A NEW LOOK AT SAUERKRAUT FERMENTATION WITH POSSIBLE APPLICATION OF NEW TECHNOLOGY

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I am honored and pleased to be invited to speak at the 75th Annual Meeting of the National Kraut Packers Association. I have already met many of you and hope to meet the rest. Mr. Mannie Siegle picked me up at the Syracuse airport and toured me through his plants and the cabbage growing area of the Preble Valley, for which I am indeed grateful. Some of us are already acquainted through our association with Pickle Packers International, Inc.

I have felt the presence of great spirits during my stay here on Otsego Lake in Cooperstown. I have sensed the magnificence of the natural forces that created this scenic marvel and the spirit of the people that molded it into what it is today. The setting has caused me to realize an even deeper appreciation for the forefathers of my area of research.

Although foods have been preserved by fermentation for many centuries, the scientific basis for preservation of foods by fermentation has been established only within the last 100 years. Much of the research that has been done on sauerkraut in this country is represented at our meeting today in Dr. Carl Pederson. Dr. J. L. Etchells, my former supervisor, and his associates did much of the work on pickles. Drs. R. H. Vaughn and W. V. Cruess did much of the work on olives. The primary emphasis of these people was to observe, characterize and ask the "whys" for the natural fermentation of vegetables. Today, we are using the vast reservoir of information gained by those pioneers, and are asking important new questions in order to create new technology for the vegetable fermentation industry. To paraphrase George Bernard Shaw, previous generations observed the nature of vegetable fermentations and asked, "Why?" We of the present generation have dreams of new frontiers with vegetable fermentations and ask, "Why not?"

I know very little about sauerkraut, and I suspect that Bill Moore and King Pharr invited me here to correct that situation. Our laboratory has done considerable pickling research on cucumbers, and some on Spanish-style green olives and various other fruits and vegetables. So, we are familiar with the general principles that govern pickling of vegetables. Many of these principles apply to sauerkraut, but some may not. Each product that we have studied has unique properties, and I suspect that is true of sauerkraut. I welcome the opportunity to learn your problems, and to share with you our experience and resources in helping to solve them. I have talked with Dr. Carl Pederson here at the meeting, and with Dr. John Stamer by telephone on several occasions. Both have been very helpful in educating me about sauerkraut.

I would like to briefly discuss the general principles involved in vegetable fermentations. In so doing, we may uncover important questions to justify further research on sauerkraut. A beginning question we might ask is, why are vegetables fermented? Vegetables and other foods were preserved by salting long before the principles of food preservation were established. Salted vegetables naturally undergo a lactic acid fermentation, which under proper conditions results in preservation of the vegetables. With modern methods of food preservation, however, why should we continue to ferment vegetables? First, there are economic reasons. Brining is a rapid, temporary means for preservation of produce that must be handled in some manner during the harvest season to prevent spoilage. Thus, brine storage serves to extend the process season and allows distribution of labor and equipment throughout the year. Brining is a low-energy-requiring method of preservation, which is an especially important consideration today.

There are also technological reasons why fermentation is justified as a means of preservation today and in the future. Desirable flavors can be achieved in properly fermented vegetables. There is great potential for enhancing the flavor through selection and adaptation of microorganisms. The food safety record for commercially fermented vegetables is excellent. In fact, the U.S. Commissioner of Food and Drugs has stated, "No instances of illness as the result of contamination of commercially processed fermented foods with *Clostridium botulinum* have been reported in the United States," (1). We want to maintain this reputation, so it is important that innovations with fermented vegetables be carefully considered as to safety to avoid any compromise of the excellent record.

Relatively little has been done to determine effects of fermentation on the nutritional value of vegetables. We know, however, that low pH and anaerobiosis created during lactic fermentation favors retention of certain nutrients such as ascorbic acid and thiamine. Vegetables do not naturally contain vitamin B_{12}, but microorganisms can produce this vitamin. Thus, fermentation offers potential for nutritional enhancement of vegetables. It is likely that our laboratory will become more involved in this area of research as we attempt to take advantage of genetic engineering to modify metabolic abilities of fermenting microorganisms. It is difficult to contain one's enthusiasm when considering possibilities for the future in this area.

How does fermentation preserve vegetables? We do not know all the answers to this question, but I will discuss some of the major factors with which I am familiar. Acid produced by lactic acid bacteria lowers the pH sufficiently to inhibit growth of food poisoning bacteria. In the case of cucumbers and certain other vegetables, we have found that complete conversion of the fermentable carbohydrates of the vegetables to acids and other products will prevent later fermentation. Then, if the fermented product is held anaerobically (absence of air), no microbial spoilage will occur (2).

Salt is important in assuring safety and quality in fermented vegetables. The concentration of salt used varies among vegetables (Table 1), depending to a major extent upon the tendency of the vegetable to soften during storage. Relatively low concentrations of salt are required to maintain the firmness of cabbage as compared to bell peppers for example. The use of calcium chloride improves the firmness of some vegetables, and is showing promise as a means of reducing salt requirements during brine storage. The presence of salt helps to direct the course of the fermentation, and to preclude growth of spoilage bacteria. Salt concentration greatly influences the type of lactic acid fermentation. In sauerkraut, the relatively low salt level favors early growth of *Leuconostoc mesenteroides*. This bacterium appears to be of lesser importance in cucumber and olive fermentations due to the higher levels of salt used in these products.

Table 1.—Salting procedures for vegetables[a].

Method of salting	Level of salt during: Fermentation	Level of salt during: Storage	Vegetable
Dry salting	2 to 3%	2 to 3%	Cabbage
Brine solution	5 to 8%	8 to 16%	Cucumbers, olives, chili peppers
	16 to 26%	16 to 26%	Bell peppers, onions, cauliflower, citron

[a] The levels of salt indicated generally are used for the commercial brining of cabbage, cucumbers and olives in the United States. Wide variations exist. From Fleming, 1982 (2).

Table 2.—Sequence of microbial types during natural fermentation of brined vegetables[a].

Stage	Prevalent microorganisms
Initiation	Various Gram + and - bacteria
Primary fermentation	Lactic acid bacteria and yeasts
Secondary fermentation	Yeasts
Post-fermentation	Open tanks - surface growth of oxidative yeasts, fungi and bacteria Anaerobic tanks - none

[a] From Fleming, 1982 (2).

Actually, the natural fermentation of vegetables involves growth sequence of various types of microorganisms. This sequence may be categorized into four stages (Table 2). These four stages are based on changes in the chemical and physical environment during fermentation and storage of the product.

The *initiation* stage may include growth by many of the faculative and strictly anaerobic microorganisms originally present on the fresh material, but as lactic acid bacteria become established, the pH value is lowered and growth of undesirable microorganisms such as Gram-negative and spore-forming bacteria is inhibited. The quality of the final product depends largely on the rapidity with which the lactic acid bacteria are established and the undesirable bacteria are excluded (2).

During the *primary fermentation* stage, lactic acid bacteria and fermentative yeasts are the predominant active microflora. They grow in the brine until the fermentable carbohydrates are exhausted or until the lactic acid bacteria are inhibited by low pH values, resulting from production of lactic and acetic acids. Buffering capacity and the fermentable carbohydrate content of the plant material are important factors which govern the extent of fermentation by lactic acid bacteria and the extent of subsequent fermentation by yeasts (2).

Secondary fermentation is essentially due to fermentative yeasts. These yeasts may become established during the primary fermentation, are acid tolerant and, if fermentable sugars remain after the lactic acid bacteria are inhibited by low pH values, continue to grow until the fermentable carbohydrates are exhausted (2).

During the *post-fermentation* stage, when fermentable carbohydrates are exhausted, microbial growth is restricted to the surface of brines exposed to air. When the surface of brines is so exposed, oxidative yeasts, molds, and ultimately spoilage bacteria may become established on the surface of improperly managed tanks. No surface growth occurs in anaerobic tanks (2).

The procedure for brining vegetables varies with the commodity, but common features are illustrated in Figure 1 for natural fermentations. At this point I would like to talk about some of our research with cucumber fermentation, which will serve to indicate that changes can be made in conventional fermentation processes to bring about improved technology. The steps underlined in Figure 2 are modifications that we (3) made in the brining of cucumbers that result in a more controlled fermentation. The cucumbers are washed to remove debris and softening enzymes, the brine is acidified to preclude growth by unwanted bacteria, and the brine is purged with nitrogen to remove CO_2 from the brine until the fermentation is complete (air is used by some briners with less cost for purging but at the expense of some risk in spoilage). About 1 day after brining, the brine is buffered to ca. pH 4.5, a selected culture of lactic acid bacteria is added (*Lactobacillus plantarum*, *Pediosoccus cerevisiae*, or both), and the product is allowed to ferment to completion. The product is then held until needed for processing.

Some briners have used the general process as outlined, with modifications. The entire process has not been widely adopted. However, most cucumber briners throughout the country are purging brines during fermentation to prevent gaseous deterioration of the cucumbers commonly termed bloater damage. Before purging, which was a critical feature included in the controlled fermentation process (3), bloater damage was a source of serious economic loss to the pickle industry. With purging, bloater damage has been greatly reduced with sizeable economic benefit.

Another recent advance in cucumber brining has been the addition of calcium compounds to brines to improve firmness of cucumbers and to allow fermentation at lower salt concentrations (4,5).

We now are considering the redesign of cucumber brining tanks, which we hope will poise the pickle industry to take advantage of recent and anticipated new technology. Our laboratory, Dr. E. G. Humphries (Department of Biological and Agricultural Engineering, NCSU), Pickle Packers International, Inc., and certain allied industries are cooperating on a special project to develop a new prototype fermentation tank. The tank will have a closed top and will be anaerobic, perhaps similar to those that have been in use by the olive industry for several years. Modifications will be necessary, however, for cucumbers. We will use the new tanks in scale-up experiments from our laboratory before they are introduced into commercial practice. Also, we are designing the tank with the possibility for application to full-scale brining tanks. We are very enthusiastic about this 5-year project, which just began. Present tank design for sauerkraut and cucumbers is similar. Both fermentations employ open-top tanks. Cucumbers must be headed down with wooden timbers to overcome the buoyancy force. The brine level must be kept above the wooden timbers. The brine surface is exposed to sunlight to prevent growth of film yeasts and molds. Brined cabbage is headed down with plastic film, overlaid with water or brine. Even with the plastic film, however, I have noted softening and off odors in the top layer of sauerkraut.

Finally, let me say that I have thoroughly enjoyed my visit and the association with you people. I am extremely enthusiastic about the future of vegetable fermentations and look forward to sharing it with you and others when we may be of service. I have the good fortune of being associated with some outstanding people in our laboratory. Dr. R. F. McFeeters (Food Biochemist) and Mr. R. L. Thompson (Chemist) have been with the laboratory for several years. Mr. M. A. Daeschel (Food Microbiologist) will be assigned to our laboratory after he completes requirements for the Ph.D. degree. We work closely with many other scientists on campus, but especially acknowledge the cooperation with Dr. D. M. Pharr (Plant Physiologist, Horticulture, who is King Pharr's brother) and Dr. Humphries, who I mentioned above in relation to the tank project.

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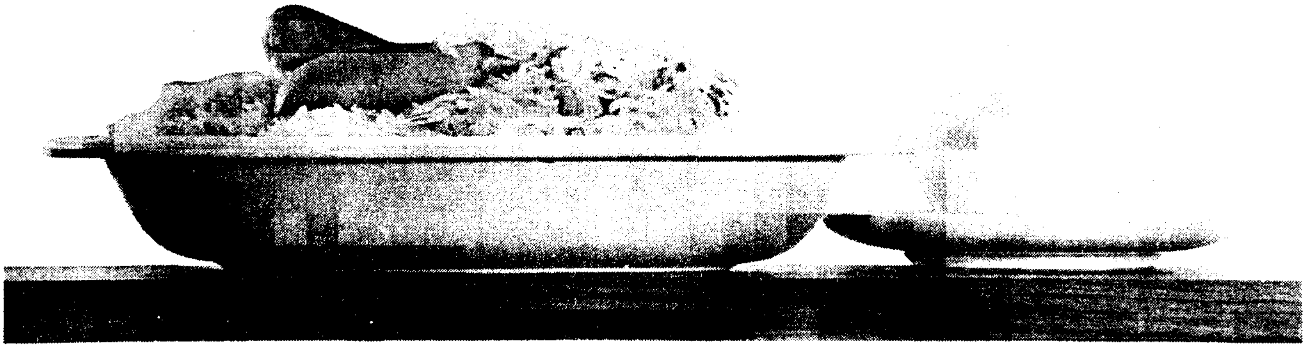

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