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Distr.
LIMITED
ID/WG. 282/89
13 October 1978
ENGLISH

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

INTERNATIONAL FORUM ON APPROPRIATE INDUSTRIAL TECHNOLOGY

New Delhi/Anand, India 20–30 November 1978

WORKING GROUP No. 6

APPROPRIATE TECHNOLOGY FOR FOOD STORAGE AND PROCESSING

PRESERVATION OF VEGETABLES IN THE REPUBLIC OF KOREA: THE PROCESSING OF KIMCHI

Background Paper

PRESERVATION OF VEGETABLES IN THE REPUBLIC OF KOREA: THE PROCESSING OF KIMCHI

by

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1. INTRODUCTION

Kimchi, spiced and lactic acid fermented vegetables, has traditionally been one of the most important side dishes for the daily meals of the Korean people. It is prepared by salting Chinese cabbages and/or radishes, washing the salted vegetables with fresh water, adding spices and seasonings to them, and then leaving the spiced vegetables to undergo a process of natural lactic acid fermentation. As far as the traditional Korean dietary life is concerned, it is hardly an exaggeration to say that Kimchi is no less important than rice, the staple food.

The process of compound lactic acid fermentation gives kimchi a refreshing sourness, which, combined with pungent spiciness, produces the unique taste and flavor of kimchi.

This traditonal Korean dish has few parallels in other countries. According to recorded history, kimchi dates back to the 17th century. It is believed, however, that kimchi began to be made in this country long before that.

One important aspect of kimchi is the fact that it represents an excellent way to process and preserve Chinese cabbages and radishes in individual Korean households, especially during winter. During the cold months when fresh vegetables were impossible to obtain, kimchi was the major source of vitamins and minerals for the Korean people. So kimchi has unquestionably been making an important contribution to the health of Koreans from old days.

To explain the kimchi making method in greater detail, selected vegetables (chiefly Chinese cabbages) are trimmed first and then salted.

The amount of salt applied should correspond to about 10 percent of the weight of fresh vegetables. The length of time for salting differs depending on the types and conditions of the vegetables used, but usually ranges between eight to 15 hours.

The vegetables that have become properly tender because of the salting are thoroughly washed with fresh water. Then, the seasoning mixture--composed of cayenne pepper, garlic, ginger, pickled seafood, etc.--is inserted between the leaves of chinese cabbages , which, in turn, are placed neatly in big earthen jars. The kimchi-filled jars are left in the open to let a process of natural fermentation proceed. Each family and each region of the country may have its own variations as to the method of kimchi preparations, especially the recipe for kimchi seasonings. This leads to a great variety of kimchi taste and flavor.

During late autumn--the time to prepare a stockpile of kimchi for the coming winter--Korean housewives must spend a great deal of time on kimchi preparation, a major annual event for every family. Whether or not the family kimchi is tasty has an immense impact on the appetite of family members during the long winter months each year.

Kimchi-making is usually topic No. 1 among housewives in autumn in Korea. The prices of Chinese cabbages, radishes, condiments and other kimchi ingredients are the major object of concern among them. The government also mobilizes its administrative machinery with a view to ensuring adequate supply of kimchi vegetables at reasonable prices. But because of difficulty with preserving Chinese cabbages, radishes, garlic and cayenne pepper in their fresh state and

also of the seasonal nature of their production, there have been wild fluctuations in their prices from year to year, influenced by shortages or surpluses of their supply.

Moreover, it is becoming increasingly more difficult to prepare and stock kimchi at individual homes nowadays. First of all, it is not easy to keep kimchi in a palatable state for an extended period of time. Secondly, as more and more women work outside their homes, many man-hours of labor that must go into preparing kimchi is becoming an excessive burden on the Korean family, the average size of which is rapidly shrinking. Changes in the housing situation also make kimchi-making more and more troublesome for average Korean families, chiefly because space available for storing kimchi for each household is decreasing. The problem is compounded by the rapid spread of apartment houses, in which finding space for big kimchi jars is usually an even greater problem than in the case of single-family houses. Accordingly, a big challenge facing the food industry in Korea now is how to develop commercial production and distribution of kimchi, which is indispensable to the Korean diet, on an all-the-year-round basis. For the development of commercial production of kimchi, more reaserach needs to be conducted into the problems of fermentation control and extended storage of kimchi.

II. SCIENTIFIC STUDIES ON KIMCHI

(1) Microorganisms Involved in Kimchi Fermentation

Lactobacilli are mainly involved in kimchi fermentation (1), which is achieved by inducing lactic acid fermentation through supressing the multiplication of other bacteria with the use of salt. But other aerobic and anaerobic bacteria. and yeasts are also involved in the process of kimchi fermentation. (2-6).

By identifying some 200 strains of bacteria and two strains of yeasts which were isolated during kimchi fermentation, it has been found that the principal species of microbes involved are: Lactobacillus plantaram; L. brevis; Streptococcus faecalis; Strep. facecalis var. liquefaciens; and Leuconostoc mesenteroides. In addition, another strain of lactic acid bacteria, named Pediococcus, has also been isolated. Thus, most kinds of bacteria belonging to the genus Lactobacillus have been found to be present in kimchi. And the aerobic bacteria involved have been found-through the examination of their morphological and biological characteristics--to consist chiefly of strains belonging to the genuses Achromobacter, Flavobacterium and Pseudomonas (5). And the strains of bacteria belonging to the B. megaterium group which were isolated from kimchi have been found to be capable of producing vitamin B_{12} (6). Another report (8) also states that it has been ascertained that vitamin B_{12} is produced in the process of kimchi fermentation. Thus, it has been established that vitamin B_{12} is synthesized in the course of the aging of kimchi.

Data needed to understand the details of the kimchi fermentation mechanism have been generated through a study of the multiplication and disappearance of various microorganisms in the course of kimchi fermentation. The data show that the number of anaerobes increases sharply during the first 30 days of kimchi fermentation, while aerobes rise slightly in number during the initial stage of fermentation, then decline in contrast to the sharp rise of anaerobes, and finally start increasing again around the time that the anaerobes begin to decrease (see Fig. 1). It has been determined that such rises and declines are due to film-forming yeasts (7).

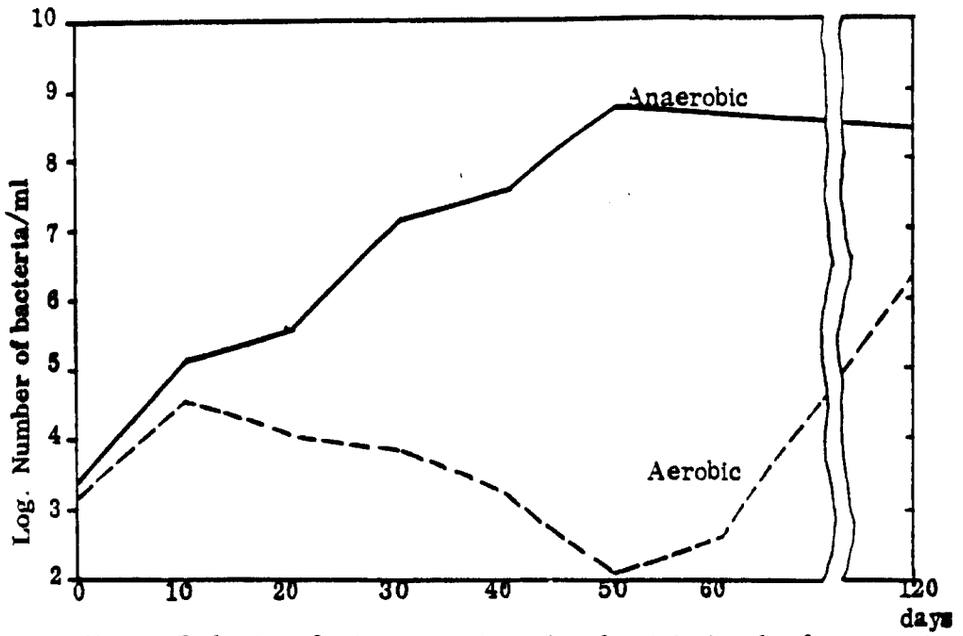

Fig. 1 Behavior of microorganisms involved during the fermentation of Kimchi (7)

An examination of the distribution of isolated and identified microorganisms indicates that Leuconostoc mensenteriodes multiply during the initial phase of kimchi fermentation, thereby producing lactic acid and CO_2 and thus acidifying kimchi, and that they create an anaerobic state, thus supressing the multiplication of aerobes. Streptococcus strains also multiply during the initial phase, but Pediococci appear in the middle period of fermentation. Microbes involved in the aging of kimchi are Lactobacillus plantarum and L. brevis, which tend to continue to multiply until the 40th day of fermentation. Accordingly, it can be concluded that the process of kimchi fermentation is set in motion by bacteria that are present in kimchi raw materials, rather than by enzymatic action on the vegetables involved. (9).

(2) Changes in Properties of Kimchi under Fermentation

The process of kimchi fermentation may be divided into three periods: the aging period; the tasty period in which a relatively homogeneous state of kimchi is maintained; and the excessive acidification phase. The lengths of these periods vary greatly depending on the temperature of kimchi. During the aging period, the sugar content and acidity increase gruadually, and pH decreases slowly owing to buffer action. In the period of excessive acidification, the acidity does not change much, but the sugar content decrease rapidly (10). As was noted earlier in discussing microorganisms involved in kimchi fermentation, such phenomena are related to the fact that the Leuconostoc group multiplies during the initial phase of fermentation, creating an anaerobic condition and thereby inducing an aging process caused by the Lactobacillus group. (9).

The pH of kimchi in its best-tasting state is found to be 4.3 (3.7.11.). When the pH falls below that level, the quality of kimchi deteriorates rapidly. This process may be termed excessive acidification. As can be seen from Fig. 2, although the total quantity of acids changes rapidly during the excessive acidification period, the pH does not change much in this phase.
This phenomenon is attributed to amino acids contained in kimchi (1).

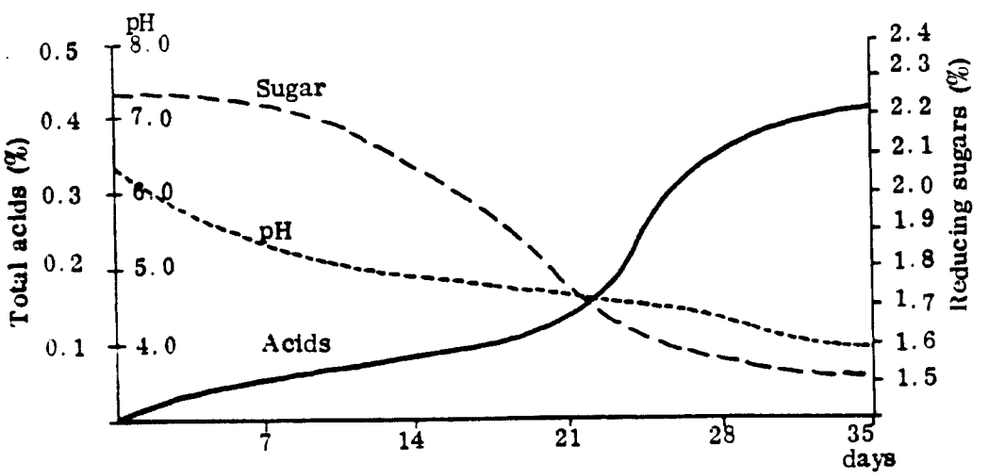

Fig. 2 Changes in reducing sugars, acidity and pH during the fermentation of Kimchi. During the period, temperature was changed gradually from 3 to 7°C (11)

The levels of vitamins B_1 and B_2 in kimchi vegetables decrease immediately after they have been placed in jars for aging. Then the levels soon begin to rise and continue to do so until the third week of fermentation, when kimchi is tasty, finally reaching a peak double the initial content. Even in the excessive acidification period, the levels did not fall below the original amounts (see Fig. 3).

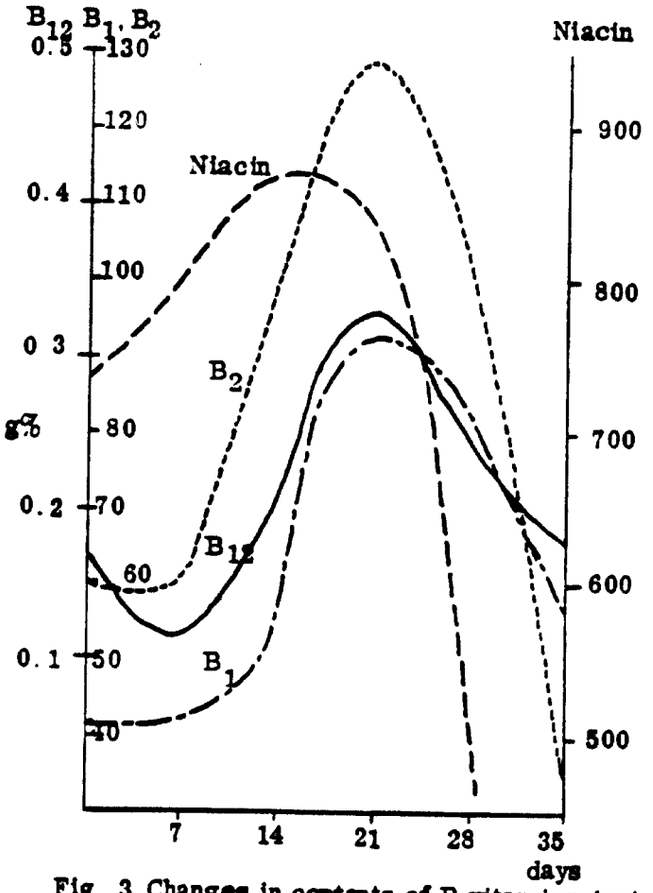

Fig. 3 Changes in contents of B vitamins during the fermentation of Kimchi (11)

It has not yet been determined whether such increases in vitamins B_1 and B_2 during the process of aging are attributable to biological synthesis by microbes during the process of fermentation, or to the dissolution of bound vitamins through their hydrolysis (11). Carotene decreases as the aging progresses, and by the time the process of excessive acidification sets in, its quantity is down to half the original level. Niacin follows almost the same pattern of quantitative change as vitamin B_1 and B_2. Vitamin B_{12} decreases to half its original quantity during the first week of fermentation, but starts to increase again thereafter, reaching a peak in the third week. Vitamin C increases slightly during the early phase of aging, but soon begins to decline, with only about 30 percent of its original quantity in existence in the excessive acidification phase (11).

The above findings imply that the levels of most vitamins involved rise to their peaks during the fermentation phase in which kimchi tastes best. In light of the fact that the average daily consumption of winter kimchi per person ranges between 200 grams to 300 grams, it can be seen that kimchi is very important as a source of vitamin supply in the Korean diet.

The fermenting temperature has a great bearing on the aging of kimchi. When the fermenting rate at 20°C is compared with that at 4°C (see Fig. 4), it is learned that at 4°C, the pH remains little changed until the 18th day of fermentation, whereas at 20°C, the pH begins to show a rapid change from the very beginning, reaching the optimum level (pH of 4.3) in the third day. At 4°C, however, the optimum level is attained in about 35 days after the commencement of fermentation. When fermentation proceeds at 25°C, the optimum pH is attained in about 50 hours. At 13°C, it takes 110 hours to reach the optimum pH. In other words, the process of fermentation takes twice as long at 13°C than at 25°C in reaching the optimum pH. But the quality of kimchi fermented at the lower temperature showed little

significant difference from that fermented at the higher temperature (14).

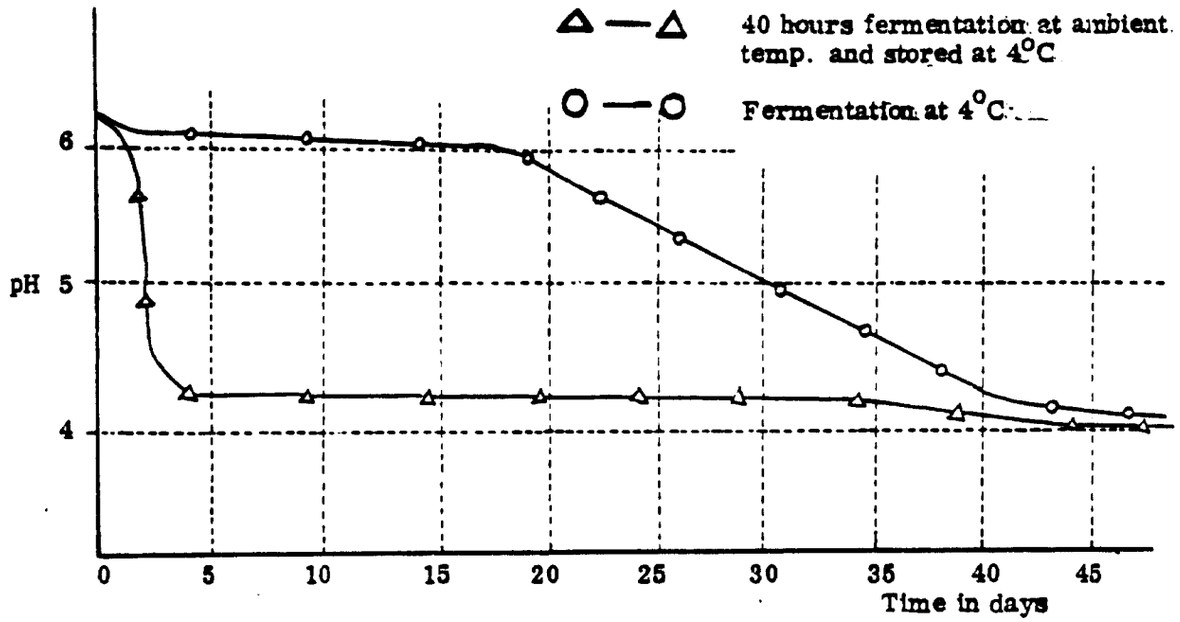

Fig. 4 pH changes during fermentation (12)

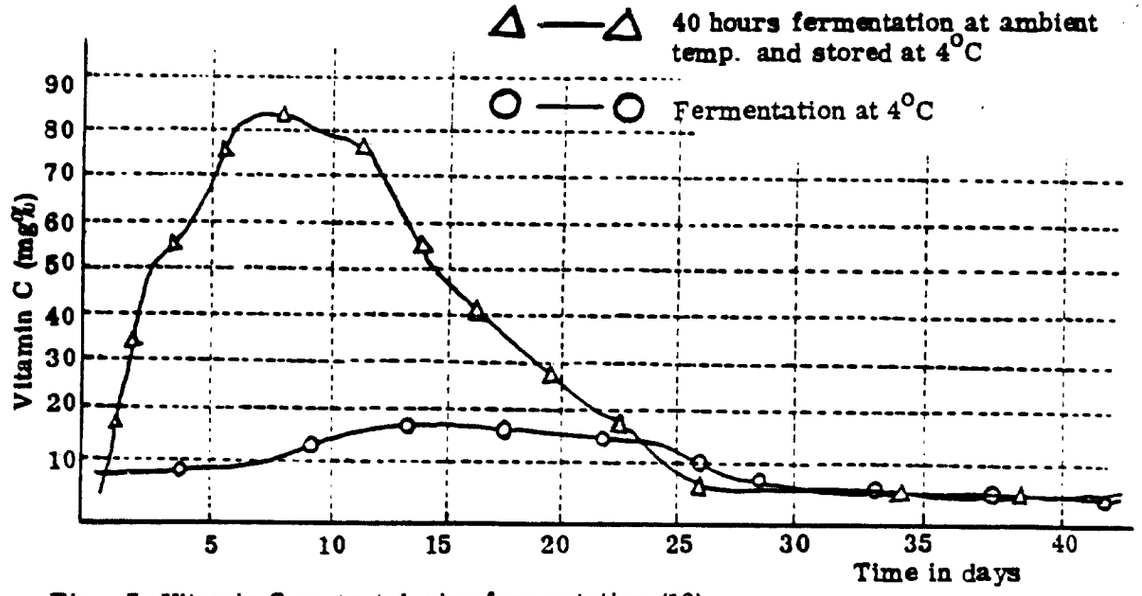

Fig. 5 Vitamin C content during fermentation (12)

Vitamin C contents of kimchi fermented at $4^{\circ}C$ and $20^{\circ}C$, respectively, are shown in Fig. 5 (12). As can be seen, the Vitamin C content increases when the aging process progresses at the higher temperature, but changes little when fermented at the lower temperature.

As for enzymatic changes occurring in the course of kimchi fermentation, the activity of amylase and protease increases as the aging progresses, but decreases when excessive acidification sets in (13). On the other hand, the activity of polyglacturonase is low in fresh kimchi, but continues to increase as kimchi becomes more and more pulpy and rancid through the process of excessive acidification. It has been learned that polygalacturonase is the principal enzyme involved in the deterioration of kimchi quality, and that this enzyme is produced by aerobic film-forming microbes (14).

As an experiment designed to identify factors expediting kimchi fermentation, the influence of cucumber extracts over L. plantarum and Strep, faecalis was observed. This experiment showed that alcohol-soluble substances in the extracts have the effect of facilitating the growth of L. plantarum (16). On the other hand, extracts from garlic and ginger expedited the growth of Lactobacilli isolated from kimchi (15). In particular, cayenne pepper had a marked effect of expediting the aging of kimchi (16). In other words, extracts from garlic, ginger and red pepper speeded the multiplication of L. plantarum and L. fermenti. Except for L. fermenti, all of them also speeded up the production of acids (17).

The above findings indicate that lactic acid fermentation is expedited, rather than impeded, by seasoning materials contained in kimchi. However, no research has been done on the relationships between the amount of seasoning materials used and changes in the properties of kimchi in the process of fermentation. However,

it has been learned that when the salt content exceeds 4% fermentation is retarded (18).

Main organic acids produced by kimchi fermentation are such nonvolatile acids as lactic acid and succinic acid. These two kinds of acid are produced in greater amounts when kimchi is fermented for a long period of time at low temperatures (6-7°C), than when it is fermented for a short period of time at high temperatures (22-23°C). On the other hand, oxalic, malic, tartaric, fumalic, malonic, maleic and glycolic acids are produced in smaller quantities at low temperatures. It is surmised, therefore, that lactic acid and succinic acid are the principal substances producing the kimchi taste (19).

Volatile acids contained in aged kimchi are formic acid, and acetic acid. CO_2 generated in the process of fermentation gives kimchi a tart taste. More acetic acid and CO_2 are contained in kimchi with low salt content (1.02% NaCl) than in kimchi with high salt content (3.16% NaCl), and also in kimchi fermented at low temperatures (4-5°C) than in kimchi fermented at high temperatures (20-25°C) (20). These findings mean that the sourness of kimchi is attributable chiefly to the presence of such organic acids as lactic acid, succinic acid, acetic acid and carbonic acid.

(3) How to Extend Storage Life of Kimchi

Various experiments have been carried out with the aim of developing suitable methods for extending the storage life of kimchi. But no dependable methods have been found for storing kimchi for a long period of time with its proper taste and flavor well preserved. Further research on this subject is urgently needed in order to develop a kimchi industry on a commercial basis.

Reseraches conducted so far have chiefly reflected attempts to apply ordinary

preservation methods based on heating or chemical additives, although some experiments have also been done as to irradiation with radioactive materials, and frozen or chilled storage.

As for the use of chemicals to preserve kimchi, the addition of brilliant green (1:100,000) or malachite green (1:100,000) has been found to retard the aging of kimchi, but to be unable to prevent excessive acidification. It has been established that sodium benzoate (4:10,000) is effective in preventing film formation by bacteria (13). Lowering pH to 1-2 has been found to destroy enzymes and suppress the growth of microbes, thereby producing an effect of preventing excessive acidification (13). As matters stand now, however, this process is too complex to be economically feasible.

As for chemical preservatives, sorbic acid (0.1%), paraoxybutyl benzoate (0.01%) and sodium dehydroacetate (0.01%) have been found to prolong the period of time during which kimchi remains palatable (21). It has been reported also that excessive acidification of kimchi can be prevented by readjusting its pH and then adding mustard oil to it (22), or by taking the following procedure: (a) Chinese cabbages are first soaked in a mixed solution of salt and calcium cholride; (b) the cabbages are then washed with chlorine water; (c) kalium sorbate is then added to the kimchi: and (d) the kimchi is pasteurized (23).

As for heat treatment of kimchi for its preservation, most experiments have been concerned with its canning. When kimchi is canned without any pre-treatment applied, the canned kimchi is usually subjected to high temperatures for a considerable length of time for sterilization. As the result, kimchi gets half-cooked, thereby losing its fresh taste and thus its marketability as well. Therefore, attempts have been made to apply various forms of pre-treatment to kimchi so that the canned

kimchi can be sterilized at relatively low temperatures in a short span of time in order to achieve an extended shelf-life. To be more specific, 0.1% benzoic acid is added to kimchi as chemical preservative and the salt content of kimchi is increased to 3% or more. In such a case, full sterilization can be achieved by subjecting the canned kimchi to a temperature of 75°C for 35 minutes. It has also been discovered that at a given level of pH, the retorting time and temperature are in inverse proportion to the salt content (3). It should be noted, however, that although a considerably long shelf-life can be achieved when a preservative is added to kimchi and the canned kimchi is then pasteurized for a short span of time at low temperatures (21), the enzymes in the kimchi are not thoroughly destroyed in such a case and the phenomena of texture deterioration and decomposition may continue. Pectic and dextrose-decomposing agents in kimchi can be suppressed by retorting it for 15 to 20 minutes at 80°C. But it has been found that preservatives that arrest the growth of microbes have no effect on those enzymes (24)

It has been reported that through an experiment to determine the heat resistance of L. plantarum, a heat-resistant microbe involved in kimchi fermentation, the D value has been found to be 3. It has also been learned that the pasteurizing time needed to achieve full pasteurization of kimchi at 85°C is 25.2 minutes(25). Such a temperature is capable of making even relatively heat-resistant enzymes inactive. But the temperature damages the freshness of kimchi by overheating it, and is, therefore, not suitable for pasteurizing canned kimchi. Accordingly, various preservatives have been used in attempts to produce palatable canned kimchi. On the other hand, a purely physical method has also been developed. This is an intermittent pasteurizing method designed to increase its sterilizing effect (26).

Research has also been conducted on various other ways of manufacturing canned kimchi, including a method using nicin as additive (27).

Experiments have also been made with the irradiation of kimchi with gamma rays from Co^{60} with a view to extend the palatable period of kimchi. The results have been that although the taste, flavor and texture of kimchi are not affected by irradiation, its color changes, presumably because carotene contained in red pepper is destroyed (28). Irradiation with X rays is found to extend the palatable period of kimchi by three to four days, and yet not to affect the color, flavor and taste of kimchi, so long as the irradiation does not exceed 50,000 r (29).

When polycello (1.5cm thick) is used, instead of tin cans, to pack kimchi, pasteurizing for 20 minutes at 65°C is found to be sufficient to give the kimchi a shelf-life of one month, with little damage done to its freshness (30).

When placed under refrigeration (-2°C to +2°C), kimchi can be stored for two to three months without much deterioration in its quality, even if preservatives or canning methods are not applied (15. 30.). Frozen storage of kimchi (at -30°C) has also been tried, but it has been discovered that although the taste of kimchi is not seriously affected by freezing, its texture tends to become tougher (15). Thus, it has been established that chilled storage is superior to frozen storage, as far as kimchi is concerned.

III. CONCLUSION

Dating from ancient days kimchi is a side dish indispensable to the Korean diet. This traditional Korean foodstuff has now come to be produced and distributed on a commercial basis in Japan and the United States.

Kimchi is made by utilizing natural lactic acid fermentation. At the beginning

of the fermentation process, the Leuconstoc and the Streptococcus groups are the principal microbes involved. The main agents in the aging phase of kimchi are L. plantarum and L. brevis, which produce enzymes that age kimchi. And various other microbes and enzymes have been found to be present in the kimchi fermentation. Thus, it can be said, kimchi is a product of compound fermentation.

Properly aged kimchi contains the highest levels of vitamins B_1, B_2 C and niacin. The pH of kimchi in such a state stands at or around 4.3. It has been discovered also that vitamin B_{12} is synthesized in the process of fermentation.

The sourness and tartness of kimchi are attributable chiefly to the presence of lactic acid and succinic acid. Kimchi fermentation, however, produces many other types of organic acids.

It is difficult to preserve the fresh quality of kimchi for more than a week under room temperature. Kimchi becomes stale, principally because of texture deterioration and decomposition caused by film-forming microbes, as well as of excessive acidification. With the aim of extending the storage life of kimchi, experiments have been carried out with the application of such preservatives as sodium benzoate, sorbic acid, para-oxybutyl benzoate and dehydroacetic acid, or such antibiotics as nicin. In light of the facts that kimchi is the principal side dish for daily meals of the Korean people and that per capita consumption of kimchi averages 200 to 300 grams daily, we must be extremely careful about the use of preservatives or antibiotics in order to keep kimchi in a palatable state longer.

As for heat treatment of kimchi, various research work has been done on the canning of kimchi. In fact, canned kimchi has been commercially produced for some time for use as an emergency food, as well as for daily consumption. But the product has failed to gain much popularity, partly because of its lack of fresh

taste and flavor and partly because of high cost of packing materials.

Researches conducted thus far indicate that as matters stand now, the most desirable method for preserving the fresh quality of kimchi for an extended period of time is through the application of refrigeration. In Korea's growing consumer markets, food distribution under refrigeration is now gradually gaining a foothold. It is believed, therefore, that now is the time to carry out systematic research efforts to develop commercially feasible systems for chilled storage of and distribution of kimchi under refrigeration. In addition, studies should be made to select and apply superior microbes that will ferment kimchi having it entirely improved taste and higher nutritive content, instead of leaving to a process of natural fermentation.

It is also highly desirable to develop techniques for preserving kimchi for an extended period of time even under room temperatures.

SUMMARY

Kimchi, a traditional Korean food item prepared from Chinese cabbages and/or radishes subjected to a process of natural lactic acid fermentation, is a major source of vitamin supply in the Korean diet. Many kinds of microorganism are involved in kimchi fermentation, the principal ones being L. plantarum and L. brevis. The vitamin content of kimchi rises to its peak during the phase of fermentation in which kimchi tastes best. The main types of organic acids contained in kimchi are lactic, succinic and acetic acids. For the purpose of preserving the fresh quality of kimchi for an extended period of time, experiments have been carried out with the application of various chemical preservatives,

antibiotics and physical-chemical techniques. The results of such researches show that the most desirable method is the cold chain type storage and distribution of kimchi chilled under refrigeration, because it is the best way of maintaining the unique taste and flavor of kimchi, and also because it involves the least risk to human health.

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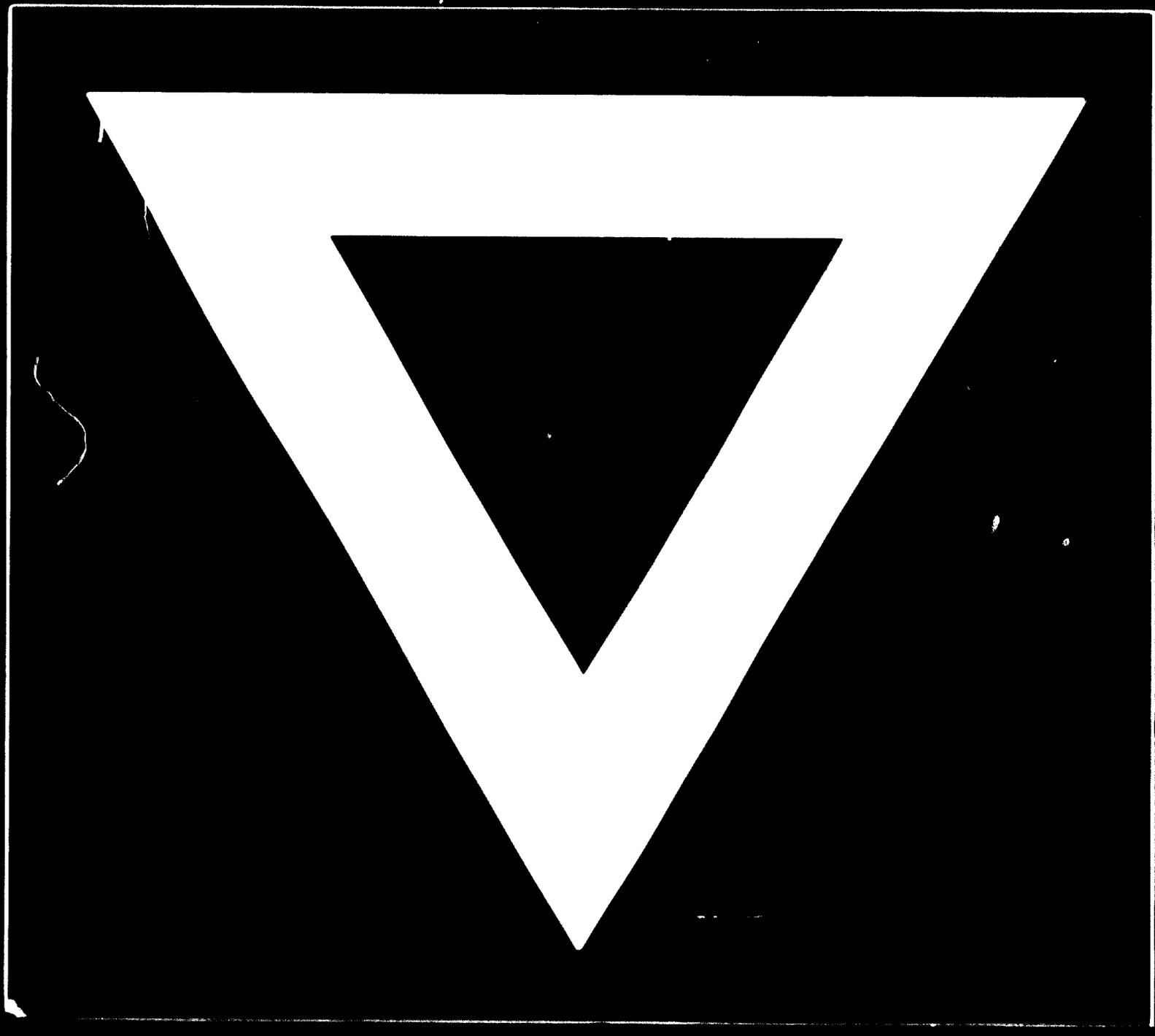

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