May 1. The greatest growth usually extends from about February 15 to May 1. Individual animal gains can be expected to average at least 0.7 kg. per day or more during this period given favorable moisture conditions. As in system 1, native range, weeping lovegrass and bermudagrass can provide

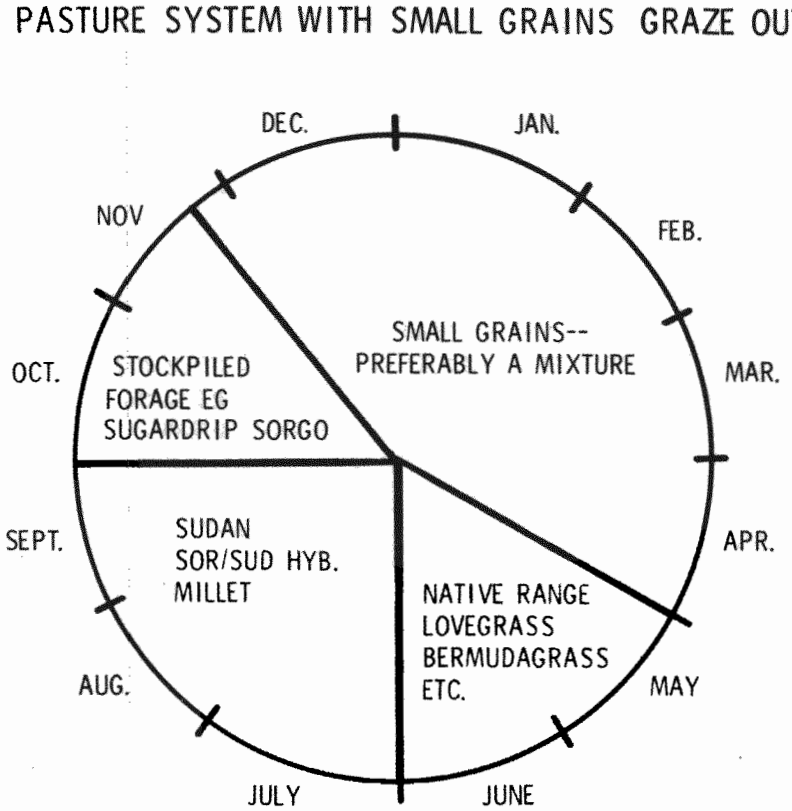


Figure 3. Potential forage-based beef finishing system founded on "graze-out" of small grains winter pasture

ample quantities of nutritious forage during May and June. Again, individual animal gains under reasonable good climatic conditions can be expected to average 0.7 kg per day or greater. To sustain reasonably good animal daily gains after July 1, annual forages such as sudangrass, sorghum x sudan hybrids or millets must be provided to complement the perennial forages. The period beginning around October 1 and extending to the beginning of small grains grazing must again be classified as a forage-deficient period requiring supplemental feeding of high-quality hay or concentrates to sustain good animal gains. Stockpiled forages from the summer annual and perennial grasses are used as the basic pastures for this period, and alfalfa hay, cottonseed meal and feed grains are used as supplements. High-quality corn or sorghum silage can be used in lieu of supplements mentioned.

Potential Problems and Pitfalls

Managerial Skill

Pasture systems in which many different forage species are used, each having its distinctive growth characteristics and specific management requirements obviously add immensely to the overall operational complexity. The system manager cannot help but have an almost daily multitude of decisions to make on diverse systems operations. Operations on which decisions must be made range from "when, what kind and how much of farmed forages to plant" to the timely rotation of animals on pasture. Grazing pressure must be adjusted to supply the quantity of nutrients needed for desired animal gains. Additional operations requiring decision making include: 1) fertilization of farmed forages and tame pasture, 2) weed control in pastures and 3) insect and disease control on both pastures and livestock. Thus, the system manager must possess specialized skills. The manager must have a basic understanding of the biology of the forages and livestock that are used in the system--so that he can apply the proper management techniques to ensure their optimum performance. Although a thorough knowledge of the basic biological requirements of plants and animals might allow the manager to derive maximum production from them, it would not necessarily ensure financial success. The manager must also consider the economic consequences of the operational decisions that are made.

The systems approach not only increases the level of technical skills needed, but also proportionally increases the amount of physical labor required. Regardless of the size of the operation, hired assistance usually is needed either intermittantly or regularly. Lack of managerial expertise, or motivation to apply may very well be the most limiting factor to the successful implementation of forage finishing-beef systems. Most livestock production units are family owned and conducted as a family enterprise.

Climate

In the forage system, "timeliness" is of major importance. Periods of undue delay in implementing any integral part of the system can

cause severe repercussions at a later date. Farmed forages must be planted "on time" during specific periods within the year if they are to fill the forage needs of grazing animals during subsequent critical periods. As any livestock producer in the semi-arid western Oklahoma and Texas area can attest, too little or too much rainfall can and often does cause extended delays in critical planting and harvesting operations. Harsh temperatures, either high or low, can prevail for extended periods of time, causing conditions very unconducive to either plant or animal growth. Consequently, great flexibility must be built into forage systems. As pointed out by Dalrymple (13), balance and flexibility in a pasture system constitutes an insurance program guarding against adverse changes in plant and livestock circumstances. Sufficient flexibility must be available so that the systems manager can compensate for adverse conditions by altering stocking rates or grazing patterns or by resorting to the supplemental feeding of harvested forages such as hay or silage. The development and incorporation of workable "stress" feeding regimes into forage systems looms as one of the most important and challenging research areas.

Forage Species

Presently, the small grains constitute the only well-adapted species with the capability of sustained production of high-quality forage. Perennial warm-season species usually provide forage of sufficient quality to produce good animal gains (0.7 kg/day or greater) for a period of only approximately 6 weeks in the spring. The summer annual species--sudan grass, sorghum x sudan grass hybrids and millets--produce high dry matter yields per hectare and although animal gains may be somewhat better on these than on the perennial forages, they still are often disappointing.

The procurement of additional forage species through breeding or selection or combinations thereof is essential to the development and refinement of "workable" forage systems for the semi-arid plains region. Plant species or varieties within species must be found to fill particular niches in the systems so that sustained production can be achieved. Annual "volunteer" plants that are currently and commonly classified as weeds and generally considered to be undesirable may deserve to be reassessed in light of their potential contribution to forage systems. Crabgrass, *Digitaria spp.*, pigweed, *Amaranthus spp.* and the annual bromegrasses, *Bromus spp.*, are examples of such species.

The farmed forages and perennial tame pastures that now must be almost exclusively relied upon, have relatively high nitrogen fertilizer requirements. If adapted nitrogen fixing legumes were available, they could replace part of the nitrogen-requiring grasses and provide the rest with a part of their needed nitrogen.

Conclusion

The semi-arid areas of the south may support finishing of beef through grain feeding on pasture or through reduced grain feeding in

feedlots, but the finishing of beef on a total forage ration will require additional research and education. The production of finished beef grading good or high-good from standing forages alone is highly unlikely in the area designated 25 in Figure 1. Adverse climatological factors affect animal and plant performance during extended periods throughout the year. Basic resources for the dramatic improvement of high-quality forage production are simply not available. The authors concluded that as long as research resources are limited in area 17, emphasis should be placed on developing systems to support the backgrounding of cattle. There is little doubt that forages can play a significant role in the preparation of beef to be finished in confinement.

Prospects for forage finishing of beef in area 17, Figure 1 are bright. Few systems are currently used to finish beef, but the basic resources necessary for the development of such systems are available. Forage-beef research in area 17 should be concentrated on efforts to "fill the gaps" apparent in the spring and fall forage feeding program.

ACKNOWLEDGMENTS

The authors wish to thank Drs. J. E. Hutchison, Director of the Texas Agricultural Extension Service and William Taggert, Associate Director for Extension Work, Oklahoma Cooperative Extension Service, for administrative approval and support of the questionnaire distributions. Appreciation is also extended to those administrators, extension specialists and cattlemen who so meticulously completed those questionnaires and thereby formed the basis for this report.

LITERATURE CITED

1. Grazing Characteristics and Clipping Responses of Small Grains. 1960. Okla. Agr. Exp. Sta. Bull. B-567.

2. Grassland Restoration. 1964. The Texas Brush Problem. USDA, Soil Conservation Service, Temple, Texas, 33pp.

3. A Stand Establishment Survey of Grass Plantings in the Great Plains. 1966. Great Plains Council Report No. 23, 60 pp.

4. Grassland Restoration--Part V. 1967. Effect on Water Yield and Supply. USDA, Soil Conservation Service, Temple, Texas, 46 pp.

5. Conservation Problems in Texas. 1970. Report of the Research Committee of the Association of Texas Soil and Water Conservation Districts, 37 pp.

6. Beef Cattle Research Needs in the Southern Region. 1974. Prepared by: A Joint Task Force of the Southern Region Agricultural Experiment Stations and the USDA research scientists with counsel from Beef Cattle Industry representatives.

7. Forage and Pasture Research Needs in the Southern Region. 1974. Prepared by: A Joint Task Force of the Southern Agricultural Experiment Stations and USDA research scientists.

8. Joint Forage-Range-Beef Cattle Research Planning and Review Conference. 1974. El Reno, Oklahoma, September 9-13, 1974. 83 pp.

9. Oklahoma Agriculture. 1974. Oklahoma Crop and Livestock Reporting Service. 105 pp.

10. Review of ARS Research Program on Western Range Ecosystems. 1974. (Technical Report), Tucson, Arizona, March 12-14, 1974.

11. Texas Field Crop Statistics. 1974. Texas Department of Agriculture and USDA Statistical Reporting Service.

12. Texas Small Grains Statistics. 1974. Texas Dept. of Agric. and USDA Statistical Reporting Service, 40 pp.

13. Dalrymple, R. L. 1972. Small Grains Winter Pasture Systems and Their Management. In Proceedings of Symposium on Management of Intensified Winter Pastures and Stocker Calves. Agricultural Division of the Noble Foundation, Ardmore, Oklahoma.

14. Dewald, C. L. and E. D. McIlvain. 1975. Forage fed 700 pound weaner calves today--1000 pound weaners by 1980. In Proceedings of Forage and Livestock Conference. Agricultural Division of the Noble Foundation, Ardmore, Oklahoma.

15. Elder, W. C. 1967. Winter grazing small grains in Oklahoma. Okla. Agric. Exp. Sta. Bull. B-654.

16. Elder, W. C. and C. E. Denman. 1966. Sudangrass and sudangrass hybrid research. Okla. Agric. Exp. Sta. Processed Ser. P-543.

17. Gray, F. and H. M. Galloway. 1959. Soils of Oklahoma. Okla. Agric. Exp. Sta. Misc. Pub. MP-56.

18. Matlock, R. S. 1971. Soil water and plant resources in Oklahoma--patterns and trends, pp. 2-27. In Report of the Twenty-eighth Southern Pasture and Forage Crop Improvement Conference. Okla. State. Univ., Stillwater, Okla. July 6-8, 1971, 144 pp.

19. McIlvain, E. H. and M. C. Shoop. 1973. Use of farmed forages and tame pasture to complement native range. In Proceedings of Great Plains Beef Symposium. Great Plains Agricultural Council Publication No. 63, pp. L-1 to L-19.

20. Thornthwaite, C. W. 1931. The Geographical Review 21(4):633-655.

EXISTING AND POTENTIAL SYSTEMS OF FINISHING CATTLE ON FORAGES OR LIMITED GRAIN RATIONS IN THE TROPICAL REGION OF THE SOUTH

G. O. Mott and J. E. Moore*

This review covers the geographical areas of peninsular Florida and Puerto Rico where tropical forages supply most of the nutrients to beef cattle. Environmental factors impose certain seasonal restraints upon the quality and quantity of forage produced during the year and upon animal performance. Grass finishing of slaughter cattle is a traditional practice in the tropics with little or no supplemental feeding. Two to six years are required to produce a slaughter animal and the resulting carcasses are lean and dressing percentages of 55 to 58 percent are common. The purpose of this paper is to examine some of the factors which have been identified as limiting beef cattle production, and to review the research which has been conducted to solve some of the problems associated with grass finishing of beef cattle.

Some relevant physiographic features of Puerto Rico and Florida are given in Table 1 (16) and Figures 1 and 2. In Puerto Rico the altitude and rainfall is much more variable than in Florida but the average daily temperature within the two regions is quite similar. The physical and chemical properties of the soils are quire variable within the two regions and the two regions are greatly different from each other. Most of the soils in both Puerto Rico and Florida are very low in fertility and soil amendments are required to produce grasses and legumes with high production potential. The exceptions to this general situation are the limited areas of alluvial deposits in Puerto Rico and the organic soils of the Everglades of Florida.

A bimodal pattern of rainfall in the central humid tropical region at Orocovis, Puerto Rico (16) is illustrated in Figure 1. The moisture availability during the seasons of the year has an effect upon the quantity and quality of forage on offer. This is more evident on the south coast of Puerto Rico where a wet-dry pattern of rainfall prevails with less than 1000 mm of total annual precipitation. The rainfall pattern in peninsular Florida is illustrated in Figure 2 on a weekly basis of the probability of a 12.7 mm (.5 inch) rainfall. The chance of rain during the seven month period beginning in late October and ending in early May is less than about 50 percent with most of the rainfall occurring during the period of late May to mid October.

* G. O. Mott, Professor of Agronomy, University of Florida, Gainesville, J. E. Moore, Professor of Animal Science, University of Florida, Gainesville.

Table 1. Physiographic features of areas of interest in Puerto Rico (16) and Florida

Puerto Rico
Altitude--sea level to 1400 m
Temperature--mean annual 20°C to 26°C
Rainfall-- < 1000 mm to 5000 mm
Soils--heavily leached oxisols to clay alluvial deposits
Florida
Altitude--sea level to about 50 m
Temperature--mean annual 22°C to 25°C
Rainfall-- < 1000 mm to 1600 mm
Soils--flat woods, sandy soils--Ona,organic soils of Everglades-Belle Glade

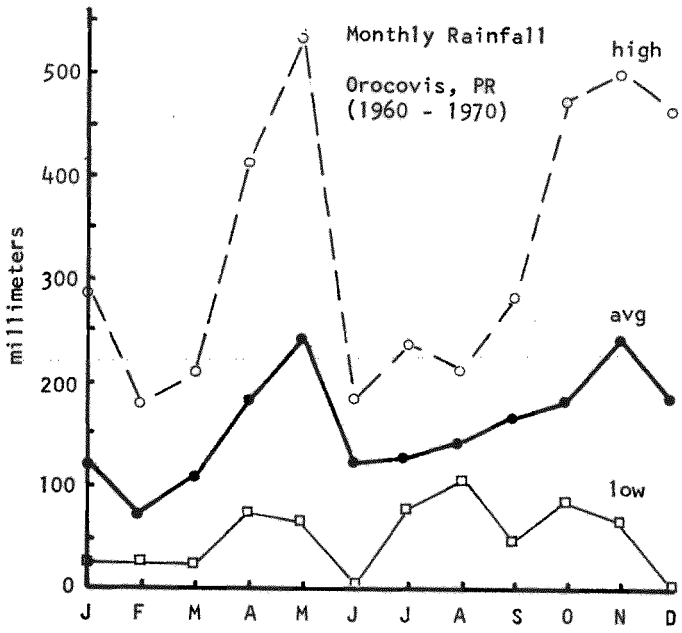


Figure 1. Monthly rainfall under conditions typical of the humid region at Orocovis, during the decade of 1960-1970 (Vicente-Chandler et al., 1974)

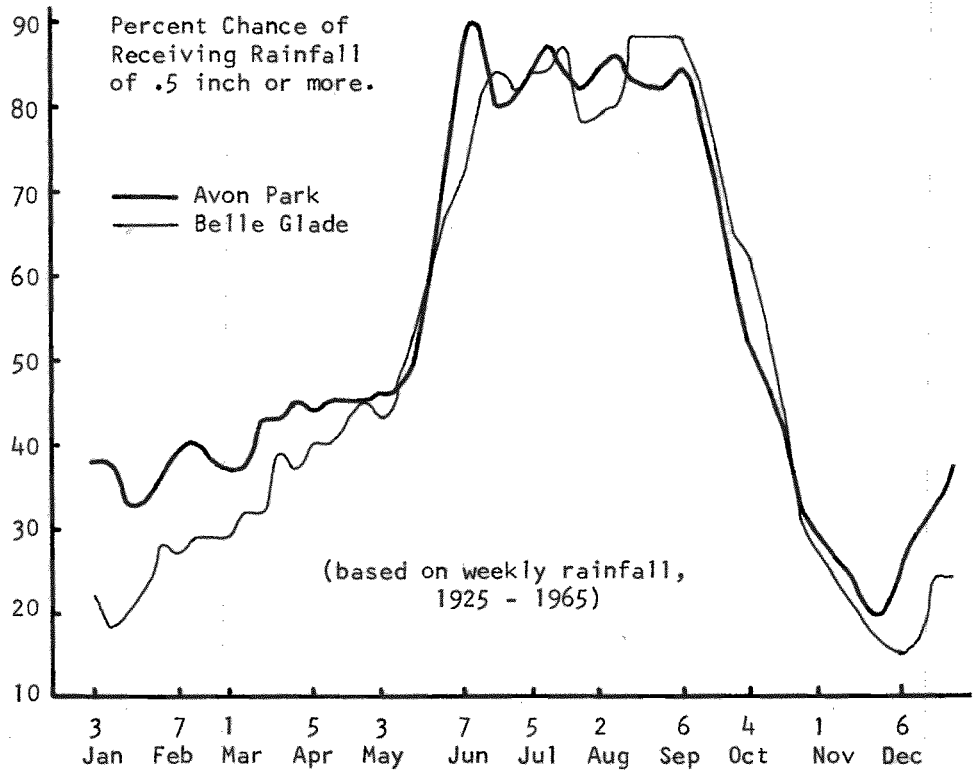


Figure 2. Probability of receiving rain at Avon Park and Belle Glade, Florida, 1925-1965

Research Efforts to Improve Beef Cattle Production

The authors have examined station reports, mimeographs, extension publications and research papers from the assigned region to determine the efforts which have been made to improve the system of beef cattle production. Somewhat to our surprise, deficiencies in the system were recognized at least 40 years ago and questions being asked then are still with us today. Efforts have been made to improve production by the: (1) introduction of grasses and legumes with greater growth potential; (2) addition of lime and fertilizer; (3) grazing of winter annuals; (4) feeding of concentrate feeds on pasture and in the feedlot; and (5) feeding of conserved forages, hay and silage, with concentrate.

Cultivated Pastures

A few cultivated grasses are used in improved pastures in both Peninsular Florida and Puerto Rico (Table 2) but elephantgrass, paragrass, guineagrass and congograss are grown more extensively in Puerto Rico; whereas carpetgrass, bahiagrass, bermudagrass, St. Augustinegrass and limpograss are more frequently found in Florida pastures. It has been estimated that about 80 percent of the improved pastures in Florida are bahiagrass. St. Augustinegrass is grown almost exclusively in the organic soil region of South Florida.

Experimental Results

The review of experimental results will follow the general pattern of least intensive to the most intensive systems of production in each area of Puerto Rico and South Florida. The philosophy of intensification in the two regions has followed two widely divergent pathways. In Puerto Rico the emphasis has been on the use of heavy application of fertilizer upon grass pastures with high growth potentials. In Florida, the research has been directed toward alternative sources of feed to meet the requirements of the beef cattle herds during stress periods.

Pasture Alone--Florida

The data in Table 3 indicate the very low animal production of carpetgrass and common bahiagrass without fertilization (8). These two grasses accounted for much of the planted pasture in Florida until the introduction of Pangola digitgrass and Pensacola bahiagrass. Over six hectares of these earlier species were required for a yearling to two-year-old steer and even then, the average daily gain for the year was extremely low. The use of fertilizer greatly increased the carrying capacity and the liveweight gains, both per animal and per hectare. The use of fertilizer and the introduction of white clover into the pastures had the most dramatic effect upon the carrying capacity and upon animal production. White clover grows well during the winter months and supplies a high level of nutrition during that season when cattle would normally be losing weight. Pangola has higher quality

Table 2. Cultivated grasses and legumes used in improved pastures in Puerto Rico and Florida

Grasses		
Elephantgrass, *Pennisetum purpurem* Schumach	PR*	
Guineagrass, *Panicum maximum* Jacq.	PR	F1**
Digitgrass, *Digitaria decumbens* Stent.	PR	F1
Paragrass, *Brachiaria mutica* (Forsk.) Stapf	PR	
Stargrass, *Cynodon nlemfuensis* Vanderyst	PR	F1
Congograss, *Brachiaria ruziziensis*, Germain C. Evrard	PR	
Carpetgrass, *Axonopus affinis*, Chase		F1
Caribgrass, *Eriochloa polystachya*, H.B.K.	PR	F1
Bahiagrass, *Paspalum notatum*, Flugge		F1
Bermudagrass, *Cynodon dactylon*, (L) Pers.		F1
St. Augustinegrass, *Stenotaphrum secundatum*, (Walt.) Kuntze		F1
Tannergrass, *Brachiaria* sp.	PR	
Limpograss, *Hemarthria altissima* (Poir.) Stapf and Hubb		F1
Legumes		
White clover, *Trifolium repens* L.		F1
Alyce clover, *Alysicarpus vaginalis* (L.) DC		F1
Joint vetch, *Aeschynomene americana* L.		F1
Tropical kudzu, *Pueraria phaseoloides* (Roxb.) Benth	PR	

*Puerto Rico

**Florida

than bahiagrass as demonstrated by higher liveweight gains per animal. However, the two grasses had similar carrying capacities in these experiments and thus Pangola gave higher liveweight gains per ha.

Seasonal variations are concealed in annual means so that changes in quality and quantity of forage on offer is not evident. Prates *et al.* (15) studied the 28-day period variation in digestible organic matter intake (DOMI) and animal performance on a group of yearling British steers (Table 4). In September and May, DOMI was 0.65 to 1.27 percent of body weight, respectively. The liveweight gain per steer varied from -.52 to 1.00 kg per day. The stocking rate was adjusted according to available forage and varied from 2.9 to 11.4 steers per ha. Some of the lowest gains and DOMIs were obtained during the periods of highest growth rates and stocking rates. The quality of many tropical grasses diminishes during the midsummer months and this is particularly true for the bahiagrasses.

Table 3. Yearlong animal production on pasture alone at Ona, Florida, five-year means (8)

Forage	Fertilized[a]	Liveweight[b]		Steer days/ha
		ADG (kg)	gain/ha (kg)	
Carpetgrass	-	.23	13	57
Carpetgrass	+	.40	68	136
Common bahiagrass[c]	-	.24	50	209
Common bahiagrass	+	.42	98	237
Carpetgrass + White clover	+	.62	405	652
Pangola digitgrass	-	.60	185	309
Pensacola bahiagrass	+	.50	155	310

[a]34 kg/ha/yr each of N, P_2O_5 and K_2O.

[b]Yearlings and two-year olds.

[c]Four-year mean.

Table 4. Seasonal variation in the digestible organic matter intake (DOMI) and animal performance on Pensacola bahiagrass (15)

Period (28 days)	DOMI	Liveweight[a]		Head/ha
	(percent BW)	ADG (kg)	gain/ha (kg)	
May	1.27	1.00	122	4.6
June	0.85	0.53	41	2.9
July	0.89	0.19	53	10.3
Aug.	0.69	0.14	32	11.4
Sept.	0.65	-0.52	-97	5.5
Oct.	0.75	0.15	10	2.9

[a]Yearling steers, 278 kg initial weight.

On the organic soils in South Florida (1) the quantity of forage produced and thus the stocking rate (Table 5) is much greater than on the flat woods sandy soils (8) of South Central Florida (Table 3). However, a similar comparison of the quality of forage consumed, as indicated by the average daily gain (ADG), shows very small differences in the range (from 0.12 to 0.64 kg/day at Ona, Table 3 and from 0.16 to 0.45 kg/day at Belle Glade, Table 5). On the organic soils, the contrast between common bermudagrass, which was one of the few grasses available in the region prior to the 1940s, and Roselawn St. Augustinegrass is very striking (1). The ADG on St. Augustinegrass was 2.5 times that of bermudagrass and the carrying capacity was 2.4 times greater, resulting in a 5.6-fold increase in liveweight gain per hectare.

Maximum production of forage per hectare occurs much later in the season than maximum quality as indicated by carrying capacity and average daily gain (Figure 3). Maximum gain per animal on St. Augustinegrass occurred during the months of March and April while maximum production of forage occurred about two months later during June, July and August (1). Figure 3 also well illustrates the low production and low quality of forage during the dry winter months of October, November, December, January and February.

Pasture Alone--Puerto Rico

The production level of improved pastures in Puerto Rico is of a different order of magnitude from the flat woods soils of South Central Florida but are quite comparable to the organic soils of South Florida. Heavy fertilizer applications on improved pastures in Puerto Rico have been researched for at least 25 years. The results have been very impressive. These studies have adequately demonstrated the growth potential of the tropical grasses and their capacity to carry large numbers of grazing animals. Data are presented in Table 6 for two locations in Puerto Rico, the first in the relatively dry region (2) under irrigation near the south coast (Santa Isabel) and the second in about the middle of the island (3) in the humid mountainous region (Orocovis). Results from the two locations for each of three grasses, guineagrass, napiergrass and Pangola digitgrass, were remarkably similar as were the carrying capacities (2, 3). It is interesting to note that the heavy fertilization did not appear to greatly improve the quality of feed on offer since the average daily gains did not exceed 0.60 kg. This rate of gain is about equal to temperate zone forages for an average of a full grazing season. These data and others presented in this paper refute the claim that temperate perennial grasses are of better quality than tropical grasses. Temperate grasses may be superior in quality during short periods in the spring prior to anthesis but lose their quality more rapidly than tropical grasses.

Stargrass and Pangola digitgrass have been compared by the Puerto Rican scientists (4, 16) in the humid region at Orocovis (Table 7). Stargrass has proven its superiority over Pangola in both experiments. The average daily gain, the carrying capacity and the liveweight gain

Table 5. Animal production on some tropical grasses at Belle Glade, Florida, year-long grazing, three-year means (1)

Grass	Management	Liveweight[a]		Head/ha
		ADG (kg)	Gain/ha (kg)	
Common bermuda	Rotational	0.16	184	3.2
Common St. Augustine	Rotational	0.24	375	5.2
Pangola	Rotational	0.45	818	5.2
Carib	Rotational	0.40	878	5.9
Para	Rotational	0.42	941	6.2
Roselawn St. Augustine	Rotational	0.41	1013	6.8
Roselawn St. Augustine	Continuous	0.37	1043	7.7

[a]Yearling heifers and steers, 180-320 kg initial weight.

per hectare were higher for stargrass than Pangola. In each experiment the annual fertilizer application was 2240 kg/ha of 14-4-10. Stargrass apparently was not as susceptible to disease and insect damage as Pangola in Puerto Rico.

Monthly beef production patterns for the two grasses were similar but stargrass was superior throughout the year (Figure 4). Greater production occurred from both grasses from May to October and the lowest during the cooler winter months with shorter days (16). Rainfall was considered adequate throughout the year.

Effect of Pasture Fertilization Upon Animal Production

Fertilization of pastures may affect the quality of feed available to the grazing animal and/or may increase the feed available. Improving the quality of feed available should be reflected in an increase in animal performance while an increase in the feed available should increase the carrying capacity of the pasture. Increasing either or both the quality and quantity of forage will increase animal production per ha. An improvement in the quality of forage on offer is clearly demonstrated in the data presented in Table 3 from the very poor soils at Ona, Florida (8). The ADG was increased wherever fertilizer was applied, thereby indicating an improvement in the quality of feed consumed by the grazing animal. This was most marked in the mixture of carpetgrass and white clover where the application

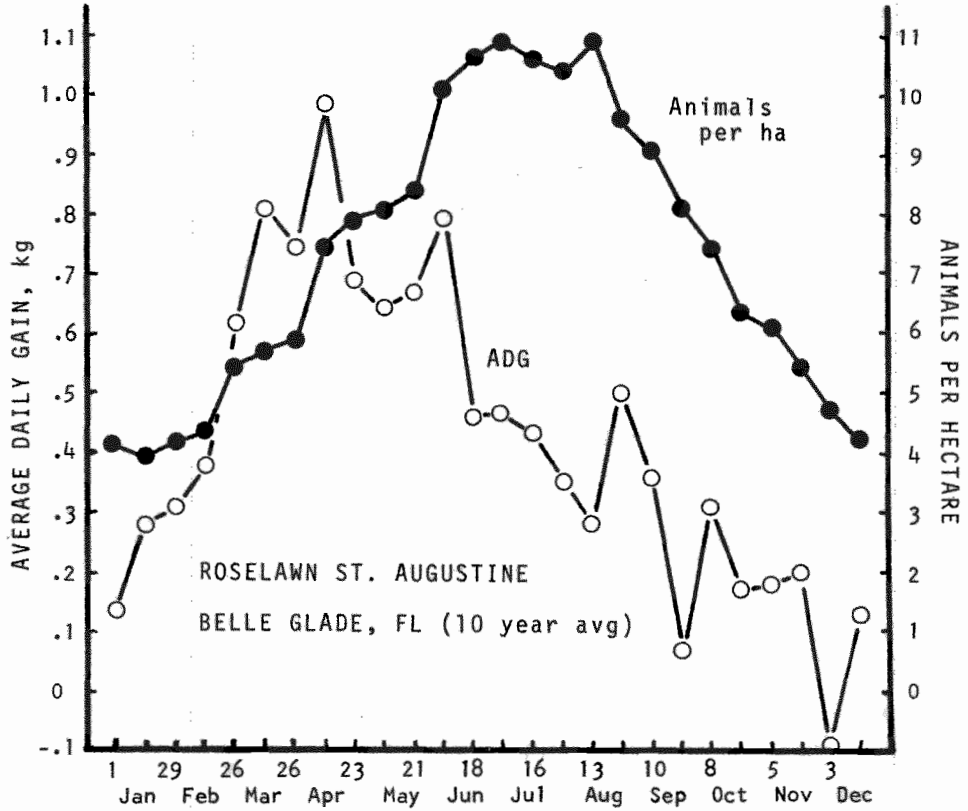


Figure 3. Seasonal variation of average daily gain (ADG) and carrying capacity (animals per hectare) of Roselawn St. Augustinegrass (Haines et al, 1965).

Table 6. Beef production on intensively managed tropical grass pastures in a semi-arid irrigated and the humid regions of Puerto Rico (2, 3)

Location and grass	Liveweight		Head/ha
	ADG (kg)	Gain/ha (kg)	
Santa Isabel, PR[a] semi-arid, irrigated			
Guineagrass	0.54	1447	7.7
Napiergrass	0.59	1486	7.2
Pangola digitgrass	0.50	1191	6.2
Orocovis, PR[b] humid			
Guineagrass	0.59	1319	6.4[c]
Napiergrass	0.57	1110	5.9
Pangola digitgrass	0.57	1124	5.9

[a]Caro-Costas et al. (2) (3360 kg/ha 14-4-10; steers, 182 kg initial weight)

[b]Caro-Costas et al. (3) (2240 kg/ha 14-4-10; heifers and bulls, 159 kg initial weight)

[c]Head/ha computed as the equivalent of a 272 kg steer.

Table 7. Comparative productivity of intensively managed stargrass and Pangola digitgrass in the humid tropics of Puerto Rico (4, 16)

	Grass	Liveweight		Head/ha[a]
		ADG (kg)	Gain/ha (kg)	
I.	Stargrass	0.59	1427	7.2
	Pangola digitgrass	0.50	1022	5.7
II.	Stargrass	0.60	1514	7.4
	Pangola digitgrass	0.49	1062	6.5

[a]Head/ha computed as the equivalent of a 272 kg steer.

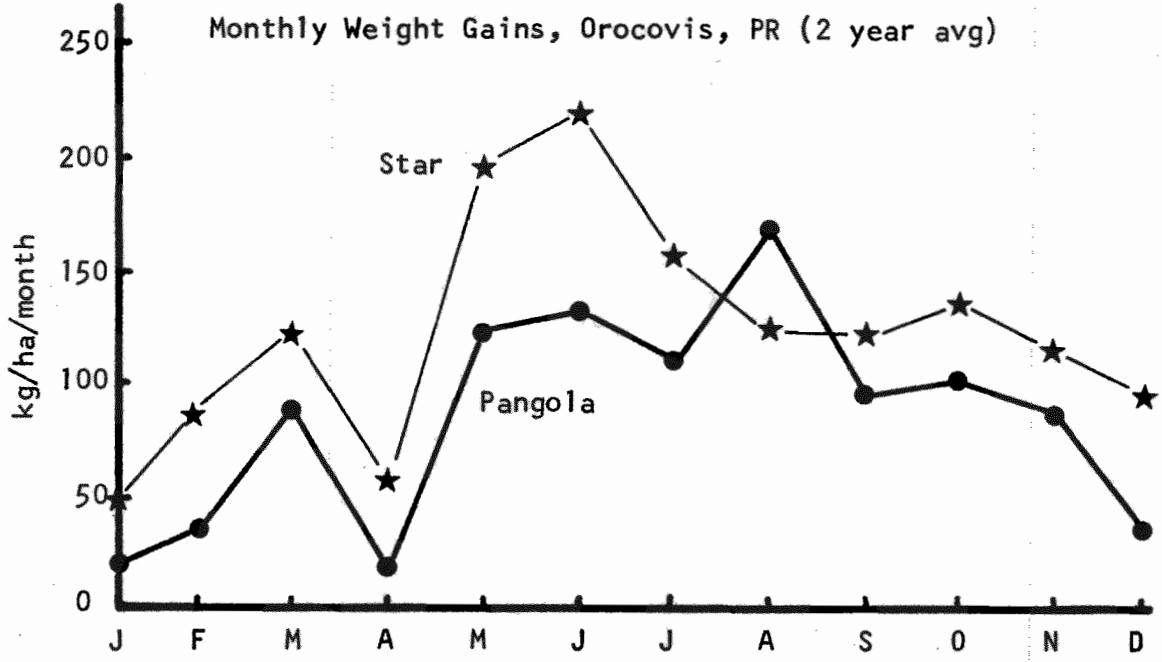


Figure 4. Average monthly gains in weight of cattle grazing intensively managed stargrass and Pangola digitgrass pastures over a two-year period at Orocovis, P.R. (Vicente-Chandler et al., 1974)

of fertilizer contributed to a change in botanical composition and the presence of white clover. Both the quality of forage and the carrying capacity of the pastures was improved by fertilization in these trials.

In pure grass pastures under intensive management in Puerto Rico, the main effect of fertilization has been to increase the carrying capacities of pastures with little if any effect upon the animal performance. Four levels of fertilization (5) and their effect upon the productivity of Pangola pastures was studied in the humid region at Orocovis (Table 8). There was a slight depression in the average daily gain as the fertilization rate was increased, but the carrying capacity and liveweight gain per ha was greatly increased. The conversion rate of applied nitrogen to liveweight increase in gain per ha over the basic rate of 448 kg/ha/year (62.7 kg/ha of N) is given in the last column of Table 8. The efficiency of nitrogen conversion remained high up to almost 400 kg N per ha.

Supplemental Pastures--Winter Annuals

Florida not only has a "summer slump" in animal production, but also a "winter slump" which is the dry period of the year. To overcome the deficiencies in both quality and quantity of forage available to the grazing animals from perennial pastures, supplemental winter annual pastures have been tested. Winter oats, rye and ryegrass are crops which have found a place as part of the feeding system for beef cattle in Florida. Oats and rye require high levels of inputs and there are high risks associated with poor establishment and unfavorable weather conditions. Ryegrass is frequently surface seeded on permanent pastures where seepage irrigation is available in the heavy beef producing area of South Central Florida.

The high quality of winter pastures (12, 13) is indicated by the relatively high average daily gains of grazing heifers and steers at the Ona station (Table 9). Carrying capacities were also quite high but the maximum grazing period was about four months and the variation between years was quite high. The profitability of winter annual pastures will be contingent upon the net improvement upon the total beef production system, and the production costs associated with their establishment.

Supplemental Feeding

A wide variety of supplements have been fed to beef cattle in Florida and Puerto Rico to alleviate the nutritional stress imposed by poor quality and the lack of sufficient quantity of pasture during certain seasons of the year. Most of these supplements are by-product feeds from the sugar, citrus and oil seed industries. A list of the most common supplements is included in Table 10.

The methods of feeding supplements can be placed into two groups: (1) pasture alone followed by concentrate feeding on pasture, (2) pasture with or without concentrate followed by feedlot finishing. Selected data are included here from each of these methods.

Table 8. Effect of four levels of (5) fertilization upon the productivity of Pangola digitgrass pastures when grazed by Holstein heifers, two-year averages

14-4-10 /ha/yr	Liveweight		Head/ha[a]	Kg LW/kg N[b]
	ADG	gain/ha		
(kg)	(kg)	(kg)		
448	0.58	398	1.9	-
1344	0.54	633	3.2	1.9
2688	0.54	976	5.0	1.8
3805	0.49	1054	5.9	0.5

[a]272 kg heifers.

[b]Kg of liveweight increase per increase of 1 kg of N/ha.

Table 9. Animal production from winter annual pastures on flatwood soils at Ona, Florida (12, 13)

Cattle and forage	Days	Liveweight		Head
		ADG	gain/ha	
		(kg)	(kg)	
198 kg crossbred heifer calves				
Oats, FL 500 (yr 1)	116	0.58	270	4.0
Oats, FL 500 (yr 2)	120	0.77	323	3.5
Oats FL 500A (yr 3)	124	0.89	493	4.5
Ryegrass, Gulf (yr 1)	99	0.76	462	6.1
Ryegrass, Gulf (yr 2)	120	0.68	257	3.1
Ryegrass, Rust Resistant (yr 3)	127	0.68	460	5.3
305 kg 2-year-old steers				
Oats, Floriland	115	0.85	302	2.6
Rye, Gator	115	0.77	185	2.1
400 kg 2-year-old steers				
Oats, Floriland	123	0.66	207	2.6
Rye, Abruzzi and FL Black	90	0.44	83	2.1

Table 10. Some energy and protein sources used in the tropics as supplemental feeds for beef cattle production

Energy:	Chopped sugarcane
	Sugarcane molasses
	Citrus--oranges and grapefruit
	Citrus molasses
	Dried citrus pulp
	Ground snapped corn
	Chopped sorghum neads
Protein:	Cottonseed meal
	Soybean meal
	Peanut meal
	Fish meal
	Urea

1. Pasture Alone Followed by Concentrate Feeding on Pasture

Spring pastures (10) are usually high in quality and this is well documented by the high ADG on both Pangola and Pensacola pastures (Table 11). The drop in quality of pasture during the summer months can be partially overcome by the feeding of supplements. The main source of energy used in this experiment was dried citrus pulp. Although the gains are not equal to those expected on full feed in the feedlot, adequate ADG were obtained to produce a finished liveweight of 400 kg. Feeding the supplement increased the ADG and the finished weight. There is a suggestion from the data on ADG during the spring months, that Pangola was slightly superior to Pensacola. The gains averaged 0.89 and 0.71 for the Pangola and Pensacola, respectively, but the differences in gain were essentially eliminated during the following summer supplemental feeding period.

The second set of data (9) also came from experiments at the Ona station (Table 12). In this trial, the summer season was divided into three periods of 60 days each with a low level of concentrate, primarily citrus pulp, fed during the second and third periods on Pangola and Pensacola pastures. The ADG for the steers on Pangola pastures was 0.85 in the first 60 days of the summer, whereas Pensacola gave only 0.68 kg/day. The supplement increased the ADG during mid and late summer on Pangola.

2. Pasture Feeding Followed by Feedlot Finishing

One of the many alternatives which have been considered by investigators in Florida was the feeding of various levels of concentrate in

Table 11. Concentrate feeding of steers on Pangola digitgrass and Pensacola bahiagrass pastures (10)

Forage	Spring		Summer			Finish weight (kg)	Carcass weight[b]
	Days	ADG[a] (kg)	Days	Concentrate per day (kg)	ADG (kg)		
Pangola	47	0.87	139	0.9	0.53	380	HStd
Pangola	47	0.91	139	3.3	0.73	411	LGd
Pangola	47	0.89	139	5.1	0.78	416	LGd
Mean	47	0.89	139	-	0.68	402	-
Bahia	58	0.76	141	0.9	0.40	374	Std
Bahia	58	0.73	141	3.2	0.67	406	HStd
Bahia	58	0.64	141	5.1	0.79	420	LGd
Mean	58	0.71	141	-	0.62	400	-

[a]Crossbred yearling steers, 265 kg initial weight

[b]Std = standard, HStd = high standard, LGd = low good

Table 12. Supplemental feeding at different periods during the summer pasture season (9)

Grass	Concentrate fed/day during summer			ADG			
	Early 60 days	Mid 60 days	Late 60 days	Early 60 days	Mid 60 days	Late 60 days	Average 180 days
	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
Pangola	0	0	0	0.82	0.48	0.24	0.51
Pangola	0	0	1.9	0.85	0.48	0.49	0.62
Pangola	0	1.9	1.9	0.85	0.74	0.44	0.69
Pensacola	0	1.9	1.9	0.68	0.70	0.44	0.61

a pasture during a period in which the quality of pasture on offer was diminishing, followed by a finishing period in the feedlot. Peacock et al. (14) at Ona, fed four levels of concentrate to Brahman heifer calves during the fall and early winter when the quality of Pensacola had decreased to a very low level (Table 13). The concentrate consisted of 40 percent citrus pulp, about 20 percent cotton seed meal, 20 percent cotton seed hulls, 14 percent corn meal, 5 percent alfalfa pellets and 1 percent mineral. The experiment was conducted for a fixed period of 120 days on pasture followed by 120 days in the feedlot.

Concentrate fed at 0.4 kg/day provided a maintenance ration and 3.7 kg/day provided an ADG of 0.55 kg/day. If we examine the differences at the extreme levels of concentrate we find that an increase in the concentrate fed of 3.3 kg/day (3.7 minus 0.4) and the difference in ADG during the pasture period of 0.51 (0.55 minus 0.04) results in a conversion rate of 6.5 kg of concentrate for each additional kg of liveweight gain. This suggests that most of the effect of feeding concentrate is additive and that the animals are not substituting concentrate for pasture (see Figure 5(b)). If the pasture is of very low quality, animals on pasture consume a minimum of forage and do not reduce significantly their consumption of forage as higher levels of concentrate are fed. At the end of the pasture period there was a difference of 64 kg (237 minus 173) in liveweights of the heifers fed at the lowest and highest levels. By the end of the following feedlot phase, this difference between the two groups was reduced to 36 kg (353 minus 317) indicating some compensatory gain effect from the previous differences in gain due to levels of concentrate fed on pasture. For each additional kilogram of liveweight gain during the pasture phase due to concentrate, there was a reduction of 0.37 kg in ADG during the feedlot phase. There was a marked difference in the total amount of concentrate fed during the 240-day period and the resulting carcass grades of the heifers.

Studies have also been conducted at the Belle Glade station by Coleman et al. (6) on levels of concentrate feeding on pasture followed by a finishing period in the feedlot (Table 14). Their study differed from that of Peacock et al. (14) discussed above, in that the steers in the Belle Glade study were fed on pasture until they reached a weight of 375 kg instead of a fixed number of days. The Belle Glade study was conducted on St. Augustinegrass pasture which was of higher quality than dry season bahiagrass. The concentrate was fed at three levels (0.0, 2.3 and 4.5 kg/day) and consisted of 40 percent dried citrus pulp, 40 percent ground ear corn and 20 percent cotton seed meal.

Concentrate feeding on pasture greatly reduced the number of days to reach a 375 kg weight and the ADG was increased from 0.38 to 0.62 kg per day. The number of days in the feedlot was nearly identical for the three groups, the final slaughter weight was about 465 kg and the average carcass grade for each of the three groups was medium good.

If we examine the differences at the extreme levels of concentrate fed, we find that 4.5 kg of concentrate per steer per day gave an

Table 13. The effect of levels of concentrate feeding on pasture upon average daily gains of Brahman heifer calves and concentrate requirements, Ona, Florida (14)

Bahiagrass pasture phase 120 days--Oct. to Feb.			Feedlot phase 120 days--Feb. to late June			Pasture and feedlot phase 240 days--Oct. to late June			
Concentrate fed per day	ADG	Liveweight per heifer	Concentrate fed per day	ADG	Final weight per heifer	Concentrate required			Carcass grade[a]
						Pasture	Feedlot	Total	
(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	
0.4	0.04	173	8.9	1.02	317	48	1068	1116	HStd
1.4	0.18	190	9.2	0.96	324	168	1104	1272	LGd
2.5	0.35	213	9.4	0.92	342	300	1128	1428	LGd
3.7	0.55	237	9.1	0.83	353	444	1092	1536	Gd

[a]HStd = high standard, LGd = low good, Gd = good

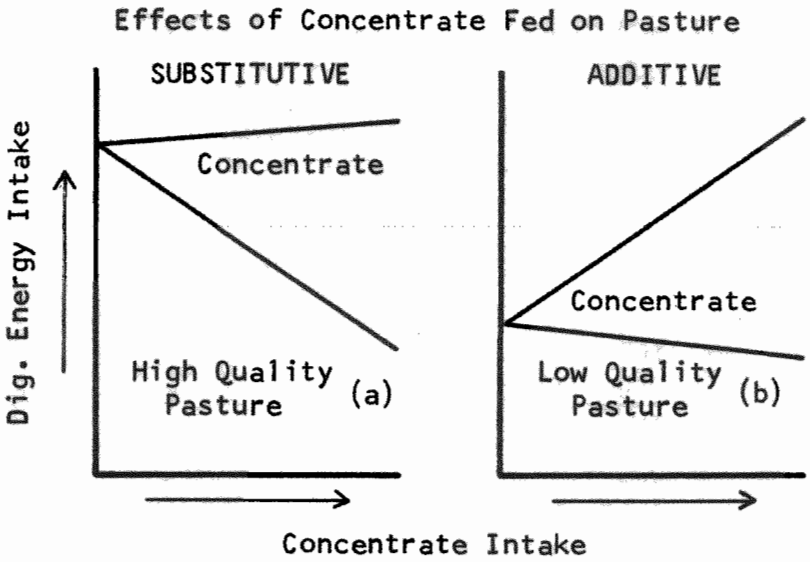


Figure 5. Schematic of the substitutive and additive effects of feeding concentrates on pasture

increase in ADG of 0.24 kg (0.62 minus 0.38) resulting in a conversion rate of 18.8 kg (4.5/0.24) of concentrate required for each additional kilogram of liveweight gain. This conversion rate suggests that there must be both an additive and substitutive effect of feeding this particular concentrate to steers on St. Augustinegrass pasture (see Figure 5a). The effect of feeding concentrate upon the consumption of pasture was not measured in these trials, but the fact that gain per animal was increased indicates an additive effect and the poor conversion rate of concentrate to liveweight gain as calculated above suggests that the steers must have reduced their consumption of pasture by substituting concentrate. A compensatory rate of gain was also observed between the pasture feeding period and the feedlot phase. For each additional kilogram of liveweight gain during the pasture period due to concentrate feeding there was a reduction of 0.46 kilograms during the feeding period.

Hay and Silage with Concentrate

There has been little interest in hay or silage in either Puerto Rico or Florida until the large package baler became available. The situation is not clear at this time as to what direction future developments will take, but there is currently a great interest among farmers in the making of hay.

Table 14. Effect of levels of concentrate feeding on pasture, upon average daily gains of crossbred yearling steers, three-year averages (6)

St. Augustine pasture phase[a]				Feedlot phase			Pasture and feedlot phase				
							Concentrate required				
Concentrate fed per day	Days fed	ADG	Liveweight per steer	Concentrate fed per day	ADG	Liveweight per steer	Pasture	Feedlot	Total	Carcass grade	Total days
kg		kg	kg	kg	kg	kg	kg	kg	kg		
0.0	424	0.38	372	10	0.90	465	0	1100	1100	MGd[b]	534
2.3	299	0.52	377	10	0.86	463	688	1020	1708	MGd	401
4.5	238	0.62	375	10	0.79	463	1071	1090	2161	MGd	347

[a] Initial weight = 223 kg

[b] MGd = medium good

Pangola hay and silage were studied by Kirk et al. (11) at Ona, Florida in the late 1950s and Table 15 presents a short summary of their results. Cottonseed meal was fed with all conserved forages. As the amount of concentrate was increased, the ADG was increased, the total digestible nutrients (TDN) from forage decreased and the kg of TDN required per kg of gain also decreased. Both additive and substitutive effects are clearly indicated in these trials where the amount of forage consumed was directly measured.

Table 15. Comparison of Pangola digitgrass hay and silage at three levels of concentrate feed, 120 days (11)

Forage	Concentrate	TDN from forage (percent)	ADG[a] (kg)	TDN/gain
Hay	CSM[b] only	77	0.52	7.8
Hay	CSM + half feed	43	0.84	6.4
Hay	CSM + full feed	25	1.03	6.2
Silage	CSM only	79	0.58	8.1
Silage	CSM + half feed	44	0.88	6.3
Silage	CSM + full feed	28	1.09	6.0

[a]Long yearling steers, initial weight 346 kg.

[b]Cottonseed meal.

Additive and Substitutive Effects of Concentrate Feeding

Concentrate feeding on pasture may have different effects depending upon the relative acceptability and consumption of the concentrate and pasture. Concentrates, even though consumed at a high level may have little effect upon digestible energy intake (DEI) if the pasture is of very high quality. Young ryegrass pasture is an example. If the concentrate is relished by the animals they may reduce their consumption of digestible energy in ryegrass by an amount equal only to the DEI from concentrate. If the efficiency of conversion of concentrate to liveweight gain is computed as indicated in the experiments by Peacock et al. (14) and Coleman et al. (6), then the investigator may be misled. Only in the case of zero substitution, will conversion rates as computed in these trials give accurate estimates. The results from each of the experiments just cited, suggest that both substitutive and additive effects are operating probably at some intermediate level to the two extremes illustrated in Figure 5.

Summary

Peninsular Florida and Puerto Rico have many features which are similar with respect to climate, soils and tropical grasses and legumes. The organic soil area of South Florida represents a unique situation where one grass, St. Augustinegrass, dominates the pastures. The Central humid area of Puerto Rico is also unique in having adequate rainfall throughout the year.

Research on pastures in Puerto Rico has been directed primarily toward high levels of fertilization on tropical grasses with high growth potential. In contrast, the Florida program has emphasized the use of by-product feeds in pasture-concentrate feeding systems and the use of winter annual grasses and legumes as supplemental pasture during periods when the perennial tropical grass pastures are dormant and of very low quality.

Recommendations

Experimental Methods

The reviewers were impressed with the lack of sufficient information in many research papers which might have provided a basis for conclusions by the authors or for further analysis. In some cases the designs used were not adequate to make treatment comparisons and most experiments did not provide estimates of coefficients useful for modelling of forage livestock feeding systems. Following are some recommendations relating to methodology and reporting of results:

1. A more complete description of the forages such as species, cultivars, stages of growth, yields and quality estimates.

2. A more complete description of the experimental animals including breed, age, condition (condition score if possible) and previous treatment before entering the experiment.

3. A description or preferably a quantitative estimate of the grazing pressure prevailing during the time course of the experiment.

4. Use of multiple experimental variables in a single experiment so that both main effects and interactions can be studied.

5. Use of response surface designs to reduce the number of treatment combinations and to provide estimates of optima of the response variables.

6. Select treatments and response variables which will separate pasture and supplement effects and provide estimates of substitutive and additive effects.

7. Use techniques which will provide estimates of inputs and outputs on a per-animal and per-unit area of land.

Research Needs

Changes in demands for the use of cereal grains for food, and also changes in economic circumstances strongly suggest a reevaluation of our research priorities in animal production systems. Following are some suggestions for research in the areas covered by this review:

1. In forage breeding programs the emphasis should be on improved quality and persistence under stress from the environment, including the grazing animal.

2. Select compatible forage grasses and legumes which either in combination or in sequence will meet the year-round requirements of the livestock.

3. Intensify research on nitrogen fixation in both grasses and legumes to reduce nitrogen fertilizer requirements in forage-livestock production systems.

4. Formulate energy and protein supplemental feeds more suitable for feeding in forage systems.

5. Intensify research on innovative techniques for the conservation of forage to provide feed of higher quality.

6. Develop forage drying systems which utilize solar energy.

7. Develop beef cattle production systems which produce a product acceptable to market demands.

ACKNOWLEDGMENT

The authors gratefully acknowledge the assistance of Doreen Swakon for her search of the literature and cataloguing the many references from which data were selected for this review.

LITERATURE CITED

1. Beardsley, D. W. and R. J. Allen Jr. 1955. Evaluating grass varieties with grazing animals. Fla. Agr. Exp. Sta., Everglades Mimeo Report 55-10.

2. Caro-Costas, R., J. Vicente-Chandler, C. Burleigh. 1961. Beef production and carrying capacity of heavily fertilized, irrigated guinea, napier and Pangolagrass pastures on the semiarid South Coast of Puerto Rico. J. Agr. Univ. of Puerto Rico.

3. Caro-Costas, R. J. Vicente-Chandler, J. Figarella. 1965. Productivity of intensely managed pastures of 5 grasses on steep slopes in the humid mountains of Puerto Rico. J. Agr. Univ. of Puerto Rico 49:99.

4. Caro-Costas, R., F. Abruna and J. Vicente-Chandler. 1972. Comparison of heavily fertilized Pangola and stargrass pastures in terms of beef production and carrying capacity in the humid mountain region of Puerto Rico. J. Agr. Univ. of Puerto Rico 56:104.

5. Caro-Costas, R., J. Vicente-Chandler and F. Abruna. 1972. The effect of four levels of fertilizer on beef production and carrying capacity of Pangola grass pasture in the humid mountain region of Puerto Rico. J. Agr. Univ. of Puerto Rico 56:219.

6. Coleman, S. W., F. M. Pate and D. W. Beardsley. 1976. Effect of level of supplemental energy fed grazing steers on performance during the pasture and subsequent dry lot period. J. Anim. Sci. 42:27.

7. Haines, C. E., H. I. Chapman, Jr., R. J. Allen, Jr., R. W. Kidder. 1965. Roselawn St. Augustinegrass as a perennial pasture forage for organic soils of South Florida. Fla. Agr. Exp. Sta. Bull. 689.

8. Hodges, E. M. and W. G. Kirk. 1946, 1947, 1948, 1949, 1950. Effect of fertilization and seedling on the grazing value of flatwoods pastures. Fla. Agr. Exp. Sta. Annual reports, state project 423.

9. Hodges, E. M., W. G. Kirk and F. M. Peacock. 1964. Supplemental feeding of steers on Pangolagrass and Pensacola bahiagrass pastures. Soil and Crop Sci. Soc. of Fla. 24:196.

10. Hodges, E. M., W. G. Kirk, F. M. Peacock and J. E. McCaleb. 1970. Supplemental feeding of steers on Pangolagrass and Pensacola bahiagrass warm season pastures. (Series II). Soil and Crop Sci. Soc. of Fla. 30:337.

11. Kirk, W. G., F. M. Peacock, E. M. Hodges and J. E. McCaleb. 1960. Value of Pangola hay and silage in steer fattening ration. Fla. Agr. Exp. Sta. Bull. 621.

12. McCaleb, J. E. and E. M. Hodges. 1969. Oats and ryegrass for beef production and pasture renovation. Range Cattle Exp. Sta. Ona, Florida, Soil and Crop Sci. Soc. of Fla. 29:214.

13. McCaleb, J. E., F. M. Peacock and E. M. Hodges. 1964. Oats and rye for grazing on Florida flatwoods. Fla. Agr. Exp. Sta. Circ. S-152.

14. Peacock, F. M., W. G. Kirk, E. M. Hodges, A. Z. Palmer and J. W. Carpenter. 1964. The effect of winter gains of beef calves on subsequent feed lot performance. Fla. Agr. Exp. Sta. Tech. Bull. 667.

15. Prates, E. R., H. L. Chapman Jr., E. M. Hodges and J. E. Moore. 1975. Animal performance by steers grazing Pensacola bahiagrass pasture in relation to forage production, forage composition and estimated intake. Soil and Crop Sci. Soc. of Fla. 34:152.

16. Vicente-Chandler, J., F. Abruna, R. Caro-Costas, J. Figarella, S. Silva and R. W. Pearson. 1974. Intensive grassland management in the humid tropics of Puerto Rico, Univ. of Puerto Rico Bull. 233:9 and 233:94.

DISCUSSION

CAPABILITIES OF VARIOUS PHYSIOGRAPHIC REGIONS

Discussion of papers by:
A. E. Spooner and Maurice L. Ray, Carl S. Hoveland and W. B. Anthony, Warren G. Monson and P. R. Utley, Floyd P. Horn and C. M. Taliaferro, G. O. Mott and J. E. Moore

MODERATOR: C. Oran Little, Kentucky Agricultural Experiment Station

COMMENT: C. Oran Little, Moderator, Kentucky. Each of the speakers has pointed out priority problems in producing forages and in producing beef from these forages. They have presented opportunities in research-able problem areas.

QUESTION: Robert Kelly, Virginia Polytechnic Institute and State University. Various speakers presented examples of research that included descriptions of carcasses. However, I wonder if additional work has been done in terms of palatability factors and has research been conducted to dispel some of the myths that exist concerning color, flavor and overall acceptability of beef finished with forage or predominantly forage.

ANSWER: Maurice L. Ray, University of Arkansas. We have attempted to do this in our work at Arkansas. Animals from this type of an experiment are slaughtered at the same packing plant in Little Rock, where desired carcass data are obtained. In cooperation with Dr. Lewis, trained taste panel evaluations have revealed no differences in organoleptic characteristics.

COMMENT: John Moore, University of Florida. I wonder if my colleague, Dr. Zane Palmer would speak for Florida on this same point. He has looked at many carcasses from various breed groups and feeding programs.

COMMENT: A. Z. Palmer, University of Florida. We cooperate with various experiment stations in Florida. We do not obtain palatability data on every experiment, but we do obtain it on 80-to-90 percent of them. We obtain palatability data when the scientists involved feel that it is necessary to augment the carcass data.

COMMENT: C. Oran Little, Moderator, Kentucky. Dr. Doyle Chambers, I know that you have conducted some interesting studies in Louisiana concerning consumer acceptance of forage-finished beef.

COMMENT: Doyle Chambers, Louisiana Agricultural Experiment Station. I will refer you to our expert on this, John Carpenter.

ANSWER: John Carpenter, Louisiana State University. We are just in the second phase of our research project now. In the first phase, essentially, we had retail acceptance through Winn-Dixie Stores, we conducted a consumer acceptance study and had a trained taste panel. There were some differences; however, these were not great and the beef was acceptable at the retail level. In all of the panels or shear studies there were no differences in tenderness in this first phase.

QUESTION: C. Oran Little, Moderator, Kentucky. Various types of cattle are available to produce beef from forage. What type of cattle were used in the Louisiana study?

ANSWER: John Carpenter, Louisiana. The cattle were Angus and Hereford-Angus crosses. Brahman crosses were not used in this study. We were trying to produce an acceptable, quality product. We knew that we could produce acceptable carcasses with the type cattle used.

QUESTION: J. C. Purcell, University of Georgia. Dr. Carl Hoveland did comment on the problem of scheduling cattle for slaughter. In the judgement of this panel, if we maintain the cow herd that we now have in order to produce beef, how many cattle can be generated in each of the five areas of the South as we have described them and when will they be available for slaughter?

COMMENT: C. Oran Little, Moderator, Kentucky. I believe that this is the type question we should be considering. Along with this question we should be asking what is the future of the cattle slaughter industry in the South? Would anyone care to comment on these questions?

QUESTION: Walter Wedin, Iowa State University. What is the net number of beef cows presently in the Southeast region? Is there a net export of calves from the region and how much has this changed in the last ten years?

ANSWER: J. C. Purcell, Georgia. Including Texas and Oklahoma, there are approximately 20 million cows in the region.

ANSWER: Doyle Chambers, Louisiana. Not including Texas and Oklahoma, I would estimate that 60 percent or more are shipped to feeding areas for subsequent finishing. A lot of calves were previously slaughtered at weaning time. This number has been reduced because we have lost some of our packing plants due to new meat inspection standards. There still is some calf-slaughter in the region, particularly those calves with Brahman breeding if they are fat enough to slaughter at weaning. However, the number of calves slaughtered at weaning in any given year varies tremendously, depending primarily upon the price of calves. When prices are low, the number slaughtered increases.

QUESTION: Curtis Absher, University of Kentucky. Many people in the field refer to forage as "cheap." I don't believe we have cheap forage. A number of our speakers this morning indicated that in order to produce finished beef from forage that managerial skills need to be improved. However, many small and/or part-time producers may not want to improve their managerial skills. What are the speakers' reactions to these points? Of the production systems that were presented this morning, much of the data have been available for many years. What other production systems are being used and how extensive is their use?

QUESTION: C. Oran Little, Moderator, Kentucky. Dr. Spooner, do you have an explanation of how forage-beef systems are being used in the upper portion of the region?

ANSWER: A. E. Spooner, University of Arkansas. I could not give a specific answer regarding the number of cattle that are finished with forages. In the state of Arkansas, more cattle are being produced, primarily on grass, to the weight range of 900 to 1050 pounds. Many of these cattle are marketed locally. One thing we don't want to forget or overlook is the increase in the family-freezer beef. We have no idea how much this is occurring. In addition, many producers may not be finishing their cattle, but they are taking them from weaning to approximately 750 pounds.

QUESTION: C. Oran Little, Moderator, Kentucky. Dr. Utley, would you care to comment on what is happening in the lower South?

ANSWER: Philip Utley, Coastal Pkain Experiment Station, Tifton, Georgia. First, I would like to comment on Dr. Curtis Absher's statement regarding managerial skills required to produce finished beef from forages. Many systems aimed at finishing beef utilize three or four different forages, and it simply requires a better manager than systems which might use a single forage. I believe that most farmers, regardless of whether they are small and/or part-time operators, can become better managers. I don't know the answer to your questions concerning the number of cattle finished on various forage systems in the lower South. We have always had a large number of cattle that were wintered or backgrounded in the region. This has been primarily due to the prevalence of double cropping. For example, peanut farmers generally plant rye whether they graze it or not. We have a lot of cattle that were simply backgrounded before, but are now being considered for subsequent finishing.

I have a question concerning evaluation of forage- versus grain-finished beef. Are comparisons being made on a similar grade, or is the difference between forage- or grain-finished beef the difference between the good and the choice grade?

QUESTION: C. Oran Little, Moderator, Kentucky. Perhaps we can come back to your question regarding differences in forage- versus grain-finished beef. Dr. Taliaferro, I believe you commented on various systems that could be used in the western Oklahoma-Texas area. How widespread is the application of these systems?

ANSWER: Charles M. Taliaferro, Oklahoma State University. My guess is that all of the components of the systems that we showed are being used. However, only in rare instances are all of the components being put together. If we have time, I would invite Pat McIlvain, whose systems we talked about from Woodward, Oklahoma, to comment on the extent of utilization of complementary pasture, i.e., the use of tame pastures and farm forages to compliment native range in the Western Oklahoma and West Texas area.

COMMENT: E. H. McIlvain, ARS, USDA, Woodward, Oklahoma. I don't have an answer to that question; it is up to us to provide answers so that the number is higher in five years than it is now. We have a big job in front of us. In our part of the country we have a large number of people who make their living from livestock. These people are progressive and they are good managers. They are "hungry" for information on how to do it which means we should provide the answers needed. We do have some part-time cattlemen who can be inefficient and stay in business for a long, long time. I don't know if we can or need to do much research that will help them.

COMMENT: C. Oran Little, Moderator, Kentucky. Among us this morning, we have an individual who started out as a small operator with about 90 head of forage-fed beef; today he is forage-finishing over 5,000 head per year. I want to introduce to you Mr. Bill Brown of Atmore, Alabama. Bill, would you care to enlighten us?

COMMENT: Bill Brown, Alabama. It is a distinct pleasure for me to have the opportunity to attend this meeting. I am pleased to see this type of meeting and people like yourselves interested in the use of forages to finish beef cattle. I believe that the next ten years in the Southeast belongs to you researchers. I love the cattle industry and I believe that the Southeast is coming into its own. We have you people to thank for doing a lot of work during the past twenty years. We have people in the cattle industry who are right now looking for answers like they have never looked before. Many of them got involved in the cattle industry seven or eight years ago and all of a sudden, profits have slipped out from under them. I feel that you research people spend many long, hard hours that are never fully appreciated by us, the American people. You not only work for agriculture, you work for the people in New York, Los Angeles and all the people around the world.

It is not often that I have an opportunity to speak before a group of this type. I speak to you as a cattleman who has faced many ups and downs. I got started in the cattle business in 1952 and I was forced out quickly with the 1953 and 1954 break. I then moved to another county to grow wheat and soybeans. I didn't care to see another cow or steer. That green, growing wheat in the winter impressed me and I turned back to cattle. In 1957, I placed 97 steer calves on wheat pasture. To give credit where credit is due, back in the early 1950s, I saw cattle grazing clover pastures at the Lower Coastal Experiment Station at Camden, Alabama. The thought of out people was that the researchers could do it because they didn't need to make a living doing it, but the idea stuck with us and we started

grazing calves on wheat and legume pastures. In 1963 another problem became evident, that of "bunching" our cattle. We found that we needed to market cattle during more than a four-week period in the spring or summer.

In 1964, we started to harvest with machines. This is when my feedlot really came into existence. Silages (corn, oats, clover and ryegrass) make our operation go. We cut the silages at the right time and store them in bunker-type silos. On a wet-basis, our plain oat silage will contain around 9 percent protein and 50 percent TDN.

In many cases people don't understand the meaning of forage-finishing of beef. When comparing forage and grain-finished beef one must contrast comparable grades, for example, good against good. It doesn't really matter how you get to the choice grade as long as it grades choice.

In our operation at Atmore, Alabama, we have turned from a cotton economy to a beef economy and we sell forage via beef. When we can graze pasture, we graze it; however, we harvest excess forage. We try to grow all of our cattle to 700 or 800 pounds on grass. We then bring the cattle into our feedlot for 40-to-100 days. In the feedlot, we feed a heavy silage ration, and I would estimate that 95 percent of the cattle in the last 25 loads graded choice. We try to have cattle ready for market 52 weeks out of the year. We never feed a ration that is over 50 percent grain because we are in business to sell what we produce.

COMMENT: C. Oran Little, Moderator, Kentucky. Thank you, Mr. Brown.

COMMENT: Milton Wise, Virginia Polytechnic Institute and State University. In Tennessee, Kentucky, North Carolina and Virginia, between 70 and 85 percent of the total calf crop is available for various finishing programs; therefore, there are a lot of cattle available for various systems of finishing in the Southeast. Another comment, I have heard very little mention of the use of intake-limiters. Of course, this applies across all regions. In many instances, I do believe we are serving part-time farmers or producers with small herds. For example, our average herd in Virginia is less than 30 cows. For many of these people, labor is critical; therefore, intake-limiters, even salt, could be used to an advantage in limit-feeding systems. Another point I want to mention relates to the management of cattle and forage during the "summer slump" that Dr. G. O. Mott mentioned. In some of our work, we have been using heifers to adjust forage consumption during the lush pasture season in the spring. The heifers are fed grain on pasture and marketed about July 10. This system makes a lot of sense because heifers have been selling for 10-to-14 cents per pound less than steers in fall sales in Virginia. It means that a producer can start with an animal that costs much less; he can take advantage of that spring flush of grass and market them in July and carry remaining animals, steers, with grain on pasture through September or October.

COMMENT: Robert C. Buckner, ARS, USDA, Lexington, Kentucky. One of the big problems that has been discussed at this conference is the need for grasses with higher digestibility and energy levels as well as greater intake during the summer. These are needed in order to produce high good and choice beef from forages. We need to consider what can be done in the future to overcome this problem.

COMMENT: C. Oran Little, Moderator, Kentucky. I appreciate your comments, Bob. I believe that several things will result from our discussions at this conference.

COMMENT: C. Oran Little, Moderator, Kentucky. Let me attempt to summarize the general discussion. Those who spoke have done an excellent job of presenting their data and observations. In my opinion, research really takes three directions: (1) solving immediate problems, (2) anticipating future problems and finding solutions to those problems and (3) identifying the potentials and assembling the knowledge and technology to develop those potentials.

My general philosophy concerning this morning's program is that it is very important to maintain a proper balance of effort directed toward immediate and future problems. The challenge to us engaged in agriculture is to put food on the table. In doing this, all segments of the industry must receive a reasonable return. As you know, today animal agriculture is being seriously questioned by some of our critics. I must wave a caution flag; as we discuss whether we are going to produce forage or limited-grain fed beef or whether cattle are going to be grain-finished, your counterparts in the soybean area are striving to replace beef on the dinner table. We must keep all of this in perspective.

It is ironic that if we had such a conference 10 years ago, I assure you it would have been on how to feed all grain rations to beef cattle. Ten years later we are talking about how to feed or utilize predominantly forages in producing beef. As researchers we don't have the "crystal ball" that we need, yet we are going to be expected to have the answers when we need them. In this respect, as we face yesterday's developments and today's situations, our concerns should not be limited to historical aspects, but we should be looking toward future developments from the standpoint of producing beef or marketing forages. We must ask the question, is beef going to be on the dinner table in the future? I believe that the South has the resource base to produce tremendous quantities of forages. It is a biological reality that we have been producing beef with forage. I think perspectives need to be defined. We need to formulate "new recipes" to cover various potentials and options.

From the standpoint of my "crystal ball," it shows tremendous development of agriculture in the South. I envision the time when we in the South will be growing grain on those acres of land that are suitable for grain, and forages on those 140 million or more acres that are suitable for forages. Economics will dictate the overlapping. We are going to be producing much more grain in the future. This alone will result in large quantities of stubble or grain-crop residues which could be marketed via beef. I believe that one of the big

questions we should be concerned about when we develop systems of beef production is whether we as an industry want to be dependent upon the price of grain. Grains have become increasingly involved in international trade and agriculture. This adds much uncertainty to animal agriculture. We as researchers must determine potentials and options which could be exercised.

USE OF MODELING SYSTEMS

THE USE OF MODELING TO HASTEN AND ENHANCE THE APPLICATION OF RESEARCH INFORMATION TO BEEF PRODUCTION SYSTEMS AND FEEDBACK TO RESEARCH

T. C. Cartwright*

The shift of the cattle/feed price ratio about mid-1973 to a very unfavorable level for producers and feedlots caused this workshop to be planned or at least precipitated its planning. The critical need for this research-planning workshop implies that in the past we have not fully anticipated research needs and most effectively organized our efforts. There are two points related to my topic that the critical nature of this workshop emphasizes. One is that it has taken two year to organize a session to plan the research after the need was dramatically demonstrated. Of course, there has been much useful previous research on forage-fed beef and there have been adjustments in research at individual experiment stations, but the point is that there is usually considerable, inevitable time lag between recognizing a high-priority research area related to production and accomplishing the needed research. The second point is that by the time the research results needed become available, it is likely that other production problems will have taken over as higher priority concerns.

These two points, research time lag and a dynamic situation with respect to research needs of the beef cattle production industry, are real problems that are not going to diminish--they will intensify if anything. Therefore, a research strategy to cope with these ubiquitous problems would be desirable. The strategy which seems best to cope with these problems is to develop production models suitable for simulation beef cattle production. The rationale is straightforward; simulation can be done quickly and there are virutally no limits as to situations which might be accommodated or examined so that adaptations to new conditions can be expeditiously designed. However, this reasoning presupposes that the production models and techniques have been worked out and that there is sufficient existing quantitative information from previous research to support simulation of varied production systems and produce results consistent with real life.

Definitions and Rationale

Before examining these points further, some terms should be clarified. The assigned tital of this paper contains many key words or

*Professor, Animal Science Department, College Station, Texas, 77843

phrases: modeling, production systems, application and feedback. Some of these key words are often used by different people to indicate different things; therefore the meaning as used in this talk will be given.

The term "model" or "modeling" is an organized, systematic mathematical description of a real-life process or event. The event chosen may be at any level from the molecular to the universal level. An intermediate level is most convenient for examining efficiency of beef cattle production systems (2); e.g., a model of a producing herd where individual cattle are the smallest units has been utilized in Texas research (4). Beef cattle production is a very complex function to describe quantitatively. Animal husbandmen have long recognized this complexity and have intuitively attempted to account for the various tradeoffs and interacting effects. However, the complexity of beef production is such that an informal, undisciplined approach cannot be expected to yield outcomes which are consistently optimal. Modeling of beef cattle production is an effort to describe objectively and systematically all of the important components affecting growth, reproduction, milk production, maintenance, etc. of cattle. These components often are interrelated in a cryptic, nonlinear manner and, therefore, must be studied simultaneously as integrated effects in order to evaluate the effect of different alternatives for a given component on final outcome. Therefore, modeling systems to study integrated processes of production systems require an interdisciplinary effort both within the field of animal science and between animal science and other disciplines, especially forage production sciences and economics.

Another term is "production systems." Again the interest of animal husbandmen often has been consumed by individual animal performance or by a single component of production such as that of finishing steers. However, in order to meaningfully evaluate efficiency, the production system should include all of the inputs and outputs. Animal scientists are still inclined to consider the animal components in detail and restrict consideration of feed inputs by assuming feed is produced independently and that markets are perfect. Any beef production system utilizing grazed forage must include the plant-animal interaction, i.e., simultaneous consideration of plant and animal production. Also, seasonal, cyclic, locational and other market effects which may outweigh other effects, must be considered.

Only a very limited number of forage-beef production-marketing systems can be examined experimentally. Modeling does open up the possibilities of examining vast numbers of production systems. The term systems analysis will be used to indicate the technique of examining beef cattle production systems by the use of mathematical models which include all of the inputs and outputs considered to have important effects.

Developing and Using a Research Base

A statement was made earlier about the requirement for basic quantitative information necessary for the construction of a model of

a production system. For example, in order to simulate beef cattle production, growth and maturing potentials must be known and described in quantitative terms for the particular cattle and conditions simulated. An example from Texas research is illustrated in Table 1. Under the assumptions programmed in the model used to simulate these results, cattle of a generally small size produced more beef but about the same return on investment as larger cattle.

The effect of nutritional level on conception rates of heifers is vividly illustrated in the results of another simulation given in Table 2.

A third example, given in Table 3, illustrates the varying optimal slaughter weights required for maximal efficiency of steers of different breeding for different cattle/feed price ratios as determined from simulations.

These examples illustrate some information and understanding gained from modeling which would be useful in designing and evaluating forage-beef production systems. The type of information required to model these production systems was basic data relating to basic processes and functions such as nutrient requirements of cattle of various ages and physiological states. Data such as beef produced per acre or fertility levels obtained under different nutritional levels were of no use except in validating or checking the models. However, too often the data required were not available in the correct form or were not based on sufficient numbers so that many approximations and intuitive estimates were necessary.

If basic information is available and the major components of forage-beef production systems are understood, i.e., if the system can be modeled, we can make extensive use of the information. Field trials are locally useful but are usually very limited in direct application. The cost/benefit ratio can be more favorable for research which produces basic information if we can, and do, meaningfully relate it to production situations. As production conditions change with time and across space, the basic information is still available and as useful as ever.

Another point to be made about modeling production systems is that simulations of beef production open new avenues for more effective research and its application. The effects of the application of newly developed or anticipated technology may be evaluated over a wide range of conditions rather than in isolated situations to which field research may be limited because of facilities, personnel or funds. General recommendations too often are inefficient but persist because they are convenient; these should be replaced with those that more adequately fit the local environment, better utilize resources and/or conform more realistically to economic or sociological constraints.

In the process of describing all of the important input-output effects of a beef cattle production system--that is, in the process of modeling a beef production system--the "gaps" or "fuzzy spots" in

Table 1. Number of cows, expenses, liveweight production, gross income, net income and relative efficiency for straightbred systems employing small and large cows in a typical pasture system[a]

	Breed size	
	Small	Large
Number of cows	956	614
Cumulative per-cow expenses, $	37,284	23,946
Nutritional expenses:		
Cows, $	30,061	24,884
Calves, $	12,023	13,512
Replacement heifers, $	6,832	5,747
Slaughter bulls, $	40,783	44,047
Slaughter heifers, $	10,301	11,810
Interest, $	31,564	27,010
Total expense, $	168,851	150,956
Liveweight sold:		
Cull cows, kg	59,499	52,030
Slaughter bulls, kg	166,295	148,984
Slaughter heifers, kg	63,995	57,327
Total liveweight sold, kg	289,789	258,341
Contributions to gross income:		
Cull cows, $	31,416	27,472
Slaughter bulls, $	123,723	110,844
Slaughter heifers, $	47,612	42,651
Total gross income, $	202,751	180,967
Net income or profit, $	33,900	30,011
Return to investment, %	14.8	14.9

[a]Cartwright (1).

knowledge tend to surface or be brought into focus. For example, information relating to nutritional requirements for weight loss is necessary for modeling almost any practical beef production system. However, it appears that nutritionists, being oriented as good husbandmen, have not been particularly interested in weight loss. Too little is known about the nutritional efficiency of fat deposition, storage, mobilization and use for maintenance. However, it is fairly obvious that as harvesting and storing feeds become relatively more expensive, storage of energy by the cow (weight gain) and later use (weight loss), in coordination with the growing and dormant seasons of forage, may be involved in the most efficient production method. It certainly is a widely used practice.

Table 2. Simulated conception percentages during an 80-day breeding season, beginning at 370 days of age, where all groups of heifers are of the same genotype (mature weight potential of 1,058 lb)[a]

Daily weight gain, lb	Weight at 360 days of age, lb					
	485	507	529	551	573	595
.0	11	26	45	65	78	87
.22	15	32	52	71	83	90
.44	20	39	59	77	87	92
.66	27	47	67	83	91	94
.88	35	56	74	88	93	95
1.10	45	65	81	91	94	95
1.32	55	74	87	92	94	95
1.54	65	80	89	92	94	95

[a]Sanders and Cartwright (4).

Table 3. Steer slaughter weights, lb, which tend to optimize efficiency for different size cattle[a]

Steer $/lb / Feed $/lb	Breed type, average daily gain, lb			
	2.0	2.5	3.0	3.5
6	570	685	790	865
8	660	820	975	1,125
10	715	915	1,115	1,315
12	775	995	1,215	1,440
14	790	1,035	1,285	1,550

[a]Joandet and Cartwright (3).

Intake is another process about which too little is known. It is known that digestibility, protein content, stage of development and palatability of the forage have effects on intake but these effects are not very well described quantitatively. Also, it is known that age, physiological status, degree of fatness and breed of the cattle have effects on intake but little more than the direction of these effects is known.

As illustrated earlier, it is known empirically that the nutrition of the heifer or cow affects her reproductive performance. It is also known that the various physiological functions associated with reproduction are closely controlled or mediated by level and balance of hormones. However, almost nothing is known about the relationship between nutritional level and hormonal level.

Too little is known about plant-soil-water-radiation-temperature-grazing pressure relationships with forage growth. There is little doubt that efforts to describe the total forage production system quantitatively and in more detail have brought and will continue to bring into focus the areas of insufficient information in forage production.

A pressing and difficult part of modeling forage production is the interaction of forage plants with cattle. Describing production systems in the form of a model and simulating production may also indicate whether or not a particular area of insufficient knowledge is very important or critical to further development. That is, modeling and simulation may be a very useful tool in establishing research objectives and in setting priorities for these objectives. An example of this use of modeling and simulation is illustrated in Tables 1 and 3. A wide range in size (breed) of cattle in straighbred operations had very little effect on efficiency of production under conditions assumed to be typical pasture production for central Texas. In contrast, slaughtering finished steers from these two types at their optimal weights versus light weight or over-finished weights reduced return on investment by as much as 50 percent.

Modeling, if done properly, is tedious work and requires a seemingly infinite amount of detail. Much time is required for searching out information, developing mathematical functions, programming, debugging, validating, etc. Consequently, this useful tool can be abused by oversimplification and failure to properly validate every component and to test the interactions. Extreme caution should be exercised in interpretations of simulations. There is a strong tendency for modelers to begin thinking that simulation results have created some important enlightenment when the results may simply have demonstrated an artifact of the model or a programming error. Therefore, it appears advisable for systems analysis research to be actively directed by biologists in the production components and by economists in economic application. The contributions of those with expertise in systems analysis techniques and computer programming are invaluable, but the leadership and responsibility for the result should remain with the biologists and economists.

Summary

It is intuitively, and probably correctly, assumed that increased use of forages in beef production in the Southern Region can lead to greater efficiency of production. Modeling of forage-beef cattle production systems is an effort to more completely and quantitatively describe the important components of the systems and their interactions. It is a systematic method of applying segmented knowledge to specific dynamic production situations--that is, it provides a method to put research information more effectively to use. The process of constructing models exposes and brings into focus areas of insufficient knowledge and emphasizes the need for basic research on plant and animal functions. The use of models to simulate production systems also can be an aid in integrating new developments into production systems in an efficient manner.

The charge to this workshop was not only to propose the research that will lead to improved forage production and beef production but to match the potentials of forage production with the production requirements of cattle in an optimal manner so that the efficiency of beef production tends to be maximal. Since forage-beef production is a very complex system with many highly interacting components, modeling the system can be an indispensible aid to approaching this problem in a systematic, organized manner. However, caution must be used not to oversimplify modeling and not to overextend its use; it is an enhancement of, not a substitute for, well conducted experiments.

LITERATURE CITED

1. Cartwright, T. C. 1974. Net effects of genetic variability on beef production systems. Genetics 78:541-561.

2. Joandet, G. E. and T. C. Cartwright. 1975. Modeling beef production systems. J. Animal Sci. 41:1238-1246.

3. Joandet, G. E. and T. C. Cartwright. 1969. Estimation of efficiency of beef production. J. Animal Sci. 29:862-868.

4. Sanders, J. O. and T. C. Cartwright. 1975. Simulation reproductive performance of cows and heifers. Texas Agric. Exp. Station, Beef Cattle Research in Texas, P.R. (in press).

DISCUSSION

USE OF MODELING SYSTEMS

Discussion of paper by:
T. C. Cartwright

MODERATOR: John A. Stuedemann, ARS, USDA, Watkinsville, Georgia

COMMENT: John A. Stuedemann, Moderator, ARS. While listening to Dr. Cartwright's paper, I made a few notes concerning modeling. Some of the important points verify the old saying, "necessity is the mother of invention." The fact that dramatic changes in prices during the past two years brought disastrous results to many sections of the beef cattle industry has brought to mind the need for a system which better reacts to situations such as this, in terms of recommendations and in terms of bridging gaps in research. During World War II, which was perhaps a major cause for the development of modeling systems, particularly in the engineering field, is when modeling really got started as we now use it to "attack" problems of the beef industry from many different angles and strive to integrate various components in order to react to a given necessity. I am glad that Dr. Cartwright defined modeling because I suppose that nearly everyone of us has a somewhat different concept of what modeling really means. I think that it is important that we realize that modeling is required for gathering the basic quantitative data and to achieve this, there must be involvement of various disciplines. We are already seeing developments of this nature with various teams of researchers. This effort must be strengthened not only to obtain the quantitative data, but to identify the components that are important. In much of our beef cattle and forage research, certain components are already known; however, much remains in terms of assembling these components. As Dr. Cartwright discussed this point, I was reminded of one of my calculus professors, who after returning a recent exam, pounded on his desk saying, "Before you can integrate you've got to know how to differentiate." I believe this applies here--one must know what components are important in a particular system before one can effectively integrate them. Dr. Cartwright also pointed out that it was important to have various types of models; for example, models could be used or developed to identify gaps in research or they could be used to give specific recommendations for solving a particular field problem. Is there discussion?

QUESTION: Anonymous. Is the model which was used to generate the data in your first slide available and is it applicable to the whole region?

ANSWER: T. C. Cartwright, Texas A&M University. We have published on that model in the Journal of Animal Science. We don't particularly like that model because it is very restricted. This does give me an opportunity to make a good point. You may have the model if you would like it, but there are many assumptions that went into that model that a person would need to be very familiar with in order to avoid being misled by the output. I believe this is one of the real dangers of modeling; i.e., it is easy to begin looking at output data as if they were data collected from an experiment. It is easy to ask the question, "Now what is the cause of that?" You may proceed to explain the output as if it were real data only subsequently to find a programming error or something was described incorrectly. The point I want to make is that you must be very cautious in using someone else's model because it is critical to know and understand the assumptions and criteria used in developing the model.

COMMENT: J. R. Johnston, ARS, USDA, College Station Texas. Dr. Cartwright, in your presentation you made references to the fact that there should be a regional effort in the area of systems science and modeling in relation to forage-beef, but that you were not an administrator and could not invite it. It seems to me that unless you researchers can give some guidelines to administrators, they really don't know what to push for. I would hope that one of the results of this conference would be to define what is needed in the southern region so that those of us in administration can work on it.

COMMENT: T. C. Cartwright, Texas. I appreciate that comment. I do think that modeling is an effort that should not involve everybody or every state.

QUESTION: Milton Wise, Virginia Polytechnic Institute and State University. Thinking in terms of beef production on a national scale, has anyone developed an empirical model which would tell us, for instance, what will happen to total beef production in the United States as we increase the use of forage for growing and finishing cattle. Knowing that we have a finite acreage level, what will happen to total beef production and the size of our cow herd?

ANSWER: T. C. Cartwright, Texas. I feel fairly certain that the answer to your first question is no. The answer to your second question, intuitively, is if you put more forage into finishing cattle, it is going to take it from somewhere. More acreage may need to go into production or we may need to increase our production per unit of land area by applying more fertilizer or using better management practices. Being realistic, I think one could assume that less beef is going to be produced as we depend more on forages.

QUESTION: J. P. Fontenot, Virginia Polytechnic Institute and State University. In modeling, it has been inferred by some people that when someone asks a question, it could be plugged into the model and they could expect an answer. Somewhere along the line, don't we need to do some testing of the model with animals? My question is how much testing?

ANSWER: T. C. Cartwright, Texas. I think we need to test every component of it individually. Then the components must be put together and the total model validated.

COMMENT: J. P. Fontenot, Virginia. That is what I meant. I believe that models must be validated at some point.

ANSWER: T. C. Cartwright, Texas. That is correct; I believe that it is absolutely essential to validate at more than one point along the production system. Then one must be cautious in going outside the validated range. I think that we can use well described data that have already been collected for validation of models. However, we are also going to be required to design research specifically for validation purposes.

QUESTION: Roy E. Blaser, Virginia Polytechnic Institute and State University. With regard to modeling, there is a danger in grazing experiments. In preparing our paper for this proceedings, we reviewed some 120 articles. We found that many experiments were hopelessly confounded because either only plant data or animal data were obtained. It was impossible to obtain estimates of grazing pressures. It seems to me that when we conduct an experiment we should obtain data on grazing pressure. This would give an idea of forage availability. This might then be used in modeling forage composition, intake, performance, etc. In these types of experiments, should we "go all the way" and try to obtain all sorts of data that might be put into some limited kind of a model to give a better idea of soil, plant and animal interplay?

ANSWER: T. C. Cartwright, Texas. I would certainly agree with you on the need to describe our experiments thoroughly, and I suppose that there is some point at which one cannot collect more data and if you do collect a lot of data, sometimes it is hard to use or know what to do with all of it. There definitely must be some balance and judgment used in determining what data to collect. I would agree with you that grazing pressure is important data. However, I am not sure that all data we collect will be useful in modeling. In some cases we can use existing information from research which was planned for other purposes. However, I think that there will be some research which will need to be specifically planned in order to obtain information to complete production models.

QUESTION: Stanley Wilson, Auburn University. Going back about 20 years in our experience with genetic simulation, I always felt our models were completely inadequate. Modeling a beef cattle system is a different "ballgame," but I feel that genetic simulation was a bad experience which hurt our experimental work because we put too much credibility in it. Our problem was that we could not really identify our genetic model well enough. Are we at a point in modeling beef cattle systems where we can identify all of the components and interactions? Do we have the necessary data to give us confidence in the model we build? This bothers me because we must be very careful in allocating our resources for modeling versus obtaining needed biological information.

ANSWER: T. C. Cartwright, Texas. I would sort of answer that question with both a yes and no. We certainly do not know enough about, for example, plant-animal grazing pressure in relation to models. Some information needed for modeling is difficult to obtain, especially those things which have interaction components. Another way of approaching that question might be to say that if we are modeling off of the top of our heads, it would help us to be more systematic, more objective, and more quantitative. We will not only gain better understanding from modeling, but I think it will be a useful tool in exploring actual production situations.

COMMENT: Roy E. Blaser, Virginia. It is hard to beat good intuition.

COMMENT: T. C. Cartwright, Texas. A lot of people have made that point during this conference. Some people can make forage systems work and other people cannot. They often arrive at good systems by doing it intuitively.

COMMENT: Ray F. Brokken, ERS, USDA, Corvallis, Oregon. I regard the output of a lot of programming models as hypotheses, possibly to be tested. There is a lot of intuition involved in judging whether outputs are something reasonable and if they look questionable it may be worthwhile actually to conduct an experiment to verify that the results are reasonable. Then the large part of the model building becomes one of saying, "Well, here is what we know and here are our definitions." By going through the models, we discover contradictions in what we thought we know. The discovery of these in themselves can be highly productive. Then if the model does not predict, if the hypotheses that it generates are not fallible, you have a basis for asking, "What is fundamentally wrong?" This provides a framework in which to broaden or deepen your understanding. A model is something you live with, work with and develop. The idea is that you put your understanding together and predict what will happen. A question which frequently arises is what will happen now that circumstances have changed? If we did this, what would be the result? It seems to me to be very practical to create theories from which you can work and say, "Yes, according to all we know, we would expect this outcome from modeling a particular system." Then one may regard that as the very best hypothesis among many to test further. Development of theories and working on predicting things under a wide range of technically feasible ways and putting these in the economic models seems to be a practical approach to research. It seems to be a practical thing for scientists to work on and far more practical than supposing a dozen systems and running tests on them all without first predicting the outcomes of each system. I support everything said, Dr. Cartwright, and certaintly applaude your effort in bringing it to the several disciplines here today.

COMMENT: T. C. Cartwright, Texas. We do need more interaction with economists if we are going to evaluate the systems in economic terms. I do not think that we have faced that issue quite as well as we should have at this workshop.

21

SOUTHERN REGIONAL TECHNICAL COMMITTEE REPORT SM-41

Economic Evaluation of Alternative Forms of Vertical Coordination in the Livestock-Meat Industry

Presented by:

Wayne D. Purcell
Oklahoma State University

SM-41 is essentially complete. A one-year extension is being used to finalize a non-technical publication which summarizes the findings of SM-41. The objective of this particular publication is to provide a document appropriate to the lay reader and to a broad industry audience.

Plans for a new regional project were begun during 1974. A "research area" was delineated and presented to the Southern Directors in late 1974. Objectives were as follows:

1. To develop and/or adopt a set of grades, standards and descriptive terms or measures for use throughout the feeder cattle producing areas of the South in describing feeder cattle and pricing them in accordance with their value as determined by their gain potential and capacity to produce high cutability carcasses of acceptable quality standards;
2. To estimate the intraregional (in the South) and regional availability of feeder cattle by seasons of the year;
3. To estimate intraregional (in the South) and regional demands for feeder cattle by seasons of the year;
4. To estimate optimal (least-cost and/or minimum time) shipments of feeder cattle by season of the year as constrained by imposing a minimum size on lots of cattle sold and/or shipped; and
5. To plan, establish a basis for, and simulate an information or data system designed to register information pertinent to the sale and movement of feeder cattle to, from and within the southern states.

The SM-41 committee recognized the emerging importance of energy costs and the developing interest in the increased use of forages in

beef production versus grain-forage price relationship changes. With the decision to organize this workshop, a decision was made to await direction from the workshop before rewriting the project area to reflect changes in energy costs and in grain-forage price relationships.

During the meeting of the SM-41 Technical Committee on October 21, as part of the workshop format, an operational procedure to generate a new project was established. A committee to write the new project was selected. Relative to the original project area, emphasis will be placed on marketing alternatives for the southern cattle producer. In particular, emphasis will be placed on alternatives which involve maintaining ownership of cattle beyond the weaned calf stage. Improved grades and/or descriptive terminology, interregional supply of and demand for feeder cattle, and concern for both technical (multiple handling, duplication of medication, etc.) and pricing (heterogeneous lots, ineffective descriptive terminology, lack of information on feedlot potential and carcass merit, etc.) efficiencies will be integral parts of the new project.

The SM-41 Committee recognizes the need for increased coordination with the efforts of the S-67, SM-43 and S-45 regional research efforts. Such coordination could be achieved by having members of other committees attend meetings with the new SM technical committee when appropriate, by encouraging the technical committee officers in each group to take more initiative in keeping each other informed and by exploiting the fact that each station usually has a representative on each of the regional projects.

SOUTHERN REGIONAL TECHNICAL COMMITTEE REPORT SM-43

Factors Responsible for Tenderness Variations in Meat

Presented by:

W. G. Moody
University of Kentucky

The southeastern region of the U. S. and similar areas of the country have a unique opportunity to capitalize on year-around grazing, temperature, climate, adequate rainfall and a readily available source of feeder cattle to maximize production of forage-fed beef.

The future of feeding grain to cattle in large amounts, as has been the case in the past, is unclear. Most of us would agree that the answer to this question boils down to the availability and cost of grain in relation to the price of cattle and other feedstuffs. In other words, grain will not be fed in a large amount unless it is economical to do so. Also, many of us believe that the U. S. will continue to sell grain on the foreign markets as a means of stabilizing the balance of payments and to help make the production of grains in this country profitable for our grain farmers. Therefore, in the long-range picture, it appears that less grain will be fed to cattle and consequently we will see a larger number of lighter weight, lower grade cattle on the market than we have seen in the past.

Therefore, it is imperative that research efforts on efficient production of forage-fed beef be accelerated in this country.

Despite the volumes of information available in the literature on the palatability characteristics of beef per se, surprisingly little controlled data are available on the various quality parameters associated with meat from young, light weight, forage-fed animals. With the increasing number of these types of cattle on the market both now and in the future, it behooves us to develop research projects that direct attention to problems that exist relative to differences in beef from forage- versus grain-fed cattle.

One of the major deterrents to wide acceptance of beef from cattle finished on grass or other forage is the fact that the majority of these cattle will not grade U. S. Choice and will have yellow fat. Also, these cattle are discredited at every level of the marketing system due to the presumed lack of desired textural properties and

flavor, and the yellow pigmentation of fat. Also, very little information is available on variations in tenderness and the effects of different cooking methods on this type of product. At the same time, we have evidence that the consumer is demanding a "choice" at the meat counter. However, in order for this "choice" to be made intelligently, the consumer must have confidence in alternative products in terms of shelf-life, nutritional content and overall eating characteristics.

One such alternative product which appears to have a promising future is the flaked and formed products which are not intended as substitutes for intact muscles but rather the formation of a new product which can utilize less tender cuts from the carcass, and make them more acceptable by the consuming public. In other words, it is a technological breakthrough which affords us a chance to expand our consumption of beef and at the same time provide more variety in the menu.

With this background information and an explanation of the problem, it seems that we need to focus attention on finding some answers to this complex, yet timely, problem. I can think of no better group to do this than those who are currently involved in meats research of a wide and diversified nature. As a replacement to the Southern Regional Project SM-43 (Meat Tenderness), the contributors of this project chose to coordinate their efforts in a new project which would address itself to the definition and associated properties of beef from cattle fed a variety of ways including a number of grain-forage combinations as well as all-forage rations utilizing efficient combinations of grasses and legumes.

In an effort to get at the problems of immediate importance, each researcher was asked to state in writing his or her area(s) of concern relative to the overall problem and in a short paragraph explain how these areas might be best approached as researchable objectives. This has now been accomplished and at present we have approximately 18 research stations with one or more collaborators who have indicated an interest in being a viable part of such an overall effort.

Six main objectives seemed to surface as areas that need attention. These objectives are as follows:

1. Methods to Improve Post Mortem Tenderness

Tenderness is very important in evaluating meat quality. Many reviews and articles been written on the subject, and a number of substantial breakthroughs have been made which help alleviate this problem. This point need not be dwelled on further except to say there is still much that we don't know about the phenomenon of meat tenderness, particularly as it relates to chilling carcasses with a minimum of external fat cover.

2. Packaging, Distribution and Shelf-Life of Meat

The color of meat including both the muscle and fat components is an important fact of meat quality. Color of the finished product, as

most would agree, is highly influenced by the time, temperature relationship, all in relation to the microbial content of the meat during various stages of processing. The color of a meat product has been identified by some to make up the largest component of this intangible thing called aesthetics. Meat that does not have a desirable color or color stability, whether wrapped, frozen or further processed, has little potential and competitiveness at the meat counter. Limited research indicates that beef from forage-fed animals does not have the stability of color needed for optimum shelf-life and is therefore an area of major concern by meat scientists.

3. Nutritional Composition

Presently there is a major concern about the obvious void and lack of up-to-date information on the nutritional content of meat. If we are to offer the consumer a choice at the supermarket, then we need to provide him with the best information possible for making this decision. You don't buy a car just on the basis of its being large or small or medium-price or low-priced until you have thoroughly compared the differences. Similarly, we shouldn't expect the consumer to switch from the traditional products to less well-known products until they have the facts to evaluate the differences. Therefore, we need up-to-date information on the vitamin-mineral composition of beef from cattle of different compositions along with better ways of identifying these at the market place. With more pressure for nutritional labeling, we need to give more attention to the nutritional content if we are to be viable and competitive in the future.

4. Consumer Acceptance and Palatability of Beef from Different Forage-Grain Feeding Systems

We can talk until we are blue in the face about the best systems for cattle production and our most sophisticated methods for tenderizing meat but until we know what the consumer thinks of this product as a food then we have missed the boat. Most of us recall the story about the dog food that contained all the fancy ingredients and the most modern thinking on portion control and texture of the feed but when asked the simple question of how do the dogs like it, the reply was "they won't eat the damn stuff." We should take a lesson from this story. We can do all we want but until we conduct consumer panels and get consumers' reactions to different meat products, we have not accomplished our goal.

5. Meat Cookery

It is a fair statement to say that the whole area of meat cookery is under scrutiny because of the wide number of procedures and methods that have been used in the past. Also, it seems to be even more important with the great variety of products available today. Should a beef roast or steak from a young light-weight, highly muscled animal be cooked the same way as one from an older, heavier weight animal that excels in intramuscular and intrafiber fat in its tissues? We do not know enough about heat transfer and the effects of various methods of

cookery on the many different products on the market today. Standardized cooking procedures along with more experimentation in methods of cookery, we feel, will go a long way in helping solve some of the problems in this area.

6. New Product Development

A good example here is the flaked and formed products which have already been mentioned. This is a whole new area and we have only scratched the surface. It is particularly appropriate that we keep exploring new uses of meat products if we are to stay ahead of the many substitute products entering the market by the various segments of the food industry.

SOUTHERN REGIONAL TECHNICAL COMMITTEE REPORT S-45

Relationship Between Properties of Southern Forages and Animal Response

Presented by:

G. L. M. Chappell
University of Kentucky

The current S-45 project will be completed in July 1976. Extensive discussion has taken place regarding a new regional project or projects; however, little or no definite direction has been established. Those attending the S-45 group meeting felt that there could be at least three areas of emphasis for regional projects. These groups were as follows:

I. Systems
   - A. Beef
     1. Cow-calf
     2. Slaughter
   - B. Dairy

II. Intake
   - A. Animal Characteristics
   - B. Plant Characteristics
   - C. Interaction of A & B

III. Characterization
   - A. Techniques
   - B. Evaluation of new genetic material

SOUTHERN REGIONAL TECHNICAL COMMITTEE REPORT S-67

Evaluation of the Beef Production Industry in the South

Presented by:

John R. Allison
University of Georgia

The S-67 members want to reemphasize their appreciation of the quality of papers presented at this conference.

Historically, the first phase of S-67 dealt with determining the organization of the beef cattle industry in the South. Results are presented in the research publications of the respective experiment stations plus three regional publications, two by Charles Butler at Clemson University and one on "Part-Time Farming" by Odel Walker et al. at Oklahoma State University (the latter is the final stage of publication). The second phase used linear programming models to analyze all phases of beef production in the farm unit context. Special emphasis was placed on forage systems. Budgets were developed with cooperation from animal scientists and agronomists and reviewed on a regional basis by a committee of scientists from the three professions. These models are now on hand and personnel of the respective stations are committed to keep prices and technical coefficients updated. This updating will need the continued cooperation of animal scientists and agronomists. The models are also available for use by animal scientists and agronomists to evaluate specific beef production or farming systems.

Current Research

We want to compliment the effort spent on researching the results of previous work for presentation at this conference. These presentations have shown the results of expenditure of time on literature reviews. Experience of S-67 workers in developing budgets makes us very appreciative of the work required in this review. But, these papers and the response to these papers concern us sufficiently that we would like to re-express the concerns mentioned by Drs. Cartwright and Brokken; as of now, we do not see enough interaction between animal scientists, agronomists and economists. We have seen a lot of partial analyses, but very little complete analyses; for example, goals of pounds of beef per acre, least-cost gain for specific weight and shortening feedlot periods presuppose many relationships. Another example is the use of annual production data for grazing forages.

Annual production data for grazing forages are useless for analyzing grazing systems; monthly or even biweekly production data are needed before we can translate forage production into beef production.

We need to remember that the goal is not to produce beef, but to help farm operators maximize profits within their constraints.

In some instances, agricultural economists are not involved in experiments or experimental design and are asked to analyze data after the fact (there are exceptions). Some experiments can be improved with earlier cooperation; for example, put-and-take systems of grazing have little meaning to farm operators who have no place to store livestock "in limbo" until another flush forage production cycle is realized. These put-and-take systems can be designed in such a manner that they provide useful data in planning forage production systems. In some instances, scope and size of experiments can be reduced if researchers are willing to work together. Some analyses of systems can be made by interfacing the results of experiments of a specific segment with previous research. This is also a re-emphasis of points made by Dr. Cartwright.

Future Research Needs

The weakest segment of the S-67 models--the animal-nutrition link--were the hardest to develop. As expressed at this conference, we encountered a lack of knowledge concerning interfacing inputs on forage enterprises with outputs of beef. This lack of knowledge concerning relationships in this area has induced several of the S-67 researchers to become involved with research efforts at the respective institution with animal scientists and agronomists to develop these linkages. What we are saying is that we need more research work along the lines as reported by Ray Brokken. We need multidisciplinary research groups or teams; these may or may not be regional. By multidisciplinary we mean working and planning together not meeting and making professional Chamber of Commerce speeches to each other, we mean understanding the problems and accepting inputs from other researchers. We will have to do this cooperation voluntarily or be forced into it by research directors. If we don't cooperate, we will be no closer to solutions 5 or 10 years in the future than we are now.

Future of S-67 Research Committee

One aspect of the S-67 Research Committee is unique compared to the SM-41, SM-43 and S-45 Research Committees. The S-67 research project was generated from ideas developed by the Southern Agricultural Management Research Work Group. The Southern Agricultural Management Research Work Group, formerly called Southern Farm Management Research Committee consisted of a group of research workers in the field of production economics sponsored by the Farm Foundation to continuously investigate areas of needed regional research. Thus, we will terminate the existence of the S-67 Research Committee once we have fulfilled our objectives and as individual researchers either participate in or be advised by ideas developed through the Southern Agricultural

Management Research Work Group. This work group is currently involved in evaluating the need and the desirability for another regional research project in the area of production economics. Members of the S-67 Research Committee have been asked to directly participate in this idea development (six of the 16 members of the Southern Agricultural Management Research Work Group are also members of S-67). Therefore, the S-67 Research Committee feels that it is premature and inappropriate for the committee to have plans as to future research projects in the area of production economics. But, as previously mentioned, several members of S-67 are interested and are currently involved in initial work attempting to develop some multidisciplinary research efforts concerning the interfacing of forage production, beef production and economic relationships. These individuals will have at the minimum an informal loose structure of cooperation. Information presented at this conference suggests that some areas of multidisciplinary research will have the most potential for success if the two or more disciplines involved cross state boundaries and/or regional boundaries. Thus, projects may develop in two or more states where there is no formal structure but where cooperation is necessary for research success. This informal structure conceivably could be very successful, particularly if the research workers from the necessity for research achievement must cooperate across disciplines and if administrators allow sufficient flexibility for the development of communication channels.

DISCUSSION

SOUTHERN REGIONAL TECHNICAL COMMITTEE REPORTS

Moderator: John A. Stuedemann, ARS, USDA
Watkinsville, Georgia

COMMENT: Stanley Wilson, Auburn University. In reference to Dr. Allison's report, I received the impression that economists feel that the commodity people should initiate the cooperation. Economists can initiate work with agronomists, animal scientists or others.

QUESTION: G. O. Mott, University of Florida. Dr. Allison, I may have misunderstood your comments, but it appeared to me that there were two successive items on your list that were contradictory. First, you indicated a need for monthly or biweekly production data, and the next was that the put-and-take grazing technique had no place in forage systems research. I would like to know how you are going to get production profiles for quality and quantity on any forage over a period of time without using put-and-take techniques.

ANSWER: John Allison, University of Georgia. I do not disagree with you, Dr. Mott. We need production profiles measured at least monthly and preferably biweekly. Cattle have minimum daily requirements which vary throughout the year. In order to use models to balance these requirements with forage production, we need forage production data, at least on a monthly basis. As to the other point, the put-and-take technique is not suited to evaluating systems for actual farm situations.

COMMENT: G. O. Mott, Florida. I think there has been a great deal of confusion about the put-and-take technique. This technique was never designed, and I don't think that you will find any place in the literature where it was recommended for studying systems. It is used for studying components of systems, and is very useful in looking at production profiles. You can't hide from the farm situation. If you will remember the slides that I showed this morning of the Puerto Rican data, average daily gains vary tremendously through the 12 months of the year. The stocking rate varies, but it has a different peak than the average daily gain. This is the kind of information the economist needs in order to be able to use linear programming models for developing systems on paper.

QUESTION: Anonymous. In the meats area, has there been work in the area of marketing frozen products? The consumer will buy fresh meat, take it home and freeze it for consumption at a later date. Apparently

there has been resistance to buying frozen meat. It seems as though this is an area where we need work.

ANSWER: William G. Moody, University of Kentucky. I am sure that some of my colleagues in the audience could address that subject. There has been a considerable amount of work done on frozen meats. I believe that Dr. Harold Tuma did a considerable amount of work at Kansas State University on the subject. Dr. Barbara Green may wish to address the topic.

COMMENT: Barbara Green, University of Georgia. I have done some color and stability work on frozen meats. If you are wondering where we stand on marketing frozen meats, about 20 years ago it was thought that the consumer would buy frozen meat. It didn't sell. Several years ago, there was a large session on this topic at the Meat Industry Research Conference. One of the large supermarket chains did an extensive study on the acceptance of frozen meats. They gave extensive thawing and cooking instructions on the labels of the frozen meat. It was found that people were not ready to accept it. I think the only problem is that consumers will cook frozen vegetables but not frozen meat. If people ever accept it, I believe that one way to enhance its quality will be to invest more money in packaging. One of the greatest factors contributing to deterioration of frozen meat is improper packaging.

QUESTION: E. H. McIlvain, ARS, USDA, Woodward Oklahoma. I want to ask the question, when is someone going to write a book entitled, "Great Myths of Meat Quality?" Everyone here recognizes that there are many myths associated with meat quality. Myths are one of the big hurdles for forage-finished beef. Many producers are "shafted" by packers because of these myths. I am being a little facetious, but I believe that a book on the subject would help.

COMMENT: Dale L. Huffman, Auburn University. If we concern ourselves with producing beef and not label it as forage- or grain-fed beef, we will solve many of our problems.

COMMENT: William G. Moody, Kentucky. I tend to agree with Dr. Huffman, terminology can be very important.

CLOSING COMMENTS

COMMENTS: R. Dennis Rouse, Alabama Agricultural Experiment Station. Let me make a few points, if I may, which I think are important relative to this conference. I feel confident that this workshop has accomplished a lot of the objectives that were established during the planning sessions. You have come together and discussed varying aspects of the potentials that exist in this great southland for producing beef using our resources in the most effective manner. Each one of you who has participated in this workshop is an expert, and collectively you, among others, are the experts for the region. I am pleased to see the various disciplines represented. As an agronomist who has served as the Administrative Advisor for a group of economists (S-67 Technical Committee), I can sympathize with your efforts in trying to gain an appreciation, a real understanding, of what other disciplines need. This workshop was planned to help us look to the future, and I am sure it has done this.

I want to comment on one other point that was alluded to time after time at this workshop, i.e., the managerial ability of the producer. Let me remind you, as scientists you have an obligation to help this manager become a more efficient manager. If we go back 100 years or so to when the U. S. Department of Agriculture and the Agricultural Experiment Station system was started, the farmer was essentially on his own. During those intervening years, the scientists together with producers have brought agriculture to where we are now. The problems and systems discussed at this workshop are very complex. In order to help this manager become a more efficient manager, it is important for us to learn how to communicate what we know to him better. All that has been discussed about models and systems, putting it together in packages that we can comprehend and relate to producers, is vital to future advancement.

I am pleased that Bill Brown was willing to take a day of his busy time to be with us. His comments show that farmers do appreciate what you researchers have done. I am convinced that much of our progress in agricultural research is due to the motivation received from people like Bill Brown. Bill's presence here should serve as an added stimulus for you to leave here knowing that your real responsibility is to provide the information that will enable a producer like Bill Brown, or someone with considerably less managerial ability than he obviously has, capitalize on the tremendous resources we have available to use.

I feel good about the workshop. As Administrative Advisor to S-67, as Director of the Alabama Agricultural Experiment Station, and as a

representative of administration, this is the kind of interaction that we must have at the state, regional or national level to help develop means of finding and communicating needed information to producers.

COMMENT: Doyle Chambers, Louisiana Agricultural Experiment Station. I am glad to see all of you gather and discuss the future of the beef industry. Cow-calf production is basic to the industry. You have heard it clearly stated that the cow-calf producer receives what is left after everyone else receives what they need to make money. I hate to think that intelligent people, such as those in this group, cannot help work out a system that will prevent our cattlemen from going broke every time the beef cattle cycle reaches a certain point. I don't believe that it will be done by forage people learning how to grow more and better forages. It is not going to be done by the animal scientists developing a better, more efficient beef cow. It is not going to be done by economists developing a better economic model to predict what will happen. It is going to be done by working together to develop alternative systems for producing beef.

I say to you that I am glad you have come together. I hope that those of you within your own shop get together and work on behalf of your own state, and I hope you will accept those opportunities to work on a regional basis when they present themselves.

COMMENT: J. C. Williamson, North Carolina Agricultural Experiment Station. I want to say that the workshop throughout its planning and conduct has been personally rewarding to me. The planning committee has done an excellent job. They identified important topics and sought capable individuals to develop and present papers on these topics. I am not going to attempt to summarize the entire workshop. We have covered a lot of territory.