Chapter 9

Surimi and other mince based fishery products

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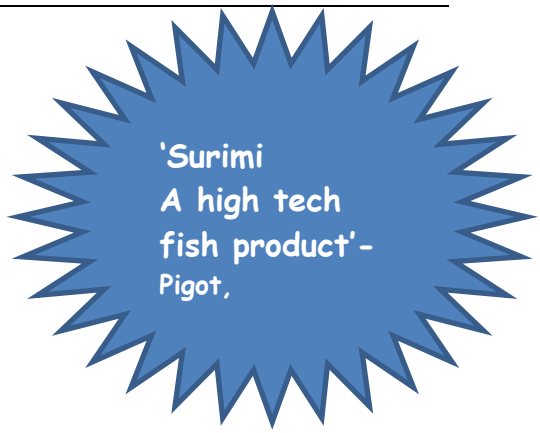
Contents



Introduction

Fish as a food has gained a greater attention in the recent past due to the awareness about the nutritional and health beneficial aspects of fish consumption. World per capita apparent fish consumption per capita for the year 2015 has been estimated to be 20 kg (FAO 2016). Fish is good source of easily digestible proteins blended with all the essential amino acids at appropriate proportion. FAO stated that the global population has obtained 17 % of animal protein and 6.7 % of total protein in the form of fish proteins. Fish lipids are known for their polyunsaturated fatty acids content and their therapeutic properties against heart related problems. From health point of view, the focus on dietary macronutrients are shifting towards the importance of micronutrients like minerals and vitamins, which are essential in the diet for the better physiological functional and normal well-being. These micronutrients are presented in fish in easily absorbable and biologically available form. In spite of this, fish is highly perishable. Its perish ability nature is due to near neutral post mortem pH, low content of connective tissue, higher water activity, highly unsaturated lipids and nutritional richness. Hence, processing of fish is essential to make it available (preservation) in one or another form for human consumption. The processing of fish leads to diversification in products based on the consumer need. Surimi is one such intermediate product. Surimi, truly

the "high tech" product can enable the human population to realize the utilization of fish as the most important source of protein.

What is surimi?

The term 'surimi referred to minced and water-washed fish muscle tissue (Ohshima et al., 1993). The word ‘surimi’ comes from the Japanese words ‘suru’ meaning ‘to process’ and ‘mash/mi’ meaning ‘meat’.

Advantages / Why should we go for surimi? / importance of surimi manufacturing

- Helps in utilization of underutilized fishery resources
- Efficient utilization of edible parts of fish
- Cuts down the cost of transport
- Frozen surimi has longer shelf life with reference to functionality
- Variety of products formulation using available process technology and ingredient technology
- Current technology employed in surimi production allows manufacturing of surimi with uniform quality

Disadvantages of surimi production

- Huge quantity of water requirement
- Nutritional loss
- Loss of taste/ flavor
- Pollution problem

History of Surimi and Milestones in Development of Surimi Industry

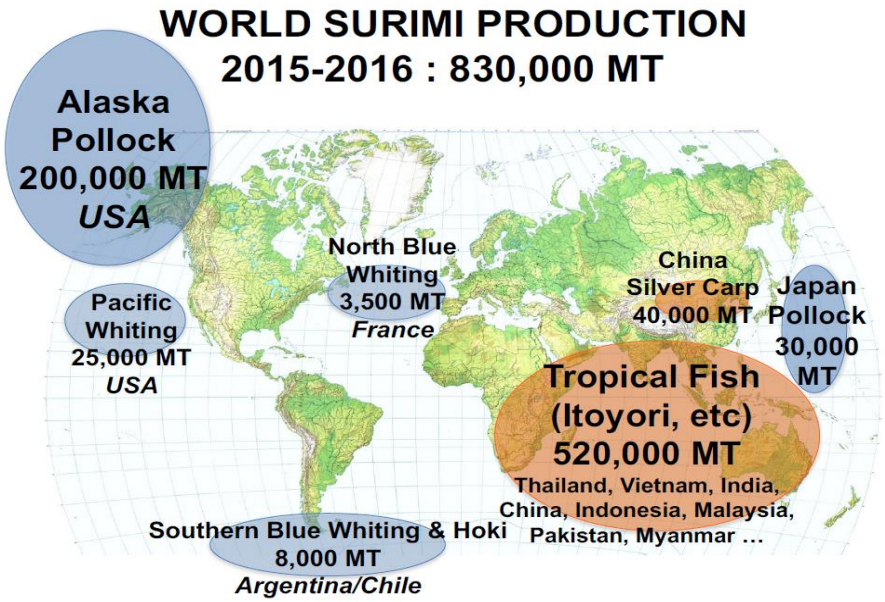
Surimi is a Japanese term meant for minced and washed fish meat. Surimi seafood was initially created by Japanese chefs hundreds of years ago, who saved any extra fish they couldn't use by salting and grinding it into a gel. The Japanese have considered it a delicacy for 900 years. The record for earlier surimi processing has been found in Japanese cookbook written in the year of 1528. Till, 1603 it was family based production and used as a major ingredient in Kamoboko-type products. The pioneering work by the scientists **‘Nishiya Kyosuke’** and ‘**Takeda Fumio’** revealed the use of sugar as cryoprotectants in surimi which protect/minimize the structural changes in fish myosin, thus preserve the gel forming capacity of fish meat. This invention shifted the fresh surimi to frozen surimi. Later, the innovation of the surimi product called crabstick in Japan during 1970s played a major role in globalizing surimi and expanding surimi seafood consumption to the United States, Europe, and Russia. Commercial surimi production process has witnessed dramatic changes due to developments and innovations in machineries and ingredients. These developments have eased the production process and enhanced the gel strength of fish meat from various species. The following are the major milestones in the surimi industry.

Years	Major Inventions	Contribution
1960	Cryoprotectants	Fresh surimi to Frozen surimi
1970	Crab stick	Expansion of Surimi market to USA
1987	Microbial Transglutaminase enzyme	Gel strength improvement
1990	Decanter	3-5 % increase in yield of surimi

Surimi- a look at world market

According to Pascal Guenneugues from Future Seafood, France, global production of surimi is almost stagnant for last five years with little fluctuation. The surimi production has been projected to be at the same level for the year 2017. The global surimi production has witnessed a sharp increase from the year 2009 to 2012. In the year 2013, the surimi

production was leveled to 80,000t. By 2014, surimi production raised back hitting to 820,000t in 2015 and 830,000t in 2016. (Figure 2). Overall production of tropical fish surimi in 2016 was stable, with a decrease in Thai and Chinese production and an increase in Indian and Indonesian production, and about the same levels in Vietnam, Malaysia, Pakistan and Myanmar.



(**The information was obtained from Pascal Guenneugues from Future Seafood, France**)

Despite investment in technology and improvement in processing conditions, the quality of surimi is decreasing due to lower supply of good quality fish, a result of overfishing, reduced access to good fishing grounds and more fish directed to direct consumption and freezing for export.

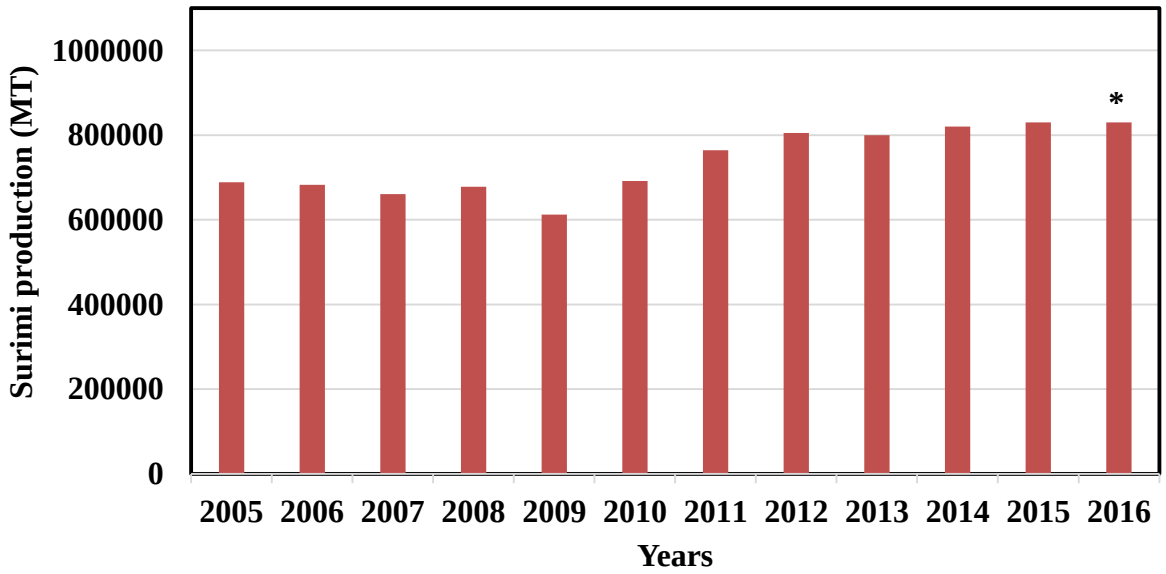


Figure 2. The world surimi production (2005-2016; *Estimated)

Indian Surimi Industry-An Overview

The Indian surimi industry developed in the 1990s on the west coast of India under the influence and support of Japanese importers as well as with Korean and Thai assistance. Production rapidly grew to reach around 20,000 MT by the year 2000, 40,000 MT by 2005, and 65,000 MT by 2010. Over the past years the industry has consolidated as some factories closed down mostly due to issues with wastewater disposal. However, new factories keep developing, which results in a strong competition for raw material. Threadfin bream is the main species (70%) used for surimi production and various other species include lizard fish, croaker, big eye snapper, goat fish, ribbon fish, and sardine. The average fish size is bigger than in Thailand and the freshness of fish is usually good since the fishing fleet is constituted of small vessels (10–12 m) operating on short trips of 3–5 days. Indian surimi production is mostly exported to Japan where it competes with Thai surimi and to East Europe. India utilizes a small portion of its production to process crabsticks for export to Europe and the United States (around 10,000 MT in 2010).

Unit operations in surimi production

The process flow involved in surimi preparation is given in Figure 1. It mainly involves separation of meat and repeated washing to obtain the refined fish meat which is a wet concentrate of myofibrillar protein.

Unit operations in Surimi production

1. Raw material
2. Dressing
3. Meat separation
4. Water washing (Leaching/bleaching)
5. Dehydration
6. Refining/straining
7. Mixing with additives (0.2% Sodium tri-poly phosphate + 4% sucrose + 4% sorbitol)
8. Panning
9. Freezing
10. Frozen storage

Note: all unit operations should be carried below the temperature of 5 ^{o}C

Raw material

The first and foremost thing to remember is ‘only some fishes have the suitability to be raw material for surimi production process’. The suitability is determined by the functionality of fish myofibrillar protein called ‘gelation’. Gelation is the ordered aggregation of fish myosin with the entrapment of water and other added ingredients upon extraction with salt and heating. The gel forming capacity of fish meat is expressed in terms of gel strength (g.cm). In general, gel-strength is higher in the salt-water fish than in fresh-water fish, and greater in white-fleshed fish than in dark fleshed fish. The high quality surimi production is possible only through using the superior quality raw material. Before choosing the raw material, the following criteria should be considered.

- Strong gel-forming capability
- White flesh
- Less fat
- Year-round availability
- Abundance
- Reasonable price

Dressing

As soon as receiving the raw material, it has to be washed using chlorinated (less than 2 ppm) chilled water. The next step is dressing of fish. Dressing include removal of head, entrails, scales and fins. At most care has to be taken not to disturb the visceral mass as it includes the stomach and intestines which are in turn rich source of proteolytic enzymes. Damaging the stomach and intestines likely to contaminate the muscle with proteolytic enzymes which act on the protein and degrade them. The degradation of protein will have drastic effect on the gel forming capacity of fish meat. Pyloric caeca contain large amount of proteases. Upon releasing, they break the proteins into peptides. Particularly, the myofibrillar protein, myosin, has to be protected from degradation and denaturation to have the better gelation. A thorough washing of belly cavity has to be exercised to remove the peritoneal membrane which is black in color and gives negative perception on the appearance of surimi and surimi based products. If kidney is disturbed, then TMAO oxidase is liberated which acts on TMA-O and convert into TMA, DMA, MMA and formaldehyde. Formaldehyde is a potent cross linker. It cross links two proteins and reduce the gel forming ability. Pancreas and liver contain lots of enzymes. If it is disturbed it also affects the quality of surimi.

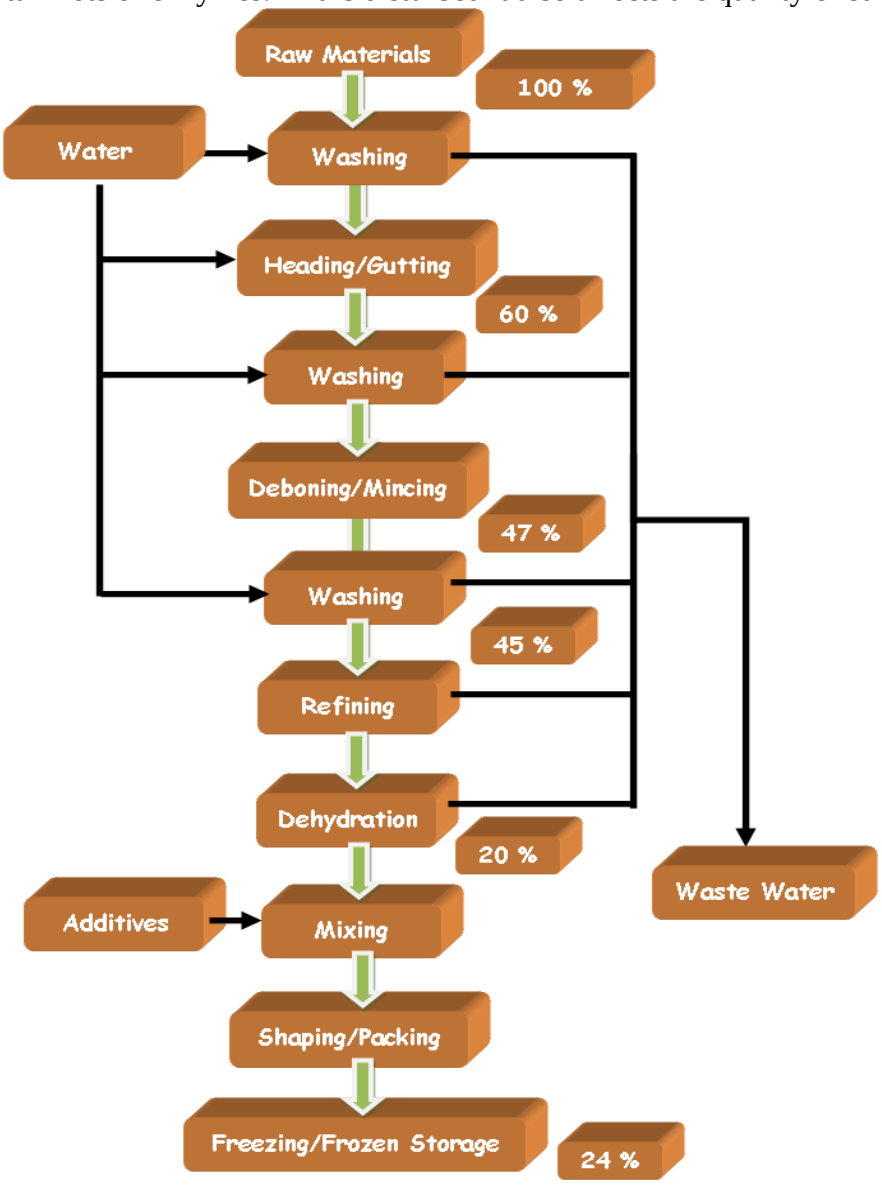


Figure. 1 The process flow for surimi production

Meat Separation

Meat separation is carried out mechanically. Commercially used meat separator is drum type separator / reciprocator type. Size of the meat particle obtained after meat separation is 2-5mm. If the meat size is 2 mm then the mincing operation can be omitted. The yield from whole fish to separated meat is 55-70%. The separated meat is referred as otoshimi in Japanese. Even today, the presence of some small fins or pin bones and scales are the technological issues remains to be addressed.

Water washing

Washing the minced meat is a critical step in the production of surimi, which not only removes fat, pigments, amines and sarcoplasmic proteins but also concentrates myofibrillar proteins. Washing also reduce the microbial load and remove the cathepsins (proteases). The water used for washing should be potable, chilled and soft water (chlorine 0.5-1ppm). Two types of washing operations are practiced in Industries. One is batch type and another one is continuous type. Batch type requires water in minimum quantity and is generally carried out using agitators. Whereas in continuous washing operation, a series of tanks are arranged.

Lean fish varieties require 3-4 times of water on the basis meat weight for water washing. Fatty fish varieties require 4-5 fold of water. The rate at which these undesirable soluble components are removed from the minced meat is a function of several factors, including water, temperature, the degree of agitation and the contact time between water and meat particle. The number of washing cycles and water/meat ratios used for washing vary among surimi processors. A water/meat ratio of 3:1 to 8:1 is often used by on-shore processors. This washing process is repeated three to four times to ensure sufficient removal of sarcoplasmic protein fractions. The majority of the soluble components are freely and rapidly removed in the first washing cycle primarily by dilution of the free soluble components. Long periods of washing would result in higher hydration of mince and degradation of myofibrillar proteins, making the subsequent dehydration process more difficult and could reduce gel-forming ability

It is important that the effect of the number of washings and other processing conditions on the physicochemical and functional properties of proteins from different fish suitable for surimi production should be standardized. The need for standardization of the number of washing cycles, especially in batch production of surimi from different fish species, is high, in order to minimize the consumption of water and to avoid environmental pollution.

Refining/Straining

Before the final dewatering process in a screw press or decanter, the unit operation called refining/straining is carried out to remove the impurities, such as skin, pin bones, scales, and connective tissues. It is done in equipment called refiner/strainer or specially designed screw press. Perforation in the refiner/strainer is small so that only meat comes out whereas fins and scales are retained. Straining is often done with the injection of water which helps in easy flow. It is done to get a fine grade surimi.

Dewatering/Dehydration

After repeated washing and refining, the moisture content of fish meat likely to increase from 82–85% to 90–92%. Hence, it is essential, to remove excess water prior to mix with additives like cryoprotectants and subject to freezing process. Removal of excess water after washing the meat is termed as dewatering/dehydration. The desirable moisture content

of the meat, prior to blending, typically ranges between 80% and 84%. Proteins have both polar and non-polar amino acid residues. Polar residues absorb water. Only 30% of total amino acid residues are non-polar remaining 70% are polar residues in fish meat protein. In order to facilitate the easy removal of water at the end of washing certain divalent ions and salts are added. In very small quantity divalent salts have greater affinity towards water molecules than that of polar residues present in protein, thus, facilitate the easy removal of water. As a part of evaluation, the industrial surimi making process have witnessed different methods by which the excess water is removed such as manual press, nylon mesh bag method, Centrifugation and screw press.

Nylon mesh bag

In this method small size nylon mesh is hung in chill room (4-6^{o}C). washed meat is placed in this and kept for few hours. The excess water drains due to gravity.

Centrifugation

In this method, perforated basket type centrifuge is used. Normally, it is centrifuged in the speed range of 4000-5000 x g. The water thrown during centrifugation can be collected, recycled and used. It is a batch process. So it is time consuming.

Screw press

The screw press is a compression machine with a 2:1 fixed compression ratio: two parts in, one part out. Entire barrel of screw press is provided with perforation. The desired moisture content out of the screw press is 82% moisture or 18% solids. During screw pressing meat and water get separated. During pressing temperature may increase. Refrigerant is used to keep temperature low. The effectiveness of water removal is governed by the length and speed of the screw, the volume reduction ratio, and the perforation of the screens. Of late, the screw press is replaced by decanter centrifuge.

Mixing with cryoprotectants

The term ‘Cryo’ means ‘low temperature’ and ‘protectants’ means the substance which shows protective activity. When the protein molecules present in the fish meat exposed to various environmental conditions, they become reactive (chemically they interact with each other). If any residues in the protein molecules combine and forms a bond or a sort of interaction, is referred as ‘aggregation’. The denaturation of proteins, to be more specific the myosin, causes loss of gel forming ability-an important functional property to be preserved during surimi process. Generally, minced meat attains a spongy texture and loses the ability to hold water upon poor freezing practice and thawing which results in loss of gel forming ability. In order to minimize the denaturation some substances are added to surimi which is mainly intended for freezing and frozen storage.

Cryoprotectants are normally small molecules having the functional groups like –OH, -COOH, -NH^{+}_{3}. They should able to orient appropriately towards water molecules present along with the protein in the fish tissue to exert the cryoprotective effect. Most widely used cryoprotectants are polyols, CHO, amino acids and certain salts. Sucrose (4%), sorbitol (4%), sodium tri-polyphosphates (0.2%) are commercially used in surimi. At high concentration of sucrose product is sweeter and at high concentration of sorbitol, products become more brownish. Commercially cryoprotectants is added by mixing it with meat in bowl and chopper/mixer

Panning

The washed and dewatered fish mince (surimi) is placed in trays with the thickness of the slab of not more than 60mm. This operation is termed as panning.

Freezing

The freezing of surimi slabs is done at -30 to -40 ^{o}C using either contact plate freezer or air blast freezer. The core temperature should be at least -20 ^{o}C and the freezing is usually carried out for 90 min.

Storage

Technically, -30 ^{o}C is more preferred frozen storage temperature. However, in most of the commercial establishments, it is maintained at -18 to -20 ^{o}C. The frozen surimi can be stored at the above mentioned condition for at least 6 months with minimum loss of gel forming ability.

Grading of Surimi

The quality of surimi is determined by the following main characteristics:

- Gel-forming properties (determined by texture analyzer)
- Colour (the whiter the colour, the higher the quality)
- purity (the more complete the absence of blood, skin and brown meat, the greater the purity)
- Regularity
- Bacteriological aspect

Theoretically, these characteristics are specified in a surimi grade system. In practice, these characteristics vary with raw material and supplier.

Example for grading of surimi from Threadfin bream

Grade	Moisture (%)	Gel strength		Whiteness		Impurities
		Force	Deformation	L*	b*	/40g
SSA	**76**	>1000	>1.30	>78	<6	<40
SA	**76**	>900	>1.20	>76	<6	<40
FA	**76**	>750	>1.15	>75	<6	<40
AA	**76**	>600	>1.10	>75	<8	<40
A	**76**	>400	>1. 05	>75	<8	<40
KA	**77**	>300	>1.00	>74	<10	<60

Surimi based products

As mentioned earlier, surimi is an intermediate product and many number of products can be developed from surimi depending on the creativity, innovation and knowledge of the one involved in this line. However, Kamaboko, Chikuwa, Hanpan and Satsum-age are the traditional surimi based Japanese products. Of late, the products like fish ball, fish sausage and fish ham were introduced. Today, surimi is used mainly in analogue or imitation products like crab stick, shrimp analogue, lobster analogue and scallop analogues. Generally, the surimi-based products can be divided as follows

- Satsuma-age (fried)
- Chikuwa, (baked)
- Kamaboko (steamed)

- Hanpen/naruto (boiled)
- Fish ball
- Flavored kamaboko (fish sausage/ ham)
- Analog/imitation seafood

Table 2. Common surimi based products

Surimi based product	Year of introduction	Processing method
Hanpen	1548	Boiling
Uo-Somen	1580	Boiling
Tsumire	1580	Boiling
Shinjio	1580	Boiling
Yaki Chikuwa (Chikuwa)	1674	Baking
Mushi chikuwa (Shirochikuwa)	1674	Steaming
Yaki Kamaboko (Itazuke)	1684	Baking
Kasutera Kamboko (Datemaki)	1785	Baking
Nikamboko (Suji)	1798	Boiling
Surimi kasutera	1804	Baking
Mushi kamaboko	1823	Steaming
Naoruto kamaboko	1823	Steaming
Tsukeage	1846	Deep-frying
Fish sausage	1953	Boiling
Kaniashi (Flake)/kanikama/Crabstick	1973	Steaming
Kaniashi (stick)/kanikama/Crabstick	1975	Steaming

(Adopted from Park, J.W. ed., 2013. *Surimi and surimi seafood*. CRC press.)

Kamaboko

Kamaboko is the most typical surimi based product in Japan. Traditionally, surimi paste is formed into a Quonset hut shape on a wood board before subjecting to any thermal treatment. Sometimes, the surface of shaped meat is coated with colored paste for appearance. The shape and texture of kamaboko vary from region to region. After shaping, the surimi paste is subjected to a low-temperature setting process (20 to 40^{o}C) for 30 to 60 min to enhance the gelation is carried out. This process yields a very strong and elastic gel. Cooking by either steaming or baking is practiced. The finished steamed product is called *mushi* (steaming) kamaboko. On the other hand, the baked kamaboko is called *yaki-ida* (baked on the board).

Another type of kamaboko is called molded kamaboko, which is also processed in a Quonset hut-shaped mold. The molding technique is mainly applied for the utilization of low-grade surimi which has low gelling capacity. In this process, surimi paste is poured into a plastic mold and “cooked” at 90°C (baking or steaming) after setting at 10 to 15°C for 10 h. The finished products are packed, pasteurized, and chilled before supplied to the market.

Chikuwa

Chikuwa is a pipe or tube shaped surimi product. Surimi paste is placed onto a grooved hole in a rectangle shape on the surface of a drum. The paste is then rolled onto a metal stick on the conveyor. To facilitate with gelation, the rolled paste on the stick is baked

rotationally in the oven on a screw conveyer. The finished products are packed, pasteurized, and chilled as like kamaboko before channeling to the market.

Hanpen

Hanpen is having the soft texture like a marshmallow or soft tofu. For the development of soft texture, whipping (agitation or stirring at high speed) is required. At the last step of mixing, gums or polysaccharides have been added as whipping agents or stabilizers. Vegetable oil is commonly mixed as well for the development of soft texture. The surimi paste is traditionally whipped using the pestles of the stone mixer at high speed. In recent years, however, the surimi paste is aerated compulsorily by a continuous mixer. The whipped paste is then boiled in hot water (80 to 85°C) to fix the soft gel texture.

Satsuma-age

Satsuma-age is a fried kamaboko product has various shapes and characteristics.

Fish Ball

Typical ingredients used for fish ball, in addition to surimi, are salt, sugar, monosodium glutamate (MSG), starch, and water. No flavors or protein additives are added to the formulations. Once the paste is prepared, it is extruded or formed into a ball shape and dropped into warm water (20 to 40°C) for 30 to 60 min. Keeping a uniform shape of fish ball, in a mass production, is critical. Thereafter, fish balls are placed in hot water (95 to 98°C) for 10 to 30 min (the core temperature should reach 80°C), followed by chilling under running tap water. The fish ball, after draining water, is then packed in a poly bag.

Fish sausage

Fish sausage is an emulsion based fish product. For the preparation of fish sausage, the thawed surimi is mixed with salt, sugar, STPP, starch, spice mixes (coriander, chilli powder, ginger garlic paste, pepper), vegetable oil and water in a bowl chopper to get a homogeneous paste. The mixing process should be ideally completed within 12-15 min. The paste is then stuffed into synthetic casings preferably PVDC and heat processed for 45 min at 90 °C followed by cooling for 15 min in chilled water and re-boiling for 1 min. Fish sausage is one of the surimi seafood products originally produced in Japan, but different from other surimi seafood based on the added ingredients (i.e., edible fat and spices). The sausage is consumed primarily as a snack and as an appetizer or used as an ingredient for salad and stir-fried food.

Fish ham

Fish ham is prepared by mixing of fish paste with cured meat made from a red fish such as tuna or marlin followed by addition of pork fat, stuffing into a large sausage-type casing in. The curing is usually carried out using salt and nitrite. The fish paste and cured meat ratio is 2:1. The heat processing is similar to sausage processing. The casing used for ham preparation is larger in dia compared to sausage casing and most of the time colored casing are used.

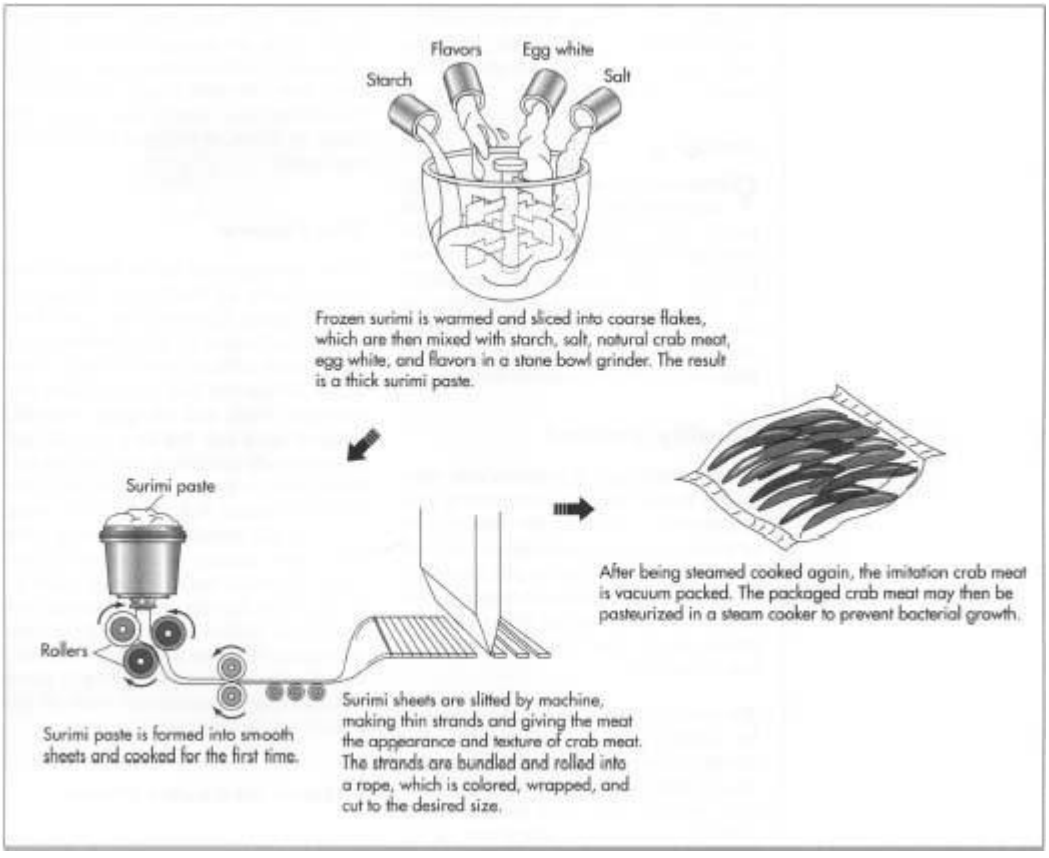
Imitation products

As surimi is bland in taste and have the gel forming property, it is used as a major ingredient to develop the imitation products with resemblance in the texture and taste. The

imitation products include shrimp analog, lobster analog, scallop analog, carb leg and crab stick.

Crab analogue

The frozen surimi is converted to imitation crab meat through various steps. First, it is tempered at -4°C, then shredded into coarse flakes and subjected to comminution during which, the surimi flakes are mixed with other ingredients include starch, salt, natural crab meat, egg white, and flavours in a bowl chopper. Comminution results in the formation of thick surimi paste, which is then transferred to a hoper (holding tank). The paste is conveyed from the hoper to the sheet-forming machine. Continuous sheets of surimi, about 10 inches (25 cm) wide and 0.05 inch (1.2 mm) thick are extruded. Due to the functional nature of surimi protein, the extruded sheets are very smooth in texture. After the sheets are formed, they are passed to machines and subjected to initial cooking. This cooking meditates the setting of the sheets and prepares them to be suitable for the further slitting process. Slitting gives the appearance and texture of crab meat. The slitting is done by a machine which is composed of two steel rollers that cut the thin sheets into strands having 1.5 mm wide. These thin strands are pulled, bundled and rolled into a rope. This rope is colour, wrapped, and cut to the appropriate size. It is then steam cooked, forming a product that imitates in texture and tastes very much like the crab meat.

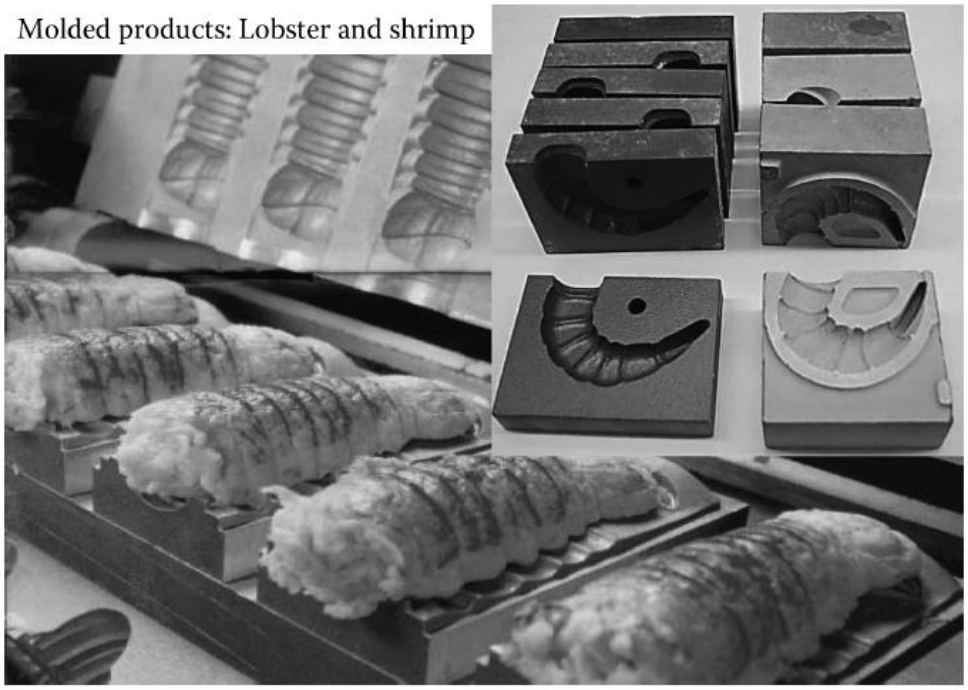


(Adopted from http://www.madehow.com/Volume-3/Imitation-Crab-Meat.html)

Shrimp and lobster analogue

For the preparation of shrimp and lobster style products, the surimi paste is commonly mixed with pre-prepared surimi meat fibers and transferred to a molding machine or cold-extruded in a three-dimensional shape. For imparting the color, a color solution is sprayed

inside the mould before stuffing. Another way to impart the colour is directly using the colored paste (brushed) on the surface of cooked moulded products. In the later method an additional, additional heating is needed to set the colour.



Molding for shrimp-flavored or lobster-flavored surimi seafood.

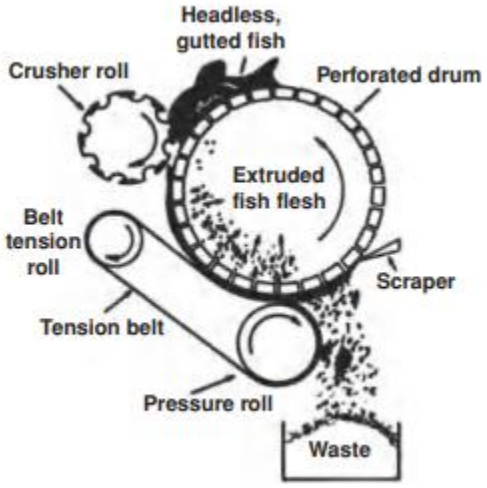
(Adopted from Park, J.W. ed., 2013. *Surimi and surimi seafood*. CRC press.)

Scallop Analogues

The plant set up for the production of scallop analogue is similar to crab analogue. For the preparation of scallop analogue, a wider and thicker surimi sheet is extruded compared to the surimi sheet extruded in crab analogue preparation. After sheet formation, surimi sheet subjected to partial cooking for facilitating the gelation and subsequently subjected to slitting. After slitting, an uncooked layer of surimi paste is added on top of the gelled surimi sheet immediately. This additional layer of surimi paste is to enhance the binding of fibres. The gelled fibres are wrapped and cut into 2-foot lengths and heat processed. The cooked fibre bundles are cut into to the desired dimension of scallops shapes using flaking machine.

Mince

Minced fish is the flesh separated in the form of reduced particle size from the skin, bones, scales, and fins. Mince could be the intermediate product for versatile product development for example, sausages, frozen battered and breaded products, and dried fish flesh flakes. It is also a starting material for surimi processing. Mince technology can also be used to recover meat from the filleting process waste. This technology is well adoptable for underutilized species including pelagic fish. Mince is preserved and marketed often in the form of frozen blocks.



Mechanical fish separator (Adopted from Marsh and Flick, 2012)

Points to be considered for fish mince processing

- Raw materials and sources
- Separation processes
- Anatomy and biochemistry consideration
- Mince stabilization (Fat, Protein, colour, bacteriological stability)

Mince based products

- Fish Wafers
- Fish Fingers
- Fish Cutlets
- Fish Cakes
- Fish Balls
- Fish Noodles
- Fish Sausages
- Fish Patties

Acknowledgement

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