Effect of Marbling Degree on Beef Palatability in *Bos taurus* and *Bos indicus* Cattle[1,2]

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ABSTRACT: This study was designed to evaluate the relationship between marbling score and breed-type (*Bos taurus* vs ≥ 1/4 *Bos indicus*) on palatability of cooked beef. One thousand six hundred sixty-seven steers and heifers (1,337 *Bos taurus* and 330 *Bos indicus* × *Bos taurus* crosses) that had been managed and fed alike were used. Shear force and tenderness rating indicated that meat from *Bos indicus* cattle was less tender ($P < .05$) than meat from *Bos taurus* cattle, regardless of marbling score. Meat from *Bos indicus* cattle decreased ($P < .05$) in shear force as marbling increased from Traces to Small. Meat from *Bos taurus* cattle also decreased ($P < .05$) in shear force as marbling increased from Traces to Small, but Small was not different ($P > .05$) from Modest or Moderate marbling. In addition, variation in shear force was lower ($P < .05$) in meat from *Bos taurus* cattle and tended to decrease as marbling increased. Meat with Modest and Moderate marbling from *Bos taurus* cattle was more juicy ($P < .05$) than meat with Traces or Slight marbling. Beef flavor intensity rating was not affected ($P > .05$) by marbling score in either *Bos taurus* or *Bos indicus* cattle. Percentage yield of retail product decreased ($P < .05$) as marbling score increased but was not related ($P > .05$) to shear force or tenderness rating. These data indicate that the small, positive association of marbling score with palatability was similar in meat from both *Bos taurus* and *Bos indicus* cattle but reinforce the need for a direct measure of tenderness to supplement marbling to more accurately segregate carcasses for meat palatability.

Key Words: Beef, Breed, Marbling, Palatability, Tenderness, Yield

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Introduction

It is well documented that meat from *Bos indicus* cattle is less tender than that from *Bos taurus* cattle (Crouse et al., 1987, 1989). The relationship of marbling to beef palatability has been the subject of numerous investigations (e.g., Smith et al., 1984, 1987) and several review papers (Blumer, 1963; Pearson, 1966; Parrish, 1974; Jeremiah, 1978). A vast majority of the information on this subject indicates that there is a small, positive relationship between marbling degree (or percentage of chemical fat) and tenderness, juiciness, and beef flavor intensity, and a small inverse relationship with Warner-Bratzler shear force. Generally, although tenderness may increase as marbling increases, the increments are very small, particularly from one marbling score to the next. These differences may or may not be important to consumers (Francis et al., 1977; Savell et al., 1987). Although a few studies have found stronger relationships, based on all available data it seems that between 5 and 10% of the variation in tenderness can be accounted for by marbling degree (Blumer, 1963; Pearson, 1966; Parrish, 1974; Jeremiah, 1978). However, Koch et al. (1988) presented data that may indicate an interaction between marbling and cattle species on meat tenderness. The objective of this study was to evaluate the relationship of marbling degree to palatability traits of meat from *Bos taurus* and *Bos indicus* cattle.

Materials and Methods

Animals

Data presented in this paper are from 1,667 cattle, including steers and heifers from the Germplasm

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[2]Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

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Evaluation (**GPE**) project at the U.S. Meat Animal Research Center (**MARC**). The *Bos taurus* cattle all had Angus or Hereford dams. The *Bos indicus* cattle were either 1/4, 1/2, or 3/4 *Bos indicus* (Brahman, Sahiwal, or Nellore) with Hereford, Angus, *Bos indicus* × Hereford, or *Bos indicus* × Angus dams. The number of animals representing each sire breed and sex combination were as follows: 38 Hereford or Angus heifers, 27 Pinzgauer heifers, 442 Hereford or Angus steers, 87 Charolais steers, 109 Gelbvieh steers, 211 Pinzgauer steers, 96 Shorthorn steers, 75 Galloway steers, 94 Longhorn steers, 79 Piedmontese steers, 79 Salers steers, 98 Nellore steers, 78 1/4, 1/2, or 3/4 Brahman steers, 17 1/2 Brahman heifers, 87 1/4, 1/2, or 3/4 Sahiwal steers, 20 1/2 Sahiwal heifers, 25 1/4 Brahman × 1/4 Sahiwal steers, and 5 1/4 Brahman × 1/4 Sahiwal heifers. These cattle were born between 1983 and 1990 (most breeds were represented in most years) in March through May and weaned on approximately October 1. After weaning, cattle were fed a growing diet for 4 mo and then were allowed ad libitum access to a mixed diet of corn silage, corn, and soybean meal ranging in energy density from 2.74 Mcal (ME/kg of DM) initially to 2.93 Mcal late in the finishing period. The cattle were slaughtered in groups spanning approximately 35 to 63 d at the MARC abattoir or at a commercial processing plant at 15 to 17 mo of age. After a 24-h chill, USDA yield and quality grade data were obtained by an experienced beef carcass evaluator. The right sides of the carcasses from the commercial plant were transported to the meat laboratory at MARC at 48 h postmortem. Percentage retail yields of saleable product trimmed to 0 cm of fat were obtained as described by Koch et al. (1982) on a random subsample of 1,160 carcasses. The longissimus lumborum (first through third lumbar vertebra) or longissimus thoracis (sixth through eighth thoracic vertebra) was removed and cut into 2.54-cm-thick steaks. The steaks were vacuum-packaged and stored at 2°C until 7 d postmortem and then frozen at −30°C for up to 6 mo before thawing and cooking for Warner-Bratzler shear force and trained sensory evaluation.

Shear and Sensory Evaluation

Frozen steaks were tempered at 2°C for 24 h, then broiled on Farberware Open Hearth Electric broilers (model 450N, Farberware, Bronx, NY) to 70°C internal temperature. The steaks were turned after reaching 40°C. Temperature was monitored with iron

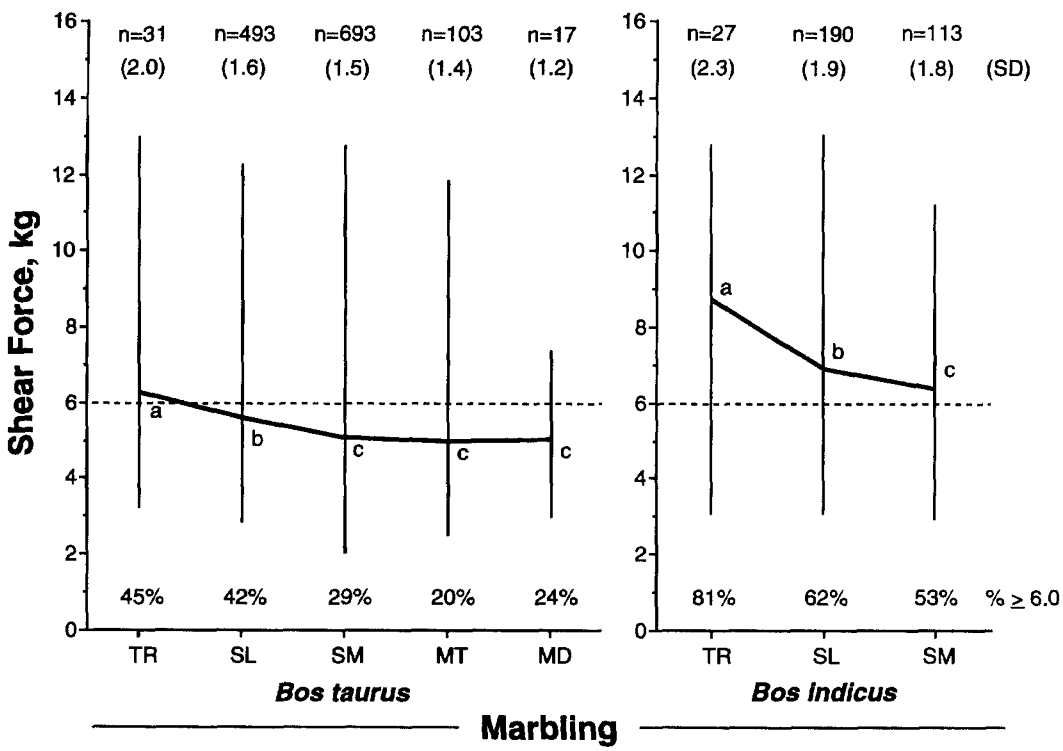

Figure 1. Warner-Bratzler shear force by breed-type and marbling score. The thickest line connects the least squares means for each marbling score. The vertical lines show the range in shear force for each marbling score. The numbers at the top are the number of cattle with each marbling score. The numbers in parentheses are standard deviations adjusted for year effects for each marbling score. The percentages at the bottom represent the percentage of cattle with shear force ≥ 6.0 kg. Means without a common superscript, within breed-type, differ ($P < .05$). TR = Traces, SL = Slight, SM = Small, MT = Modest, MD = Moderate.

constantan thermocouple wires inserted into the geometric center of a steak and attached to a Honeywell potentiometer multipoint recorder (model 112, Honeywell, Scarborough, ON, Canada). The cooked steaks for shear force were chilled 24 h at 3°C, then six cores 1.27 cm in diameter were removed parallel to the muscle fiber orientation and sheared once each on an Instron model 1132/Microcon II (Instron, Canton, MA) with a Warner-Bratzler shear attachment. The crosshead speed was 5 cm/min.

Steaks for trained sensory evaluation were cut into 1 cm × 1 cm × steak thickness cubes and served warm to an eight-member sensory panel trained according to Cross et al. (1978). Each panelist independently evaluated each sample for juiciness, tenderness, and flavor intensity on 8-point scales (8 = extremely juicy, tender, and intense; 1 = extremely dry, tough, and bland).

Statistical Analyses

Data were analyzed by ANOVA using GLM procedures of SAS (1989) for the fixed effects of marbling group, breed-type, marbling group × breed-type (using common marbling groups), and birth year. Retail yield data were pooled across breed-type due to low numbers of observations in some subclasses. Least squares means were computed and mean separation was accomplished with the PDIFF option (a pairwise t-test) of the least squares procedure. Bartlett's test for homogeneity of variance among marbling scores was used.

Results

The interaction of marbling score and breed-type was not significant ($P > .05$) for Warner-Bratzler shear force. Shear force was not different ($P > .05$) between marbling scores ranging from Small through Moderate for meat from cattle with *Bos taurus* breeding (Figure 1). Slight marbling was higher ($P < .05$) in shear force than Small through Modest marbling scores, and Traces marbling had a higher ($P < .05$) shear force than Slight marbling in meat from *Bos taurus* cattle. For meat from cattle with *Bos indicus* breeding, shear force decreased ($P < .05$) as marbling increased from Traces to Small. In addition, the percentage of *Bos taurus* cattle with shear force ≥ 6.0 kg (the mean shear force for 4.5 tenderness rating obtained by regressing shear force on tenderness

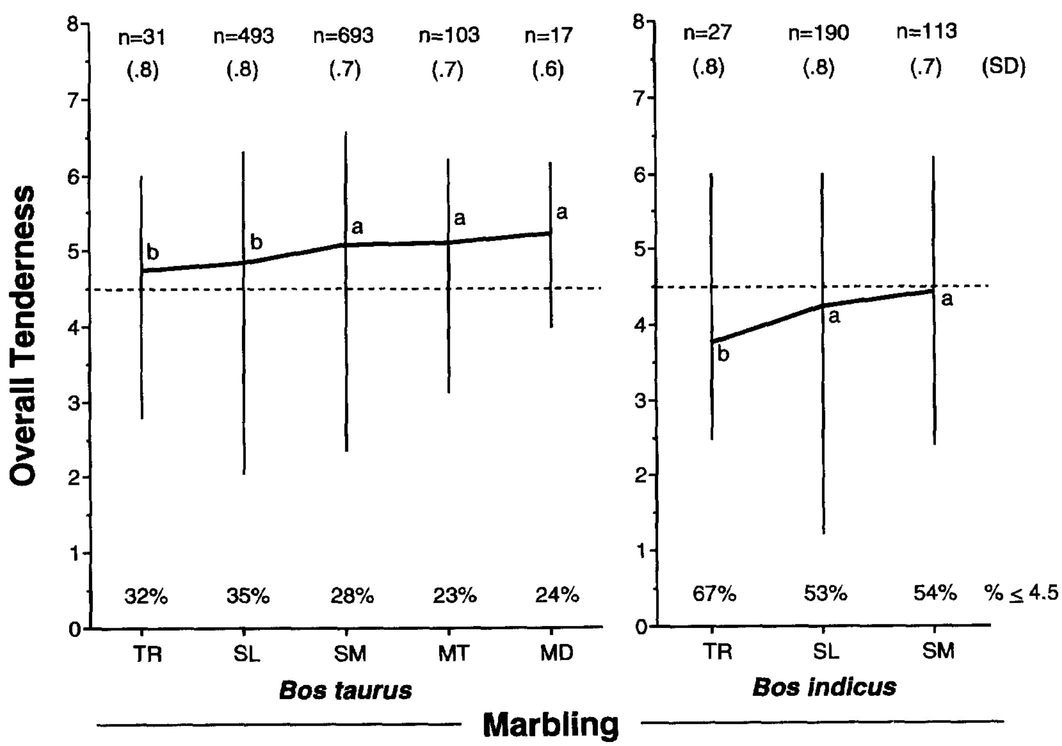

Figure 2. Sensory tenderness rating by breed-type and marbling score. The thickest line connects the least squares means for each marbling score. The vertical lines show the range in tenderness rating for each marbling score. The numbers at the top are the number of cattle with each marbling score. The numbers in parentheses are standard deviations adjusted for year effects for each marbling score. The percentages at the bottom represent the percentage of cattle with a tenderness rating ≤ 4.5 ("slightly tough"). Means without a common superscript, within breed-type, differ ($P < .05$).

rating) was similar between Small, Modest, and Moderate marbling scores, but slightly higher for Traces and Slight marbling scores. Thus, more than half the meat with Traces or Slight marbling had shear force values comparable to "slightly tender" or better sensory tenderness rating. In addition, meat with Traces marbling from *Bos indicus* cross cattle had a higher percentage of meat with ≥ 6.0 shear force value compared with Slight and Small marbling scores. The variability in shear force (indicated by SD) tended to decrease ($P < .05$) as marbling scores increased within *Bos taurus* but were similar across marbling scores in *Bos indicus* cattle, although SD were slightly higher in *Bos indicus* than in *Bos taurus* cattle. The range in shear force within a marbling score was similar (approximately 9 kg) across marbling scores and breed-types, except Moderate marbling in *Bos taurus* cattle had a smaller range, probably due to the smaller number of observations.

A similar response was found for sensory tenderness rating (Figure 2). Traces and Slight marbling scores of meat from cattle with *Bos taurus* breeding received slightly lower ($P < .05$) tenderness ratings than the higher marbling scores, but variability in tenderness rating was not different among marbling scores. Sensory tenderness ratings for Slight and Small marbling scores were not different ($P > .05$) for meat from *Bos indicus* cattle and were higher than for meat with Traces marbling. Variability in sensory tenderness ratings was similar across marbling scores in meat from *Bos indicus* cattle. Contrary to shear force values, variability in sensory tenderness rating was not different within *Bos taurus* or between *Bos indicus* and *Bos taurus* meat. The percentage of tenderness ratings less than 4.5 (midpoint of rating scale) was slightly higher for Traces and Slight than for the other marbling scores in meat from *Bos taurus*, but only Traces marbling had a higher percentage of sensory tenderness rating less than 4.5 in meat from *Bos indicus* cattle. Regardless of marbling score, meat from *Bos indicus* cattle was less tender than that from *Bos taurus* cattle.

Juiciness rating increased slightly as marbling score increased in meat from *Bos taurus* cattle, but Small marbling was not different ($P > .05$) in juiciness from any other marbling score (Figure 3). Meat from *Bos taurus* cattle with Traces or Slight marbling scores received lower juiciness ratings than meat with Modest or Moderate marbling scores. A slightly greater percentage of meat with Traces and

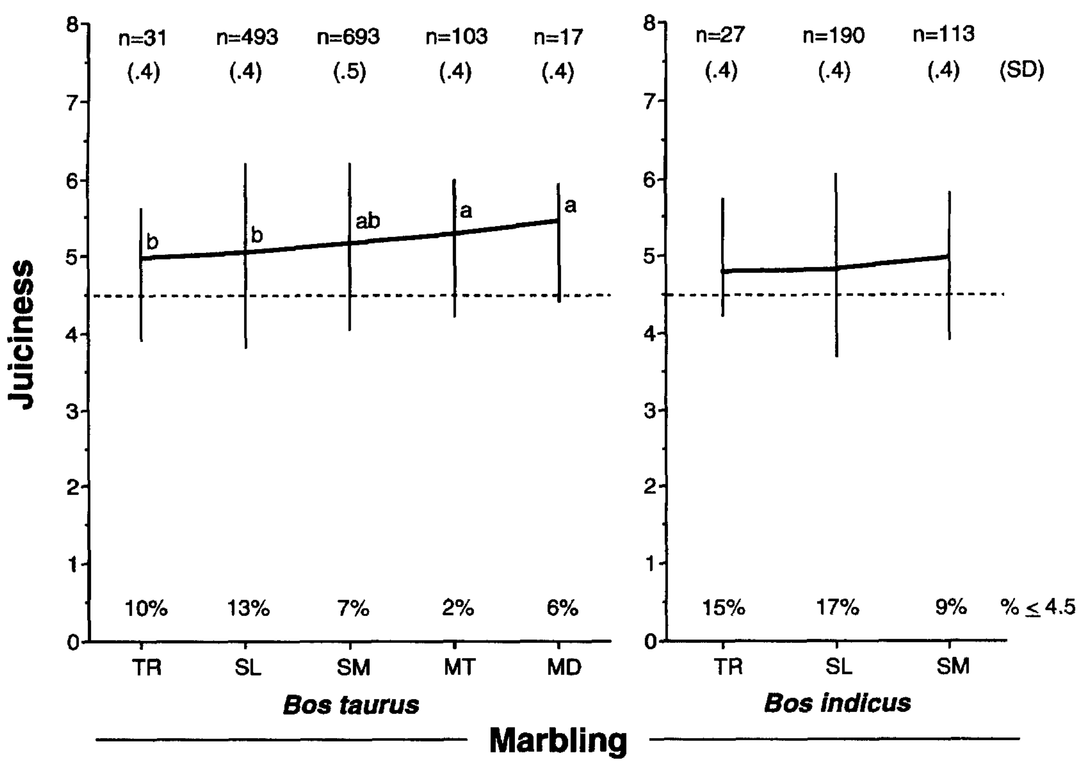

Figure 3. Sensory juiciness rating by breed-type and marbling score. The thickest line connects the least squares means for each marbling score. The vertical lines show the range in juiciness rating for each marbling score. The numbers at the top are the number of cattle with each marbling score. The numbers in parentheses are standard deviations adjusted for year effects for each marbling score. The percentages at the bottom represent the percentage of cattle with a juiciness rating ≤ 4.5 ("slightly dry"). Means without a common superscript, within breed-type, differ ($P < .05$).

Slight marbling scores received juiciness ratings of less than 4.5 compared with Small, Modest, and Moderate marbling scores. Marbling score did not affect ($P > .05$) juiciness rating of meat from cattle of *Bos indicus* breeding, although a slightly higher percentage of meat with Traces and Slight marbling scores than of meat with a Small marbling score received juiciness ratings of less than 4.5. Variability in juiciness rating was not affected by species or marbling score. Beef flavor intensity was not affected ($P > .05$) by marbling score of meat from either *Bos indicus* or *Bos taurus* cattle (Figure 4).

Percentage yield of retail product trimmed to 0 cm of fat declined ($P < .05$) as marbling score increased, although yields of Modest and Moderate carcasses were not different ($P > .05$; Figure 5). The data in Figure 5 were pooled across species because of low numbers of observations in some subclasses.

Regression of shear force and sensory traits on marbling indicates the low association of marbling score to meat palatability (data not shown), despite the fact that palatability traits generally increase as marbling increases. Only shear force and juiciness regression equations were significant and the coefficient of determination (**CD**) ranged from < 1 to 5% in equations for data pooled across species. Thus, marbling was of little value in explaining the variation in palatability of the meat in this study.

Discussion

It has been well documented that meat from *Bos indicus* breeds of cattle was less tender (higher shear force and lower sensory tenderness rating) than meat from *Bos taurus* breeds of cattle (Carpenter et al., 1961; Ramsey et al., 1963; Carroll et al., 1964; Luckett et al., 1975; Koch et al., 1982; Peacock et al., 1982; McKeith et al., 1985; Crouse et al., 1987, 1989; Johnson et al., 1990; Wheeler et al., 1990a,b; Whipple et al., 1990; Shackelford et al., 1991). Meat from *Bos indicus* cattle also has been shown to be more variable in tenderness than meat from *Bos taurus* cattle (Crouse et al., 1989; Wheeler et al., 1990a). Although several studies have indicated that the decreased tenderness of meat from *Bos indicus* cattle is largely due to reduced postmortem proteolysis resulting from elevated calpastatin activity (Wheeler et al., 1990b; Whipple et al., 1990; Shackelford et al., 1991), the possibility existed for an interaction between species

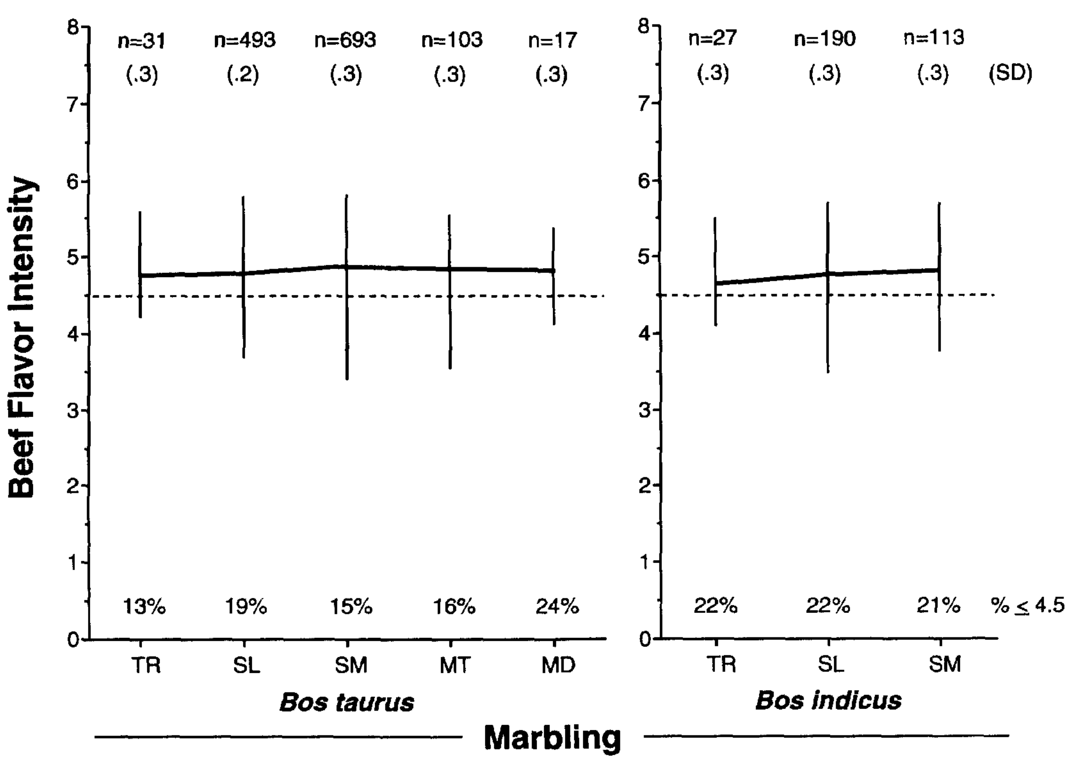

Figure 4. Sensory beef flavor intensity rating by breed-type and marbling score. The thickest line connects the least squares means for each marbling score. The vertical lines show the range in beef flavor intensity rating for each marbling score. The numbers at the top are the number of cattle with each marbling score. The numbers in parentheses are standard deviations adjusted for year effects for each marbling score. The percentages at the bottom represent the percentage of cattle with a beef flavor intensity rating ≤ 4.5 ("slightly bland"). Means without a common superscript, within breed-type, differ ($P < .05$).

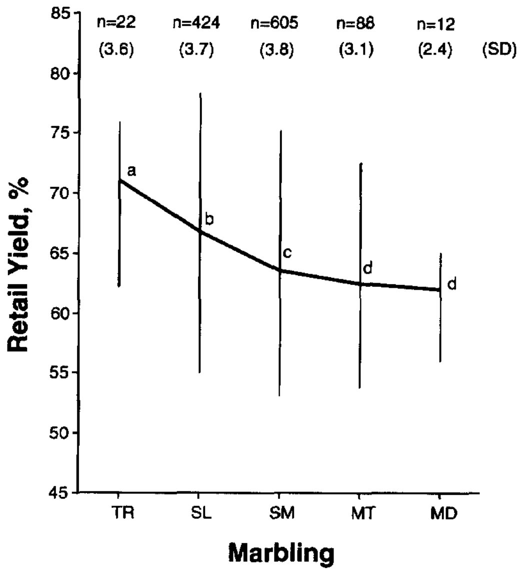

Figure 5. Percentage of retail product yield by marbling score pooled across breed-type. The thickest line connects the least squares means for each marbling score. The vertical lines show the range in retail yield for each marbling score. The numbers at the top are the number of cattle with each marbling score. The numbers in parentheses are standard deviations adjusted for year effects for each marbling score. Means without a common superscript differ ($P < .05$).

and the effects of marbling score on tenderness. Koch et al. (1988) reported data indicating a larger increase in sensory panel tenderness as marbling increased from Slight to Small in meat from *Bos indicus* compared with that of *Bos taurus* cattle. However, we did not detect such an interaction.

Due to the USDA quality grading standards for carcass beef (USDA, 1989) and their implied segregation of meat based on palatability, the U.S. beef industry has placed a high value on marbling at the 12th rib interface of the longissimus thoracis. The emphasis on marbling in determining carcass value is based on the slight increases in juiciness, flavor, and tenderness that are obtained as marbling is increased. There are, however, several problems with palatability estimation based solely on marbling score. An abundance of research stretching over the last 30 yr indicates that marbling/intramuscular fat has a low relationship to palatability and explains only approximately 5% of the variation in tenderness of the longissimus thoracis et lumborum (for review see Parrish, 1974). The variation in marbling in the longissimus thoracis has little effect on palatability of other muscles (Smith et al., 1984). Furthermore, the "insurance theory" or the ability of marbling to maintain tender meat when cooked to high end point temperatures is supported by some data (Luchak et al., 1990), but not by other data (Parrish et al., 1973). Finally, the pursuit of higher amounts of marbling results in more time on feed and, thus, in fatter, lower-yielding carcasses (Figure 5 and Koch et al., 1979). Thus, use of a visual assessment of the amount of fat exposed in a cross-section of the longissimus thoracis at the 12th rib as the primary determinant of the value of the entire carcass may not be justified.

Our data, involving a large number of cattle of various genotypes that were fed and managed the same, support previous research indicating that marbling has a low association with meat palatability. However, they do indicate there is a small, positive relationship of tenderness and juiciness with marbling score, and that variation in tenderness may be decreased slightly as marbling increases. It is clear, though, that there was a large amount of variation in sensory tenderness rating and shear force within one marbling score or another. Thus, segmenting carcasses based on marbling results in many carcasses with tough meat in the "tender" group and many carcasses with tender meat in the "tough" group. This conclusion is supported by surveys (Morgan et al., 1991; Smith et al., 1992) indicating that despite the application of USDA quality grades, inconsistent meat tenderness is a major defect in current beef production. Our data are generally supportive of the concept of Savell and Cross (1989) called the "Window of Acceptability" regarding the fat content of meat. They proposed that a minimum of Slight marbling (or 3.0% intramuscular fat) was needed for palatability and a maximum of 7% fat (mid-Modest marbling) not to exceed recommendations for percentage of calories from fat and total fat in the diet in two 85-g servings of meat per day. Our data indicate this "window" (3 to 7% intramuscular fat) would provide the contribution of marbling to palatability and that higher levels of marbling contribute little more to palatability.

Implications

Shear force, tenderness rating, and juiciness rating improve slightly and shear force variation decreases slightly as marbling increases in meat from both *Bos taurus* and *Bos indicus* cattle. However, marbling explained at most 5% of the variation in palatability traits. There was a large range in tenderness within each marbling score, indicating there could be a large amount of both tough and tender meat within each marbling score. USDA quality grade does not sufficiently segregate carcasses for palatability differences, and thus a direct measure of meat tenderness is needed to supplement USDA quality grade.

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