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Surimi Processing Technology and Its Current Market in Korea

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1. Introduction

The concept of washed fish mince was developed around AD 1100 by Japanese fishermen and introduced in making Kamaboko product (steamed surimi gel). The present surimi technology based on cryostabilization started in 1960 and expanded rapidly from 1970's (Okada, 1963; Okada et al., 1973).

Surimi is a Japanese term for mechanically deboned fish flesh that has been washed and mixed with cryoprotectants for extended shelf life. It is being used as an intermediate product for variety of fabricated seafoods. Surimi has a unique gel forming and water binding property because of highly concentrated myofibrillar proteins. These produce an elastic and chew texture and are used for the fabrication of shell fish analog products (Lee, 1984) as well as restructured meat (Siegel and schmidt, 1979; Akeng'o, 1988; Mccomick, 1983). Because of its usefulness in the manufacture of seafood products and the present upsurge in its market share, surimi has aroused the interest of the world seafood industry (Kim and Lee, 1987). Since the introduction of surimi and surimi-based products to the US in 1987, the comsumer acceptance of the fabricated seafood has increased drastically up to hundreds million pound in 1900 . Forecasts predict a steady increase in surimi-based products sales. The future for surimi holds many challenges. The development of variety of surimi-based products with their own identity, not as an imitation products, is one challenge (Lee, 1987a). New product may require the modification of textural properties as well as an improvement of the nutritional quality. Modification of texture can be achieved not only by the mechanical texturization process but also by the incorporation of gel forming ingredients such as starches and proteins (Ikeuchi, 1964; Kaneko et al., 1970). Ingredient play an important role in textural modification, thermal processing, freeze-thaw stability as well as economic and nutritional

points (Lee and Kim, 1995; Lee, 1986, Chung and Lee, 1988; Niwa et al., 1988).

Another development will be the use of surimi as a functional protein ingredient. For example, surimi used as a binder can increase the protein content and improve the textural properties of meat product. Surimi for these purpose can be made from different processes and fish species, depending on the desired product. It is important for the future of surimi to keep the price down and the functionality up.

2. Functional Properties of Surimi

The key component in producing surimi gel is the myofibrillar protein, mainly the salt soluble actomyosin. The functional myofibrillar protein is obtained and concentrated through surimi manufacturing process including mincing, washing, straining and dewatering (Iwata et al., 1977; Suzuki, Lee, 1984; Babbit, 1986). The refined myofibrillar protein of fish muscle possesses a heat-induced gelation property that is unique among available food protein (Okada et al.,1973; Cheng et al., 1979) of myofibrillar protein can be affected by freshness, seasonality of fish, fish species, concentration of actomyosin and surimi processing conditions such as temperature and pH (Ikeuchi, 1963a, Sumizu, 1974, Lee, 1986). The functionality of myofibrillar protein is determined by measuring the gel-forming ability in terms of gel strength and water binding ability of comminced tissue. The level of functional actomyosine can be determined by measuring extractable actomyosin or ATPase activity (Suzuki, 1981)

3. Functional Properties of Fish Muscle Protein

The functional proteins in fish are generally classified into three groups: myofibrillar, sarcoplasmic (water soluble protein) and stroma (mostly connective tissue) protein (Umemoto and Kanna, 1969; Ziegler and Acton, 1984).

1) Myofibrillar proteins

Myofibrillar protein is the protein that forms myofibrils, which contains myosin, actin and regulating proteins such as tropomyosin, troponin and actin. Myofibrillar protein comprises 66~77 % of the total protein in fish meat, and plays an important role in coagulation and gel formation of processed fish meat (Okada,1964; Yasui et al., 1979; Suzuki, 1981; Liu et al., 1982; Lee 1984).

The ability with which tissue water and added water are bound by muscle protein is of great importance for the quality of meat and meat-based products. There is no doubt that myofibrillar protein are primary responsible for the binding of water in tissue. Almost all procedure for the

storage and processing of meat are influenced by the water holding capacity (WHC) of tissue. It is well known that WHC is important in quality of meat sausage (Hamm, 1986) and surimi-based product Lee, 1984). Changes in WHC are a sensitive indicator of physicochemical and structural changes in WHC of meat will be, in great part, due to variation in immobilization of bulk phase water in the inter-filamental space and the filament themselves. Hamm (1986) believe that water-imbibing power of the myosin in the thick filament plays an important role in WHC of meat, particularly after mincing. It is well known that myosin, which makes up about half of the myofibrillar protein, has an enormous capacity to imbibe water.

The immobilization of water in the tissue apparently determined by the spatial molecular arrangement of the myofibrillar proteins (mainly myosin) or filaments (Hamm, 1986). If the attraction between adjacent molecules or filament is decreased, by increasing electrostatic repulsion between similarly charged protein group or by weakening of hydrogen bond or hydrophobic bonds, the protein network is enlarged, swelling increased, and more water can be immobilized within the layer meshes. The result in an increase in WHC in relation to expressible juice or cooking loss. If the attraction between adjacent molecules is increased, when the electrostatic attraction between oppositely charged groups increases or by the effect of inter-linked bonding, less space is available for the retention of immobilized water in the protein network. Thus, shrinkage occurs, and a part of immobilized water becomes free to move and flows out of low pressure (Hamm, 1960). Hamm (1986) conclude that changes in WHC of meat are determined not only by alteration in the interaction between thick and thin filament, but also by the alteration in the interaction between the protein molecule of myosin system.

The functionality of actomyosin can be determined by measuring ATPase activity of actomyosin. The activity depends on the ration of actin and myosin in the actomyosin. Suzuki and Kanna (1966) suggested that the amount of extractable myofibrillar protein is slightly greater in rigor than in prerigor or post rigor (Suzuki and Migita, 1962; Suzuki and Kanna)

4. Preparation of Surimi

In the surimi processing, A flow diagram of conventional rotary screen surimi manufacturing process is shown in Fig. 1 in which headed and gutted fish are ground by a meat separator (deboner). Meat is mechanically separated from the bone and skin by placing the meat side of fish in on the perforated steel drum, applying pressure, causing the soft meat to be pushed through the hole.

Drum perforations of 3~4mm while preventing skin from passing through the holes appears to be optimum with respect to quality and yield (Lee, 1984 and 1986).

The next step is washing the mince to remove fats and undesirable matters, such as blood, pig-

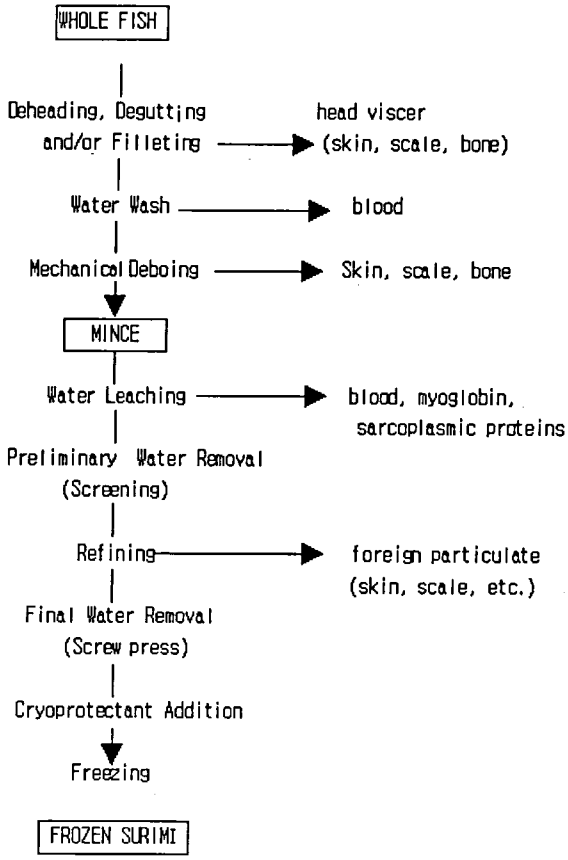

Fig. 1. The traditional surimi manufacturing process.

ment, salcoplasmic proteins and any odorous substances. Washing increases the concentration of myofibrillar protein (mainly actomyosin), functional protein for surimi (Okada, 1964; Iwata et al., 1977; Lee, 1984). The ratio of water to meat, number of washing cycles, washing time (agitation), and water temperature are critical to good quality surimi. These factors should be chosen based on fish species, freshness and finished product quality since repeated washing generally increases the hydrophilic properties of the meat, cause swelling that makes the removal of water difficult. For the last washing, 0.01~0.3 % of salt (NaCl) solution is often used to ease the removal of water (Lee, 1984). The washing is followed by straining which removes residual black skin, bone, scale and connective tissue. The resulting fish flesh is dewatered with aid of either a centrifuge or a screw press. The moisture level of top-grade surimi before addition of cryoprotectants is about 82 %. After addition of cryoprotectants at a level of 8-9 %, the final moisture runs around 75~78 % (Lee, 1986). This process can be operated either in a batch or continuous mode through an appropriate arrangements, where a continuos flow can be set with a set of washing tank (at least three).

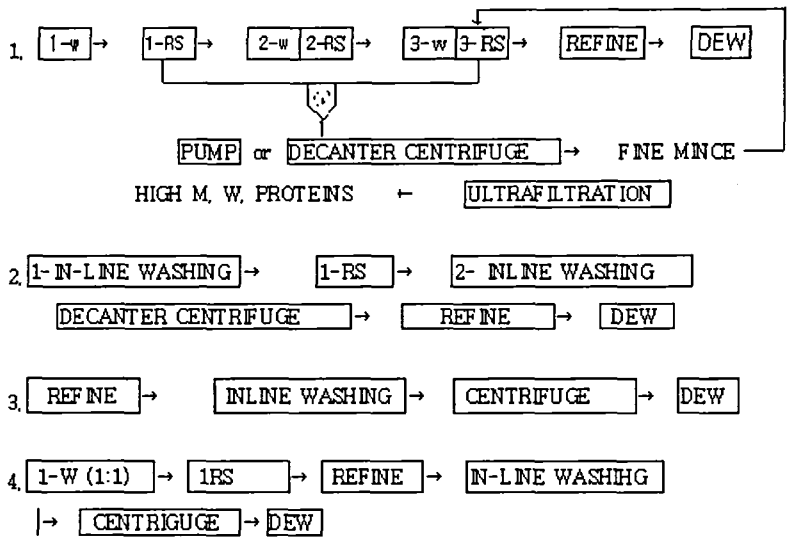

Fig. 2. Modified surimi manufacturing processes based on recycling, in-line mixing and decanter centrifugation.

Conical collector which can be pumped back directly or through a decanter centrifuge to the third rotary screen. This modification is designed primarily to increase the yield. If a major portion of such fine mince is recovered, the yield could be increased by approximately 17% (from 23% to 27% surimi from round fish) when a decanter centrifuge is used (French and Babbitt, 1991). A further consideration can be made in recovering the water soluble high molecular weight protein fractions from the effluent by ultrafiltration.

System 2 consists of a continuous in-line mixing and decanter centrifuge.

The unique feature of this system is no washing tanks and rotary screens are utilized.

This system not only streamlines the process, but also saves space. In order to achieve the necessary leaching, adequate residence time and mixing in the in-line system is required with at least one rotary screen which removes unwanted water-soluble components from the first washing before the decanter centrifuge is used as a final step of water removal.

System 3 is a simple rearrangement of system 2, where refiner is placed right after de-boner in order to produce a mince of finer particle size. This would in turn facilitate leaching of the muscle tissues. Should the theory stand, the product should be whiter and blander perhaps with greater gel strength than that from system 2.

System 4 is supposedly an improved version of system 3 incorporating one washing step between de-boning and refining in order to allow leaching before the in-line washing is initiated. The incorporation of one wash between be-boning and straining will reduce temperature rise and the occurrence of enzymatic reactions during the consecutive mechanical process.

Comparing these systems, any one of them should offer substantial improvement in the yield and/or production rate, and water and energy savings as long as sufficient leaching (washing) is to be carried out with adequate water to meat ratio and number of washing cycles or residence time provided. In some cases, it is expected to produce surimi of better quality. However, there will be some differences among these systems in the yield and the energy cost depending upon how each system is arranged with or without a decanter centrifuge. although these systems have not been closely compared, their performance may vary with species, the condition of fish and the speed of production. since the unit operations are not much different among them, one can make test runs by simply rearranging the processing steps in determining the best choice to suit the individual needs. In selection, however, one should carefully look at the quality of the product desired, the yield, the energy cost, and frozen storability.

5. Factors affecting the Surimi Quality and Yield

Factor which affect the surimi quality (gel-forming ability) and yield include storage technique (refrigerated sea water (RSW) or ice), raw material quality and various processing factors. Figure shows how storage techniques could affect the gel-forming ability when fish was held in either chilled sea water (CSW, comparable to REW) or ice during storage. It was interesting to note that for up to two days of storage the CSW produced surimi superior to that prepared from the fish held in ice, but after two days of storage the trend was reversed and the difference was quite marked.

This suggests that care must be taken not to exceed two days when the REW/CSW technique is employed in storing the fish from catch to landing.

Currently, most of the on-shore surimi manufacturing plants employ a REW storage system which yields surimi of high quality through quick chilling and minimum impact.

The gel-forming ability of surimi decreases as the quality of raw fish deteriorates as a result of the proteolytic breakdown of the muscle tissue.

The raw fish quality is determined by the extent of proteolysis which depends upon the freshness (or age), the proteolytic activity of the muscle tissue and the seasonality, especially during a spawning season. The gel-forming ability of fish mince is a function of the concentration of extractable actomyosin as measured by the ATPase total activity (Kawashima *et al.* 1973). The extent of muscle proteolysis which affects the ability of fish to hold during ice storage, appears to vary from species to species (Okada and Tamoto, 1986).

There are several important processing factors which are involved in the manufacture of surimi. They include the extent of dressing (headed and gutter, H&G or fillet), mince particle size (fine or coarse), water quality (soft or hard), the temperature of fish, water and equipment, and the

mode and extent of leaching. Regarding the extent of dressing prior to surimi processing, for the maximum yield with good quality surimi it is suggested that the fish of small size (e.g. theadfin bream and croaker) be dressed in H & G, while those of medium large size (pollock and hoki) be cut into fillets. As for the mince particle size, theoretically the smaller the particle size, the more effectively the water soluble components are leached out. However, under the conventional rotary screen process, the fine mince will escape through the screen. This situation will prevail especially when the particle size of the mince is small. In contrast to this rotary screen system, the in-line and decanter centrifuge system will benefit from the increased leaching efficiency of the small particle mince and the recovery of the fine mince by centrifugation.

In washing, important factors include washing mode, conventional dynamic stirring or in-line passive mixing, the water-to-mince ratio, the number of washing cycles, and water temperature. In general, the selection of the type of washing mode depends upon the process requirements where the in-line mixing system allows a continuous washing and works best with fine mince and decanter centrifuge as mentioned earlier. However, the relative effectiveness of its performance in terms of the quality of surimi and production rate has not been closely evaluated yet.

The amount of water to be used and the number of washing cycles are determined by the condition of fish and the quality requirements. Generally, the oilier and older (less fresh) the fish is, the more washing is required. Using a given amount of water, one can achieve a more effective leaching with more frequent washing cycles than with greater amounts of water and fewer washing cycles. Another point to be made is whether the ratio of mince be kept constant or can be varied at the different points of washing cycle. Can it be decreased as the washing cycle progresses? The use of the less water with progressive washing may work well and will save on the amount of water usage and subsequently the energy cost. The extent of the extraction of TMA-O and sarcoplasmic protein may be used as indices of the washing efficacy. It is interesting to note that no further extraction of TMA-O occurred after two washings at a 3:1 water-to-mince ratio, while the sarcoplasmic protein was extracted continuously with a concomitant increase in myofibrillar proteins, although not as rapidly as in the first washing cycle. This suggests that most small molecular weight substances are removed within two washing cycles, while the removal of large molecular weight substances such as sarcoplasmic protein may require a longer washing cycle. At the same time, one might be interested in finding at what point in the washing cycle a maximum gel-forming ability is attained. If one is just interested in gel-forming performance of surimi, there is no reason to extend washing beyond two cycles based on the result of this particular experiment done on red hake (*Urophycis chuss*)(Lee,1986b). However, surimi quality is not confined to gel-forming properties only.

6. Gelation of Surimi

Comminution of fish meat with salt is a necessary process to extract myofibrillar protein to produce a sticky sol. During extraction of protein through the "salting-in" effect of salt and tissue disintegration, an increase in the water binding capacity of the myofibrillar protein occurs. The addition of NaCl produces a shift in the isoelectric point of the myofibrillar protein to a lower pH, creating a larger net negative charge at the existing pH from the ionizable carboxyl groups of the protein (Acton *et al.*, 1982). Repulsion between these negatively charged groups causes the protein to open up its spatial arrangement and increase in hydration. This results in further increase in the effective negative charge and in turn enhances greater water attraction and binding (Hamm, 1960). The concentration of 2~3 % salt based on a meat weight is optimal to solubilize the myofibrillar protein (Suzuki, 1981). If the salt concentration is too high, salting-out of protein occurs and reduces the solubility of myofibrillar protein, resulting in a poor gel-forming ability (Samejima *et al.*, 1969; Siegel and Schmidt, 1979; Suzuki, 1981). Hydrated fish protein, especially myofibrillar protein, is responsible for the development of a firm and elastic texture of surimi gel and meat sausage, upon heating (Arocha and Toledo, 1982; Lee, 1984; Katoh *et al.*, 1984). When surimi is communited with salt and the resulting sol is left at room or refrigeration temperature, it gradually forms a rigid gel, changing from sol to gel.

This phenomenon is called "setting" which is a temperature dependent reaction. Okada (1963) suggested that in addition to hydration of myofibrillar protein, formation of network structure was considered to be essential in setting phenomenon (Migita and Okada, 1954 a; Okada, 1963). The apparent rate of setting was remarkedly different for each fish species (Yabe *et al.*).

The mechanism of gel forming of fish meat paste (Migita and Okada, 1952, 1954, a, b; Niwa and Miyake, 1971) involves two step reactions. The first one is a structure-setting reaction which occurs below 50℃, optimal at 30~40℃. This reaction was considered to be responsible for the so called "suwari" phenomenon showing elastic gel property. The second reaction is a structure-disintegration occurring at 60℃ or above and is known as "modiri" possessing a less elastic gel property. Based on structure-setting and disintegration rate, Shimizu *et al.*(1981) classified the gel forming ability of fish into 4 different groups : 1) difficult-setting and difficult-disintegration group such as sharks, chicken and rabbit, 2) difficult setting and easy disintegration group, red -meat fish other than sardines, 3) easy-setting and easy-disintegration group, sardines, croaker and cold water fish such as Alaska pollock and ice fish, 4) easy setting and difficult disintegration group, flying fish, barracuda and grub fish. The physicochemical behavior of polypeptide chain of protein during the setting of fish meat paste was studied by Niwa and Miyake (1971). Based on X-ray diffraction pattern, IR spectrum, optical rotation, and dispersion curve, they found that the protein responsible for the setting was actomyosin. No change in the conformation of the polypeptide was observed in either raw or ground meat. However at the setting temperatures, a part of the alpa-helical structure of the polypetide was transformed into a random coil. Differential

scanning calorimetric analysis of surimi has shown that myosin is a major component with a thermal transition at a temperature of 43℃, the setting temperature of surimi sol (Davies *et al.*, 1988).

7. Evaluation of Textural Properties of Surimi Gel

Textural properties can be evaluated by measuring tensile force, compressive force, expressible moisture and penetration force using Instron testing machine or textural analyzer. All testing was done at a crosshead speed of 50mm/min and chart speed of 100mm/min. The dimension of gel sample was 25mm diameter and 25mm long. Tensile force was measured to determine the strength of partially heat-set extrudate and the force required to break a sheet of extrudate during stretching. To determine the degree of gel cohesiveness, compressive force at failure was measured upon 90% deformation using a 10 cm diameter compression head(Lee and Chung, 1989). At the same time the amount of moisture expressed upon compression was measured by collecting the fluid on three layer of filter paper (fast grade) and expressed as percent of the moisture content. This value was used as a measure of water binding ability (WBA). Penetration force was measured at 90% deformation using a 5mm diameter plunger with a spherical end. It measures the degree of compactness or density of gel, namely, hardness, not the binding property.

8. Market Status of Surimi Gel Products in Korea

There was no available statistical data on the production of surimi gel product until 1991 (Table 1). showed market trend of surimi gel product in terms of production capacity, total sales, total production and increasing rate against previous year. The average annual amount of surimi gel production from 1991 to 2001 was 563,731 M/ which was 51.10 against annual average production capacity. The amount of total production showed up and down trend. The highest production rate was observed in year of 1994 as 2,063,617M/T, while the lowest in year of 2000 as 112,865M/T.

The amount of annual average sales of surimi gel production was 2,245,866 million won. The highest sales showed in year of 1998 as 3,193,379 million won, while showed the lowest in 1996 as 1,758,093 million won.

Table 2 showed the number of surimi-based product manufacturing company, amount of total production, Total shipment and increasing rate against previous year. The number of surimi gel (including crab leg analogy) manufacturing company in 2001 was 124 which was 11.71 % increase compared to that of 1995 as 111. The average growth rate of surimi gel manufacturing industry in recent 3 years showed higher trend than that from 1995 to 2001. It is expected to

increase the number of surimi gel including crab leg product manufacturing company.

There are major surimi based product maker in Korea, namely, Dong won F&B, Oyang Fishery, Sam Ho Ltd., Han Sung Ltd., and Dae Lim Fishery. Table 3 showed the total amount of sales, and market share in year of 2000 and 2001.

Table 1. Market trend of surimi gel products

Year	Production status			
	Production capacity(M/T)	Total production (1,000 won)	Total production (M/T)	Increasing rate against previous year
1991	1,817,892	1,600,680	199,429,443	-
1992	962,883	1,321,956	203,366,894	1.97%
1993	229,308	143,691	183,759,886	-9.64%
1994	6,468,088	2,063,617	231,525,540	25.99%
1995	791,151	157,179	211,454,759	-8.67%
1996	739,906	273,557	175,809,272	-16.86%
1997	181,387	123,750	201,792,245	14.78%
1998	212,194	138,664	319,337,929	58.25%
1999	229,815	117,488	244,672,242	-23.38%
2000	227,093	112,865	249,347,261	1.91%
2001	274,925	147,594	249,950,932	0.24%

Source : KFDA, Accomplishment of food and food additives (1991~2001).

Table 2. Status of surimi gel manufacturing

Year	Product	Number of company	Total production (Million won)	Total shipment (million won)	Increasing rate against previous year
1995	surimi gel product	111	338,212	338,800	-
1996	Surimi gel product	104	359,995	358,487	5.81%
1997	Surimi gel product	108	426,746	427,524	19.26%
1998	Surimi gel product	105	370,624	367,066	-14.14%
1999	Surimi gel product	103	318,100	316,907	-13.66%
2000	Surimi gel product	101	320,798	316,465	-0.14%
2001	Surimi-based prouct	124	379,729	383,393	21.15%

Source : The adminstration of statistics, "Statistical report for manufacturer" (1995~1997, 1999~2001).

As showed in Table 4, Dong Won F&B showed the highest sale and market in year of 2000, while Oyang and Sam Ho Ltd showed the highest values among producers. Since year of 2000, trend of new product development in most of producers was focused in producing high grade surimi gel product which contains various ingredients such as yellow corvina, shrimp, mushroom DHA as well as vegetables.

Table 3. Current status of surimi gel product in sales (unit : billion won, %)

Year / Maker	2000		2001		Increasing rate against previous year
	Total sales	M/S	Total sales	M/S	
Dongwon F&B	174	17.4	165	15	-5.2
Oyang fishery	168	16.8	176	16	4.8
Sam Ho Ltd.l	166	16.6	176	16	6
Hansung Ltd.	110	11	154	14	40
Daelim Ltd	110	11	110	10	-
Other	272	27.2	319	29	17.2
Total	1,000	100	1,100	100	10

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