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Fish Fermentation Technology

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The historical background of fish fermentation in Asia and other regions of the world is reviewed. The classification of fermented fish products in different regions is attempted with respect to the technology involved. The fermented fish products are largely divided into three groups; (1) high-salt, (2) low-salt, and (3) non-salt fermented. High-salt fermented products contain over 20% of salt and are represented by fish sauce, cured fish and fish paste. Low-salt fermented products contain 6-18% salt and are subdivided into lactic fermented products with added carbohydrate and acid pickling associated with low temperature. Non-salt fermented products are represented by the solid state bonito fermentation and some alkaline fermentation of flat fishes. The local names of the products in different regions are compared and classified accordingly. The microbial and biochemical changes during fish fermentation are considered in relation to the quality of the products, and their wholesomeness is reviewed.

Fish fermentation is an old technology used for the preservation of fresh water and marine animals, which are highly perishable and localized in production and seasonally fluctuating in catching (1). The technology appears to have evolved with the availability of salt and non-pastoral way of life. There is a strong correlation throughout the world between the use of fermented fish products and the use of cereals, especially rice, and vegetables (2). Although the use of fermented fish product is nowadays mainly confined to East and Southeast Asia, traces of this technology can be found throughout old human civilizations.

Liquamen and garum was an important condiment in the cuisine of the Romans who had adapted it from the Greeks. It was made on a commercial scale at several sites around the Mediterranean from a variety of small fish including red mullet, sprats, anchovies and mackerel (3, 4). The Italian anchovy paste is a vestige of this old technology. In Northern Europe, salted fish was an important commodity, and around the end of 12th century barrel-salted herrings became an important export item of many towns near the Baltic sea. The salted herrings were regarded as cheap food and even up to start of this century they were part of the daily menu in many places in Scandinavia. This has changed drastically recently, and traditional wet-salted herrings are now mostly being used as raw materials for less salty, semipreserved herring products which are sold as expensive delicacies (5).

On the other hand, the East and Southest Asian regions preserves this traditional technology and benefits the people with the simple and materials-saving method of food supply. Ishige (2) explains this as resulting from the dietary pattern of the people in this region. The main region for the consumption of fermented products coincides with the principal region of irrigated rice cultivation. Those parts of Asia where rice is the staple food are

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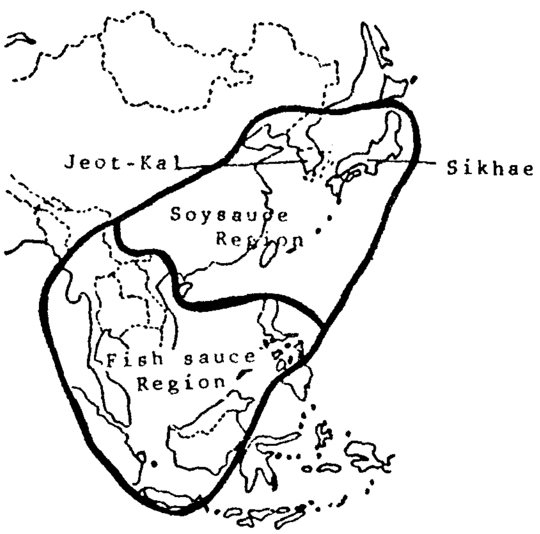

Fig. 1. Cultural area of fermented condiments in East Asia (2, 6).

characterized by a low consumption of meat and dairy products but a high consumption of fish and fish products. The consumption of large quantities of rice, which is bland in taste, necessitates the use of side dishes which are small in quantity and highly salty. Fermented fish products and soybean products are the most suitable items for this purpose. They have the advantage of being simple to preserved and have a long shelf-life. They do not require elaborate cooking for each meal, and provide meaty flavor, amino acids, vitamins, and other minor nutrients needed in the diet.

Although it is difficult to preclude that fish fermentation technology has been developed independently in different regions of the globe, the Mekong Basin is the most probably the place of origin of fermented fish products (2). In the original form fish was probably salted for preservation, and exuded liquid drained off and used as the condiment for rice meals, same as the ancient type of soysauce and soybean paste production. Later, soybean fermentation technology was developed in Northestern Asia, where soybean cultivation was possible, and fermented soybean products became the dominant condiment in this region. Fig. 1 divides the two cultural regions of soysauce and fish sauce in Asia (2, 41).

Classification of fermented fish products

- **Fish**
  - **High salt (Ca. >20)**
    - **Liquid separation-Fish sauce**
    - **Residue or no-separation - Cured fish**
    - **Comminution and partial-drying-Fish paste**
  - **Low salt (Ca. 6-18%)**
    - **Lactic acid fermentation**
    - **Acid pickling and low temperature**
  - **No salt**
    - **Dried bonito fermentation**
    - **Alkaline fermentation**

Fig. 2. Classification of fermented fish products.

Since the most original form of fermented fish products was probably salted fish and the exuded liquid was used as fish sauce, fermented fish products are basically salt-fermented products. Depending on the amount of salt added, the products are classified into high-salt (>20% salt of total weight), low-salt (6-18% salt) and no-salt products, as shown in Fig. 2.

When the salt concentration is higher than 20% of total weight, pathogenic and putrifactive microorganisms cannot grow and the product does not need other preservative means. The first criterion for the subdivision of this group is the degree of hydrolysis, which is influenced by fermentation time and temperature, added enzyme sources and the water content. The fully hydrolysed liquid is fish sauce. The name cured fish is confined here to represent the partially hydrolized fish products which retain the original shape of fish immersed in the exuded liquid, and this form as such is frequently used as side dish for rice meals (7, 8). Fish paste is characterized in that the salted fish is partially dried in order to restrict the degree of hydrolysis and comminuted to produce the homogeneous, solid condiment. Each class can be further subdivided by the kind of raw materials, such of fish species, portion of fish, etc, and thus numerous kinds of products can be named. In Korea, in the category of cured fish, more than 30 kinds of products are produced (41).

When the salt concentration is lower than 20%, the salted fish undergoes rapid spoilage, and other means of preservation is needed. Lactic fermentation with added carbohydrate is an old method of fish preservation in low-salt processes. Rice, millet, flour, and even syrup or sugar are used as the carbohydrate source. The amount of added carbohydrate and salt concentration primarily control the extent of acid fermentation and the keeping quality. An alternative method is keeping the low-salt fermented fish with added vinegar in low temperature. This method is widely practiced in the Scandinavian countries (5). Many of Asian countries produce salt cured and dried fish products, for example, Plakem in Thailand (8) Jambalroti in Indonesia (9), Maldive fish in Sri Lenka (10) and Gulbi in Korea (11) but the role of fermentation in these products is not fully understood.

Fish fermentation without added salt is not a common practice. In some local specialities, half-spoiled fish or alkaline fermentation in leafy plant ash is used (12). The propagation of mold on the dried bonito (katsuobushi) processing in Japan is another example of non-salt fish fermentation (13).

Three kinds of Chinese ideographs indicating fermented fish products appear in an old Chinese literature "Churai" written in third century B.C,; i.e. Hae (醢), Ja (鮓) anad Chi (鮨) (14). Hae is a fermented meat or fish made by mixing and aging with salt, and occasionally with added wine, Koji and Nuruk, an alcohol fermentation starter. A Chinese dictionary "Solumn" describes Hae as meat or fish sauce, Ja as acidic fermented fish. Chi is a fish sauce, which is considered quite similar to Hae but the detailed characteristics are not known. Adams (4) classified fermented fish product into two groups; i.e. fish/salt products and fish/salt/carbohydrate products. A similar classification was also made by Ishige (2).

Owens & Mendoza (15) tried to divide fermented fish products on the basis of enzyme hydrolysed versus microbial fermented. They subdivided the products primarily involving enzymic hydrohysis into four groups; (1) hydrolysis in >20% salt, (2) hydrolysis in salt + drying (3) hydrolysis at low temperature and (4) hydrolysis at low pH values. The products preserved by microbial fermentation are subdivided into two groups; (1) fermented with added carbohydrate, and (2) fermented without added carbohydrate. However, a large controversy exists on the role of microorganisms in high-salt fish fermentation.

Microbial fermentation vs enzymic hydrolysis

Great controversy still continues as to the name of fermented fish when high salt concentration is used. Many microbiologists prefer to use to the term enzymic hydrolized, instead, or "cured fish" because no microorganisms can grow such a highly osmolytic conditions, created in high-salt fish fermentation (15, 16). However, some recent findings support the possible role of microbial degradation in the formation of fermented fish flavor in high-salt fermentations.

Ito *et al.* (21) found that mysis and shrimp had a factor which increases halophlic characteristics of some halophlic bacteria. The halophilic characteristics of bacteria increased when they were grown in a medium with added extracts from digested shrimp or salt fermented mysis. They explained that these halophilic bacteria kept the halophilic characteristics by getting energy from other substrate rather than oxygen respiration of salt. It was suggested that halophilic bacteria gain energy through the activity of lactate oxidase linked cytochrome b_4, because this oxidase has halophilic character. By the addition of shrimp or mysis extract, they could grow *Paracoccus halodenitrificans* under the higher concentration of salt than had previously been thought possible.

Knochel (5) pointed out the importance of selecting suitable methodologies for the microbiological examination of high-salted foodstuffs. The environment in high-salt fermented fish product is extreme, with over 20% salt in the aqueous phase. Often counts are obtained on media with low salt content reflecting neither the quantity nor the composition of the active microflora. The cell of *P. halodentrificans* plasmolyses in 12% brine (21).

Many of investigations on the microflora in high-salt fermented fish products indicate the growth of halophilic bacteria during the fermenation (18-25). Mheen (18) demonstrated the favorable effect of starter culture, *Bacillus* species, on the ripening and flavor formation of high-salt fermentation of anchovy.

It is still unclear the share of importance between microbial degradation and enzymic hydrolysis in high-salt fish fermentation. Therefore, it is reasonable to use the term of fermentation for this process, which allows for the transformation of organic substances into simpler compounds by the action of enzymes and microorganisms (26). Ishige (2) made the distinction between salting and fermentation. The objective in salting fish is to retain the shape of the fish and prevent decay, and thereby to produce a preserved cooking ingredient akin to original raw material, whereas the intent of

Table 1. Classification of high-salt fermented fish products in different countries.

Country	Fish sauce	Cured fish	Fish paste
Burma	Ngan-pya-ye	—	Ngapi
Cambodia	Nuoc-mam	—	Prahoc
China	Yu-lu	—	—
Indonesia	Ketjap-ikan	Pedah	Trassi
Japan	Shottsuru	Shiokara	—
Korea	Jeot-Kuk	Jeotkal	—
Malaysia	Budu	—	Belacan
Philippines	Patis	Bagoong	Bagoong
Sri Lanka	Blood pickle	Jaadi	—
Thailand	Nampla	—	Kapi
Vietnam	Nuoc-mam	—	Mam-ca

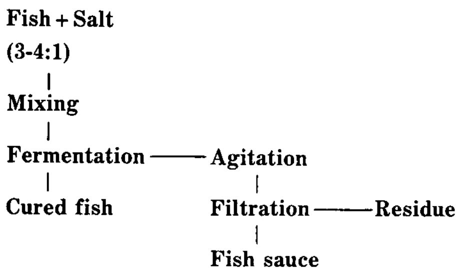

Fig. 3. General processing flow diagram of cured fish and fish sauce.

fermentation is to create a material that does not exist in nature. In this context, it can also be added to the definition of fermentation that it can be a process by which inedible raw materials are made edible without cooking by the action of microorganisms.

Synonyms and variations

Comparing the products of different regions, identical but differently named products are frequently found, and this situation creates confusion and difficulties in communication. Table 1 shows the synonyms found in high-salt fermented fish products. Most of the countries in the East and Southest Asia have fish sauce, but it varies in the flavor, physical properties and the raw materials used.

Fig. 3 shows the general processing procedure for fish sauce and cured fish. Depending on the degree of hydrolysis or fermentation time and the separation method, two types of sauce, namely, clear and turbid, are produced. Ngan-pya-ye, Nuoc-man, Nampla, Shottsuru and Yu-lu are clear type fish sauce, while Budu, Patis, Ketjap-ikan and Jeot-kuk are turbid. Some of turbid sauces are obtained from the exuded liquid of cured fish, for example, Patis from Bagoong production in the Philippines and Jeot-kuk from Jeot-kal production in Korea. In Northeastern Asia cured fish products are more important than fish paste. Fish paste, especially those made from shrimp and planktonic animals such as Seinsa Ngapy, Belacan, Trassi, Prahoc and Kapi, are important in Southeastern Asian diets. Fig. 4 shows the general processing procedure of fish paste. For the more elaborated quality improvement partial drying and packed fermentation can be repeated.

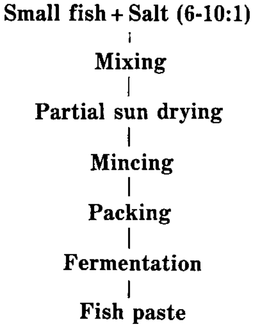

Fig. 4. General processing flow diagram of fish paste.

Table 2. Classification of low-salt fermented fish products in different countries.

Country	Lactic fermented	Acid pickling
Norway	Rakeorret	—
England	—	Tidbits
Germany	—	Schnell-maatjes
Japan	Narezushi	—
Korea	Sikhae	—
Malaysia	Bekasam	—
Philippines	Brong-isda, Balao-balao	—
Thailand	Pla-som, Pla-ra, Pla-chom	—
Vietnam	Mum-Tom	—

Table 2 summarizes the low-salt fermented fish products in different countries. In Scandinavia most of traditional low-salt fermented fish products are transformed into pickled products in vinegar. And these products generally require low temperature storage.

On the other hand, most of Asian products are

Degutted fish + Salt (10:1)

Over night salting

Mix with cooked cereals

Packing

Fermentation

Lactic fermented fish product

Fig. 5. General processing flow diagram of lactic fermented fish products.

lactic fermented with added cereals, as shown in Fig. 5. Rice either cooked or roasted, is the most frequently used carbohydrate source, but other sources such as millet in Sikhae are also used (17). In some cases fruits and vegetables, for example tamarind in Bekasam for the reduction of pH, and garlic and pepper in Sikhae, are added. The antimicrobial effect of garlic to some putrifactive microorganisms such as *Bacillus* in lactic fermented fish products has been demonstrated (27).

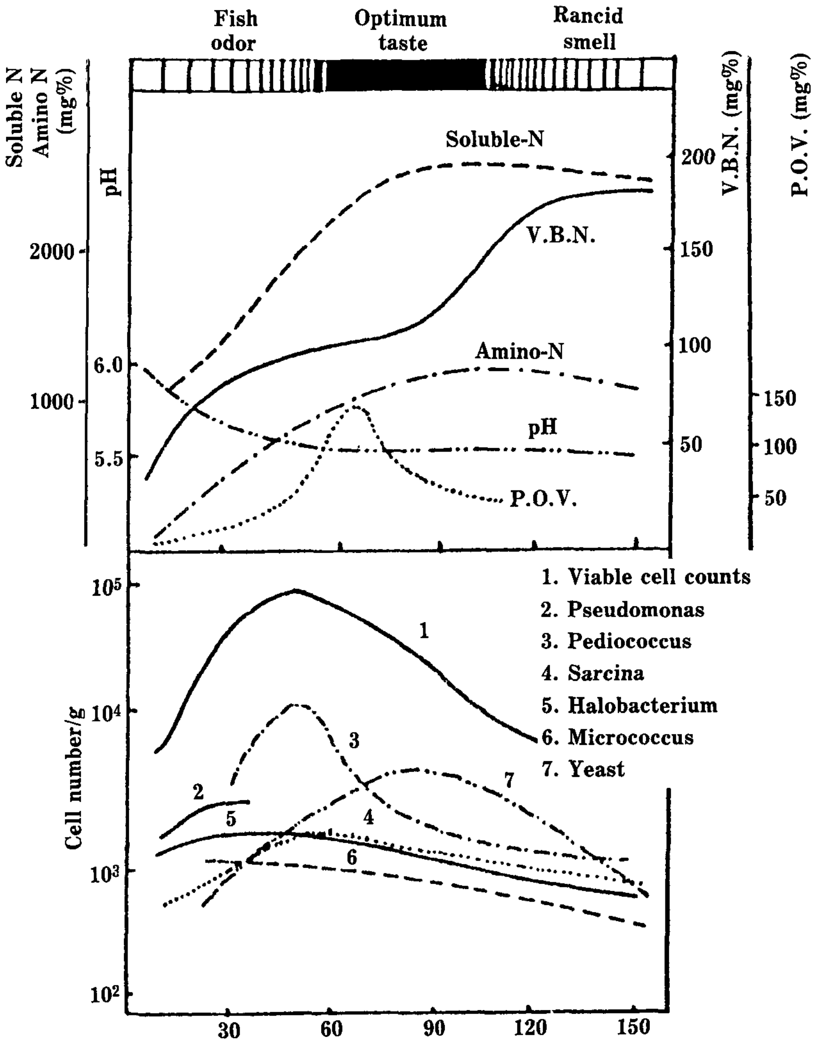

Fig. 6. Microbial and biochemical changes during the fermentation of a cured fish, anchovy Jeot-kal (28).

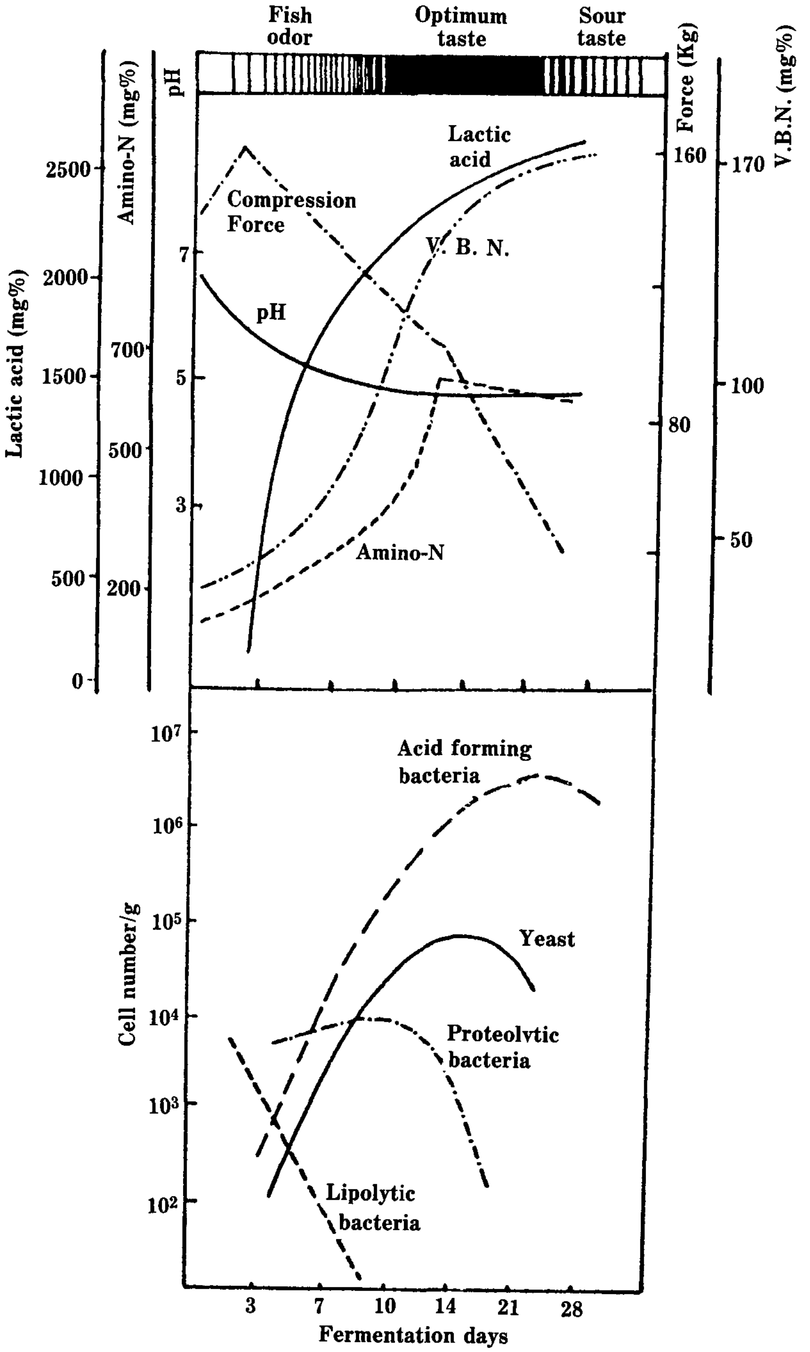

Fig. 7. Microbial and biochemical changes during the fermentation of a lactic fermented fish product, Sikhae(28).

Microbial and biochemical changes during fish fermentation

Fig. 6. shows the microbial and biochemical changes of a typical high-salt cured fish made from anchovy (28). The salt content of the product was 20% (w/w) of total weight. The total number of viable cell increased during the first 40 days and then decreased. This was mainly attributed to the growth

Table 3. Maximum sodium chloride concentrations and minimum temperatures, pH values and water activities for growth of food poisoning bacteria under otherwise optimal conditions (15).

Bacterium	Conditions allowing growth/toxin production			Maximum salt concentration (% w/w)
	Minimum values			
	Temp. (°C)	pH value	Aw	
Bacillus cereus	7	4.4-5.0	0.93-0.95	7.5
Clostridium botulinum				
types A and B	10-12	4.8	0.94-0.95	10
type E	3.3	5.0	0.97	5
C. perfringens	15-20	5.0	0.95-0.96	4-6
Salmonella species	5.2	4.1-5.5	0.95	8
Staphylococcus aureus				
growth: aerobic	6.7	4.3	0.86	16-18
anaerobic	6.7	4.7	0.90	14-16
toxin: aerobic	10	4.3	0.90-0.93	12-13
anaerobic	10	6.5	0.90-0.93	12-13
Vibrio parahaemolyticus	3-13	4.8	0.94	8-10

of *Pediococcus* and Halobacterium. The concentrations of soluable-N and amino-N increased steadily during the first 60 days and this coincided with the development of optimum taste. The volatile basic-N content increased in two steps and the second step coincided with the start of taste deterioration and this was also related to the maximum growth of yeast in the system.

Fig. 7. shows the microbial and biochemical changes of a typical lactic fermented fish product incubated at 20°C. The salt concentration of the product was 8% (w/w) of total weight and cooked millet was the carbohydrate source and garlic and red pepper powder were added (17, 28). The pH decreased rapidly during the first 3-5 days from 6.5 to below 5.0 and texture softening took place from the 3-4 days after fermentation. The amino-N concentration increased steadily up to 14 days and this coincided with the attainment of the optimum taste. The number of lipolytic bacteria decreased rapidly during the initial stage of fermentation and the proteolytic bacteria increased until 12 days of fermentation and thereafter decreased rapidly. The acid forming bacteria increased rapidly and became the dominating microorganisms in one week of the fermentation and reached a maximum at 16 days of fermentation. In this case, the taste deterioration was also associated with the maximum growth of yeast and acid-forming bacteria.

The important bacteria for the lactic fermentation were identified as *Leuconstoc mesenteroides* and *lactobacillus plantarum* (29). The role of these acid forming bacteria for the preservation of fish is apparent, but a more important aspect is their ability to produce acceptable flavor during the fermentation. The mechanism of the production of palatable flavor components by these acid forming bacteria in cereal substrate is presently under investigation.

Wholesomeness of fermented fish products

The major potential hazard associated with proteinaceous foods like fermented fish is from the growth of food poisoning bacteria, presence of parasitic worms and the production of physiologically active amines. Of particular concern with non-heated foods offering anaerobic conditions is the possible growth of and toxin production by *Clostridium botulinum* (5, 15).

Table 3. shows the intensities at which various environmental factors are singly able to prevent the growth of the main food poisoning bacteria under otherwise optimum conditions (15). It is evident that neither the high-salt nor low-salt lactic fermented fish products will support the growth of any of these bacteria once they are prepared due to their salt content and/or low pH value. However, the improper

storage of raw fish before salting and insufficient acid production in very low salt fermentation can cause the outbreak of botulism. The botulinum toxin is relatively easily destoryed by cooking but very stable in salty and acidic environments (30). The fermented fish products most often incriminated in *C. botulinum* type E poisonings are Isushi (a type of Narezushi) and Kirrikomi (a type of Shiokara) in Japan, salmon egg cheese (fermented crushed salmon roe) among Eskimos and Indians in Canada and Alaska, and Rakeorret in Scandinavia (31, 32). The Norwegian Rakeorret has caused several outbreaks in Denmark by both *Clostridium botulinum* type E and B (5). Therefore, the Danish legislation decrees that commercial products with less than 6% NaCl (w/w) and pH > 5 can only be made by authorized manufactures and all distribution and storage should be at less than 5°C.

A number of parasitic worms may be contracted by eating raw or partially cooked fish, but the relative importance of high salt fermented or low-salt lactic fermented fish products are rarely reported. Larvae of the parasite Anisakis are often found in North European pelagic fish. They may cause appendicitis-like symptoms in humans and in several cases salted Matjes has been reported as a vehicle. One solution is to freeze Matjes after salting. Danish regulations demand that marinated herring should be pre-treated with brine (1:1) consisting of mininum 15% NaCl and 5% acetic acid for at least one week before being marinated in retail packs in order to kill the larvae (5).

The physiologically active amines such as histamine formed by the bacterial decarboxylation of histidine, may be produced in amounts sufficient to cause poisoning in certain fishes (33). However, to what extent such amines are problems of potential problems with fermented fish is net clear (15).

Recent developments and future prospect

The needs for quality imporvement and process innovation in the area of fish fermentation have been widely recognized in recent years. The accelearation of enzymic hydrolysis in fish sauce making has been the major concern in the Philippines, Taiwan, Indonesia and other Southeastern countries (9, 34, 35). Enzymes from koji and fruits were added and in some cases selected proteolytic bacteria, for example *Brevibacterium sp. Bacillus sp.*, and *Micrococcus sp.*, were used for the acceleration of fish sauce fermentation. Many of investigators found substantial flavor change by the addition of enzymes, but the result from added microrganisms were generally satisfactory (18, 35). The traditional cottage level small scale fish sauce factories are amalgamating in many countries, and quality standardization including proper packaging are required in most of Southeastern countries. One successful case of the industrialization of fish sauce is Ngapi production in Burma (36).

The prime concern in cured fish fermentation is to keep the salt content as low as possible. During the scale-up of cured fish production from the traditional household level, more salt is added in order to ensure the prevention of health harzard microorganisms and quality changes during the long distribution process. However, high salt concentration generally reduces the sensory quality of the products. In addition, the strong correlation between salt intake and high blood pressure makes people more wary of eating salt food. Lee, E.H. (39) has conducted an extensive study on the reduction of salt concentration of different type of Jeotkal. He could successfully preserve Jeotkal products with 8% salt incorporated with 0.5% lactic acicd, 6% sorbitol and 4% of alcohol extract of red pepper. This type of products is distributed through the cold chain system and growing in popularity in Korea.

A similar requirement is also imposed on lactic fermented fish products. The shelf-life of lactic fermented fish products is primarily dependent on the salt concentration, storage temperature, amount and kind of carbohydrate source and the use of other preservative materials useful for vegetable lactic other chemical agents. The search for a natural preservative materials useful for vegetable lactiv fermented products has been widely conducted in Korea (27, 37). The optimum processing conditions for the production of stable, low salt and safe products by using different lactic acid producing starter cultures have been studied (38, 39).

The production of fish sauce and fish paste has faced strong competition with soybean sauce and paste and other condiments such as yeast extract beef extract etc. However the deep roots of traditional taste preference will keep fermented fish products the dominating condiment in the Southeastern Asian countries, as long as the products meet the requirement of today's market such as convenience good packaging and consistent quality. An alternative form of fish sauce in the future will be the mixture of fish sauce and soysauce or other form of condiments (25).

For the cured fish and lactic fermented fish products in Asia, the developments in the Scandinavian countries, such as pickling of salted fish associated with low temperature storage, indicate a significant future direction. The cold-chain distribution of low-salt cured fish and lactic fermented fish products is already well established in Korea and Japan. With this new development the consumption of fermented fish products is again increasing in Korea.

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References

1. Ruddle, K.: The availability and supply of fish for fermentation in Southeast Asia, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul, 47-80 (1989).
2. Ishige, N.: Cultural aspects of fermented fish products in Asia, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publi. Co., Seoul, 21-36 (1989).
3. Wilson, C.A.: Food and Drink in Britain, Penguin Books, Harmandsworth, England, 24-25 (1976).
4. Adams, M.R.: Fermented flesh foods, Progress in Industrial Microbiology, Ed. M.R. Adams, **23**, 179-180 (1986).
5. Knochel, S.: Processing and properties of North European pickled fish products, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul, 195-210 (1989).
6. Lee, S.W.: Cultural aspects of Korean fermented marine products in East Asia, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul, 37-47 (1989).
7. Lee, C.H., E.H. Lee, M.M. Lim, S.H. Kim, S.K. Chai, K.W. Lee and K.H. Koh: Fermented Fish Products in Korea, YuRim Publi. Co., Seoul (1987).
8. Boon-Long, N.: Traditional Fermented Fish Products of Thailand, Report to UN University, Tokyo (1987).
9. Putro, S.: Fish fermentation technology in Indonesia, in Fish Fermentation Technology, Ed.C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul, 99-118 (1989).
10. Subasinghe, S.: Fermented fishery products in Sri Lanka, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul, 153-160 (1989).
11. Kim, Y.B., Y.G. Seo and C.H. Lee: Growth of Microorganisms in dosal muscle of Gulbi during processing and their effect on its quality, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkaus & P.J.A. Reilly, YuRim Publish. Co., Seoul 257-266 (1989).
12. Souane, M.: Fish fermentation technology in Senegal. Presented at UNU Workshop on Fish Fermentation Technology, June 22-26, Seoul, Korea (1987).
13. Kanazawa, A.: Katsuo-bushi, Seminar on traditional foods and their processing in Asia, Tokyo University of Agriculture, Nov. 13-15, Tokyo, Japan (1986).
14. Chang, C.H.: Studies on the history of Korean traditional fish fermentation technology, Thesis Collection of Sung Sim Womens University, Seoul, Korea. **7**, 79(1976).
15. Owens, J.D. and L.S. Mendoza: *J. Food Technol.*, **20**, 273(1985).
16. Reilly, A. and L.E. Barile: Cured fish production in the tropics, College of Fisheries University of the Philippines in the Visayas and GTZ, GmbH. (1986).
17. Lee, C.H., T.S. Cho, M.H. Lim, J.W. Kang and H.C. Yang: *Korean J. Appli. Microbiol. Bioeng.*, **11**(1), 53 (1983).
18. Mheen, T.I.: Microbiology of salt fermented fishery products in Korea, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul, 211-226 (1989).
19. Lee, J.G. and W.K. Choe: *Bull. Korean Fish. Soc.*, **7**(3). 105(1974).
20. Chung, S.Y. and E.H. Lee: *Bull. Korean Fish. Soc.*, **9**(2) 79(1976).
21. Ito, H., H. Tachi and S. Kikuchi: Halophilic mechanism of isolated bacteria from fish sauces, in Fish Fermentation Technology, Ed. C.H. Lee, K.H Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul 161-170 (1989).
22. Ito, H., H. Tachi and S. Kikuchi: Fish Fermentation Technology in Japan, in Fish Fermentation

Technology, Ed. C.H. Lee, K.H Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul 161-170 (1989).
23. Karim, M.I.A.: Fermented fish products in Malaysia, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul, 89-98 (1989).
24. Phithakpol, B.: Fish Fermentatio Technology in Thailand, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publ: Co., Seoul, 143-152 (1989).
25. Steinkraus, K.H.: Handbook of Indigenous Fermented Foods, Marcel Dekker, INC., New York, 487-526 (1983).
26. Mackie, I.M., R. Hardy and G. Hobbs: Fermetend Fish products, Rome, FAO
27. Souane, M., Y.B. Kim and C.H. Lee: *Korean J. Appl. Microbiol. Bioeng.*, **15**(3), 150(1987).
28. Lee, C.H. E.H. Lee, M.H. Lim, K.H. Kim, S.K. Chae, K.W. Lee and K.H. Koh: *Korean J. Dietary Culture,* **1**(3) 267(1986).
29. Souane, M.: Studies on Gajami sik-hae, Fellowship Training Report submitted to UNU. Tokyo, Japan (1987).
30. Huss, H.H. and E. Rye Pedersen: *J. Food Technol.* **15**, 619(1980).
31. Bartl, V.: Semi preserved foods: general microbiology and food poisoning, in The microbiological Safety of Food, Ed. B.C. Hobbs & J.H.B. Christian, Academic Press, London, 89-106 (1972).
32. Sakaguchi, S.: Botulism, in Foodborne Infections and Intoxications, 2nd edition, Ed. H. Rieman & F.L. Bryan, Academic Press, New York, 389-442 (1979).
33. Eitenmiller, R.R., J.H. Orr and W.W. Willis: Histamine formation in fish; microbiological and biochemical conditions, in Chemistry and Biochemistry of Marine Food Products, Ed. R.E. Martin, G.F. Flick, C.E. Hebard & D.R. Ward, AVI. Westport, Conn., 39-50 (1982).
34. Mabesa, M.C., and J.S. Baban: Fish fermentation technology in the Philippines, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul, 81-88.
35. Chen, H.C.: Fish fermentation technology in Taiwan, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publishing Co., Seoul, 185-194 (1989).
36. Tyn, M.T.; Trends of fermented fish technology in Burma, in Fish Fermentation Technology, Ed. C.H. Lee, K.h. Steinkraus & P.J.A. Reilly, YuRim Publish. Co, Seoul, 119-142 (1989).
37. Yoon, S.I.: Studies on the preservation of Kimchi, Report of Food Research Institute, Association of Korean Food Industries. Seoul (1987).
38. Cooke, R.D., Twiddy, D.R. and P.J.A. Reilly: YuRim Publish. Co., Seoul, 267-278 (1989).
39. Lee, E.H.: Microbiology and biochemistry of low-salted fish fermentation, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publishing Co., Seoul, 237-256 (1989).
40. Lee, C.H.: Fish fermentation technology in Korea, in Fish Fermentation technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul, 171-184 (1989)
41. Lee, C.H., M. Souane, and C.S. Kim: Microbiology of Gajami sikae fermentation, in Fish Fermentation Technology, Ed. C.H. Lee, K.H. Steinkraus & P.J.A. Reilly, YuRim Publish. Co., Seoul, 279-293 (1989).

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