RESIDUAL SUGARS AND FERMENTATION PRODUCTS IN RAW AND FINISHED COMMERCIAL SAUERKRAUT

H. P. Fleming and R. F. McFetters
Food Fermentation Laboratory, U. S. Department of Agriculture,
Agricultural Research Service, and
North Carolina Agricultural Research Service,
Department of Food Science, North Carolina State University,
Raleigh, NC 27695-7624

Sauerkraut is one of the oldest fermented foods and is made commercially and in the home throughout the world. Although sauerkraut is simple to make, the commercial production and distribution of sauerkraut of high and consistent quality is not simple. A food product must be of consistently high quality to compete with the many fresh and processed foods available to the American consumer today. The food also must meet the taste preferences of the consumer, and these preferences are subject to change. Sauerkraut apparently has not faired well over the past few decades in its competition for the American food dollar. Per capita consumption of sauerkraut has gradually declined from 2.3 lbs in 1930 to 1.4 lbs today. In contrast, cucumber pickle consumption has increased from 1.8 lbs in 1930 to over 8.0 lbs today, a 400+ percent increase! The increase in consumption of pickles generally has been associated with the introduction of milder-acid-flavored products, including fresh-pack (pasteurized) pickles in the 1940's and refrigerated pickles in the 1960's.

The need to enlarge the consumer base for sauerkraut by manufacture of a product that will improve consumer perception has been expressed (1). Some representatives of the industry have indicated that a milder-flavored product might be more widely accepted. Although a strong acid flavor is desired by many "true kraut lovers," the industry might benefit from the production of a mild-flavored sauerkraut. Also, there are indications that the consistency in quality of American sauerkraut could be improved, based on the variability that has been found in evaluations made by the sauerkraut packers themselves over the past several years at their annual meetings.

The objectives of this study were to analyze raw and finished sauerkraut for indications of possible sources of variation and factors influencing quality of

sauerkraut. Of particular interest were variations in residual sugars and fermentation products in bulk fermentation tanks and in the finished products. In addition, we wanted to obtain an indication of variations of these constituents within the tanks as influenced by tank depth.

Sauerkraut manufacturers were asked in 1982 at their 75th Annual Meeting if they would participate in a survey for the purpose of determining the composition and variability of sauerkraut held in bulk tanks and in the finished products obtained therefrom. Five companies participated in this survey. They were asked to send samples of year-old sauerkraut stored in bulk tanks. The samples were taken as the tank was being unloaded for processing according to normal scheduling. Approximately 1-lb samples of raw sauerkraut were taken 1/3, 1/2, and 2/3 down from the top surface as the tank was unloaded. A 1 qt sample of brine was taken from the bottom of the tank, below the lower layer of sauerkraut, before tank unloading began. Finally, triplicate containers of the finished product from the tank were taken. These samples, 7 per tank, were shipped to the U. S. Food Fermentation Laboratory (Raleigh, NC) in October of 1983. The products were analyzed for pH, salt, and titratable acidity according to Etchells and Bell (2) and organic acids and residual sugars by the high performance liquid chromatography (HPLC) method of McFeeters et al. (6).

Chemical composition of year-old sauerkraut

None of the samples from the ten tanks of year-old raw sauerkraut contained measurable concentrations of fermentable sugars (Table 1). The pH varied between 3.2 and 3.4, indicating a high level of acidity. Titratable acidity of the raw sauerkraut was 2.1 to 3.3 percent and for the finished sauerkraut was 0.93-2.75 percent.

The lower acidity in the finished sauerkraut from most tanks was assumed to be due to leaching of the acid from the raw product to obtain a finished product of lower acidity. The ratio of titratable acidity in raw/finished sauerkraut varied form 0.93-2.75 (Table 1). In other words, acidity in the finished products was diluted by this amount. This conclusion is

Table 1. Fermentable sugars, titratable acidity, and salt in year-old sauerkraut held in bulk storage and in the finished product

	Raw sauerkraut[a]		Acid in sauerkraut[b]			Salt in sauerkraut		
Tank	Sugar		Raw	Finished	Raw	Raw	Finished	Raw
No.	(%)	pH	(%)	(%)	Finished	(%)	(%)	Finished
80	0.0	3.2	2.92	2.02	1.44	2.27	1.45	1.56
12	0.0	3.2	2.95	1.47	2.01	1.83	1.05	1.74
14	0.0	3.2	3.16	1.42	2.22	1.60	0.70	2.29
22	0.0	3.2	3.12	2.22	1.40	1.53	1.45	1.06
8	0.0	3.2	3.26	1.19	2.74	1.67	1.13	1.48
13	0.0	3.2	3.28	1.47	2.23	1.62	1.23	1.32
15	0.0	3.2	3.22	1.17	2.75	1.88	1.17	1.61
65	0.0	3.4	2.67	2.12	1.26	1.62	2.25	0.72
3	0.0	3.2	2.13	2.29	0.93	2.18	2.07	1.05
5	0.0	3.4	2.36	1.80	1.31	1.31	1.35	0.97

[a]Sugars determined as glucose, fructose, and sucrose by HPLC from samples taken at mid-depth of the tanks.
[b]Determined as titratable acidity and calculated as lactic acid.

reached by assuming that no acid was added to the finished products, and this assumption was validated upon questioning the packers. The purpose of washing the sauerkraut before packing presumably was to lower the acidity in the finished product and thereby appeal to more people.

The final acidity reached in the year-old sauerkraut was two or more times that reached in cucumber fermentations, due to the greater amount of fermentable sugars in cabbage than in cucumbers. Cucumbers usually contain less than 2.5 percent sugars, as glucose and fructose. We found fresh market cabbage obtained at a local grocery to contain 4.9 percent total fermentable sugars as glucose (2.3 percent), fructose (2.3 percent) and sucrose (0.3 percent). Pederson and Albury (7) reported 2.9 to 8.7 percent sugars in cabbage. Hughes and Lindsay (5) found 6.3 to 9.4 percent sugars as glucose, fructose, and sucrose in various cabbage cultivars. Thus, it is understandable that sauerkraut would attain high levels of acidity if allowed to ferment to completion.

It would be helpful for communication purposes if sauerkraut people would accept a common definition of what is meant by "completely fermented" or "fully fer-

mented" sauerkraut. These terms appear to be vaguely comprehended within the sauerkraut industry. In general, packers using these terms indicate their meaning to be that the sauerkraut has stopped fermenting, presumably forever. The problem with this definition is that sugar may remain but is used so slowly by fermenting microorganisms as to not be readily recognized as undergoing fermentation while the sauerkraut is held in bulk tanks. This slow fermentation during bulk storage may be of no consequence, but could be a cause of gaseous spoilage when the product is packed without proper heating or refrigeration to prevent continued fermentation. Also, sugar could remain that is not fermentable by the microorganisms present in that particular sample of sauerkraut, but would ferment if the product should later become contaminated with such microorganisms. Yeasts, for example, will ferment sugars in brined cucumbers after the growth of lactic acid bacteria has been inhibited by low pH; this phenomenon has been referred to as "secondary yeast fermentation" (3). Therefore, we propose that the terms "completely fermented" or "fully fermented" be defined as sauerkraut that has been fermented to contain no fermentable sugars. "Incomplete" or "partially fermented" sauerkraut would contain residual sugars of the cabbage.

Complete fermentation, while resulting in high acid production, could be useful in minimizing requirements for heat processing. If no fermentable sugars remain, it is conceivable that heat processing would not be required to preserve anaerobically packaged sauerkraut. In fact, one packer in The Netherlands packages and distributes fully fermented sauerkraut in plastic bags without heat processing or the addition of preservatives. We have found that several vegetables were microbiologically stable in hermetically sealed containers provided they were fermented to completion and the pH was 3.8 or below (4).

Vertical distribution of constituents in bulk tanks

Titratable acidity was uniform throughout the sauerkraut depth of the tank, but slightly lower in the brine below the sauerkraut when averaged over all 10 tanks (Table 2). The concentration

Table 2. Vertical distribution of constituents in year-old sauerkraut held in bulk storage[a]

Compound	Tank Location[b] Top	Middle	Bottom	Brine
By titration				
Titratable acidity (%)	2.87	2.87	2.84	2.70
Salt (%)	1.62	1.70	1.81	2.14
By HPLC				
Lactic acid (%)	2.78	2.85	2.60	2.19
Acetic acid (%)	0.60	0.66	0.70	0.76
Total acids (%)	3.38	3.51	3.30	2.95
Ethanol (%)	0.54	0.43	0.41	0.53
Mannitol (%)	1.06	1.06	0.86	0.39

[a]Data are averages from ten tanks.

[b]Sauerkraut samples were taken from the top (1/3 depth), middle (1/2 depth) and bottom (2/3 depth). The brine sample was taken from the bottom of the tank and below the sauerkraut.

of salt gradually increased at greater depths in the tanks. None of the tanks contained fermentable sugars, as mentioned earlier. Fermentation products measured by HPLC were lactic acid, which decreased at greater depths; acetic acid, which increased at greater depths; ethanol, which showed no clear trend; and mannitol, which decreased at greater depths. These products may indicate the type of lactic fermentation that occurred throughout the tanks according to known compounds that bacteria associated with sauerkraut fermentation produced from glucose, fructose, and sucrose contained in the cabbage.

LACTIC ACID BACTERIA		MAJOR PRODUCTS
Homofermentative	——————>	Lactic acid
(*Pediococcus pentosaceus*)		
(*Lactobacillus plantarum*)		
Heterofermentative	——————>	Lactic Acid, acetic acid
(*Leuconostoc mesenteroides*)		CO_2, ethanol
(*Lactobacillus brevis*)		Mannitol

From the data in Table 2, there is an indication of different types of fermentations at various tank depths, for as yet unknown reasons.

Composition and taste panel evaluation of finished sauerkraut

Samples of finished sauerkraut were chemically analyzed and organoleptically compared. These samples consisted of samples from 4 of the tanks analyzed (categorized as 2 with high, 1 with moderate, and 1 with low acid) and a sample of highly sweetened sauerkraut (Table 3). All 5 samples were prepared from fully

Table 3. Composition and taste panel evaluation of finished sauerkraut

Assay	Fully fermented				Partially fermented		
	High acid	High acid	Moderate acid	Low acid	Sweet	American	European
Tank no.[a]	65	80	13	15			
Finished product dilution	1.26	1.44	2.23	2.75			
By titration							
Salt (%)	2.25	1.45	1.23	1.17	0.60	1.47	1.00
Acid (%)	2.11	2.02	1.47	1.17	1.31	1.48	1.22
Salt/acid	1.06	0.72	0.84	1.00	0.46	0.99	0.82
pH	3.28	3.33	3.29	3.29	3.34	3.37	3.73
By HPLC							
Sugars							
Glucose	0.43	0.00	0.00	0.00	1.51	0.21	0.95
Fructose	0.10	0.00	0.00	0.00	1.33	0.12	0.79
Sucrose	0.00	0.00	0.00	0.00	5.54	0.04	0.15
Total sugars	0.53	0.00	0.00	0.00	8.38	0.37	1.89
Fermentation products							
Lactic acid (%)	2.08	2.02	1.52	1.13	1.32	1.68	1.19
Acetic acid (%)	0.50	0.48	0.32	0.29	0.23	0.25	0.53
Total acids (%)	2.58	2.50	1.84	1.42	1.55	1.93	1.72
Ethanol (%)	0.35	0.39	0.13	0.11	0.14	0.11	0.55
Mannitol (%)	1.20	0.66	0.72	0.44	0.54	0.61	1.06
Taste panel[b]							
Flavor	6.0	4.4	6.0	5.9	6.2	5.3	8.0
Overall preference	6.4	4.9	6.3	6.0	6.3	5.2	8.0

[a] Tank nos. correspond to those in Table 1.

[b] Panel scores are based on 10-point scale, from 1 = not acceptable to 10 = excellent. Data are averages from evaluation by 8 panelists.

fermented sauerkraut. In addition, 2 samples of partially fermented sauerkraut were analyzed (1 of American and another of European origin). Salt in these products varied from 0.6 to 2.2 percent and the salt/acid ratio from 0.46 to 1.06 percent. Interestingly, the finished sample from tank 65 contained sugars while the raw sauerkraut from this tank did not, indicating addition of sugar to the finished product. It has been found that addition of sugar to dill pickles improves the flavor of this strongly acid product, and this packer may have taken advantage of this fact. No sugar was found in the products from tanks 80, 13, and 15. The partially fermented sauerkraut contained 0.3 percent (American) and 1.899 percent (European) total fermentable sugars.

Fermentation products varied widely among the various sauerkrauts. Of particular interest were the relatively high concentrations of ethanol and mannitol compared to lactic acid in the European, partially fermented sauerkraut. The European sauerkraut received decidedly higher taste panel ratings than any of the American sauerkrauts. The relatively high mannitol content in this sauerkraut is indicative of a relatively high proportion of the sugar that was fermented being utilized by heterofermentative lactic acid bacteria. The relatively high ethanol content was probably due to wine, which the can label indicated was added, in addition to heterofermentative lactic acid bacteria.

Although milder-acid-flavored sauerkraut may be desired, simple dilution of the acid present may not improve the flavor, as indicated by evaluation of the American sauerkraut samples of varying acidities (Table 3). When acid is washed from the sauerkraut, other constituents also are removed, thus the ratio of constituents may remain unchanged. Much remains to be established as to what constituents are important to the flavor of sauerkraut, as well as methods to prevent development of off flavors.

Results of the limited survey of commercial sauerkraut reported herein have raised potentially important questions in two general areas. The first area of concern relates to the quality and acceptance of sauerkraut as currently manufactured in the United States. The second area of concern relates to methods of bulk fermentation/storage and processing of sauerkraut as they influence product quality.

If one accepts the premise that a milder-acid-flavored sauerkraut would broaden consumer demand, then there is the question of how best to obtain such a product. Some possible approaches for reducing the concentration of acid in sauerkraut are as follows: (1) Cabbage varieties now in use apparently contain more sugar than required for the production of acid to yield a mild-flavored product. If allowed to ferment to completion, such cabbage will yield a strong-acid flavored final product. There is no assurance that cabbage bred for the desired sugar level would yield a desirable sauerkraut, but the possibility seems worthy of consideration. (2) Fully fermented sauerkraut can be washed to dilute the product to the desired level of acid before packing, as seems to be the practice of some U. S. sauerkraut manufacturers. A problem with this approach, however, is that all of the other constituents also are diluted and some of these constituents are important to the flavor and nutritive value of sauerkraut. In some countries, dilution of sauerkraut is not permitted, probably for this reason. (3) Sauerkraut may be pasteurized

when it ferments to the desired concentration of acidity. By so doing one retains the desirable flavor constituents produced early in the fermentation by L. mesenteroides, and perhaps a better balance of these constituents with lactic acid. Also, residual sugars remain in partially fermented sauerkraut that may be beneficial to the flavor. (4) Partial neutralization of acid by chemical means is a possibility, but the handling procedures for such treatment and regulatory approval must be considered, in addition to effects such a process would have on all aspects of product quality. (5) Finally, end product manipulation by controlled growth of selected microorganisms offers an interesting, long-term possibility for production of mild and desirably flavored sauerkraut. This approach may involve control of the physical and chemical environment, and genetic modification of selected bacteria to product superior cultures for use in controlled fermentation procedures.

Partial fermentation of cabbage to the desired level of acidity followed by pasteurization is currently used by many European, and a limited number of U. S., sauerkraut manufacturers. Thus, this is a practical and proven way to obtain partially fermented sauerkraut. Use of this method, however, creates a dilemma for sauerkraut packers who wish to take advantage of the economy of bulk storage. Bulk storage has the advantage of reducing inventory costs for product containers. Also, the packer has more flexibility as to when to open a bulk tank for processing. This flexibility serves to distribute labor and equipment needs throughout the year and to minimize storage time of product in the final container.

It is clear that this brief survey has raised more questions than it has answered. These and other questions await answers that we and other researchers hopefully can help resolve by cooperation with the sauerkraut industry.

ACKNOWLEDGMENTS: The authors thank R. L. Thompson and A. C. Hopkins for assistance with chemical assays. The senior author expresses his appreciation to Dr. C. S. Pederson for conferences with him and for the major contributions he has made to the vegetable fermentation industry, particularly sauerkraut. Also, I thank Dr. J. R. Stamer for his advice on tank sampling and other matters related to the project reported herein.

This investigation was supported in part by the National Kraut Packers Association, Inc., St. Charles, IL.

PEFERENCES

1. Burson-Marsteller Research. 1983. A study of the reasons for use/nonuse of kraut. Prepared for the National Kraut Packers Association, Inc., St. Charles, IL.
2. Etchells, J. L. and Bell, T. A. 1976. Pickle products. In "Compendium to Methods for the Microbiological Examination of Foods," pp. 574-593, M. L. Speck, ed., American Public Health Association, Washington, DC.
3. Fleming, H. P. 1982. Fermented vegetables. In "Economic Microbiology. Fermented Foods," pp. 227-258, Vol. 7, A. H. Rose, ed., Academic Press, Inc., New York.
4. Fleming, H. P., McFeeters, R. F., Thompson, R. L., and Sanders, D. C. 1983. Storage stability of vegetables fermented with pH control. J. Food Sci. 48:975-981.
5. Hughes, A. and Lindsay, R. 1983. Data presented at the Winter Conference of the National Kraut Packers Association, Inc., Chicago, IL, December 15.
6. McFeeters, R. F., Thompson, R. L., and Fleming, H. P. 1984. Liquid chromatographic analysis of sugars, acids, and ethanol in lactic acid vegetable fermentations. J. Assoc. Offic. Anal. Chem. 67:710-714.
7. Pederson, C. S. and Albury, M. N. 1969. The sauerkraut fermentation. N. Y. State Agr. Expt. Station Bull. 824.

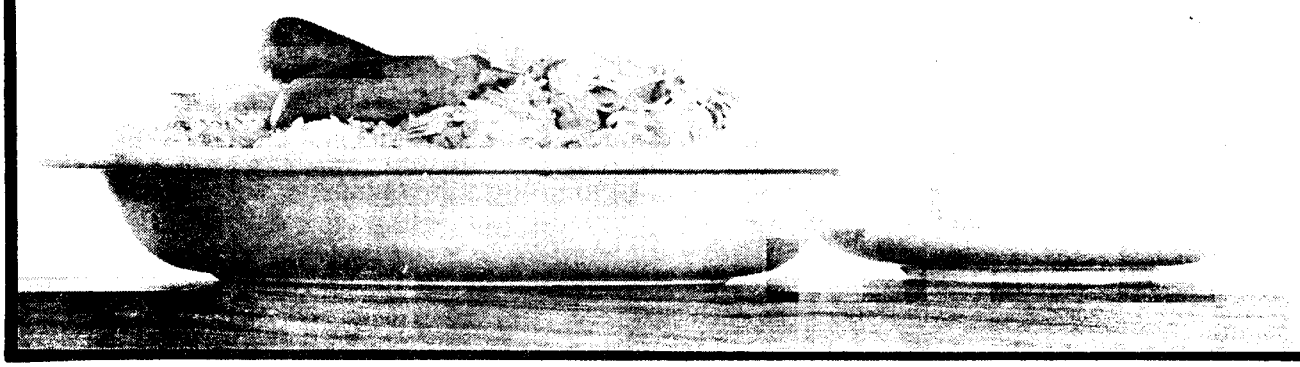
NOTE: Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture or North Carolina Agricultural Research Service, nor does it imply approval to the exclusion of other products that may be suitable.

APRIL 1985 NUMBER 56

·SPECIAL REPORT·

NEW YORK STATE AGRICULTURAL EXPERIMENT STATION, GENEVA, A DIVISION OF THE NEW YORK STATE COLLEGE OF AGRICULTURE AND LIFE SCIENCES, A STATUTORY COLLEGE OF THE STATE UNIVERSITY, CORNELL UNIVERSITY, ITHACA

1984 SAUERKRAUT SEMINAR



Edited By:
Donald L. Downing

Sponsored By:
NATIONAL KRAUT PACKERS ASSN., INC.
NEW YORK STATE AGRICULTURAL EXPERIMENT STATION
CORNELL COOPERATIVE EXTENSION