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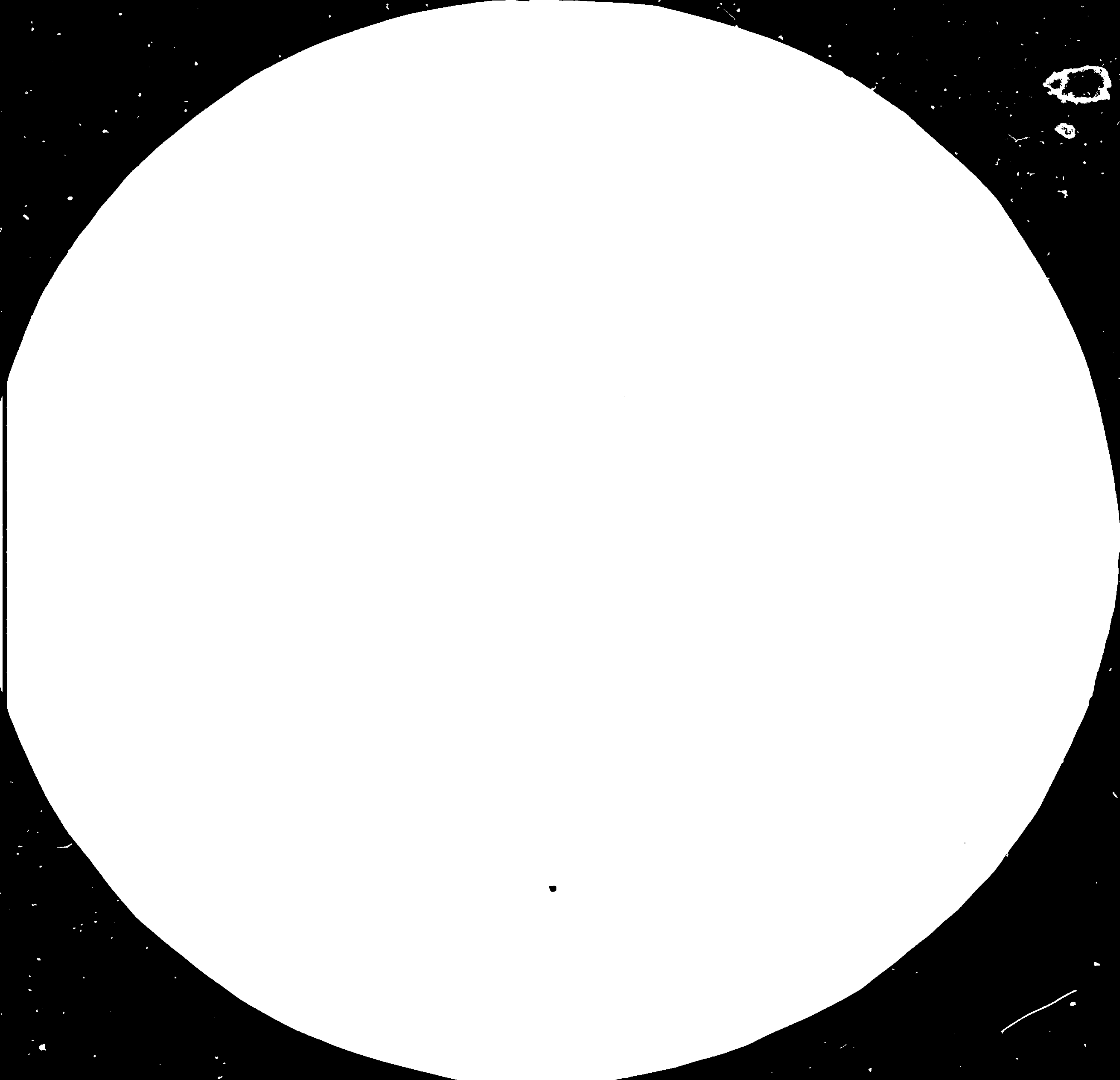

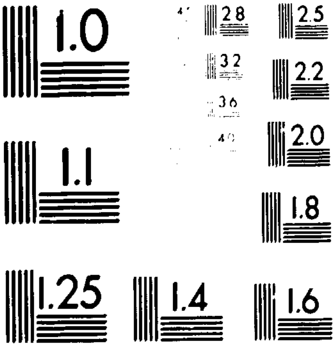

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PRESENT STATUS AND DEVELOPMENT OF LACTIC ACID FERMENTED FOODS IN THE REPUBLIC OF KOREA*

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I. BACKGROUND

The lactic acid fermented foods in the Republic of Korea can be classified into three groups; (1) the traditional non-milk fermented foods, such as kimchi and sikhae, (2) fermented milk products, mainly yogurt type, (3) pharmaceutical or unconventional food products.

The lactic acid fermentation of different substrates will be explained by taking Kimchi as the typical lactic acid fermentation using vegetables, Sikhae using mixture of fish and cereals and yogurt using milk.
Recent developments in the study of lactic acid fermentation on vegetable milk products will be introduced.

The production of β-galactosidase and other enzymes from lactic acid forming microorganisms will also be an important area attracting industrial interest.

II. INTRODUCTION

Lactic acid fermentation is an important process in many traditional fermented food making. Historically, it has been emphasized in fermented milk products, such as yogurt and cheese. But even in non-milk eating societies like the Republic of Korea and other Asian countries, it is realized that lactic acid fermentation has played a very important role in preparation of fermented cereals and vegetable products. The Embden-Meyerhoff pathway suggest that many microbial processes can convert starch and sugars into lactate.[1] Cereals, soybeans and vegetables are excellent substrate providing sugars and ultimately glucose to microbial process. In fact, the traditional fermented food made from soybeans, cereals, vegetables and fishes invariably contain lactic acid bacteria. The role and importance of these bacteria vary with the type of fermented food.

In the Republic of Korea, the lactic acid fermented foods can be classified into three groups: (1) traditional non-milk fermented foods, such as kimchi, fermented soybean paste and sikhae, (2) fermented milk products mainly liquid yourt type, and

(3) pharmaceutical or unconventional food products. The lactic acid fermentation on different substrates will be explained by taking Kimchi as the typical lactic acid fermentation using vegetables, Sikhae using mixture of fish and cereals, and liquid yogurt using milk. In addition, recent developments in the study of lactic acid fermentation on vegetable products will be introduced.

Kimchi

Kimchi is the name given to a group of fermented vegetable foods of long tradition in the Republic of Korea. It has been a main sidedish served along with cooked rice and other dishes. The kimchi making is the original method of preserving the fresh and crispy texture of vegetables during winter when fresh vegetables are not generally available. Kimchi has an unique sour, somewhat sweet and carbonated taste and usually served cold. In this respect Kimchi differes from sauerkraut which is only acidic in taste and served warm.

The kinds of Kimchi may count up to more than 65 depending on the use of raw materials and processing methods. Raw materials of Kimchi are mainly divided into 3 groups. Cabbages and radish are the major materials and minor ingredients include garlic, red pepper, green onion, ginger and salt, and lastly fermented fishery products and other seasoning agents are often used as the optional ingredients.

Figure 1 shows the procedure for a typical Kimchi preparation.(2) A recipe for the simplest Kimchi may include Korean cabbage 100 g, garlic 2 g, green onion 2 g, red pepper powder 2 g, ginger 0.5 g with optimum salt content of 3.0%. Whole cabbages(or cutted) are salted with 15% brine for 3-7 hours, which are then washed with fresh water and drained. Other minor ingredients, chopped and combined, are mixed to the treated cabbages and placed in a container tightly sealed. The length of time for completion of the fermentation depends on the salt content and temperature.

The microorganisms involved in the fermention of Kimchi have been studied widely. More than 58 different species of microorganisms were identified from Kimchi.[3] Figure 2 shows the changes in the important microflora of Kimchi during fermentation.[4] The number of Leuconostoc mesenteroides increased rapidly during the initial stage and decreased after 10 days of the fermentation. The numbers of lactobacillus and yeasts started to increase after 10 days of the fermentation, and this accompanied with the over ripening and souring of Kimchi. It indicates that Leuconostoc mesenteroides is the important microorganisms responsible for Kimchi fermentation, whereas Lactobacillus plantarum, which is considered to be responsible for Sauerkraut making, deteriorates the quality of Kimchi.

Both CO_2 and organic acids, which are produced during the fermentation, play an important role for Kimchi taste. Figure 3 shows that the concentration of CO_2 increases rapidly by 15-30 hrs of fermentation at 20-22°C.
Lactic acid and succinic acid are the major organic acids in Kimchi.(Fig. 4)
Figure 5 shows the changes in reducing sugar, total acid and pH during the fermentation of Kimchi. The optinum pH and acidity for the best taste are 4.2 and 0.6% (as lactic acid), respectively. It shows that the best taste is attained after 3 days of fermentation at 20°C and 3% NaCl.
It is also worthy to note that there are considerable increase in B vitamines during fermentation. That is the contents of B_1, B_2, B_{12} and niacin may reach as high as twice of initial contents at the optimal maturation of Kimchi and then decrease as the taste of Kimchi deteriorate due to the over fermentation.[7]
According to a recent nutrition survey, an adult consumes 50-100 g/day of Kimchi in summer and 150-200 g/day in winter.[8]
Table 1 snows chemical compositions of some fermented vegetable products and it clearly indicates that Kimchi serves as an important vitamin source to the people during winter in particular.

However, the changes in life style and rapid urbanization are making the preparation of Kimchi in individual households no longer convenience. In addition, there are also growing export markets, and thus the industrial production of Kimchi is considered inevitable. The major obstacle for the mass production, however, is the inherent short self-life of Kimchi after completion of the fermentation. Although a number of attempts have been made to preserve Kimchi in the past, there is not a single procedure yet to ensure satisfactory product. So far, preservation of Kimchi under refrigeration of around 5°C is known to be a best way, while canning of Kimchi, though good for preservation, usually brings softening of texture and some off flavors.

Sikhae

The long coastal line of the peninsular provides a variety of marine products for human consumption.

Numerous kinds of traditional fermented fishery products are found in the Republic of Korea; both high salt and low salt fermented products. Sikhae is a type of low salt fermented fishery products, in which lactic acid fermentation plays an important role.[9] Figure 6 shows the schematic diagram of Sikhae processing.

Flat fishes are eviscerated, washed and cutted, and then salted overnight by adding 6% NaCl. Salted and sliced flat fishes are mixed with cooked millet, red pepper powder and garlic and fermented at 20°C for 2-3 weeks.

The pH of Sikhae decreases rapidly down to 4.5 for the first 2-3 days of fermentation, as shown in Figure 7. The rapid decrease in pH is caused by the production of organic acid from the added cereals by acid forming bacteria.

Figure 8 shows that the numbers of acid forming bacteria and yeast increase rapidly for two weeks of fermentation, while the number of lipolytic bacteria decrease rapidly at the early stage of fermentation.

Figure 9 shows that among organic acids lactic acid is the predominant acid formed during the fermentation. It prevents the putrifaction of fish and yields hygenically safe product.

Same as in Kimchi, the self-life of Sikhae is limitted by the excess production of acids. It can be stored for up to 1 month in a refrigerator at 5°C.

Yogurt

The history of the use of yogurt in the Republic of Korea is not longer than 15 years. It has been introduced from Japan as liquid type drink in 1971 and become a popular fermented milk drink.

The annual production of yogurt in the country was 116,200 M/T in 1983 as shown in Table 2, and all was produced by several large scale dairy factories.[10] The microorganisms used for yogurt production are found to be L. bulgaricus, L. helveticus and L. casei, and vary with the producer.[11]

Figure 10 shows the schematic diagram of liquid yogurt processing in Korea.

The chemical composition and the number of viable cells vary with the producer, and are summarized in Table 3. The Korea Food Regulation requires that fermented milk should contain minimun 3% of non-fat milk solid and more than 1×10^7 cells of lactic acid bacteria.

A few attemps have been made to introduce gel-type yogurt into Korea, but they were not successful until today.

III. RECENT STUDIES ON LACTIC ACID FERMENTATION

As people of the Republic of Korea consume large quantities of spices, such as red pepper, garlic, ginger etc., the effect of these spices on the growth of lactic bacteria is important to know for the fermentation process itself as well as to evaluate their beneficial action in the intestine. Park et al[12] studied the effect of spices on the growth of Lactobacilcus casei. Spices were added aseptically into sterile TGY broth and L. casei in MSR broth culture were inoculated. The growth of L. casei on TGY broth was inhibited by 1% garlic, 0.1% ginger and 4% red pepper, but did not influenced by 1% red pepper and was enhanced by 1% welsh onion.[13] The acid production was influenced similarly to the growth of bacteria by the addition of different spices.

Figure 11 shows the effect of garlic and red pepper on the growth and pH change of L. casei. The inhibitory effects of garlic and ginger were disappeared by heating the spices at 90°C for 10 min.

Lee and Kim[14] studied on the effect of soybean meal degradation products on the growth of lactic acid bacteria. Soybean protein extracts were heated at 121°C for 20 min and hydrolyzed with crude pancreatic enzyme preparation at pH 8.4 for 15 min. The protein hydrolysate were added to MRS broth medium and the growth of lactic acid bacteria were compared to those added with peptone. They found that the amino acid supplementary effect of soybean protein hydrolizate was superior to that of peptone, as shown in Figure 12.

Although not yet successful in industrial practice, many attemps have bean made to develop lactic acid beverages from vegetable milk. Lee et al.[15] compared the growth of L. casei and the acid production in soymilk to those in the mixture of milk and soymilk. The growth of L. casei and their acid production were low in soymilk, but increased by the addition of milk, lactose or yeast extract. Similar results were obtained with L. bulgaricus, S. thermophilus, and the mixed culture of L. bulgaricus and S. thermophilus. As shown in Fig. 13, the acid production of L. bulgaricus increased by the addition of cheese whey to soymilk to the level of 10% skim milk substrate.[16] The optimum mixing ratio of whey to soymilk was 1:9. Kim and Kim, however, showed that L. acidophilus could grow much faster than L.bulgaricus on soybean milk, as shown in Fig. 14.[17] Lee[18] studied the production of lactic beverage from malt syrup. The optimum sugar concentration of malt syrup for the growth of L. lactis was 10 °Brix and the addition of yeast extract(0.5%) and sodium citrate(0.08%) improved the growth. When skim milk was added to malt syrup in equal amount

(50:50), the growth and acid production were improved greatly. The mixed culture of L. lactis and S. diacetilactis gave the most acceptable sensory quality. The fermented malt syrup was competable to the commercial fermented fruit juices in the Republic of Korea.

Other cereal substrates including coix agretis and lupinseeds are tested for lactic beverage fermentation. Recently in the authors laboratory, the lactic acid fermentation of lupinseed protein concentrate is under investigation. This experiment has two purposes ; the production of lactic acid and at the same time break down of polysaccharide fraction in the concentrate. Several lactic acid bacteria including L. fermenti and Leuconstoc mesenteroidus are tested for this experiment.

Kim et al.[18] studied on the production of extracellular β-galactosidase by L. sporogenes. The fermentation medium giving maximum enzyme yield was found to consist 1% lactose, 1.5% peptone, 0.2% ammonium sulfate, 0.8% ammonium phosphate dibasic, 0.05% potasium chloride and 0.001% ferric chloride. In the fermentor culture, the maximum extracellular enzyme activity was 45 u/ml. Recently, application of galactosidase in milk to reduce the lactose concentration has been introduced in the Republic of Korea. The product is sold in the market by the name of "Lacto milk" and is gaining good appeal with the elderly people, who have lactose intolerance symptoms.

IV. FUTURE RESEARCH NEEDS

Although lactic acid fermentation plays an important role in many traditional foods in the Republic of Korea, little attention has been paid to elucidate the mechanism and function of the fermentation in food system. Many traditional cereal foods including fermented soybean products are made by natural mixed fermentation and the lactic acid production has significant function in forming the characteristic flavor and enhancing the keeping qualities of the product.

The food functionality of lactic acid fermantation should be studied more extensibly especially in the traditional food systems. When the specific functions of lactic acid fermention are understood and well defined, the emerging biotechnology and genetic engineering concepts can be applied to improve the functionalities, and to develop new food products. Establishment of an international cooperative research network is necessary in order to exchange the methodologies and research finidings in similar traditional food categories.

Table 1. Chemical composition of fermented vegetables in 100g edible portion.

	Baechu-Kimchi	Kkakdugi	Dongchimi
Calories (Cal.)	19	31	9
Water (%)	88.4	87.0	93.6
Protein (g)	2.0	2.7	0.7
Fat (g)	0.6	0.8	0.2
Carbohydrate (g)	1.3	3.2	1.1
Ash (g)	0.5	0.7	0.2
Ca (mg)	28	5	1
Thiamine (mg)	0.03	0.03	0.01
Riboflavin (mg)	0.06	0.06	0.03
Niacin (mg)	2.1	5.3	1.0
Ascorbic acid (mg)	12	10	7
B-carotene (ug)	295	568	0

Table 2. Annual production of milk and fermented milk in the Republic of Korea (1000 M/T)

Year	Raw Milk	City Milk	Fermented Milk
1977	263.5	121.0	47.8
1978	324.3	145.9	80.0
1979	384.7	170.9	114.5
1980	457.6	188.4	98.1
1981	517.7	279.9	82.7
1982	580.1	350.3	104.4
1983	716.4	448.2	116.2

Table 3. Ranges of chemical composition and the number of viable cells found in liquid yogurt products sold in the Republic of Korea.

Property	Range
No. of lactic acid bacteria($\times 10^7$/ml)	4.5 - 41.8
Titratable acidity	0.46 - 0.57
Total solids(%)	16.7 - 20.7
Ash (%)	0.20 - 0.28
Protein (%)	0.53 - 1.23
Reducing sugar (%)	11.7 - 15.5

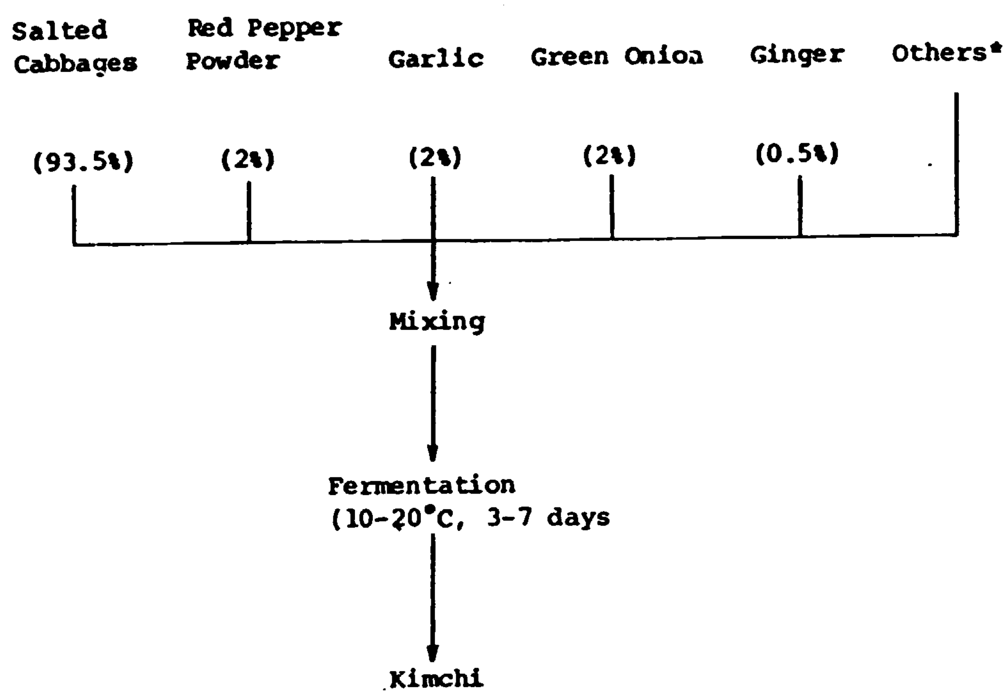

Figure 1. Flow sheet of Kimchi making process

* Sugar
Monosodium glutamate
Fermented fishery products

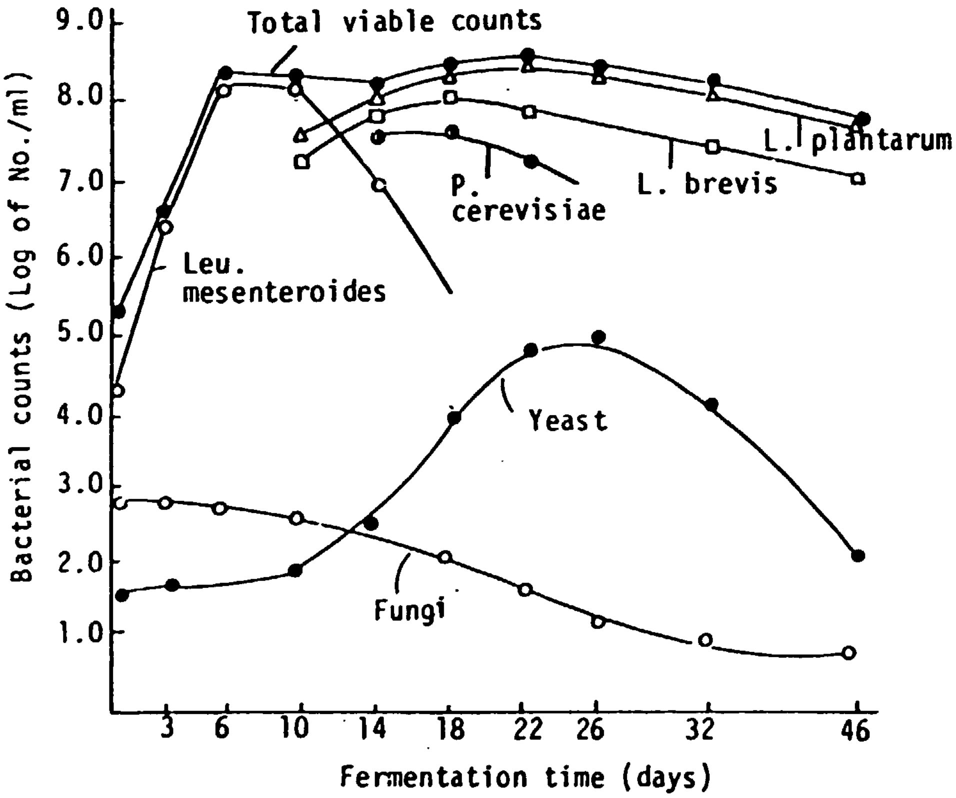

Figure 2. Changes in microflora during Kimchi fermentation at 14°C (3.5% NaCl)

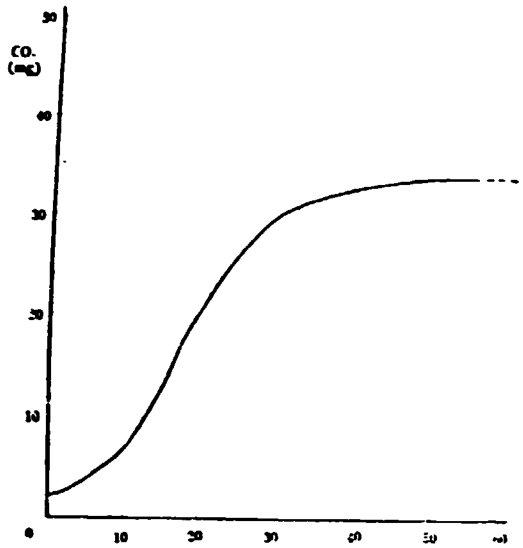

Fig. 3. Changes of CO_2 content during fermentation.

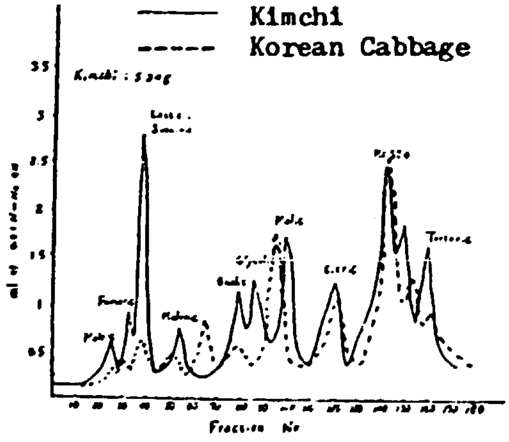

Fig. 4. Separation of acids from Kimchi fermented at 22°-$23^{\circ}C$ by silicic acid column chromatography.

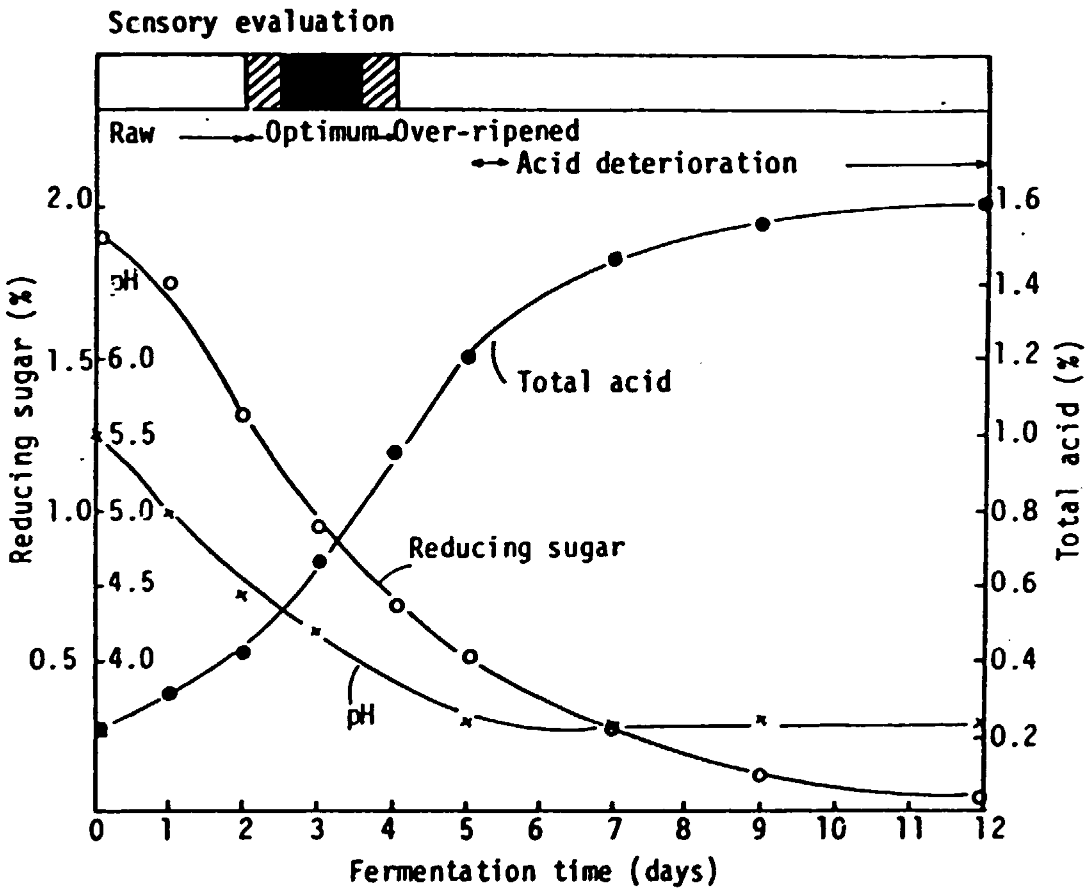

Figure 5. Changes in reducing sugar, total acid and pH during Kimchi fermentation at 20°C (3% NaCl)

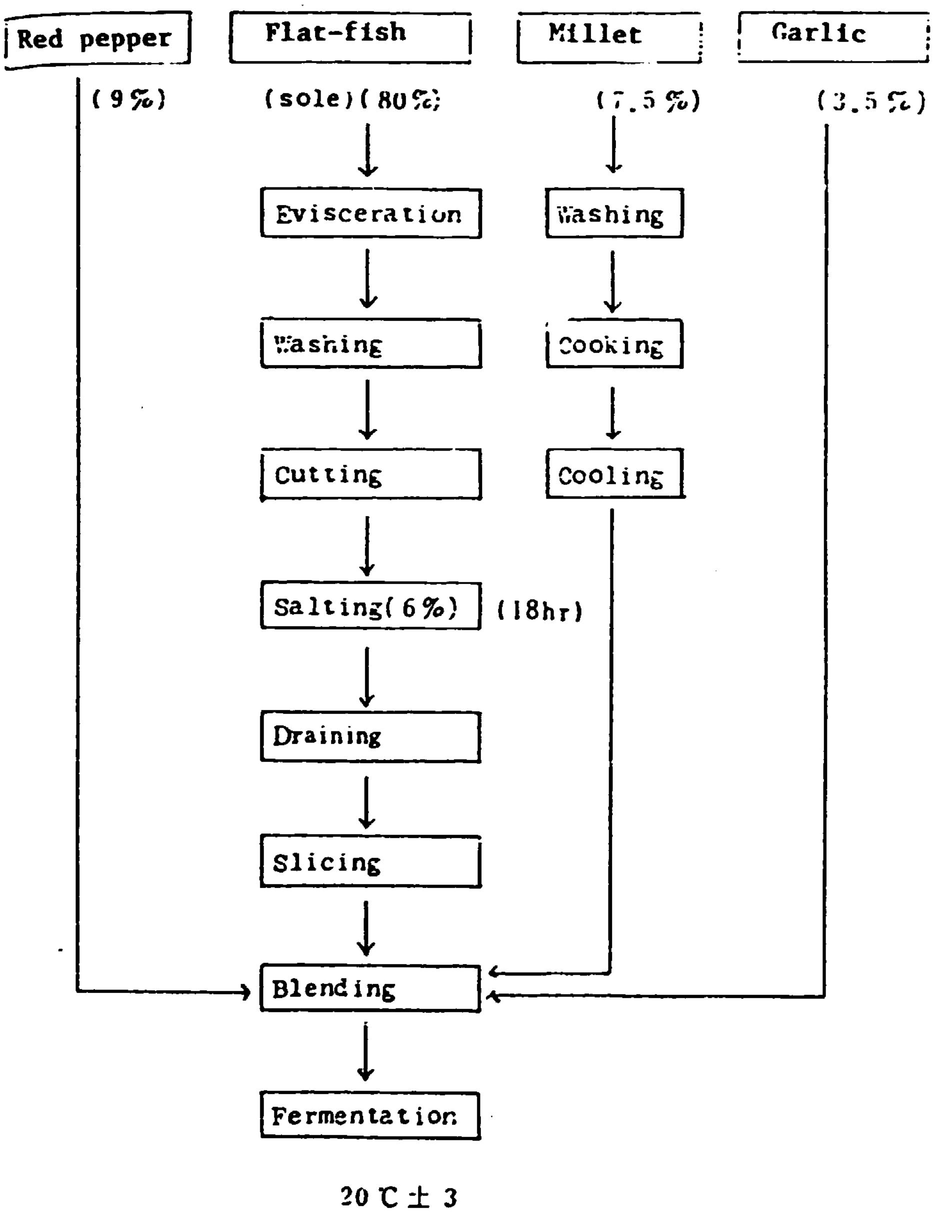

Fig. 6. Schematic diagram of Sik-hae processing

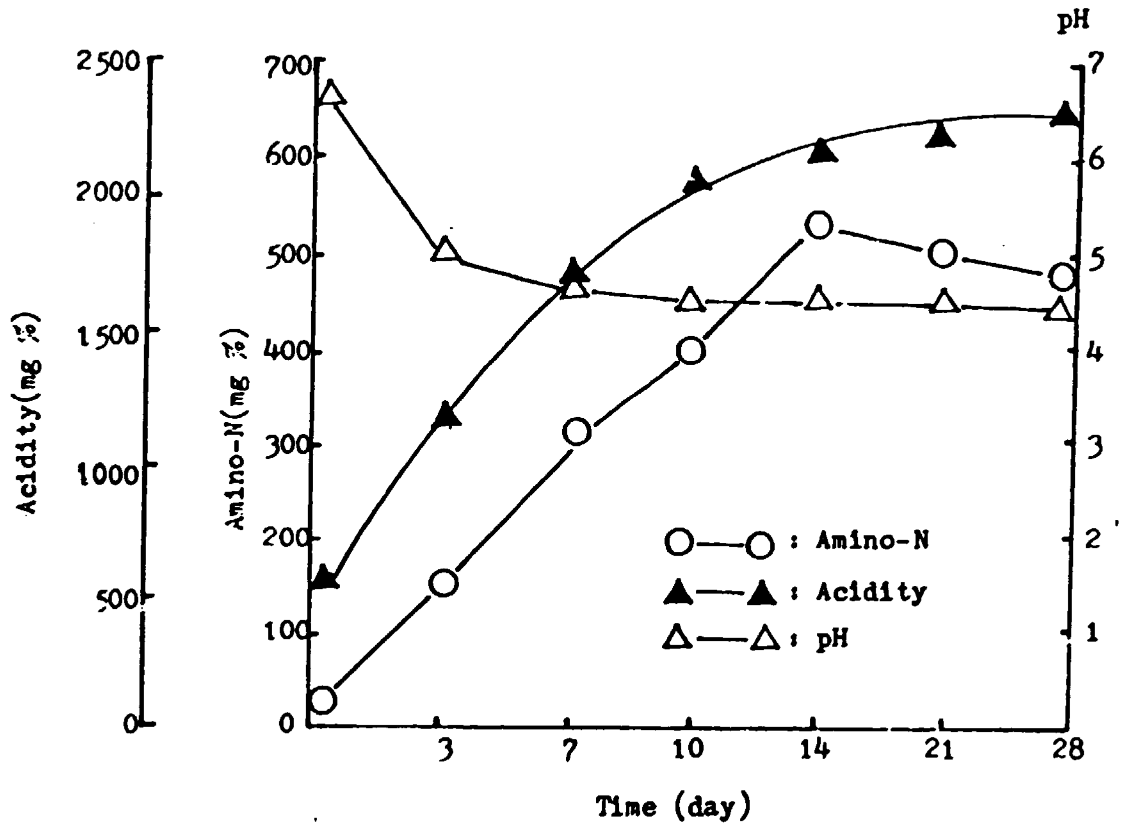

Fig. 7. Changes in acidity, pH and Amino-N during Sikhae fermentation.

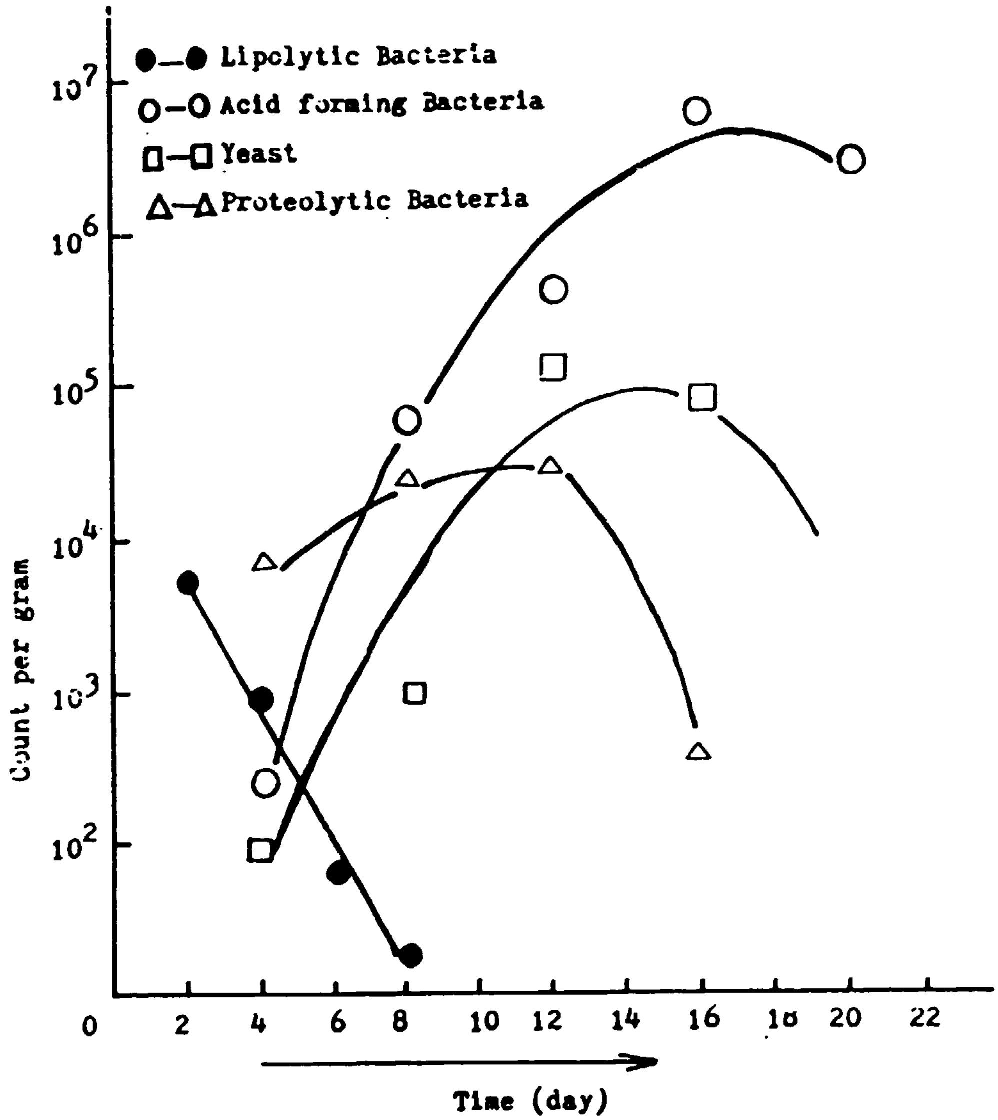

Fig. 8. Changes of Microflora during Sikhae Fermentation

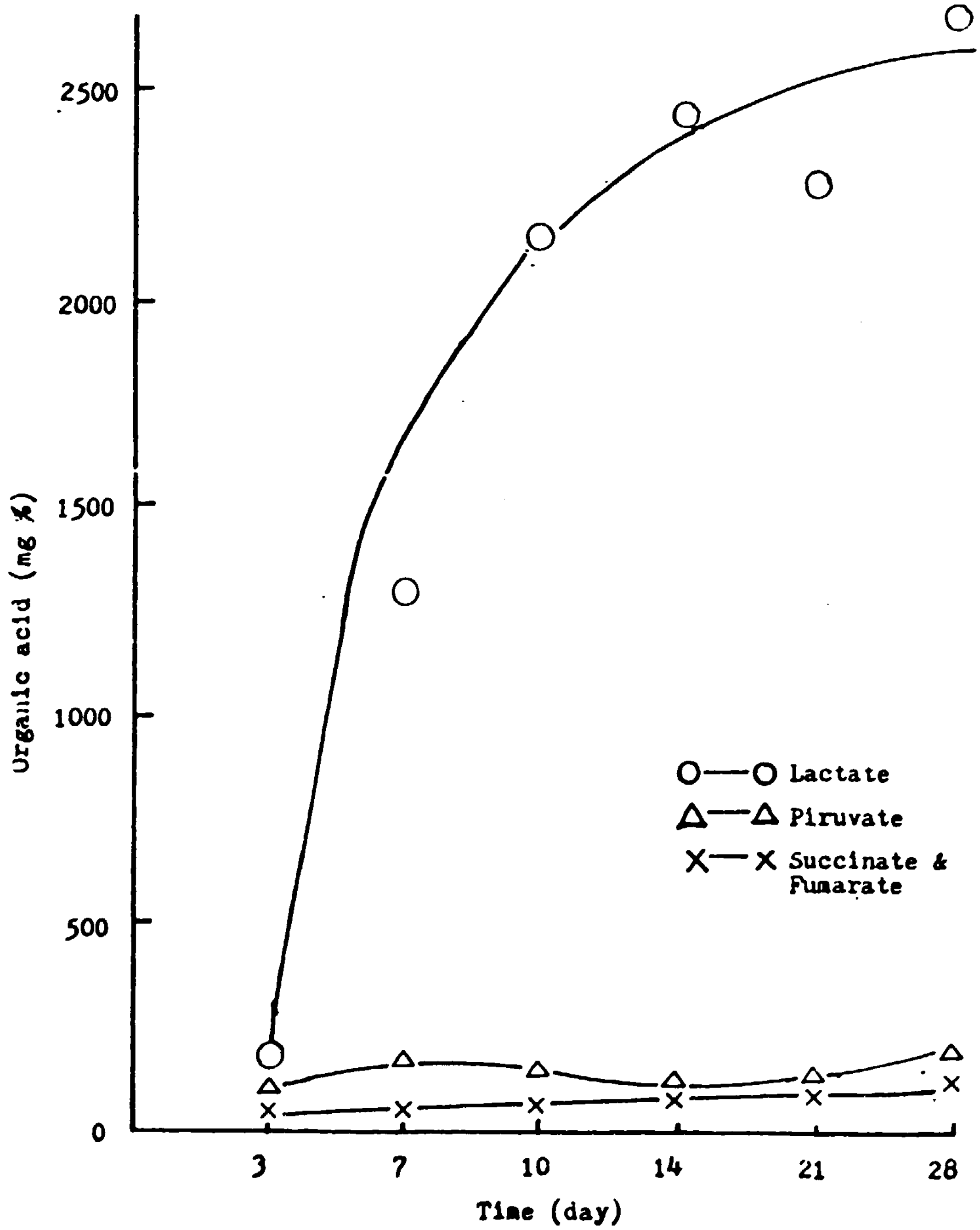

Fig. 9. Changes in the organic acids during Sik-hae fermentation

Raw Milk

↓

Filtration

↓

Homogenization

↓

Pasteurization

↓

Cooling

↓

Starter inoculation

↓

Flavoring, syrup addition

↓

Homogenization

↓

Cooling

↓

Dilutio

↓

Liquid yogurt

Fig. 10. Schematic diagram of liquid yogurt processing

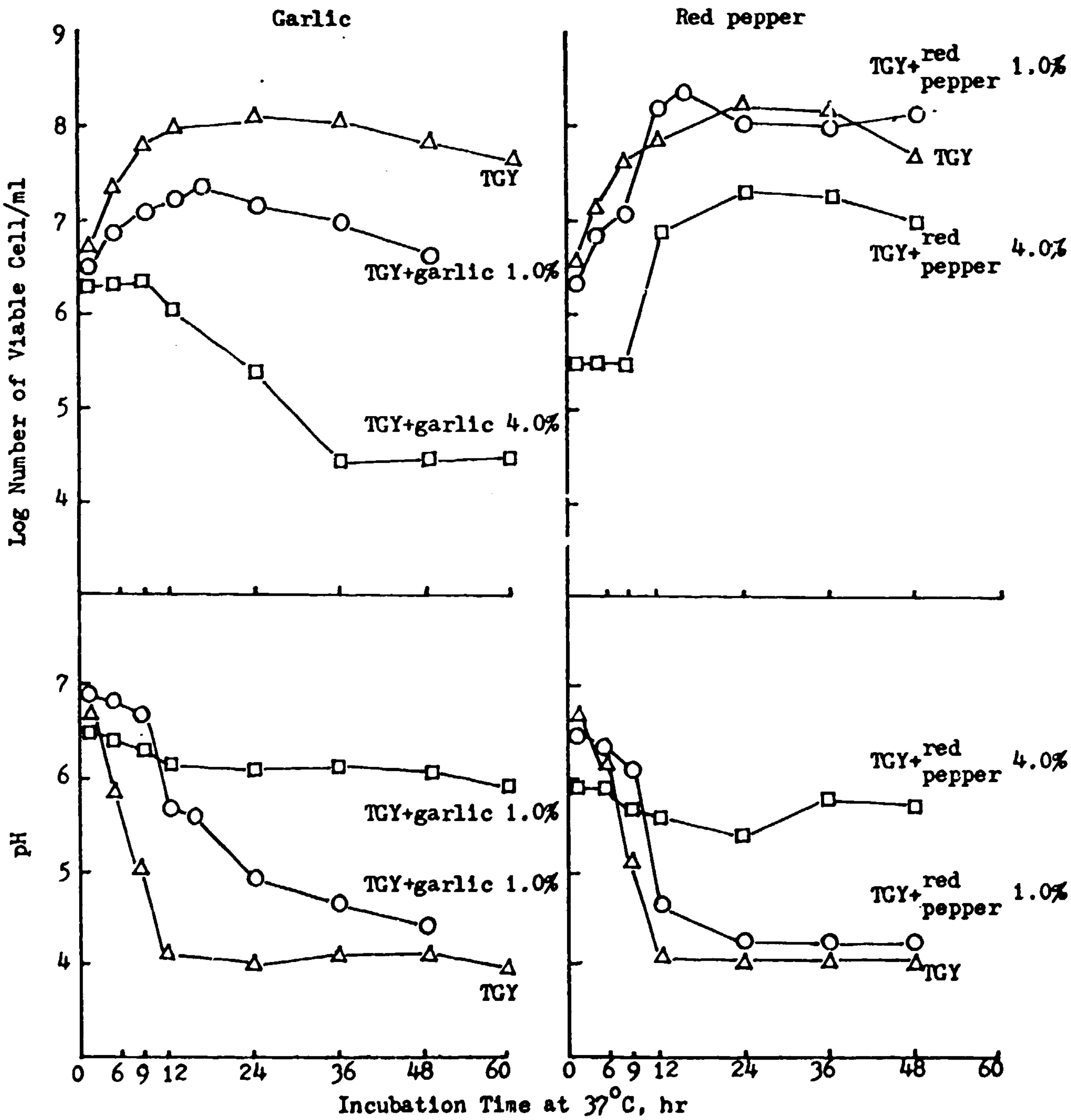

Fig. 11. Effects of garlic red pepper on the growth and pH changes of *L. casei* in TGY broth.

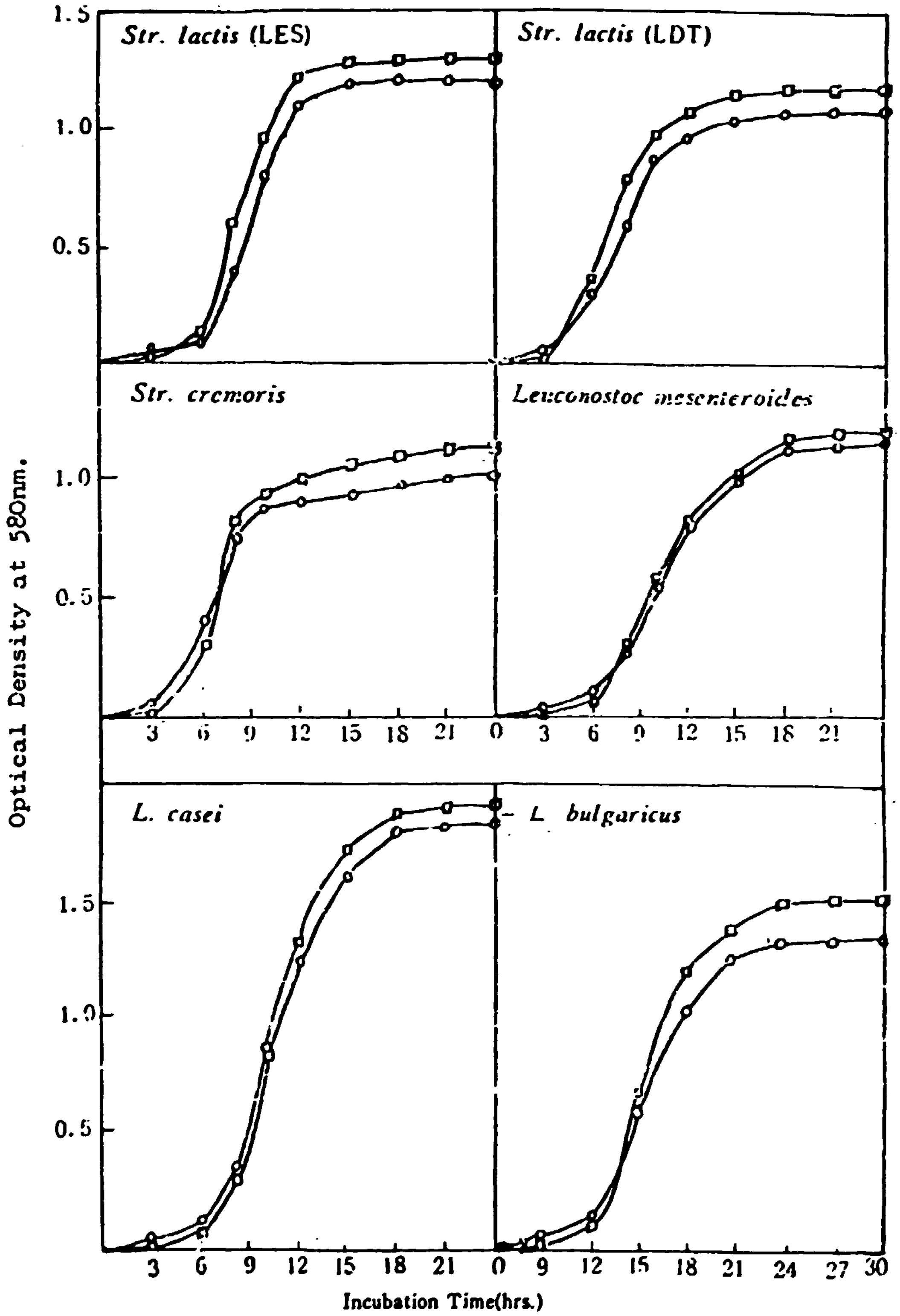

Fig. 12. Comparative growth responses of lactic acid bacteria in MRS medium made with Eiken peptone and soybean degradation product.

□-□ soybean degradation product O-O Eiken peptone

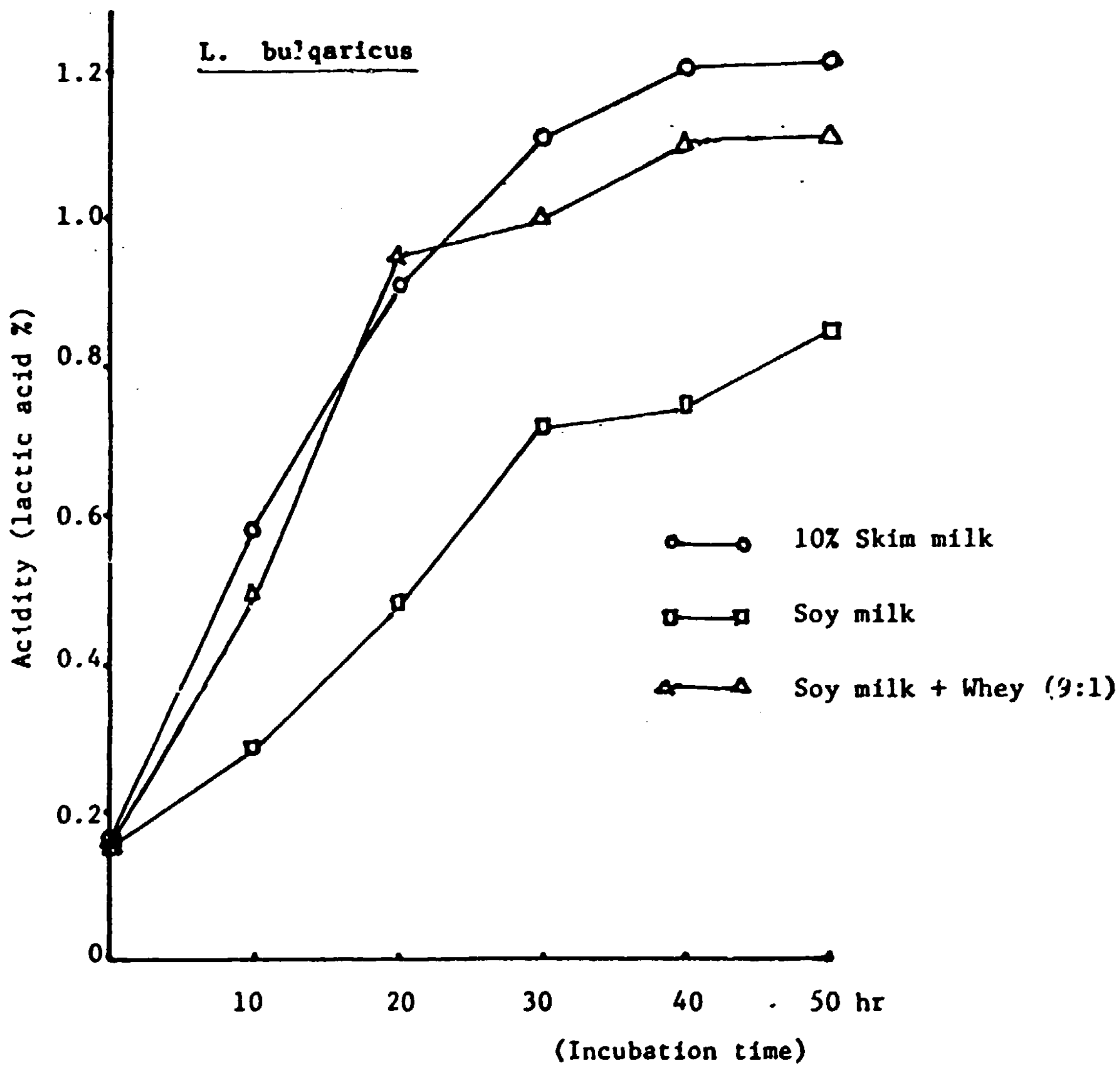

Fig. 13. Acid production by L. bulgaricus in skim milk, soy milk and soy milk + whey.

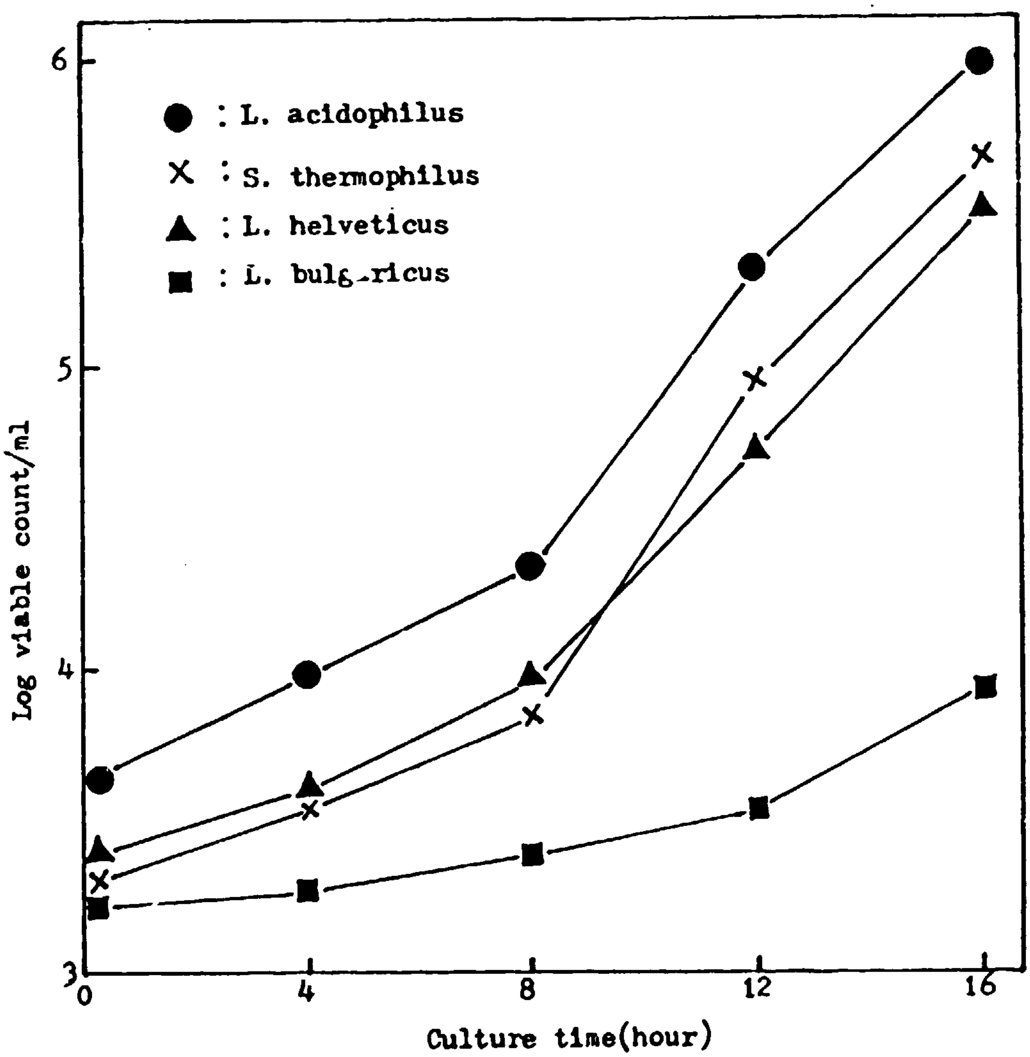

Fig. 14. Growth of S. thermophilus, L. acidophilus, L. bulgaricus and L. helveticus in Soy Milk.

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