

## Fish Sausage Manufacturing

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### I. Introduction

Fish sausage manufacturing in Japan is attracting world wide attention because of the rapid expansion of the industry, a growth rate that was never expected even by the entrepreneurs. Before the Second World War, experimental preparation of fish sausage had on occasion been tried by a few fish processing technologists, with rather unsuccessful results. The lack of suitable packaging materials was perhaps the main technological deterrent to the introduction of the new fish product in Japan, but in addition, consumers were not ready to accept a product of this kind. The fish sausage industry in Japan was actually begun in 1953

by small-scale manufacturers. Average daily production at that time was low, but the industry gradually grew and was taken over by large fishing firms that were able to obtain abundant raw material by using their own fishing fleets.

The remarkable increase in production may be seen in Table I: the 1962 output is almost twenty-five times larger than that of 1954. The following factors account for this rapid growth.

TABLE I  
ANNUAL PRODUCTION OF FISH SAUSAGE, 1954-1963

Year	Amount (metric tons)	Year	Amount (metric tons)
1954	4,081	1959	64,697
1955	11,978	1960	85,442
1956	26,103	1961	91,639
1957	38,217	1962	114,125
1958	49,190	1963	118,369

(1) The technological groundwork for the new industry had already been laid by the "kamaboko" manufacturers. "Kamaboko," another Japanese fish product, resembles meat loaf. The manufacture of fish sausage is quite similar to that of "kamaboko," except for the use of pork fat, spices, film casings, etc. Annual production of "kamaboko" is close to 0.5 million metric tons.

(2) A general improvement came about in the manufacture of synthetic materials, such as rubber hydrochloride or vinylidene chloride, for film casings. Prewar types of rubber hydrochloride were not suitable for food packaging because they left an unpleasant odor in foodstuffs. Postwar elimination of this drawback, along with the introduction of a new synthetic film, vinylidene chloride, aided development of the industry.

(3) A change has taken place in dietary patterns in Japan since the war, marked by increased consumption of meat, meat products, and milk, although the rice-eating habit is still firmly established. Thus, fish processed in the style of meat sausages has appealed to customers.

(4) The relatively low prices of fish sausages have fostered the industry; a 100-g. piece costs only 30 Yen (8.4 cents in United States currency). This brings wide marketability in rural sections where the living standard is lower than in urban areas.

(5) The use of chemical preservatives has been legally permitted in Japan and now plays a significant role in maintaining acceptable shelf-life of the sausages. (Time and temperature employed in processing are not sufficient to destroy all microorganisms.)

## II. Chemical Aspects

From the standpoint of consumer preference, the resilient quality of the finished fish sausage is an important factor influencing its general acceptance. The manufacturer's primary concern, therefore, is learning how to retain resiliency in the final product. This resiliency is related not only to the flavor but also to the keeping quality of the sausages. If the texture of fish sausage is coarse and inelastic, water exudes from the meat during storage and forms a small pool, ideal for bacterial growth, between film and skin.

The effect of resiliency is more pronounced in kamaboko since the latter are generally marketed without the film casing that averts direct microbial invasion. Exposure of the product surface of kamaboko permits rapid spoilage by allowing oxygen, that may promote bacterial growth inside, to enter freely. But the degree of air penetration differs with the texture. The resilient product is able to resist spoilage longer than that lacking this property (Yokoseki, 1959).

An explanation proposed for the elastic structure of agar-agar or gelatin jelly, an intertwined arrangement of their long-chained molecules that permits retention of water, can be applied to the resiliency of fish sausage or "kamaboko" (Okada, 1959a). The myosin of the fish flesh supposedly affects its structure. Apart from this, Okada and Migita (1956) observed by microscopic examination a fine network in thin slices of extra quality "kamaboko." Their finding led the authors to an opinion that a network structure of not only colloidal, but also microscopic, dimension may have something to do with the elastic property of "kamaboko," though an assumption that the elasticity of gel is due to the presence of a network structure of colloidal dimension has been generally accepted.

Miyake and Hayashi (1957) made a determination of the myosin content of 21 different fish (Table II). They observed that fish with less myosin gave a weaker resiliency when processed into "kamaboko."

Dark-fleshed fish, such as tuna or mackerel, show a comparatively small amount of myosin. Shimizu and Shimidu (1958) noticed, however, that myosin decreases in amount with storage time after catching, and suggested that the myosin yield might be larger in the flesh immediately after the capture.

Myosin in muscle tissue seems to be in an orderly, fixed arrangement, not free to regroup for the making up of a network. Possibly myosin must be treated with certain neutral salts before it becomes capable of such basic reorientation.

The reason for mixing common salt into fish sausage preparations is unquestionably to modify the flavor, but at the same time it affects the

extraction of myosin fraction from the fish muscle tissues. The key factor in reinforcing the jelly strength of fish sausage is in effect the myosin solubility. The use of salt, alkali, and/or polyphosphates is considered effective for this purpose.

TABLE II  
AMOUNT OF MYOSIN IN VARIOUS SPECIES

Species <sup>a</sup>	Dry matter (%)	Myosin (%)
1. Croaker ( <i>Nibea argentata</i> )	19.22	9.97
2. Croaker ( <i>Pseudosciaena manchurica</i> )	18.96	9.97
3. "Hira" ( <i>Ilisha elongata</i> )	20.40	8.22
4. Silver conger eel ( <i>Muraenesox cinereus</i> )	22.08	8.38
5. Cutlass fish ( <i>Trichiurus japonicus</i> )	29.95	2.62
6. Ray ( <i>Dasyatus akajei</i> )	18.57	2.27
7. Pacific saury ( <i>Cololabis saira</i> )	30.14	6.97
8. Flying fish ( <i>Cypselurus agoo</i> )*	28.92	9.90
9. Turbot ( <i>Limanda angustirostris</i> )*	20.42	6.99
10. Bluefin tuna ( <i>Thunnus thynnus</i> )	23.27	8.90
11. Mackerel ( <i>Scomber japonicus</i> )*	22.29	6.23
12. Sardine ( <i>Sardinops melanosticta</i> )	23.92	6.60
13. Cuttlefish ( <i>Sepia esculenta</i> )	26.53	9.64
14. Shark ( <i>Galeorhinus manazo</i> )	24.34	9.99
15. "Mutsu" ( <i>Scombrops boops</i> )	23.90	14.62
16. Sea bass ( <i>Lateolabrax japonicus</i> )	20.42	12.80
17. Horse mackerel ( <i>Trachurus trachurus</i> )	24.03	11.15
18. Ocean perch ( <i>Sebastiscus marmoratus</i> )	20.17	9.75
19. Squid ( <i>Sepioteuthis lessoniana</i> )	22.59	13.05
20. Snapper ( <i>Branchiostegus japonicus</i> )	19.50	12.31
21. "Hata" ( <i>Epinephelus septemfasciatus</i> )	18.44	11.42

<sup>a</sup> Fishes 1-7 were sent frozen to the laboratory. Japanese common names are in quotation marks; very fresh samples are marked with an asterisk. From Miyake and Hayashi, 1957.

#### A. SODIUM CHLORIDE AND MYOSIN EXTRACTION

Using mackerel meat, Shimizu *et al.* (1954b) observed that the amount of extractable myosin varies with the concentration of sodium chloride. A strength between 1.2 and 1.5 M NaCl solution gave a maximum extraction of myosin as well as the best resiliency in the finished product. Use of common salt in such an amount is not practical, however, since it makes the product very salty.

#### B. PH OF RAW JELLY

While grinding and mixing the raw fish jelly, adjustment of pH value to a pertinent range is another means of extracting myosin. The extractability of myosin is greater when the pH of the flesh is slightly alkaline.

Shimizu *et al.* (1954a) demonstrated that the jelly strength of the finished product was lower, although the amount of extracted myosin was greater, on the alkaline side. Perhaps high pH media prevent network formation. Okamura *et al.* (1959) reported a close correlation between the pH value of raw jelly and jelly strength of the cooked product and added the observation that the jelly strength decreased as the pH value of the raw fish jelly exceeded 7.5. In cases where tuna or marlin is used as the main ingredient in fish sausage, a slight shift of pH to about 7 may be effective in attaining good resiliency, because the original pH values of the flesh of these fish lie in the range 5.6–6.0, i.e., more acid than that of white fish. No adjustment of pH is required to make fish jelly from species such as Alaska pollock, croaker, and lizard fish, since the natural pH values of the flesh from these species range between 6.5 and 7.0 or more.

### C. POLYPHOSPHATES

Polyphosphates are added to raw fish jelly in order to attain greater resiliency in the finished product. By measuring the jelly strength, breaking strain, and amount of expressible water, Okada and Yamazaki (1958) examined the effect of polyphosphates on the texture of fish sausages. Concentrations from 0.2 to 0.5% of the product were found most effective, with the upper limit impairing taste. With regard to both palatability and meat-binding, concentrations between 0.2 and 0.3% are preferable when using commonly available polyphosphates.

The effect varies with cooking temperature. Resiliency increases proportionally with the temperature up to 80°C., but drops sharply when the temperature exceeds 90°C. This is explained in part by excessive denaturation of meat protein at the higher temperature, and in part by hydrolysis of polyphosphates to less effective orthophosphates under heating. Tripolyphosphates have been found best for improving resiliency.

Shimizu and Shimidu (1953) examined the effect of NaCl, LiCl, and KCl for their effect on the solubility of myosin from mackerel meat and found no appreciable differences in the effects of these salts. Anions, however, seem to affect the solubility to some degree. Using potassium salts with different anions, the strengthening effect on the jelly increased in the following order:  $\text{SO}_4^- < \text{Cl}^- < \text{Br}^- < \text{I}^-$ . Iodine ions proved most active in solubilizing the proteins.

### D. SETTING PHENOMENON OF RAW FISH JELLY

Raw fish jelly normally has a glutinous texture immediately after the preparation. This is a commonly observed characteristic of fish meat that has been ground and mixed with sodium chloride. On standing, this

texture changes, gradually giving a kind of elastic response. The phenomenon of losing the adhesive property of the ground meat has been referred to by "kamaboko" manufacturers as "setting" (literally translated from Japanese term). It is believed to be disadvantageous because "set" meat is hard to mold into a product of desirable shape. The same is true of fish sausage processing, since raw fish jelly with low viscosity is difficult to stuff into film casing.

The explanation for the setting phenomenon has not been found. After extensive works by using various kinds of metallic and alkali earth salts, Migita and Okada (1952) postulated that the water-binding capacity of fish muscle protein is playing an important role in these physicochemical changes. These workers assumed that the setting is caused by hydration of protein molecules on which certain anions are adsorbed by their surface active property. These molecules are subsequently brought into a kind of network formation. The solubility of myosin is reduced as the setting proceeds in the raw fish jelly. Myosin molecules arrayed in the network may be no more soluble than those just dissolved in neutral salt (Okada, 1959b).

Easiness of setting varies with each species of fish. There seem to be few effects that can be attributed to environmental conditions. Fish

TABLE III  
A GROUPING OF FISH ACCORDING TO EASE OF SETTING<sup>a</sup>

Fish that set readily	Sardine, round herring, lizard fish, flying fish, barracuda, mackerel, hairtail, horse mackerel, goby, Alaska pollock, turbot
Fish that set moderately well	Croaker, flounder, plaice, cod, bonito, yellowtail, big-eye tuna, sea bass, rockfish
Fish that hardly set	Conger eel, carp, saury, dolphin ( <i>Coryphaena sp.</i> ) yellowfin tuna, black marlin, shark

<sup>a</sup> From Okada, 1959b.

species grouped according to the degree of ease with which their flesh sets are given in Table III. Much more research is needed to explain the specific characteristics of setting.

### III. Raw Materials

#### A. RAW FISH

Almost any kind of fish can be used to make fish sausage, since chopping and grinding of the flesh are involved in the course of processing. In Japan, however, tuna varieties are preferred, possibly because the meat color stands up well in the finished product. Croaker or lizard fish are used in kamaboko, where a white product is preferred.

Yellowfin tuna, big-eye tuna, and black marlin are the main species employed but whale meat may also be used. Bluefin is most often consumed "sashimi" style (one of the indispensable dishes for a Japanese cook), and is seldom processed into fish sausages. Albacore is not used either, as this variety is generally canned or frozen for subsequent canning.

In the quick expansion of the industry, the tuna shortage has become a significant problem and recently such fish as croaker, Alaska pollock, horse mackerel, and shark have been mixed with tuna. These fish are probably chosen for two reasons: (1) their suitability for this product and (2) their abundance.

More than two species of fish are usually blended, because tuna flesh alone does not give the product sufficient resilience.

#### B. STARCH

In general, starch is added, in the proportion of 5–10% of the sausage weight, as a thickening. This is not necessary, however, when fish yielding a good jelly strength are available. Alpha-type starch, moreover, does not improve the resilient texture. Too much starch might be construed as an attempt to replace fish with a cheaper ingredient.

Potato starch gives better jelly strength than wheat starch, but is usually loaded with more bacteria, particularly heat-resistant spore formers of soil origin. These spores may survive heat processing and cause spoilage during transportation and storage of the product. An effort to reduce the bacterial contamination of potato starch has been made by producers with promising results. Corn starch is satisfactory.

#### C. FAT

Since the major varieties of fish made into fish sausage are normally lean, fatty tissue of pork and/or shortening oil are generally mixed into the product. Diced pork fat, with about 0.5 cm. of edge, is mixed into the raw fish jelly, so that the cut surface of sausage may show a mosaic pattern of white fat tissue scattered throughout the red flesh portion. An average amount of fat added is about 5%, although this differs considerably with individual maker's recipes.

#### D. SPICES

Spices are generally added for flavoring; these include pepper, nutmeg, mace, allspice, sage, clove, cinnamon, cardamon, garlic, onion powder, and mustard. Milled spices, however, can also be a source of contamination by soil-borne bacteria. To render a smoke aroma, a liquid

smoke concentrate needs to be employed, as smoke per se would normally not permeate artificial casings.

#### E. FOOD ADDITIVES

Because of the dull color of cooked tuna or whale meat, coloring agents such as amaranth, erythrosin, and Ponceau SX are widely employed by the industry.

Sodium or potassium nitrite can be used to retain the color of tuna and whale meat. The maximum permissible amount of the nitrite is 0.05 g./kg. of the product. The nitrite is added when the raw tuna or whale meat is cured with common salt under refrigeration for 10–20 hours.

Polyphosphates are incorporated into the fish sausage during the grinding process. Basic polyphosphates make the flesh alkaline and affect the solubility of protein as mentioned earlier (Section II,C). Pyrophosphate or tripolyphosphate exerts a weak bacteriostatic action, possibly due to its capability of chelating minerals (Vishniac, 1950; Dirheimer and Jean-Pierre, 1956). The growth of *Bacillus pantothenticus*, which causes "softening spoilage" of fish sausage, can be partially arrested by these polyphosphates (Uchiyama and Amano, 1959).

Taking advantage of the broad-minded attitude of public health authorities, three different chemical preservatives are being used by the industry. In Japan, legally approved preservatives, confined to fish sausage and "kamaboko," are 5-nitro-2-furfural semicarbazone, nitrofuryl acrylamide, and sorbic acid. Additions of 0.005 g. of the nitrofurazone/kg., or 0.02 g. of the acrylamide, or 2 g. of sorbic acid are designated as maximum permissible amounts.

It is quite obvious that the industry could have developed to the recent level of production more quickly if the shelf-life of the fish sausage had been improved from the start by more extensive use of these preservatives. But there prevails some uncertainty about their toxicity. Keeping fish sausage in a refrigerated show case is more desirable, particularly at retail stores, than the use of chemical preservatives; however, the reversion of starch to beta-forms is a drawback in the storage of the product at low temperatures.

#### F. CASINGS

Artificial casings now in use are vinylidene chloride and rubber hydrochloride. No natural casings of animal origin are employed. Each film possesses its own merits and drawbacks. Rubber hydrochloride is elastic and tough, so it is shrinkable when heat processed. But it is opaque, rather permeable to gas, and liable to become brittle under direct sunlight or after long storage. Vinylidene chloride film is less permeable, transparent, and chemically inert, but is not resistant to strong



mechanical injury. Both films tolerate a temperature of 100°C. for 1 or 2 hours, but lately the vinylidene chloride film is becoming more widely used.

#### IV. Preparation and Processing

After washing and dressing the raw fish, fillets of the proper size are placed in meat mincers of the motor-driven type in order to comminute the flesh. When frozen fish is allotted for preparation, the thawing process must come first. However, a complete thawing may not be necessary, because ordinary meat mincers operated with motors can be used on semithawed fillets. This is even an advantage, since ice crystals remaining in the tissues lessen damage from heat generated during the grinding operation.

The minced flesh is placed in a food cutter or a kneading machine and subjected to high-speed cutting or continuous grinding for about 10 min. The flesh is watched carefully for the onset of jelly formation. Whether the use of a food cutter or of a kneading machine is more beneficial for the final texture of the sausage is a matter of personal choice. Normally, a preparation from a food cutter has a less compact texture than that from a kneading machine. The latter is better for macerating the muscle fiber since a tripod pestle runs through the basin bottom; it gives a texture resembling "kamaboko," with a smooth cut surface. Owing to the friction between pestles and the bottom, the kneading machine is apt to generate heat during operation and may consequently cause heat denaturation of the fish meat protein, which is detrimental to attaining good jelly strength. To avoid high heat generation, the basin of the kneading machine is usually made of stone (granite), the pestles of wood. In some cases, crushed ice is added to keep the meat cool.

Approximately 1–2 min. after starting the operation in these machines, about 3% sodium chloride is added to the ground meat. This addition brings about jelly formation in the meat being ground, as a result of the muscle protein dissolving in the presence of salt. During the grinding other ingredients, such as starch, spices, monosodium glutamate, artificial color, and chemical preservatives, are also added. They may be mixed in, one after the other, but are usually all dissolved in water previously.

Toward the end of the grinding and mixing, diced pork fat tissue is added. This gives the mosaic pattern of fat and meat, mentioned earlier, when the sausage is sliced. Similarly, diced tuna meat that has been processed overnight with a curing agent is mixed into the ground flesh during the last part of the grinding operation. Products prepared in this fashion are called "ham-style."

It is very necessary to keep the fish jelly at a low temperature during

grinding and prior to heat processing. Major Japanese fish sausage plants are now equipped with air-conditioned facilities, particularly for the butchering and grinding operations. Average temperatures of the fish jelly before heat processing range from 10° to 15°C.

The fish jelly thus prepared is then transferred to a stuffer. Stuffing is not very different from that practiced in meat sausage making. However, closing the end of the casing after the fish jelly is stuffed is much more mechanical. A semiautomatic closing machine seals one end of the casing with aluminum wire. The other end has been sealed in a similar way by the casing manufacturer before delivery. More recently, fully automatic closing machines have been developed that include a mechanism to wrap the fish jelly with a film sheet which subsequently is sealed in a high frequency field.

The sealed sausages are then taken by conveyer through the lower section of a large cooker filled with water at a temperature between 90° and 95°C., where they are heat-processed. A continuous heat processing machine is able to process about 100,000 pieces of fish sausage, each weighing 120 g., in 8 hr. Sausage with a diameter of 3 cm. are heated to a temperature of 85°C. for 20 min., then the pieces are dipped in water heated to 90°C. for 50 min.

The continuous cooker is linked to a cooling tank, in which is a conveyor similar to that in the cooker; 30–40 min. are required to cool the processed fish sausage. With rubber hydrochloride casing, the surface of the film becomes wrinkled when cooled, but a 10- to 30-sec. dip in hot water smooths it. This step, however, is not necessary when vinylidene chloride film is used.

After heat processing and cooling, the finished products are wrapped with cellophane paper, packed in cartons, and marketed.

## V. Recipes

Recipes differ considerably with each plant and change with the season even in the same plant because of the pattern of fish landing. The following recipes have been obtained from five different plants. It is noteworthy that in each case either black marlin or croaker, both of which act as binding materials in fish sausage, is used.

### A. WHALE MEAT AND TUNA

Equal amounts of black marlin, yellowfin tuna, and big-eye tuna	60 parts
Whale meat (blue or fin whale)	40 parts
Common salt	2–3 parts
Spice mixture	0.5 part

## B. SALMON AND TUNA

Black marlin	30 parts	Wheat starch	5-8 parts
Yellowfin tuna	20 parts	Cane sugar	1.5 parts
Big-eye tuna	20 parts	Common salt	3 parts
Salmon	20 parts	Spice mixture	Not specified
Pork fat	10 parts		

## C. SHARK, TUNA, AND SALMON

Black marlin	40 parts	Pork fat	10 parts
Yellowfin tuna	40 parts	Potato starch	10 parts
Shark	5 parts	Common salt	3 parts
Salmon	15 parts	Spice mixture	0.5 part

## D. CROAKER AND TUNA

Due to the shortage of marlin this sausage type has been developed:

Yellowfin tuna	50 parts	Wheat starch	6 parts
Big-eye tuna	20 parts	Na-glutamate	6.2 parts
Croaker	20 parts	Cane sugar	2 parts
Pork fat	8 parts	Common salt	3 parts
Shortening oil	2 parts	Spice mixture	0.5 part

## E. BLACK MARLIN

Black marlin	100 parts
Potato starch	7 parts
Na-glutamate	0.6 part
Spice mixture	Not specified

From the statement about the preceding (croaker and tuna) sausage, it should be apparent that this type (using black marlin exclusively) is rare. The firm that produces it is quite small and processes fewer than 3,000 pieces of sausage daily.

## F. GENERAL REMARKS

Monosodium glutamate is frequently used to enhance fish sausage flavor. Some firms are considering the use of sodium 5'-inosinate and sodium 5'-ribonucleotide, which have appeared on the market recently. Mixing proportion of spices is another item for which exact figures have not been given. One example was a mixture of onion powder (0.1), mace (0.05), nutmeg (0.05), and white pepper (0.3) to 100 parts of fish jelly.

The fish sausage now being manufactured in Japan, could be referred to as a sort of semipreserved food, since the heat processing is not enough

to kill all the microorganisms contained in the product. In other words, the product is pasteurized, not sterilized.

#### VI. Shelf-Life and Bacteriological Problems

A raw fish jelly, prior to cooking, may contain from 100,000 to 1,000,000 microorganisms per gram, that originate in the raw fish, starch, spices, and other ingredients. The bacterial load from the raw fish, however, seems to be less significant in relation to storage life than that from the other sources, because the bacteria involved are not heat-resistant and are killed by heat processing without much difficulty, except when the fish has been contaminated by heat-resistant types after landing and transport.

The majority of spoilage bacteria survive cooking. Changes in the bacterial flora taking place before and after heat processing are outlined in Table IV (Yokoseki, 1957).

TABLE IV  
CHANGES IN MICROFLORA IN FISH SAUSAGE DURING HEAT PROCESSING

Temperature at core of product <sup>a</sup>	Bacterial count in 1 g. of sample	Species of bacteria identified
60°C.	$5.3 \times 10^5$	<i>Micrococcus varians</i> <i>Micrococcus epidermis</i> <i>Bacillus megaterium</i> <i>Bacillus firmus</i>
65°C.	$7.3 \times 10^4$	<i>Bacillus megaterium</i> <i>Bacillus firmus</i> <i>Bacillus subtilis</i>
70°C.	$6.3 \times 10^4$	<i>Bacillus coagulans</i>
75°C.	$3.8 \times 10^4$	Not identified
88°C.	$8.1 \times 10^3$	<i>Bacillus subtilis</i> <i>Bacillus megaterium</i>

<sup>a</sup> Test samples were taken when the core of the product reached these temperatures; the 88°C.-sample was the finished product. The samples examined contained the ordinary mixture of fish, starch, spices, and other ingredients, except sugar.

Even when carefully handled, bacteria will be found in both the raw material and the final product. Sanitation is therefore a primary concern of both producers and distributors.

Fish sausage prepared in the conventional way may remain palatable for 2 weeks if kept under refrigeration. If exposed to room temperature, it becomes spoiled within 3 days if no preservatives are used. Sausages to which starch has been added show rapid decomposition. The elimination of starch from the ingredients may not necessarily be a prerequisite to assure good keeping properties. Contamination by aerobic spore formers, e.g., from the bacillus groups, takes place in the spices as well as

during handling and transportation of the raw fish. Recently, frozen tuna fish sent to remote plants that had been newly erected in inland areas had a heavier load of bacteria than tuna that was otherwise handled.

The use of legally permitted chemical preservatives has afforded producers of fish sausage a means of extending their market into distant, rural parts of the country, since such additives may prevent spoilage for more than 3 weeks at normal atmospheric temperatures. Nitrofurazone in particular retards the growth of surviving bacilli.

Even when preservatives are used, however, there might occur a particular spoilage due to the growth of *Bacillus pantothenicus*, resulting in so-called softening spoilage, which is characterized by a flabby texture in the sausage meat. This organism is very active in splitting down starch under the low oxygen tension maintained in ordinary products, and in due course leaves a sour odor without any penetrating foul odor. Yokoseki *et al.* (1958) observed more than 10 million cells of *Bacillus pantothenicus* in 1 g. of the softened portion of fish sausage, whereas the bacterial count in the sound product was less than 10,000.

More recently, a peculiar type of spoilage, characterized by the formation of small discolored spots on the surface of the product, has been noted in fish sausage. The spots vary in color; some are brown, others black. Some form gas. Bacteriological examination revealed that the spots were dense colonies of heat-resistant organisms such as *Bacillus coagulans*, *Bacillus firmus*, *Bacillus circulans*, and *Bacillus subtilis* (Yokoseki, 1962). The portions apart from these spots contained very few bacteria. This indicates that the growth of the bacteria is limited to the area near the spots, diameters of which range from 1 to 7 mm.

The organism primarily responsible for the discolored spots was *Bacillus coagulans*, which has been reported as the causative bacteria of flat sour spoilage of canned products. It is quite thermophilic and grows well at temperatures between 40° and 50°C. The feature that *Bacillus coagulans* lacks the ability to develop on casein or gelatin may account for the fact that the spots impart very little evidence of decomposition.

*Bacillus firmus* or *Bacillus circulans* are frequently isolated, in conjunction with *Bacillus coagulans*, from the spots that are inflated by gas. No gas analysis was conducted on the content of these areas, but the addition of nitrite or nitrate for improving meat color might have favored the growth of *firmus* or *circulans* type, since these are able to denitrify nitrous or nitric compounds. It was also evident that the spots containing gas were seen only in the product with added nitrite.

From these findings, the preservative effect of nitrofurazone or nitrofurylacrylamide at a concentration within the legally permissible limit

has become questionable. Amano and Uchiyama (1963) examined the effect of the legally permitted concentration of both nitrofurantoin compounds on the germination of spores of *Bacillus pantothenicus* and found no inhibition of spore germination. These bacilli showed an active growth of the cells from the stage of outgrowth after careful removal of the nitrofurantoin compound by washing. Thus there is presumably very little, if any, chemical attachment between the cell wall ingredients and nitrofurantoin compounds.

Since the optimum growth temperature of the bacteria that cause both softening and spot spoilage is 40°C., damage can be avoided by keeping the storage temperature low. The use of chemical preservatives should be discouraged, not only from the standpoint of public health but also because of the risk that the industry might lower its sanitary standards. One reason for the wide use of preservatives in Japan is that the majority of retailers lack refrigerators on their premises. Completion of the cold chain (from catch to retailing) emerges as a more attractive alternative.

## VII. Quality Control

Quality control of commercial products forms part of a program of the Japan Fish Sausage Association, the central body of producers. Actual examination is consigned to the laboratory of the Japan Export Frozen Food Inspection Association under contract. Samples of fish sausage are drawn from retailers' shops and from plants at random, and are subjected to organoleptic, chemical, and bacteriological examinations.

Moisture content, pH value, starch content, and bacterial count are the main areas of examination. Determination of fat and volatile acid are occasionally made, if necessary. In 1962, the Ministry of Agriculture and Forestry introduced a standard of quality for the manufacture of fish sausage and related products. This standard is wide in scope, controlling the construction of plants, equipment, machines, handling of raw materials, ingredients, processing, chemical composition of finished product, and labeling.

As for the index of quality assessment of fish sausage, it is difficult to fix a suitable method of evaluation. However, determination of volatile acid seems workable because volatile acid, rather than volatile basic nitrogen, develops primarily on decomposition of the product (Uchiyama and Tanaka, 1958). A shortage of oxygen inside the product, assisted by impermeable synthetic casings, may favor the formation of volatile acids by bacterial action. A fish sausage without added nitrofurantoin compound may swell considerably from gas formed mainly by *Clostridium*.

Similar spoilage with gas formation can also be observed in products to which considerable shark flesh has been added.

### VIII. Chemical Composition

In the 1960 season, routine examination by the Association showed that the average fish sausage contains 67–68% moisture, 14–15% protein, 5–6% fat, and 8–9% starch. This is much less fat content and a little less protein than ordinary meat sausage. Enrichment of the nutritive value of fish sausage with vitamins A or D is reported by certain firms, but assessment of these vitamins has not yet been made by the Association.

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