

"Kamaboko," an immensely popular staple in the Japanese diet, gives U.S. fishery products researchers food for thought.

"Kamaboko"—The Giant Among Japanese Processed Fishery Products

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ABSTRACT

About 25 percent of the Japanese fish catch is processed into "Kamaboko," an elastic heat-pasteurized fish cake. In 1970, over 1 million metric tons of "Kamaboko"-type products were produced. To make "Kamaboko," the fish muscle is separated mechanically from skin and bones, washed, and mixed with other ingredients while being ground into a sticky paste. The fish paste is then shaped and heat-pasteurized. The authors describe factors affecting the quality of "Kamaboko."

INTRODUCTION

The fish catch of the United States in 1970 totaled 2,758,300 metric tons, of which about 66 percent was utilized as food. About 40 percent of the total catch was marketed fresh or frozen, 24 percent was canned, and 2 percent was cured. Even though the per capita consumption of fishery products remains at about 10 to 12 pounds, the consumption of fishery products in the United States has been increasing owing to the increase in population.

Most species of fish for which a strong consumer demand exists are fished intensively. Many are overfished. To provide for this increasing demand, we must therefore look toward those few resources that remain underutilized and develop methods of preservation and processing into products that will be attractive to the domestic consumer.

In comparison, the consumption of fish in Japan is among the highest per

capita in the world. The fish catch of Japan in 1970 totaled 9,314,300 metric tons, of which 80 percent was utilized as food (Figure 1). The Japanese use several hundred different species of fish to produce a wide variety of processed fishery products. Dependence on seafood as the principal source of animal protein has resulted in the use of this protein in many ways that are unique to the Japanese. Some of these products and processing procedures could have application to the use of the fishery resources of the United

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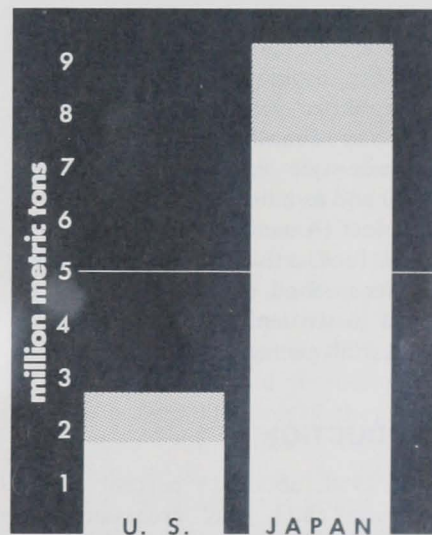


Figure 1.—The U.S. fish catch in 1970 totalled 2.7 million metric tons, of which about 66 percent (unshaded area) was utilized as food; the 1970 fish catch in Japan totalled 9.3 million metric tons, of which 80 percent (unshaded area) was utilized as food.

States for food. This paper is the first in a series to describe some Japanese fish products, processing techniques, and how we might apply them in the United States.

The products that may be of most interest to American food processors appear to be "Kamaboko" and fish sausage. "Kamaboko" and fish sausage are produced by grinding raw fish muscle with salt and other ingredients

and then cooking. They are marketed in a variety of forms, textures, flavors, and even colors. All of these properties can be modified to suit the demands of U.S. consumers. This paper describes the preparation and properties of "Kamaboko"—a Japanese-style fish cake.

The Japanese word "Kamaboko" is used in two ways. As a generic term, it is the name of an elastic or rubbery Japanese-style fish cake. As a specific term, kamaboko (used in this paper with no quotation marks) is the name of a particular type of fish cake.

"Kamaboko," the elastic fish cake, is made with ground fish muscle as the principal ingredient; starch as a thickening agent; and sugar, salt, and monosodium glutamate for flavoring. The mixture is heat-pasteurized by steaming, broiling, immersing in boiling water, or deep-fat frying. "Kamaboko" is described by others as a Japanese-style fish paste (Tanikawa, 1971) and as a fish product resembling meat loaf (Amano, 1965). It is a traditional food relished by the Japanese and its method of production can be found in written Japanese documents of the 15th century.

PRODUCTION

In 1968, about 25 percent of the Japanese catch was processed into "Kamaboko" products and fish sausages. Close to 1 million metric tons of product were made as follows (Tanikawa, 1971):

Product	Production (metric tons)
Chikuwa	194,035
Kamaboko	336,365
Satsumaage	289,501
Fish sausage and hams	161,753
Others	17,722
Total	999,376

In comparison, the total production of these products in 1958 was 436,592 metric tons (Figure 2) and in 1970 was 1.08 million metric tons (Anonymous, 1971).



Figure 2.—Production of "Kamaboko" products and fish sausages in Japan more than doubled from 1958 to 1968.

The following factors were instrumental in the rapid growth of "Kamaboko" production:

1. With the recent rise in incomes, changes in the dietary patterns resulted in a greater consumption of proteinaceous and ready-to-eat types of foods.
2. Appearance and flavor of "Kamaboko" can be easily altered to meet consumer demands by adding various ingredients to the minced flesh.
3. Underutilized species and fish having low acceptance because of flavor deficiencies or poor appearance in the fresh state can be used successfully as raw materials.
4. Recent development in processing machines permits large-scale production.
5. Keeping quality has been improved with recent advances in packaging and processing.
6. Basic studies on fish muscle protein have hastened the development of a technology that improves quality and the economics of production.

TYPES OF "KAMABOKO"

"Kamaboko" is made in various shapes, colors, and flavors depending upon the ingredients and heating methods used. The three main types are as follows:

1. Kamaboko (used as a specific term): a fine-textured white elastic fish cake that is mounted on a small board and cooked by steaming and/or broiling.

2. Chikuwa: a tubular-shaped fish cake, which is cooked by broiling.

3. Satsumaage: a deep-fat fried fish cake made in various shapes such as a ball, square, disk, or cylinder.

MANUFACTURING PROCEDURE FOR "KAMABOKO"-TYPE PRODUCTS

In making "Kamaboko," the muscle from headed-and-gutted fish is separated from skin and bones, washed with water, and mixed with other ingredients while being ground into a homogeneous sticky paste. The fish paste is then shaped and heated.

Separation of Flesh

The fish are headed and eviscerated. After washing, the headed-and-gutted fish are put through a flesh-separator machine, which has either a perforated steel drum or plate and a press. The fish is passed under the press, which forces only the muscle through small holes of the perforated drum or plate, thus conveniently and effectively separating muscle from skin and bones.

The yield of minced flesh depends on the pressure applied to crush the fish as well as on the species of fish used. The yields of flesh from Pacific Ocean fish using a small drum-type separator varied from about 28 percent for Pacific cod to 66 percent for Pacific herring (Miyachi and Steinberg, 1970).

Washing the Flesh

The separated minced flesh is washed well with chilled water to remove blood, flesh pigments, mucus, and fat. Washing improves the color and odor of the muscle and significantly improves the elasticity of the processed product.

One part by weight of flesh is stirred with five to seven parts by weight of water in a tank, the flesh is allowed to settle, and the supernatant

is removed. The same volume of chilled water is added again to the flesh and stirred. The washing operation is repeated three to five times. The washed flesh is dewatered by pressing or centrifuging.

Grinding Fish Muscle with Ingredients

The dewatered minced flesh is reduced to a pulp in a meat chopper and then ground with salt and other ingredients in a stone mortar for 30 to 50 minutes. The stone mortar has three or four pestles which rotate while pressing the inside of the mortar. By the kneading and crushing action of the pestles, the texture of the muscle is gradually demolished and ingredients are mixed uniformly into a sticky paste. The temperature of the flesh mixture is kept below 15°C (59°F) during this grinding by using prechilled or refrigerated stone mortars, which serve to absorb the heat generated during this operation.

The ingredients used in "Kamaboko" vary widely according to the type of product, the cost, or the locality of the production. Salt content ranges from 2.5 to 4 percent. Lower salt content results in poor texture, and a higher content gives too salty a taste. Sugar and monosodium glutamate are most commonly used as flavoring ingredients. Sodium inosinate, flesh extractives, or "mirim" (specially flavored rice wine) are also used as flavor intensifiers. Egg white is added to improve the glossiness of the product. Starch is added when necessary to improve elasticity of the product. More starch is used in cheaper products because starch enables the addition of as much as two to three times its weight of water while maintaining the desired cohesiveness.

Shaping

"Kamaboko"-type products are made into different shapes and sizes by machines. Each of the three main types—kamaboko, chikuwa, and sat-

sumaage—has its own shaping machine. The ground fish paste is shaped as soon as possible after preparation because the fish paste often sets, if stored, and then cannot be shaped. Since setting occurs more rapidly at higher temperatures, the fish paste is kept chilled to prevent setting.

Cooking

Three main types of cooking processes are used: steaming, broiling, and deep-fat frying.

Steaming is used for most kamaboko today; the raw kamaboko on the wood board is cooked continuously as it is conveyed through the steam box.

Broiling, formerly the cooking process for all kinds of "Kamaboko," is now used mainly for chikuwa, the tubular fish cake, and for a high quality "Kamaboko" called "yakinuki kamaboko" (broiled kamaboko).

Deep-fat frying is used for satsumaage. Soybean, rapeseed, and sesame seed oils are the usual frying oils.

After cooking, the fish cakes are rapidly cooled and packaged.

FACTORS AFFECTING QUALITY OF "KAMABOKO"

Elastic Quality or "Ashi"

The distinctive eating characteristic of "Kamaboko" is its elastic quality, called "ashi" in Japanese. Elasticity and flexibility are the basic characteristics of a good "ashi." In addition to being a determining factor of the eating quality, "ashi" also affects the appearance, especially glossiness, and the keeping quality. "Kamaboko" with better "ashi" has better appearance and better keeping quality.

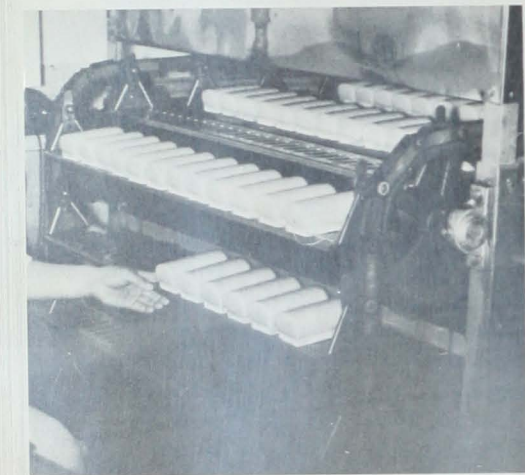
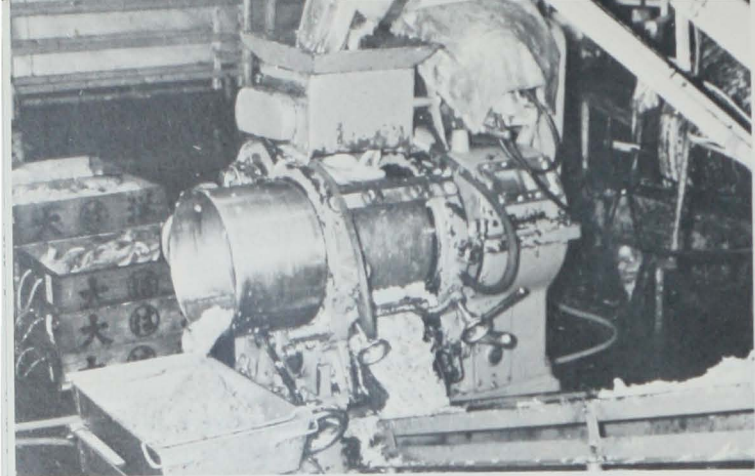
The "ashi" of "Kamaboko" depends on factors such as the species of fish used, freshness of the fish, and processing techniques. The best quality "Kamaboko" is produced from fish that have the proper gel-forming capacity and by the use of good established processing techniques.

Species

It is well known that "ashi" or elasticity of "Kamaboko" made from different species of fish varies greatly. For example, fish such as black marlin or croaker will make a very elastic product but many small pelagic fish and fatty fish such as sardines, mackerel, or saury will make products with very poor elasticity. Some of these fatty fish immediately after death, however, will make good elastic products, but their "Kamaboko"-forming capabilities decrease rapidly after rigor mortis sets in. After these fish have been iced for two or three days, they make only a crumbly product.

Lizardfish is considered one of the best raw materials for "Kamaboko" in those areas where fish can be caught in nearby waters and can be processed soon after catching; but lizardfish loses its high "Kamaboko"-forming capabilities within three or four days of iced storage after catch. The gel-forming capability of black marlin and croaker, on the other hand, is not markedly affected by their freshness. Even after being iced for periods as long as two or three weeks, they make an elastic "Kamaboko." Thus, the classification of species on the basis of their "Kamaboko"-forming capabilities is not easy. Fish having good gel-forming capability irrespective of freshness are regarded as the best raw material; and fish whose gel-forming capability is rapidly lost after catch are considered an inferior raw material. The suitability of a species for making "Kamaboko" must be judged by the functional properties of the muscle proteins at the time the fish is processed into "Kamaboko."

According to experienced "Kamaboko" producers, the age of the fish, fishing ground, and the time of year are important factors. Young fish have better "Kamaboko"-forming capability than old fish, and fish immediately after spawning have the lowest "Kamaboko"-forming capability.



Some of the various parts of the process in producing surimi and "Kamaboko," from top left, counterclockwise: Flesh separation by machine; surimi ready for packing in polyethylene bags; conveyer bringing "Kamaboko" from continuous cooker; cooling "Kamaboko"; storage of frozen surimi; a view of the interior of a Japanese surimi and "Kamaboko" plant (1967 model) including wash tanks for extruded flesh, a centrifuge, hydraulic press, strainer, and block former.



Relation of "Ashi" to Extractability of Myofibrillar Proteins

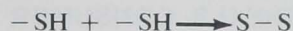
"Kamaboko" with good "ashi" is produced from fish muscle containing nearly maximum amounts of extractable myofibrillar protein. It cannot be produced from denatured muscle proteins such as those found in dried, salted, or poorly stored frozen fish.

A concentration between 1.2 and 1.5M NaCl gives maximum extraction of myosin from fish muscle as well as the best resiliency in the finished product (Shimizu et al., 1954; Shimizu and Simidu, 1955). The use of salt at these concentrations, however, would make the product too salty, and 2.5 to 3.5 percent (0.4 to 0.6 M) NaCl is used in the commercial "Kamaboko" production. The enhancing effect of polyphosphates on the elasticity of the product is attributed in part to their ability to extract myofibrillar proteins.

Formation of Network Structure

Elasticity of the finished product is also a function of cooking temperatures (Okada, 1959). "Ashi" is usually the poorest when the fish paste is cooked between 60°C (140°F) and 65°C (149°F) and is best when cooked rapidly at higher temperatures. This suggests that there is another important factor besides extraction of myofibrillar proteins that influences the elasticity of "Kamaboko." This factor is the formation of a network of myofibrillar proteins. The threadlike shapes of the myofibrillar proteins are suitable for building up the network structure of "Kamaboko." The increase in elasticity that results from the addition of very small amounts of oxidants indicates the existence of such a structure (Okada and Nakayama, 1961). Thus, the addition of 0.1 to 0.2 percent potassium bromate to horse mackerel muscle during grinding with salt improves the jelly strength of the cooked product. Comparative measurements of elasticity and the content of

free sulfhydryl groups of "Kamaboko" showed that elasticity is increased as free sulfhydryl groups are decreased by the addition of bromate. The effectiveness of bromate might be attributed to crosslinking of polypeptide chains by the reaction:



Thus, formation of good "ashi" requires both the extraction of myofibrillar proteins from the muscle and the formation of a network structure of the extracted proteins.

Water-Soluble Proteins and "Ashi"

Elasticity of "Kamaboko" can be improved significantly by washing the muscle before grinding. A large amount of the fat and water-soluble substances can be removed from the muscle by the washing process. The improvement in "ashi" of the product, however, is not attributable to the removal of fat because no significant decrease in "ashi" is observed by the addition of as much as 10 percent fat to the washed muscle. Okada (1964) has demonstrated that water-soluble proteins have deleterious effects on "ashi" formation. When concentrated water-soluble substances were added to the washed muscle, a significant decrease in "ashi" of "Kamaboko" was observed. Removal of the water-soluble protein from concentrated washings by heat coagulation before addition to the washed flesh produced no decrease in "ashi" of the "Kamaboko." The explanation has been offered that the water-soluble proteins reduce the elasticity of the "Kamaboko" by interrupting the continuum of cross-linked myofibrillar proteins or by interfering with the cross-linking process itself. It has also been proposed that proteolytic activity of the water-soluble protein fraction may adversely affect the ability of the myofibrillar protein to form cross-linkages.

KEEPING QUALITY OF "KAMABOKO"

Keeping quality of "Kamaboko" depends on a variety of factors but the ingredients used, processing temperatures, and packaging seem to be critical.

Ingredients

Owing to the nature of minced flesh, the potential for high bacterial contamination of the minced flesh during processing exists. Chilling, rapid handling, and thorough cleaning of the fish and good sanitation practices are essential for keeping the microbiological load of the minced flesh low. Other ingredients, in addition to the fish, affect keeping quality.

Kimata (1951) found that different types of spoilage of "Kamaboko" were due to the kinds and amounts of carbohydrates (sugar or starch) used as ingredients. Several investigators (Kimata and Kawai, 1951; Kimata and Sosogi, 1956; and Suzuki, 1959) have shown that starch is the primary source of thermotolerant bacteria responsible for spoilage. Potato starch, among the starches, is reported to contain the largest number of bacteria (as high as 5.0×10^4 per g) with about 70 percent of them thermotolerant.

Processing Temperature

During the processing, the temperature at the center of "Kamaboko" is highest when broiled, next highest when deep-fat fried, and is lowest when steamed. In one study, Yokoseki (1958), starting with raw fish paste containing about 10^7 bacteria per gram, found a considerable number of surviving micrococci when the "Kamaboko" was cooked to an internal temperature below 70°C (158°F); found 1.3×10^4 /g of aerobic spore-forming rods of *Bacillus* species and no anaerobes in "Kamaboko" cooked to 75°C (167°F); and found only $6.0 \times$

10¹/g of aerobic *Bacillus* in "Kamaboko" cooked to an internal temperature of 85°C (185°F). On the other hand, he usually found cocci in "Kamaboko" with starch cooked to an internal temperature below 70°C and found survivors that were mainly strict aerobic organisms such as *Bacillus megatherium*, *B. subtilis*, and *B. cereus* in those cooked to an internal temperature of 75°C and higher. Commercially, "Kamaboko" is cooked to an internal temperature about 75°C to give the product good keeping quality.

Packaging

Prevention of contamination by microorganisms in the air by packaging "Kamaboko" before or immediately after cooking is very effective in improving the keeping quality. Even a simple package such as a cellophane overwrap can increase the keeping quality as much as twofold. Vacuum packaging with laminated cellophane is a much better means of preventing bacterial growth. After vacuum packaging, the product is cooked again to kill the bacteria on the packaging material as well as the bacteria in the product.

The most effective method of preventing bacterial contamination is sealing the raw flesh paste tightly with a plastic film and then cooking above 75°C. The plastic film should be heat-resistant, gas- and water-impermeable, and heat-shrinkable. Vinylidene chloride fulfills these requirements.

Fish sausage, a semi-processed food, is a product packaged by this method; fish paste is packed into a casing of vinylidene chloride, sealed tightly with aluminum wire, and finally cooked in a hot water bath at 85° to 90°C for about 50 minutes.

"KAMABOKO"-TYPE PRODUCT AND THE U.S. CONSUMER

"Kamaboko" and fish sausage are produced by mixing fish flesh with salt and other ingredients, shaping in various forms, and then cooking to get elasticity or cohesiveness. These products are higher in protein and lower in calories than many processed meat products, such as wieners and bologna. As each nation has its own food preferences, the flavor and texture of Japanese "Kamaboko" is not always appealing to others. Whereas the Japanese prefer a rubbery "Kamaboko"-type product, the Americans generally prefer a wiener-like, only slightly elastic product. The flavor, texture, and appearance of the "Kamaboko"-type products can be easily modified to suit the preferences of the U.S. consumer by blending various species of fish and by varying the other food ingredients to obtain the desired flavor, texture, and appearance. The results of our studies along these lines are presented in some of the following papers.

LITERATURE CITED

Amano, K. 1965. Fish sausage manufacturing. In G. Borgstrom (editor), *Fish as food*, vol. III, p. 265-280. Academic Press, N.Y.

Anonymous. 1971. Zusetsu Gyogyo Hakusho (Illustrated Fisheries White Paper for 1971). In Zaidan Hojin Norin Tokei Kyokai (Agric. For. Coop. Found.), Tokyo, Japan, 319 p.

Kimata, M. 1951. Studies on the spoilage of "Kamaboko" I. On the appearance of the spoilage. [In Jap., Engl. summ.] Bull. Jap. Soc. Sci. Fish. 16:428-432.

Kimata, M., and A. Kawai. 1951. Studies on the spoilage of "Kamaboko" VII. Microbiological studies of refined starch on the market. [In Jap., Engl. summ.] Bull. Jap. Soc. Sci. Fish. 16(12):55-58.

Kimata, M., and T. Sosogi. 1956. Studies on the spoilage of "Kamaboko"—VIII. Microbiological studies of refined starch on the market (2). [In Jap., Engl. summ.] Bull. Jap. Soc. Sci. Fish. 22:269-272.

Miyachi, D., and M. Steinberg. 1970. Machine separation of edible flesh from fish. U.S. Fish Wildl. Serv., Fish. Ind. Res. 6:165-171.

Okada, M. 1959. Influence of cooking conditions on the jelly strength of *Kamaboko*. [In Jap., Engl. synop.] Bull. Tokai Reg. Fish. Res. Lab. 24:73-79.

1964. Effect of washing on the jelly forming ability of fish meat. [In Jap., Engl. summ.] Bull. Jap. Soc. Sci. Fish. 30:255-261.

Okada, M., and M. Nakayama. 1961. The effect of oxidants on jelly strength of *Kamaboko*. [In Jap., Engl. summ.] Bull. Jap. Soc. Sci. Fish. 27:203-208.

Shimizu, Y., and W. Simidu. 1955. Studies on jelly strength of *Kamaboko*—IX. On influence of salts (2)—sodium chloride. [In Jap., Engl. summ.] Bull. Jap. Soc. Sci. Fish. 21:501-502.

Shimizu, Y., W. Simidu, and T. Ikeuchi. 1954. Studies on jelly-strength of *Kamaboko*—IV. Influence of salts (1). [In Jap., Engl. summ.] Bull. Jap. Soc. Sci. Fish. 20:295-297.

Suzuki, S. 1959. On the thermotolerant bacteria in potato starch and wheat starch. Rep. Jap. Assoc. Fish Sausage Ind. 52:8.

Tanikawa, E. 1971. Japanese style fish meat pastes. In E. Tanikawa, *Marine products in Japan*. Size, technology and research, p. 340-421. Koseisha-Koseikaku Co., Tokyo.

Yokoseki, M. 1958a. Studies on the internal spoilage of fish-jelly products—I. Surviving micro-organisms in fish-jelly products cooked at different temperatures. [In Jap., Engl. summ.] Bull. Jap. Soc. Sci. Fish. 23:539-542.

1958b. Studies on the internal spoilage of fish-jelly products . . . II. Relationship between cooking temperatures and spoilage. [In Jap., Engl. summ.] Bull. Jap. Soc. Sci. Fish. 23:543-546.

MFR Paper 1019. From *Marine Fisheries Review*, Vol. 35, No. 12, December 1973. Copies of this paper, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.