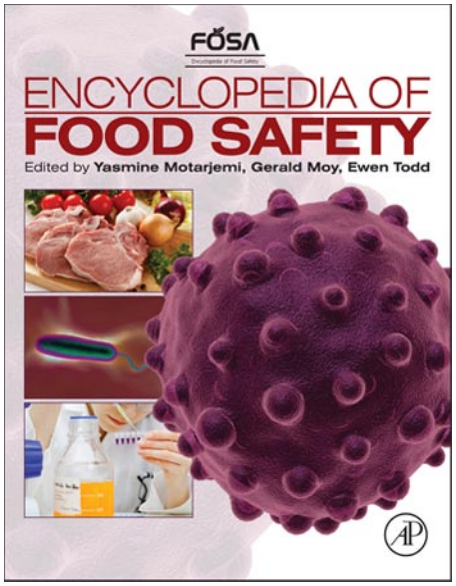

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SAFETY OF FOOD AND BEVERAGES

Safety of Regional Specialities – Korean Fermented Foods

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Glossary

Critical control point A processing factor of which a loss of control would result in an unacceptable food safety or quality risk.
Fermentation A kind of food processing that is the conversion of carbohydrates to alcohols and carbon dioxide or organic acids using yeasts, bacteria, or a combination thereof, under anaerobic conditions.
Food safety A scientific discipline describing the handling, preparation, and storage of food in ways that prevent foodborne illness.
Hazard A biological, chemical, or physical agent in, or condition of, food with the potential to cause an adverse health effect.
Hazard Analysis Critical Control Point A systematic preventive approach to food safety and pharmaceutical safety that addresses physical, chemical, and biological hazards as a means of prevention rather than finished product inspection.

Soybean Sauce and Soybean Paste

Korean-style soybean sauce (*Kanjang*) and soybean paste (*Doenjang*) are produced in a single process using *Meju*, a fermentation starter. The *Meju* is prepared from cooked soybeans. Soybeans are soaked overnight in water, cooked for 2–3 h, and mashed by pounding. The substance is shaped like a brick or a ball, dried in the sun, and stored in a stack covered during the night for several days. Through this process, molds (especially *Aspergillus oryzae*) are grown on the surface, and bacteria (typically *Bacillus subtilis*) are generated inside the *Meju*. The enzymes from molds and bacteria hydrolyze the soybean proteins into amino acids, and the carbohydrates into sugars and organic acids. The amino acids and sugars interact with each other in a browning reaction, resulting in the characteristic dark brown color and meaty flavor. Well-fermented *Meju* is immersed in an earthen jar filled with brine and ripened for several months. The brown color and meaty flavor leach into the brine. During this period, salt-tolerant yeasts grow in the mash, particularly *Saccharomyces rouxii*, which produces the aroma of soybean sauce. The liquid portion becomes soybean sauce (*Kanjang*) and the precipitates become soybean paste (*Doenjang*). Soybean sauce produced thusly is boiled once and stored in an earthen jar for years.

Gochujang, a unique hot bean paste, is one of Korea's most common and popular seasonings. It is made with *Meju* and malt made from barley. Malt powder is mixed with cereal porridge made from rice, glutinous rice, or barley. The enzymes in malt hydrolyze the starch into sugars and reduce the consistency of the mixture. *Meju* powder, red pepper powder, and salt are added to the partly saccharified porridge, with thorough mixing, to form a paste that is transferred to an earthen jar. The top is covered with salt to prevent mold growth. The jar is placed in the sun for further fermentation. The proteins in soybean and cereals are degraded into amino acids to produce a meaty flavor. During fermentation, a wonderful harmony of the meaty flavor from hydrolyzed proteins, the sweet taste of hydrolyzed starches, the pungent taste of red pepper, and the saltiness is achieved, and a new characteristic flavor stimulating the appetite of Koreans is formed.

Safety concerns of these fermented soybean products include possible contamination with mycotoxin-forming molds during *Meju* fermentation, biogenic amine formation during the aging process in brine, and contamination with *Bacillus cereus*. Much research has been conducted in Korea on these safety concerns. It has been proven that aflatoxins are degraded to 80–90% after 2 months of fermentation and degraded to 100% after 3 months of fermentation.

In addition, samples of soybean sauce and soybean paste were collected from various markets in Korea to detect aflatoxin levels. According to a report supported by the Korea Food and Drug Administration (KFDA) in 2006, aflatoxin levels were not detected in a total of 14 samples of *Doenjang*, *Kanjang*, and *Gochujang*. Another report performed in 2004–2005 showed that aflatoxin B_1 was detected in one of the seven soybean sauce samples and in 2 of the 56 soybean paste samples by enzyme-linked immunosorbent assay/high-performance liquid chromatography (ELISA/HPLC). Because the detected levels were 1.81 and 0.05–0.17 ppb, respectively,

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they were under the permitted level (10 ppb) of Korea Foods Standards (Table 1). Although they are within safe levels, right manufacturing processes and management practices (including cultivating and storage technology) are important to minimize the contamination with aflatoxin, ochratoxin, biogenic amines, and *B. cereus* at every stage of production.

Several factors can be considered in degrading aflatoxins during fermentation. Ammonia produced during the fermentation, light, microbial competition with *Bacillus* spp., and addition of charcoal or vitamin C were reported to help reduce aflatoxins in soybean products. In addition, increasing concentrations of CO_2 or N_2 suppressed the formation and growth of aflatoxin because aflatoxin producing molds are aerobic organisms requiring O_2. The most important factor is the prevention of any mold growth, which results in aflatoxin production because any subsequent cooking will not destroy it.

Table 1 Regulatory standards for traditional Korean fermented foods

	Fermented soybean products	*Kimchi*	*Fermented fish products*
Aflatoxin (μg kg^{-1})	$<$10 ppb (vitamin B_1) $<$15 ppb (total aflatoxin)	– ($<$10 for red pepper powder)	–
B. cereus	$<$10 000 per 1 g (excluding *Meju* and soy sauce)	–	–
Coliform group	Negative (limited to sterilized mixed paste)	Negative (limited to sterilized packaged products)	Negative (limited to *Jeot* and spiced/seasoned *Jeot*)
Escherichia coli	–	–	–
Harmful metals (mg kg^{-1})	–	Lead $<$0.3 Cadmium $<$0.2	–

'–' Indicates no regulations.
Source: Reproduced from Korea Food & Drug Administration (KFDA) (2008) *Food Code*. Seoul: Korea Food Industry Association.

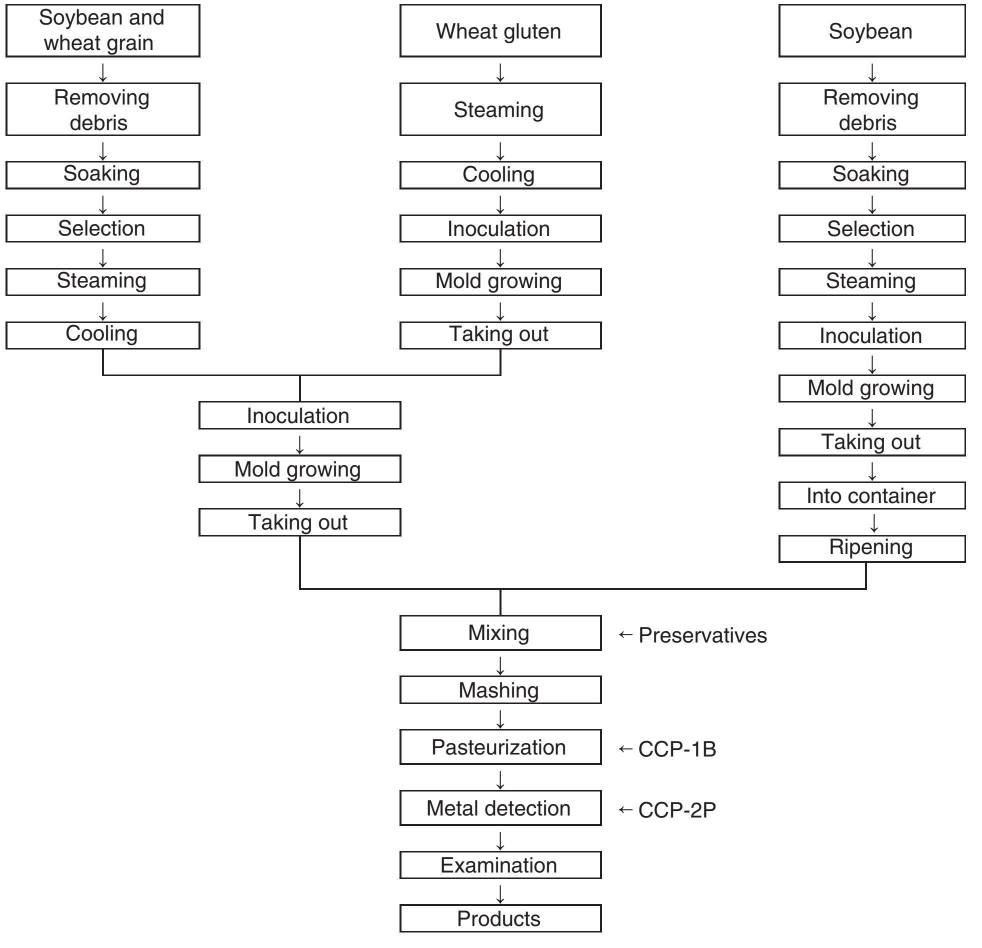

Figure 1 Flow chart of the procedure for *Doenjang*, marked with CCPs.

It was suggested that storage temperatures should be maintained at 0–7.5 °C because the optimal temperature for aflatoxin production is 25–30 °C. The food industries in Korea are therefore launching refrigerated soybean products for enhanced safety. Current refrigerated soybean paste accounts for 16% of the sales. This method was also reported to remove off-flavor and improve taste.

Adopting controlled fermentation techniques using *Koji*, a starter of Japanese soybean products, is a safe alternative to replace the traditional method. Most of the industrial production of soybean sauce and soybean paste in Korea utilizes *Koji* instead of *Meju* because *Koji* contains *A. oryzae* rather than *Aspergillus flavus*, which produces aflatoxin. However, the taste and flavor of soybean products fermented with *Koji* are not as rich as those made in traditional ways. It is thus worthwhile to introduce both these methods in the food market to meet consumer preference.

As an approach to eliminate, minimize, or prevent hazards from farm to fork, the hazard analysis critical control point (HACCP) system is highly regarded. This control system includes seven principles designed to prevent problems before they occur and to correct deviations as soon as they are found. The critical control points (CCPs) are placed in the flow chart of operational steps, where practices can be applied. The KFDA has put efforts in developing HACCP models for improving safety and reducing hazards in Korean fermented foods. The following models for soybean products are the examples. The potential hazard lists of fermented soybean products, *Doenjang*, *Kanjang*, and *Gochujang*, can be summarized as follows: biological hazards (pathogens, such as *E. coli* and *B. cereus*, yeast, and molds), chemical hazards (aflatoxin and pesticide residues), and physical hazards (foreign substances, such as grass, seeds, sticks, and wood waste). According to the HACCP model suggested by the KFDA, the CCPs of *Doenjang* and *Gochujang* are identical (Figures 1 and 2). Two CCPs (CCP-1B and CCP-2P) were noticed in their procedures. It mentions that pathogens, such as *E. coli* and *B. cereus*, should be controlled in the pasteurization step (CCP-1B) with critical limits, appropriate time, and temperature (60–80 °C). The metal detection step (CCP-2P), a procedure to remove iron and stainless steel using a metal detector just before packaging, is another critical point. The quality control for the raw material (soybean) is relatively easy in Korea because most companies purchasing it in bulk from the Korea Jang Cooperative.

Kanjang has only one CCP (CCP-1B) for a pasteurization step at 80–85 °C to manage pathogenic bacteria (Figure 3). Bacterial count of *B. cereus* should be less than 10^4 cells per gram in these soybean products after the thermal treatment.

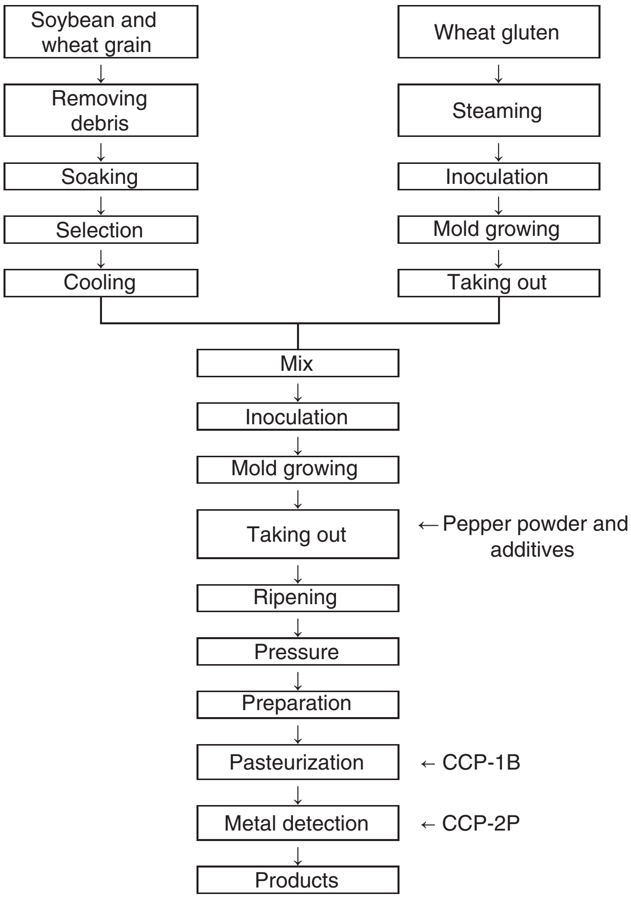

Figure 2 Flow chart of the procedure for *Gochujang*, marked with CCPs.

Fermented Fish Products

Fermented fish products in Asia are generally salt-fermented products: fish sauce, fish paste, and cured fish. When the salt concentration is higher than 20% of the total weight, growth of pathogenic and putrefactive microorganisms can be prevented. In this case, the products do not need other preservative means. The first criterion for classification in this group is the degree of hydrolysis, which is influenced by fermentation time and temperature, added enzyme sources, and the water content. The fully hydrolyzed liquid is defined as fish sauce. The cured fish is confined to represent the partially hydrolyzed fish products that retain the original shape of fish in the exuded liquid, and this form is frequently used as a side dish for rice meals. Fish paste is characterized by partially dried salted fish, which restricts the degree of hydrolysis and produces a homogeneous and solid condiment. Each type can be further subdivided by the type of raw materials, such as fish species, portion of fish, etc.; accordingly, numerous products can be named. In Korea, more than 30 products are included in the category of cured fish.

When the salt concentration is lower than 20%, the salted fish undergoes rapid spoilage, and other means of preservation is needed. Lactic fermentation by the addition of carbohydrate is an old method for 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 the salt concentration primarily control the extent of acid fermentation and maintain quality. An alternative method keeps the low-salt fermented fish with vinegar at low temperatures. This method is practiced widely in the Scandinavian countries. Many Asian countries produce salt-cured and dried-fish products, for example, *Plakem* in Thailand, *Jambalroti* in Indonesia,

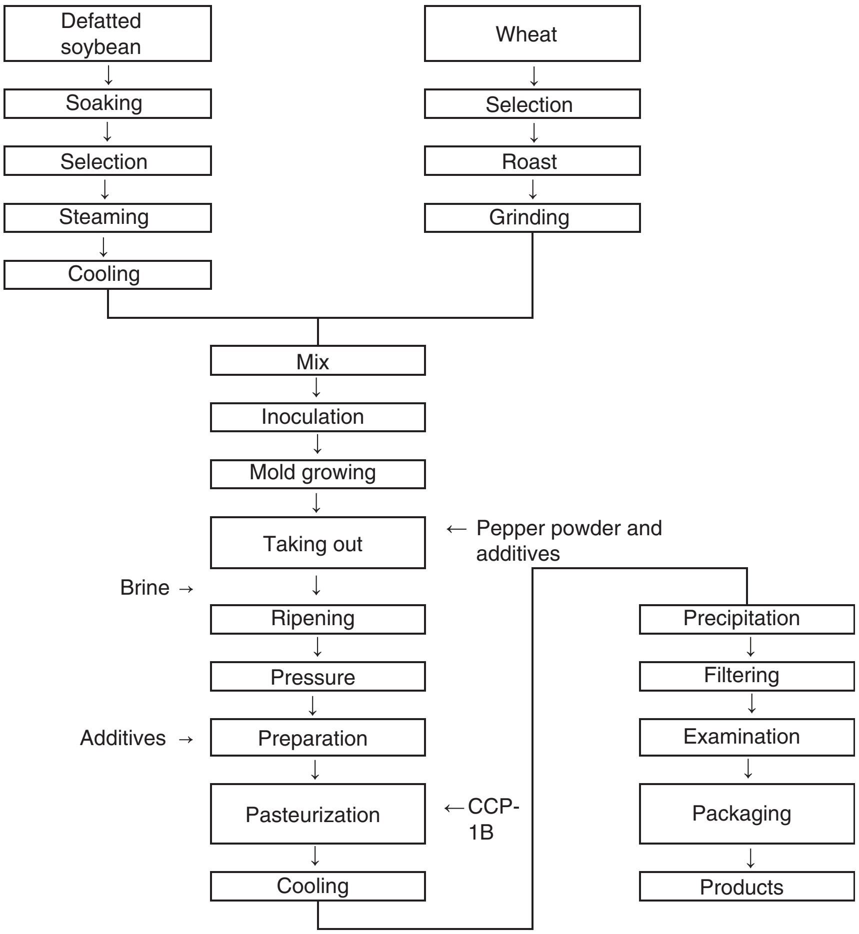

Figure 3 Flow chart of the procedure for *Kanjang*, marked with CCPs.

Maldive fish in Sri Lanka, and *Gulbi* in Korea, but the role of fermentation in these products is not fully understood.

Fermented fish products can be divided on the basis of the enzyme hydrolyzed versus the microbial fermented. The products are subdivided into four groups depending on the enzymatic hydrolysis: (1) hydrolysis in >20% salt, (2) hydrolysis in salt + drying, (3) hydrolysis at low temperature, and (4) hydrolysis at low pH. The products preserved by microbial fermentation are subdivided into two groups: (1) fermented with added carbohydrate and (2) fermented without added carbohydrate.

The major potential hazard associated with proteinaceous foods, such as fermented fish, is from the growth of pathogenic bacteria such as *Vibrio* spp., presence of parasitic worms, and the production of physiologically active amines. Of particular concern for unheated foods in anaerobic conditions is the possible growth of *Clostridium botulinum* and its toxin production.

It is evident that neither the high-salt nor the low-salt lactic fermented fish products will cause the growth of any pathogenic bacteria once they are prepared with the appropriate salt content and/or low pH. However, the improper storage of raw fish before salting and insufficient acid production in a very low-salt fermentation can cause an outbreak of botulism. The botulinum toxin is destroyed relatively easily by cooking, but it is very stable in salty and acidic environments. The fermented fish products most frequently incriminated in *C. botulinum* type E poisonings are *Sushi* (a type of *Narezushi*) and *Kirikomi* (a type of Shiokara) in Japan, and salmon egg cheese (fermented crushed salmon roe) among British Columbia First Nation Peoples and Alaska Indians.

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. *Jeot-gal* is the generic name of high-salt fermented fish products, which are used not only for side dishes but also for additives in making *Kimchi*. *Jeot-gal* contains large amounts of precursor amino acids of biogenic amines because it is made from the muscles and viscera of seafood and salts. It is therefore important to reduce the biogenic amine content. Several studies suggested that the addition of garlic and glycine can inhibit amino acid decarboxylase activity in *Myoelchi-jeot* (made of anchovies). In fact, the cadaverine and tyramine contents were reduced by up to 18.4% and 30.9%, respectively, in the culture treated with garlic extract. Glycine has the greatest inhibitory activities on biogenic amine production. The contents of putrescine, cadaverine, histamine, tyramine, and spermidine were reduced by 32.6%, 78.4%, 93.2%, 100%, and 100%, respectively, compared with the control. Therefore, there is no doubt that these findings can help improve safety. Nowadays, many people are trying to reduce sodium intake because they

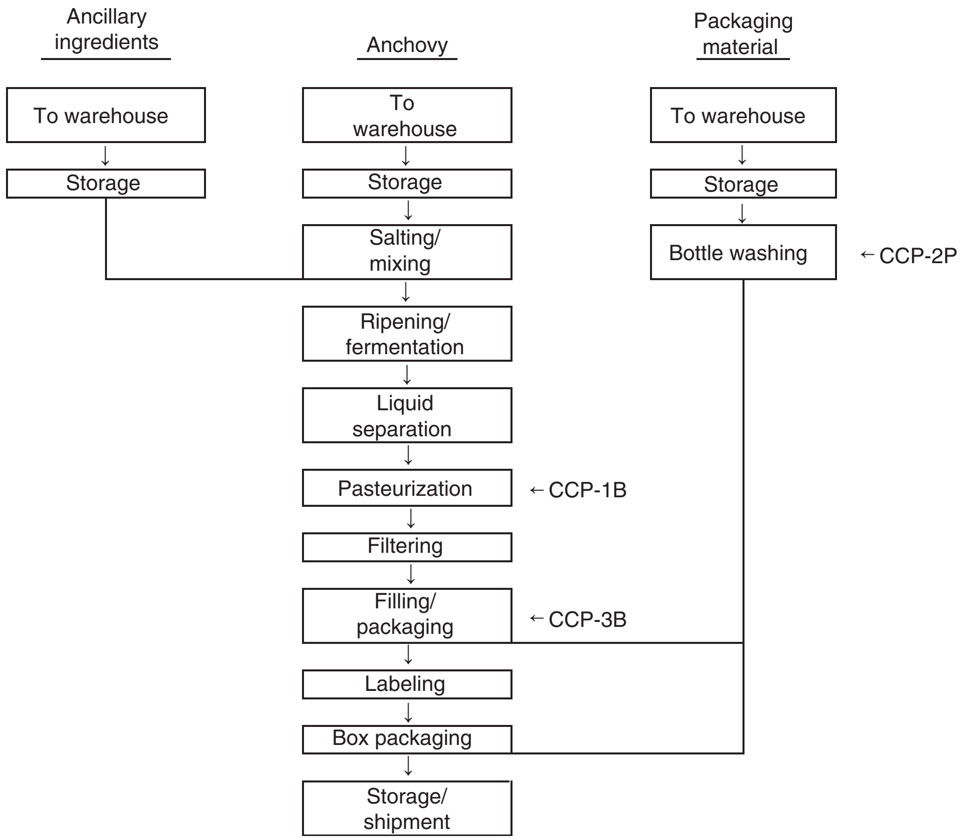

Figure 4 Flow chart of the procedure for liquid fermented anchovy, marked with CCPs.

are paying attention to their health and well-being. Keeping this in mind, companies are investing in cooling systems to produce refrigerated products with less salt. Following the HACCP, plan for liquid fermented anchovy is based on products that are produced not in a cooling system but in a traditional way (Figure 4). The possibility of pathogen growth results in a CCP at the pasteurization step (CCP-1B). Sufficient bottle washing is required to eliminate debris inside the bottle (CCP-2P). Proper filling and a packaging system (CCP-3B) are essential to prevent decomposition and microbial contamination due to poor sealing.

Fermented Vegetable Products

Kimchi is a unique fermented vegetable product with a long tradition in Korea. It is a common side dish served with cooked rice and other dishes. There are more than 50 varieties of *Kimchi* classified by the use of raw materials, processing methods, and the season and locality of preparation. Korean cabbage and Korean radish are the most popular vegetables for making *Kimchi*; but cucumber, carrot, onion, and even eggplant can be used as the primary vegetable. Fermented fish sauce is an important subingredient providing enzymes and flavor substances for fermentation. Salt, garlic, and red pepper play an important role in controlling the type of microflora in *Kimchi*. Production of organic acids at the cost of carbohydrates and resultant pH reduction contribute to maintaining freshness of the vegetables during the storage period.

A recipe for the simplest *Kimchi* may include Korean cabbage 100 g, garlic 2 g, green onion 2 g, red pepper powder 2 g, and ginger 0.5 g with an optimal salt content of 3.0%. Whole (or cut) cabbage is salted with 15% brine for 3–7 h, washed twice with fresh water, and drained. Other minor ingredients are chopped, combined, mixed with the treated cabbage, placed in containers, and tightly sealed. The length of time for completion of the fermentation depends on the salt content and temperature, 3 or 4 days at 20 °C and 2–3 months at 5 °C.

The content of reducing sugar decreases rapidly at the beginning of *Kimchi* fermentation, whereas the total acidity increases. The optimal pH and acidity for the best taste is 4.2 and 0.6% (as lactic acid), respectively. The number of aerobic bacteria decreases rapidly at the beginning of *Kimchi* fermentation, when anaerobic bacteria dominate. However, at the later stages of fermentation, surface film-forming aerobic bacteria start to grow, and texture softening and taste deterioration take place. During *Kimchi* fermentation, the type of microflora changes. The number of *Leuconostoc mesenteroides* decreases after 10 days of fermentation in a 3.5% salt content at 14 °C, whereas *Lactobacillus plantarum*, which is considered to be a key to the *Sauerkraut* production process, reduces the quality of *Kimchi*. It is also worthwhile to note that there is a considerable increase in the vitamin B group during winter *Kimchi* fermentation. That is, the amounts of vitamin B_1, B_2, B_{12}, and niacin may reach as high as twice the initial amounts at the optimal maturation of *Kimchi* and then decrease as the taste of *Kimchi* deteriorates due to overfermentation. Vitamins A and C are reduced slightly during the fermentation, but it is an excellent way of preserving these vitamins during the winter season.

There have been several controversial debates on the safety of *Kimchi* in terms of nitrate, nitrite, secondary amines, and biogenic amines. It was reported that the levels of nitrate in the vegetable decrease rapidly over 4 days of fermentation at 20 °C, whereas the contents of nitrite and secondary amines increase slightly and before decreasing. The change in nitrate reductase activity during *Kimchi* fermentation follows the same pattern as the change in nitrate concentration. This indicates that *Kimchi* fermentation reduces the nitrate level in vegetables through the action of microorganisms without increasing the concentrations of nitrite or secondary amines to any significant level.

The formation of nitrite and secondary amines during *Kimchi* fermentation was of great concern to many researchers in Korea in the 1970s. However, it was found that the amounts of nitrite and secondary amines in *Kimchi* were very low compared with those in sausages and fish. The possibility of nitrosamine formation during fermentation was investigated because fresh cabbages contain large amounts of nitrate varying from 55 to 2500 ppm. However, the levels of nitrate are reduced rapidly from 135 to 70 ppm after 4 days of *Kimchi* fermentation and further down to 50 ppm after 10 days of fermentation at 20 °C. Thus, the subject is of less concern.

To examine the biogenic amine contents in commercial *Kimchi*, eight types of *Kimchi* products were analyzed by HPLC. The biogenic amine contents were between 0 and 150 mg kg^{-1}, which is an acceptable level for human health. The putrescine and cadaverine levels seem to be slightly high in the *Baechu Kimchi* sample compared with those of other samples. To reduce these amines, addition of *Jeot-gal* can be adjusted because the biogenic amines in *Jeot-gal* are transferred to *Kimchi*.

It is well known that *Kimchi* has strong antipathogenic and antimicrobial activities. In fact, *Clostridium perfringens* disappeared after 2 days of *Kimchi* fermentation; *Staphylococcus aureus* and *Salmonella typhimurium* after 4 days; and *Listeria monocytogenes*, *Vibrio parahaemolyticus*, and *E. coli* after 5 days, whereas the number of lactic acid bacteria increased from 10^5 to 10^8. This antimicrobial effect of *Kimchi* appears to result from the combined effects of the organic acids and bacteriocin produced during fermentation, and the *Kimchi* ingredients (garlic, onion, ginger, etc).

Contamination with parasite eggs in *Kimchi* imported from China was a big scandal in Korea in 2005. The types of parasite

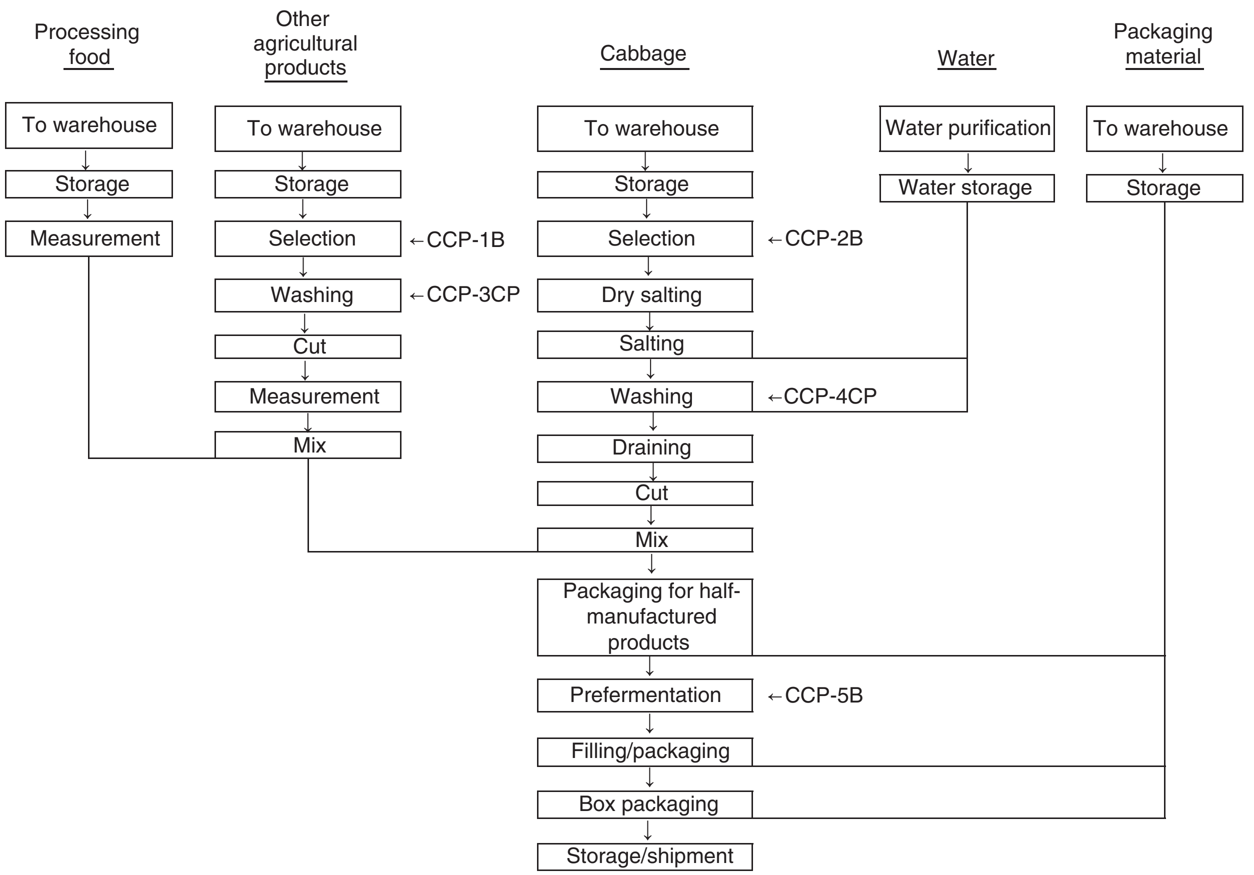

Figure 5 Flow chart of the procedure for *Baechu Kimchi*, marked with CCPs.

eggs found in *Kimchi* were *Ascaris lumbricoides* (roundworm), *Ancylostoma duodenale* (hookworm), *Trichostrongylus orientalis*, and *Isospora belli*. Although parasite eggs are mostly inactivated in *Kimchi* juice, which contains 3–5% salt, 0.8% organic acids (mainly lactic acid and acetic acid), and CO_2, the KFDA considered this issue as a safety incident at that time. It created a severe trade conflict with China, and the import and export of *Kimchi* were severely damaged.

To identify potential problems and possible corrective actions in the production of *Kimchi*, the KFDA has suggested the HACCP model, as shown below (Figure 5). Several CCPs (CCP-1B, CCP-2B, CCP-3CP, CCP-4P, and CCP-5B) have been identified by the analysis of biological, chemical, and physical hazards. Because *Kimchi* is a ready-to-eat product, a hazard analysis must be conducted to determine whether there are food safety hazards that are reasonably likely to occur. Among these items of hazard analysis, both microbiological evaluation and detection of pathogens of cabbages, ingredients, instruments, utensils, employees, and working area are essential. Therefore, the selection steps CCP-1B and CCP-2B (choosing good raw materials and removing decomposition and spoilage parts from materials) in the beginning of the HACCP plan is very significant for preventing pathogens, molds, parasites, and other contaminations from the raw materials to the final products.

The next step to consider is the washing procedure for other agricultural products and cabbages (CCP-3CP and CCP-4CP). Sufficient washing in accordance with the standard operating procedure (SOP) can help to remove the pesticide residues and foreign substances. Unlike other HACCP plans, the prefermentation step (CCP-5B) can be a critical point in making *Kimchi* because inappropriate temperature and time can result in abnormal fermentation.

Another example of pickled vegetable products, *Danmooji* (also known as *Takuan* in Japan), can be introduced. It is made from radish and used widely in Korea and Japan. In addition to being served alongside other types of Korean dishes, it is also used as a filling for *Kimbab* (rice roll in laver sheet). *Danmooji* is made by first salting radish, desalting it, and seasoning it with vinegar and sugar. The finished *Danmooji* is usually yellowish because food industries use coloring agents for this effect. The HACCP plan for *Danmooji* suggested by KFDA indicates five CCPs (CCP-1C, CCP-2CP, CCP-3B, CCP-4B, and CCP-5B) (Figure 6). They include proper seasoning preparation (CCP-1C) not to exceed the limits of food additives, proper washing (CCP-2CP) to remove the pesticide residues and foreign substances, proper filling/packaging (CCP-3B) to prevent decomposition and microbial contamination from poor sealing, and proper pasteurization (CCP-4B) and proper cooling (CCP-5B) to ensure microbial contamination and growth at the final stages. The amount of free chloride (more than 1 ppm) is required to maintain microbiological control in cooling water.

HACCP systems introduced in this article are one of the models that verify the safety of traditional foods. To ensure the validity and the good performance of a HACCP system, the system must be applied in combination with other food safety

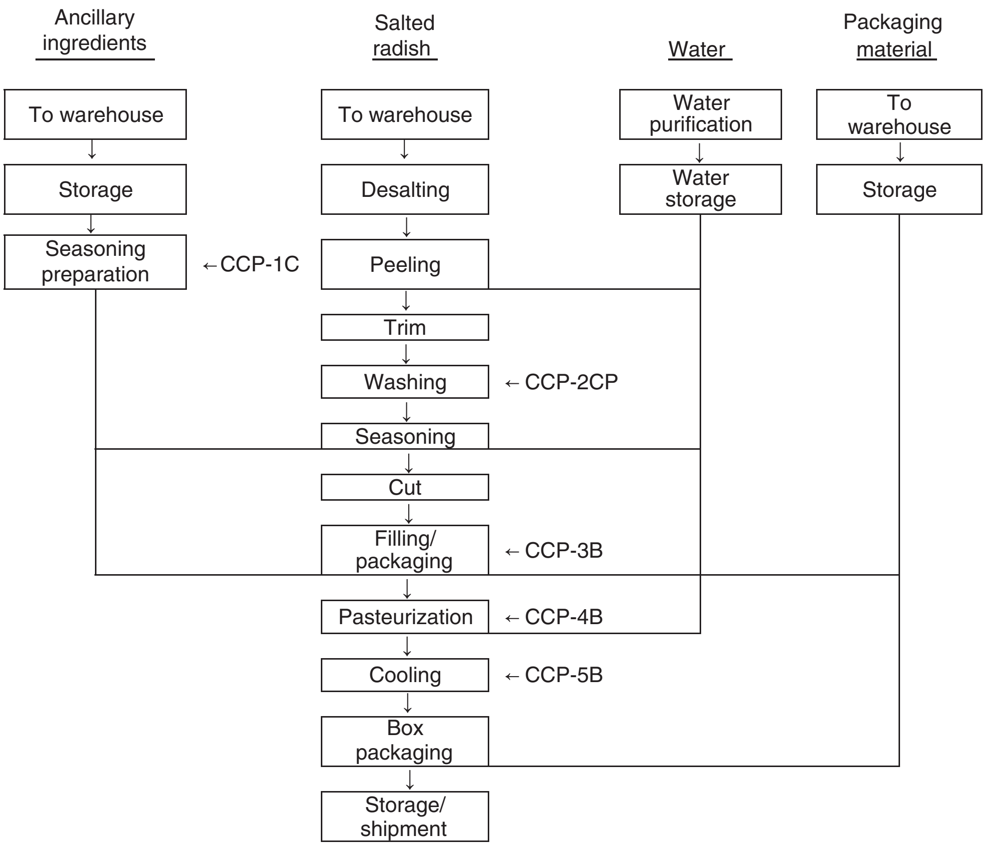

Figure 6 Flow chart of the procedure for salted radish (*Danmooji*), marked with CCPs.

assurance systems, such as good manufacturing practice (GMP), good handling practice (GHP), as well as personnel training. In fact, quite a number of industries have already obtained certification schemes, such as good agricultural practice (GAP), GMP, GHP, and International Organization for Standardization (ISO) standards. In addition, international standards, such as Codex standards, can facilitate the global trade of traditional foods as free trade agreement is increasing between countries. *Kimchi* was first registered in Codex in 2001, followed by *Gochujang*, *Doenjang*, and *Ginseng* in regional Codex 2009. Having Codex standards for more traditional foods will facilitate exports.

See also: History of Food Safety and Related Sciences: History of Foodborne Disease in Asia – Examples from China, India, and Japan

Further Reading

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