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SURIMI

Sunee C. Sonu

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Region

NOAA Technical Memorandum NMFS

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Sunee C. Sonu

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1.1. DEFINITION AND SCOPE

A. DEFINITION OF SURIMI

Surimi is a refined form of minced fish meat. It is not itself a food stuff. It is an intermediate raw material from which the traditional Japanese kneaded foods called "kamaboko" are manufactured. Imitation shrimp, scallop and crab meat products are also made from surimi.

The Japanese word "surimi" literally means "minced meat". However, surimi is more than minced meat. Its two major distinguishing features are its gel-forming capacity, which allows it to assume almost any texture desired, and its long-term stability in frozen storage, imparted by the addition of sugars as cryoprotectants.

When fish muscle is separated from bones, skin, and entrails, and then comminuted, it is called minced meat (Figure 1-1). Minced meat becomes raw or unfrozen surimi after it has been washed to remove fat and water-soluble constituents.

Raw surimi is a truly bland material, since its flavor components are removed by the leaching process. More importantly, the washing isolates the fish meat's myofibrillar protein, which is insoluble in fresh water and possesses the essential gel-forming capacity so prized by the kamaboko-maker.

When raw surimi is mixed with anti-denaturants and frozen, the product is called frozen surimi. The anti-denaturant additives, usually sugar compounds such as sucrose and sorbitol, give surimi the ability to resist freeze denaturation. If these cryoprotectants are not used, the surimi's gel-forming capabilities will be lost due to denaturation of its proteins, which can occur even while the material is frozen. Thus, the term "frozen surimi" has more to do with the use of anti-denaturants than with the freezing process itself. Since about 95 per cent of all surimi produced today is frozen using cryoprotectants, the term surimi generally denotes frozen surimi.

Just as surimi is more than minced fish meat, a surimi-based product such as imitation crab is more than surimi. To make the imitation crab and other more traditional kamaboko products, surimi is partially thawed, mixed with a small amount of salt to make the protein soluble, blended with other ingredients and flavors, kneaded and formed to create the desired texture and shape, and cooked by steaming, broiling, or frying (Figure 1-2).

For approximately 1,500 years, the Japanese have practiced the art of manufacturing surimi-based products (Okada, 1981a). Traditional methods consisted of processing the fish into raw

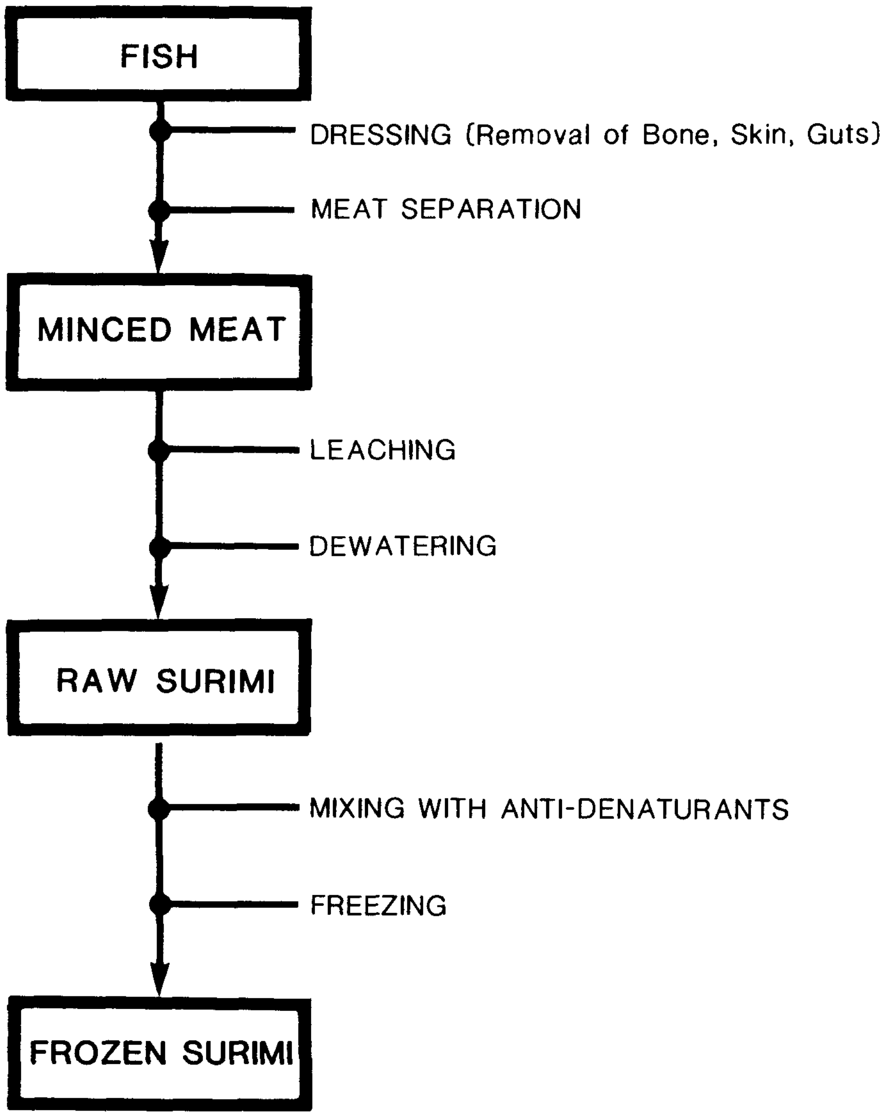


FIGURE 1-1. DEFINITION OF SURIMI

surimi and then kneading it immediately into a finished product. Since both fish and raw surimi would denature quickly, the entire process had to be performed without much delay after the fish was landed (Okada, 1981b).

The advent of frozen surimi in 1960 revolutionized the traditional methods for making surimi-based products. With year-round availability of frozen surimi, kamaboko manufacturers were no longer dependent on unstable local fish catches and raw

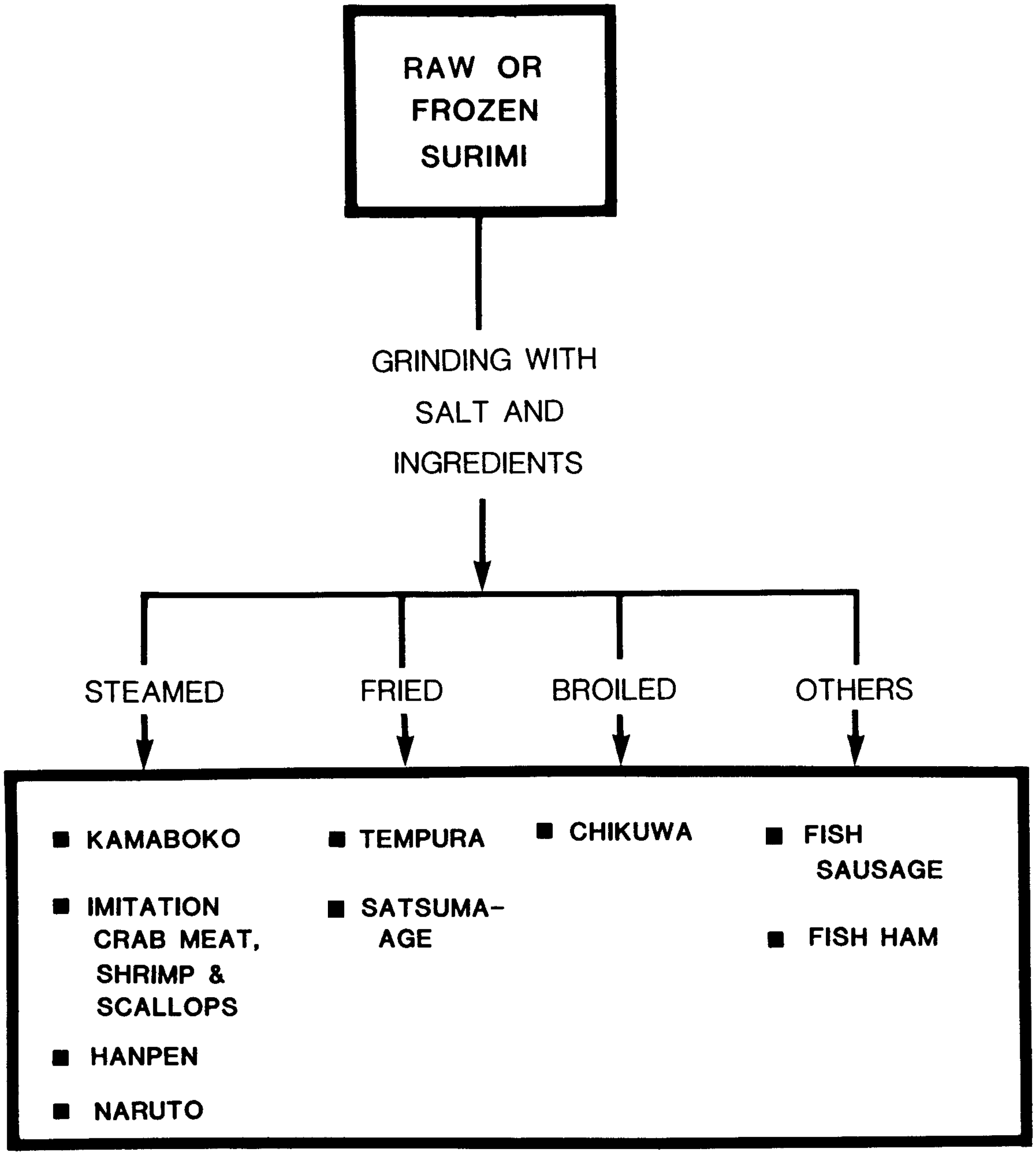


FIGURE 1-2. DEFINITION OF SURIMI-BASED PRODUCTS

surimi. Tremendous expansion of the surimi-based product industry was made possible by this important change in the nature of its raw material. The surimi industry also rapidly modernized its productivity, to keep pace with the growing demand for frozen surimi.

Thus technological developments, plus the vast resources of hitherto underutilized Alaska pollock in the North Pacific Ocean, helped fuel phenomenal growth of surimi and surimi-based product industries during the 1960's. Within thirteen years after the introduction of frozen surimi in 1960, the Japanese surimi-based product industry doubled in size. The frozen surimi industry by that time was producing 355,000 metric tons annually. As of 1984 the surimi industry is a $500 million business in Japan.

Alaska pollock is the staple raw material fish for the Japanese surimi industry. Though almost any fish can be used to make surimi, no other species can match the combination of abundance, economy, and quality advantages provided by the pollock resource. During the five years from 1980 to 1984, an annual average of about 1.5 million metric tons of Alaska pollock was used for surimi production in Japan or on Japanese vessels. This tonnage represented about 87 per cent of all the raw material fish used for surimi during that time.

B. IMPORTANCE OF THE JAPANESE SURIMI INDUSTRY TO THE UNITED STATES

The Japanese surimi industry is an object of special interest to the United States.

Among the important reasons are:

* The U.S. waters in the Bering Sea, Aleutian Islands, and the Gulf of Alaska are the principal source of Alaska pollock being used to manufacture high-grade surimi by Japan.
* Japan's exports of surimi-based products to the U.S. have risen sharply in recent years.
* The popularity of surimi-based products among American consumers favors the development of a viable U.S. surimi industry.

As can be seen in Figure 1-3 and Table 1-1, around 50 per cent of Japan's catch of Alaska pollock has been taken from waters that came under U.S. jurisdiction in 1977. However, from 1974 to 1976, the contributions from these waters were relatively low due to restricted fleet operations in response to the energy crisis. In 1977 and 1978, the share from U.S. waters rebounded to the levels of the early 1970's as the U.S.S.R. instituted catch restrictions. Since 1978, Japan's Alaska pollock landings have averaged about 1.5 million metric tons annually. An average of about 0.8 million metric tons (about 52 per cent) have been taken from U.S. waters and about 0.3 million metric tons (about 19 per cent) from U.S.S.R. waters.

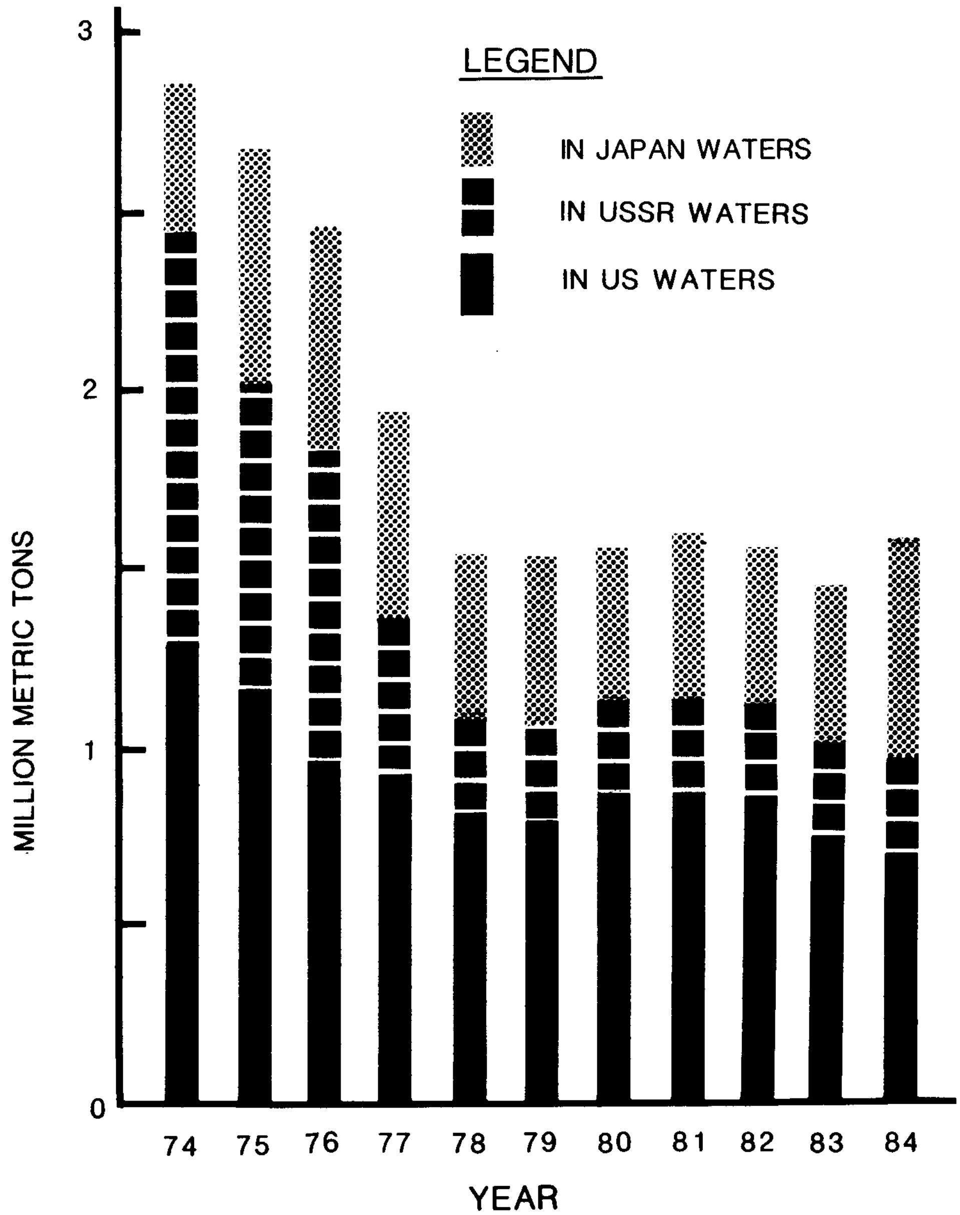


FIGURE 1-3. JAPAN'S ANNUAL CATCHES OF ALASKA POLLOCK BY AREAS, 1974-84

In terms of economic value, pollock catches in U.S. waters play a pivotal role in the Japanese surimi industry. About 95 per cent of Japan's top-grade surimi comes from factoryship operations in U.S. waters. Since 1978, ship-processed surimi has accounted for an average of 59 per cent in volume but as much 70 per cent in value of Japan's yearly surimi output.

TABLE 1-1. JAPAN'S TOTAL ANNUAL CATCHES AND SHARE FROM U.S. WATERS, OF ALASKA POLLOCK, 1970-1984

Year	Total Catches 1,000 Metric Tons	Catches in U.S. Waters* ...Per cent of Total...
1970	2,346.9	53
71	2,655.8	57
72	3,035.4	55
73	3,022.9	49
74	2,855.9	45
1975	2,677.4	43
76	2,445.4	38
77	1,927.6	47
78	1,546.2	52
79	1,551.1	52
1980	1,552.4	56
81	1,595.3	54
82	1,567.0	53
83	1,434.4	51
84	1,621.4	45

* From 1970 through 1976 "catches in U.S. waters" represent those in the area that would become the U.S. Fishery Conservation Zone.

Source: Fisheries of the United States, 1985
Ministry of Agriculture, Forestry and Fisheries, Japan.

It was not until the development of imitation crab that Japanese exports of surimi and surimi-based products to the U.S. rose to significant levels. Shellfish analogs were developed to win back Japanese consumers who were becoming increasingly alienated from kamaboko because of its bland taste. By the late 1970's they became a major "hit" in Japan, and at the same time began to enjoy positive responses overseas (N.S.K., 1985).

Figure 1-4 shows the recent dramatic expansion of Japanese export of imitation crab meat. From 1979 to 1983, export volume doubled every year. In 1983, exports totaled 18,828 metric tons, with nearly 14,000 metric tons (about 73 per cent) going to the U.S.. In 1984, Japanese exports of imitation crab meat rose 72.4 per cent to 32,462 metric tons, of which 26,756 metric tons or 82.4 per cent was directed to the United States.

Exports represent a growing proportion of Japan's crab analog production. In 1981, 16 per cent of the output was exported, and by 1984, the proportion exported had grown to over

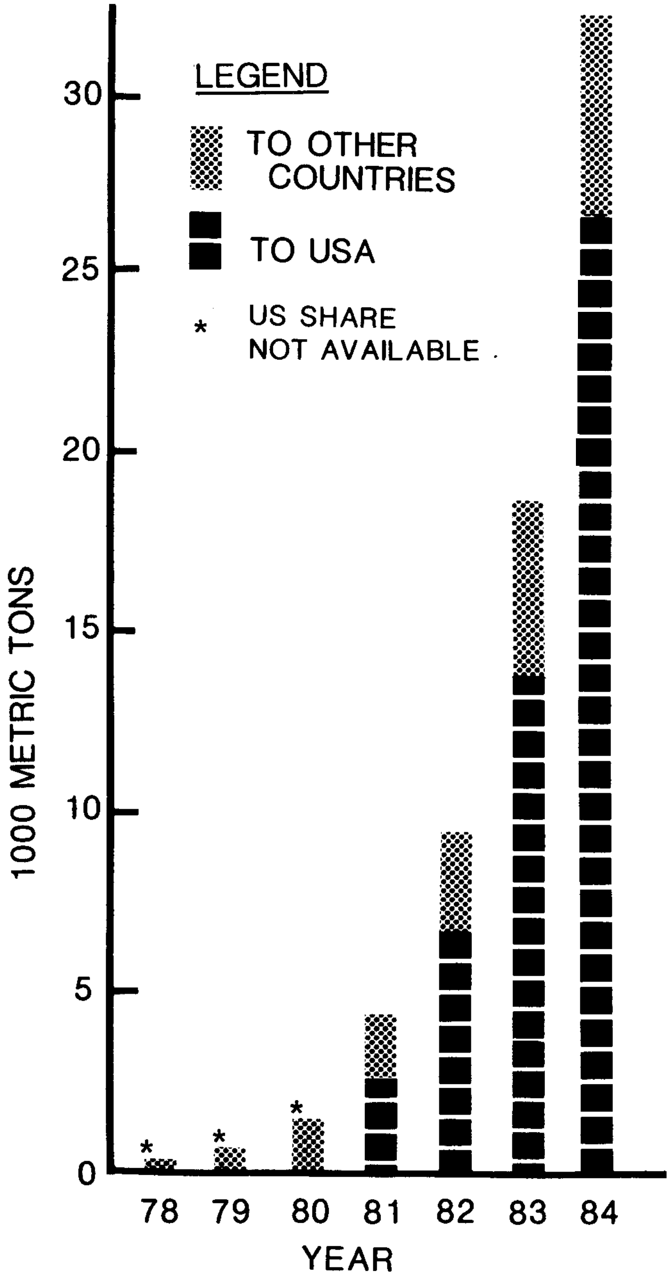


FIGURE 1-4. JAPAN'S EXPORTS OF SIMULATED CRAB MEAT, 1978-84

46 per cent. About 38 per cent of the imitation crab produced in Japan in 1984 was exported to the United States.

It is important to realize also that the imitation shellfish products require as raw material the exclusive use of ship-processed surimi, which originates aboard factoryships in U.S. waters. These conditions obviously favor the development of viable, U.S.-based surimi and surimi-based product industries which can utilize Alaska's pollock resource and serve the rapidly expanding domestic market (Thrash, 1983).

1.2. Important Milestones

A. Brief History

Although the art of making surimi has been practiced in Japan for many centuries, only during the past 26 years has the tradition evolved into a major industrial operation. Setting the stage for this truly dramatic growth phase was the invention in 1960 of frozen surimi. Two other milestones, automated production facilities and the introduction of factoryships, provided further impetus for expansion. From 1961 to 1973, the Japanese surimi industry enjoyed uninterrupted growth.

One of the few negative impacts on the industry during its growth phase was the water pollution act of 1970, which began to control waste-water disposal, adding to the costs of producing land-processed surimi.

The long period of steady growth was followed by a downturn in the supplies of Alaska pollock. Initially, the decline was a result of the oil shock in 1974, which made fishing operations very expensive. The industry was dealt a second blow by restrictions on Japanese catches in U.S. and U.S.S.R. waters, instituted in 1977.

Adjustments to accommodate these situations continue today. With industry and government working together, methods have been developed for making surimi from dark-fleshed species such as the abundant sardine and Pacific mackerel. The success of imitation crab legs, developed in 1973, has also helped to compensate for the increased surimi production costs that resulted from tightened pollock supplies.

B. INTRODUCTION OF FROZEN SURIMI TECHNOLOGY

The early history of the Japanese pollock fishery was based on its yield of roe, a highly prized gourmet food item once called "golden egg" by the fishermen in Hokkaido. After extraction of the roe, the fish had little value because its quality deteriorated rapidly. Disposal of the fish after roe extraction became a major problem for the industry in Hokkaido during the 1950's when as much as 300,000 metric tons of Alaska pollock were being landed annually.

At the same time, kamaboko processors were searching for a way of storing raw surimi in order to liberate the manufacturing process from fluctuations in quality and supply of raw material fish. Even if they froze raw surimi, it lost its gel-forming capacity in a matter of weeks or months, and its quality was inconsistent from one lot to the next.

Freeze denaturation is still a poorly understood phenomenon. When a protein becomes denatured, it loses its native chemical structure and its ability to perform certain biochemical functions such as forming a gel or holding onto water. In the terminology of food science, this is called loss of functionality. Denaturation of proteins can be triggered by extreme temperatures (usually heat), by pH changes, or by the formation of ice crystals between or inside muscle cells. Metal ions such as the iron in hemoglobin, or water-soluble enzymes, can catalyze denaturation. All of these forces are at work in frozen minced fish, so sorting out the mechanism of freeze denaturation is a complex problem (N.S.K., 1982).

The successful development of Alaska pollock frozen surimi, which is protected from freeze denaturation, was announced independently by researchers at Hokkaido Fisheries Research Laboratory (Nishiya et al., 1960; Tamoto et al., 1961; Nishiya et al., 1961) and at Kyoto University (Ikeuchi and Shimizu, 1963) in the early 1960's. The anti-denaturant additives applied by the Hokkaido group consisted of 4 per cent sucrose, 4 per cent sorbitol and 0.25 per cent tripolyphosphate, while the formula developed at Kyoto University consisted of 5 per cent sucrose, 5 per cent sorbitol, and 2.5 per cent salt. Frozen surimi with these additives was called respectively "muen" (salt-free) surimi and "kaen" (salt-added) surimi. Although additional refinements have been introduced to the surimi manufacturing process in subsequent years, the formulae for anti-denaturant additives have remained essentially unchanged.

C. AUTOMATION OF SURIMI PRODUCTION

The discovery of methods for producing a stable frozen surimi from Alaska pollock allowed surimi manufacturing to evolve into an automated mass-production system to keep pace with expanding demand. Automation of surimi manufacturing procedures was essentially completed within about 10 years following the introduction of frozen surimi. The most important machines contributing to this achievement were the screw press and the rotary washing screen or sieve.

The screw press is a highly efficient dewatering machine which reduces the water content of the washed mince, thus maximizing the concentration of protein in the surimi. Prior to the development of the screw press, the dewatering process was accomplished by a basket-type centrifuge, into which the washed minced meat was fed batch by batch.

The efficiency of the centrifuge was limited, and it became the major bottleneck in surimi production operations. While a centrifuge could process only about 0.5 metric ton of minced meat a day, a single screw press could handle as much as 20 metric tons, and, more importantly, the screw press could be integrated into a continuous operation with the washing procedure.

Surimi production was further streamlined with the introduction of a rotary screen, a device that combines the functions of washing and preliminary dewatering. Inserted between the washing tank and screw press, the rotary screen considerably improved the efficiency of both washing and dewatering procedures.

Another machine of special note is the refiner. Previously, the straining procedure aiming to remove membranes, bones, and tendons from the washed minced meat was applied after dewatering. The straining procedure was slow, and also adversely affected the quality of the surimi because the mechanical pressure applied to the meat generated heat. The refiner is not only more efficient in removing impurities, but also is exempt from the heat problem because it works directly on the washed meat, which is temperature-buffered by its high water content.

D. PRODUCTION OF SHIP-PROCESSED SURIMI

The advent of an automated surimi production process meant that surimi production could be performed aboard a factoryship using freshly caught fish directly on the fishing grounds. It also meant that the Alaska pollock resources far from home, such as those in the Bering Sea and the Gulf of Alaska, could be exploited.

Freshness of fish is the most important factor affecting the quality of surimi. A factory trawler can process the fish as soon as they are caught, and the mothership with a delay of only a day or two, whereas the processing of fish at shore plants takes place up to a week after the fish are caught. Thus, the production aboard factoryships will guarantee a quality of surimi generally unmatched by the land-based operation. A shore plant located very close to commercial concentrations of fish could be expected to match the quality of mothership surimi.

The first production of surimi at sea began with two mothership fleets in 1965. A factory trawler then made its debut in 1966. A typical mothership had a production capacity of about 20 to 30 metric tons in an 8-hour day. With three shifts, actual daily production was as high as 60 to 100 metric tons. Daily production of a factory trawler was reportedly 25 to 40 tons. By 1968, total factoryship output surpassed that of the shore plants, with production of 73,625 metric tons at sea against 69,635 metric tons made on shore for that year. In 1984, the factoryships produced 224,444 metric tons against 183,314 metric tons of land-based surimi.

E. DEPENDENCE ON U.S. WATERS FOR RAW MATERIAL FISH

Figure 1-5 shows the dramatic surge in frozen surimi production during the 8 years following the introduction of frozen surimi technology in 1960. It is obvious that the phenomenal increase in frozen surimi production during this period of time was achieved due to the increase in the production of Alaska pollock surimi. Over the four years from 1965 through 1968, Alaska pollock frozen surimi represented an average of 81 per cent of all frozen surimi production (Yamamoto, 1974).

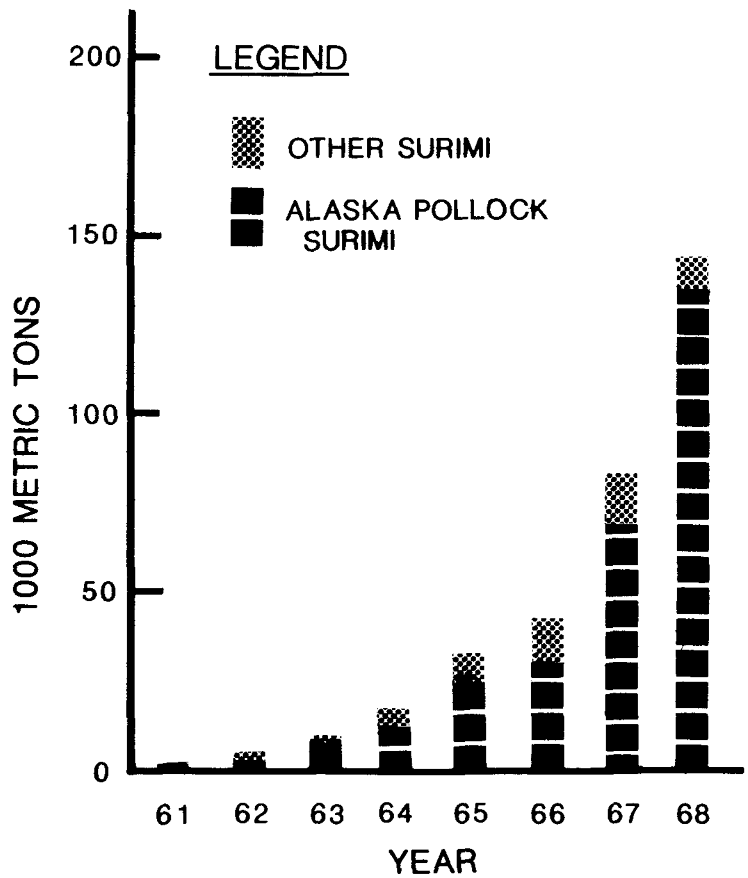


FIGURE 1-5. JAPAN'S SURIMI PRODUCTION, 1961-68

Prior to 1960, Japan's Alaska pollock catch was approximately 300,000 metric tons a year, mostly caught in her home waters and off the Siberian coast. To accommodate the increasing dominance of Alaska pollock as the raw material for surimi in Japan, landings were expanded rapidly.

By 1972, the annual catch of Alaska pollock had increased ten fold to more than 3 million metric tons, and Japan had expanded its Alaska pollock fishing fleet as well as its range of operations throughout the North Pacific Ocean.

Already in 1970, as much as 53 per cent of Japan's catch of Alaska pollock was being derived from U.S. waters in the Eastern Bering Sea and around the Aleutian Islands where its factoryship operations were concentrated. During a recent 6-year period between 1978 and 1983, after the declaration of 200-mile Fishery Conservation Zones by both the U.S. and Soviet Union, Japan's catch of Alaska pollock in U.S. waters ranged between 51 and 56 per cent of its total catch of this fish annually.

F. SURIMI-BASED IMITATION SEAFOOD PRODUCTS

Adoption of the bland-tasting Alaska pollock as the overwhelming staple raw material for surimi meant that kamaboko products were lacking in variety. As early as 1970, some surimi-based product manufacturers began to experiment with new product concepts and with ways of incorporating new flavors into their kamaboko. The initial market success came in 1973 when the first surimi-based crab meat with imitation flavor was introduced. Another major breakthrough occurred in 1976 when a process was developed that could create a fibrous texture extremely similar to that of a natural crab leg.

The invention of imitation crab legs was called the greatest achievement of the postwar seafood processing industry in Japan. Today, there are imitation scallops and shrimps and many other varieties, manufactured by nearly 50 producers, all employing basically the same technology.

Reflecting wide-spread consumer acceptance, the production of shellfish analogs has risen sharply; 40 per cent from 1980 to 1981, 44 per cent from 1981 to 1982, 62 per cent from 1982 to 1983 and 20 per cent from 1983 to 1984. Statistics compiled by the Japanese Ministry of Agriculture, Forestry and Fisheries show that the 1984 production of shellfish analogs was 71,323 metric tons, constituting about 7 per cent of all the surimi-based products manufactured that year. The surge of imitation crab production since 1981 coincided with, and is largely responsible for, the recovery of kamaboko production as a whole since 1981 (see Table 1-11). **Table 1-2 and Figure 1-6 exhibit the production history of this unique product dating back to 1973, the year in which the original version of imitation crab meat was introduced.**

TABLE 1-2. PRODUCTION OF IMITATION CRAB MEAT, 1973-1984

Year	Metric Tons
1973	16,869
74	15,446
75	10,761
76	20,401
77	24,304
78	16,615
79	17,589
80	18,037
81	25,300
82	36,555
83	59,328
84	67,990

Source: Kamaboko Nenkan (N.S.K., 1985)

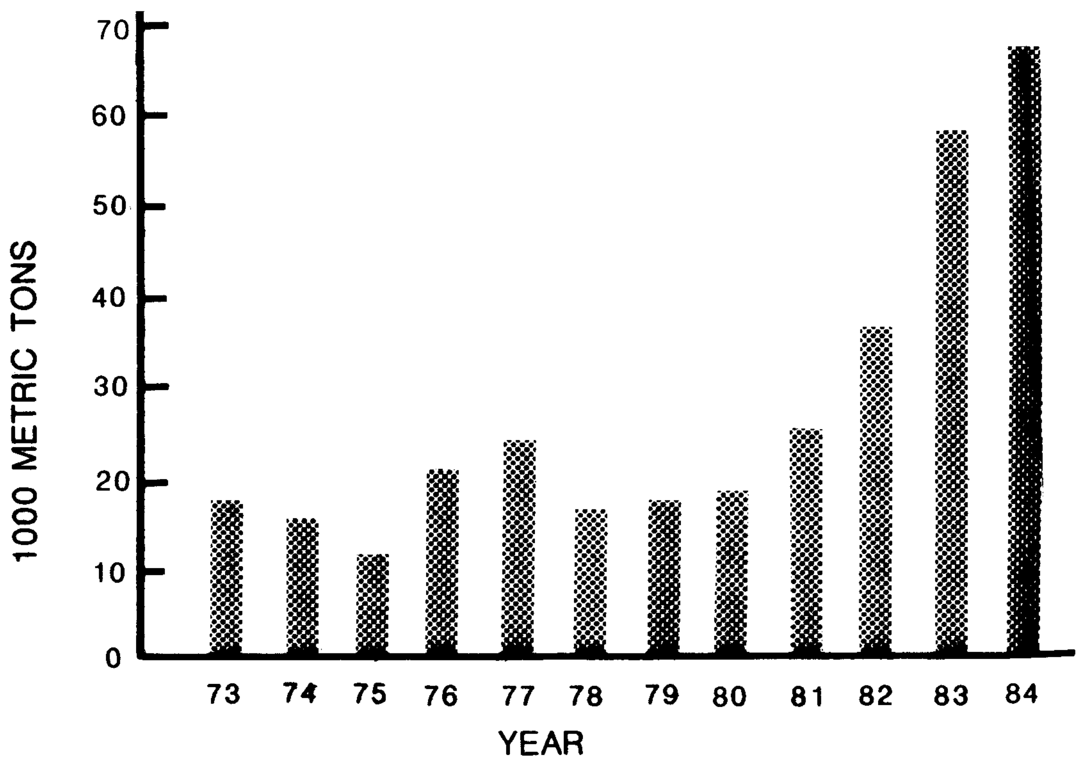


FIGURE 1-6. PRODUCTION OF IMITATION CRAB MEAT IN JAPAN, 1973-84

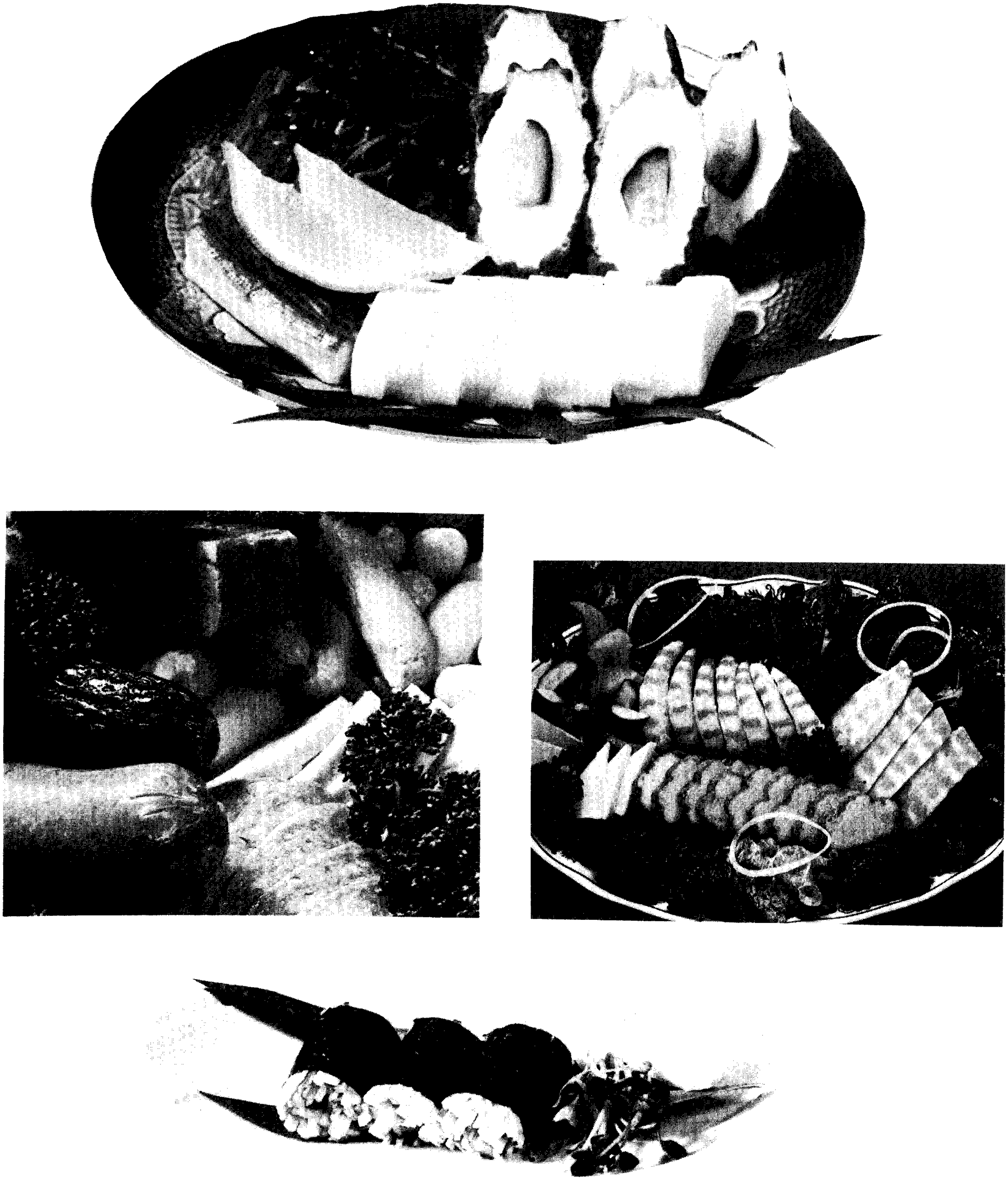
Japanese exports of surimi-based products to the U.S. were insignificant until about 1979. The surimi-based products in their traditional "kamaboko" style offered little taste appeal to U.S. consumers, despite their advantages as healthy, high protein, low calorie, low cholesterol foods. The advent of imitation scallop, shrimp and crab meats now has changed this trend. As shown in Table 1-3 , between 1981 and 1984, Japan's exports of these products to the U.S. increased ten-fold, from 2,600 metric tons to nearly 27,000 metric tons. Over the same period of time, exports to the U.S. accounted for 64 to 82 per cent of the total exports by Japan. Also in this year, shipments of this product to the U.S. east coast tripled those of the previous year, reflecting a rapidly expanding popularity of this product across the country. Thus for the first time in history, surimi-based foodstuffs are being exported actively to the U.S..

Figure 1-7 shows selected examples of surimi-based products including imitation seafood by leading manufacturers in Japan.

TABLE 1- 3 . JAPAN'S EXPORTS OF IMITATION SEAFOOD TO THE U.S., 1981-1984

Year	Total Exports	East Coast	West Coast	Sub Total	Share of Exports to U.S.A.
	..................Metric	Tons................			.Per cent..
1981	4,044	---	---	2,600	64.3
82	9,330	2,231	4,518	6,749	72.3
83	18,828	3,921	9,902	13,823	73.4
84	32,462	12,572	14,184	26,756	82.4

Source: Japan Frozen Foods Inspection Corporation



(COURTESY OF YANAGIYA MACHINERY WORKS, LTD. & AOBA KASEI CO., LTD.)

FIGURE 1- 7. EXAMPLES OF SURIMI-BASED PRODUCTS

G. SURIMI FROM UNDERUTILIZED SPECIES

Since about 1970, Japan has carried out extensive tests aiming to utilize various fish species other than Alaska pollock as raw material for frozen surimi. Species included in these tests were those belonging to the white-fleshed deep-sea cod family, the abundant domestic species such as sardine and Pacific mackerel which feature dark meat, the Antarctic krill, and sharks (Noguchi, 1984).

Deep-sea cod (Mora pacifica Waite) off New Zealand was studied as early as 1970 for its suitability in surimi-based products. In 1976, a high-grade surimi was successfully produced from hoki (Macrourus novaezelandiae) and deep-sea whiptail (Lepidorhynchus denticulatus) aboard a factory trawler. Similar tests were performed using forked hake (Podonema longipes), a species caught in large quantities along with Alaska pollock, and on blue whiting (Micromesistius poutassou), an Atlantic species of the cod family.

Two test products of Antarctic krill surimi were prepared in 1982 as a result of a government-funded research effort (Fisheries Agency, 1982a). Because of the extreme difficulty of performing a sufficient dehydration on the krill meat, which has a strong tendency to swell when washed, the krill surimi exhibited poor gel strength. An attempt to use shark meat as raw material for surimi was begun as a government-funded program in 1982. Already, a method for producing a high-grade surimi from shark meat is said to have been ascertained (Noguchi, 1984).

In 1977, the Japanese government launched an $8.5 million 5-year program aiming to develop surimi from the dark meat of sardine and Pacific mackerel, abundant domestic species (Fisheries Agency, 1982b). As shown in Figure 1-8, it was obvious that the rapidly growing landings of sardine as well as large landings of Pacific mackerel would more than offset the impact of declining Alaska pollock catches if their meat could be converted to surimi.

A new method had to be developed to achieve this objective because of the unique characteristics of the meat of sardine and Pacific mackerel. The dark fish muscle loses its freshness very quickly after the death of the fish. Its pH level drops below 6, prompting denaturation of actomyosin. The large amount of fat and pigment in the dark meat can not be removed with regular washing procedures such as used for Alaska pollock (Fujii, 1981).

The program, a joint effort among government laboratories, universities and industry, progressed rapidly, leading to the launching of a pilot plant at Hachinohe in 1978 and another at Nagasaki in 1979. The first commercial production began at Hachinohe in 1982. While the production of dark-meat surimi still remains low-keyed, the popularity of the products based on dark-meat surimi points to a promising future.

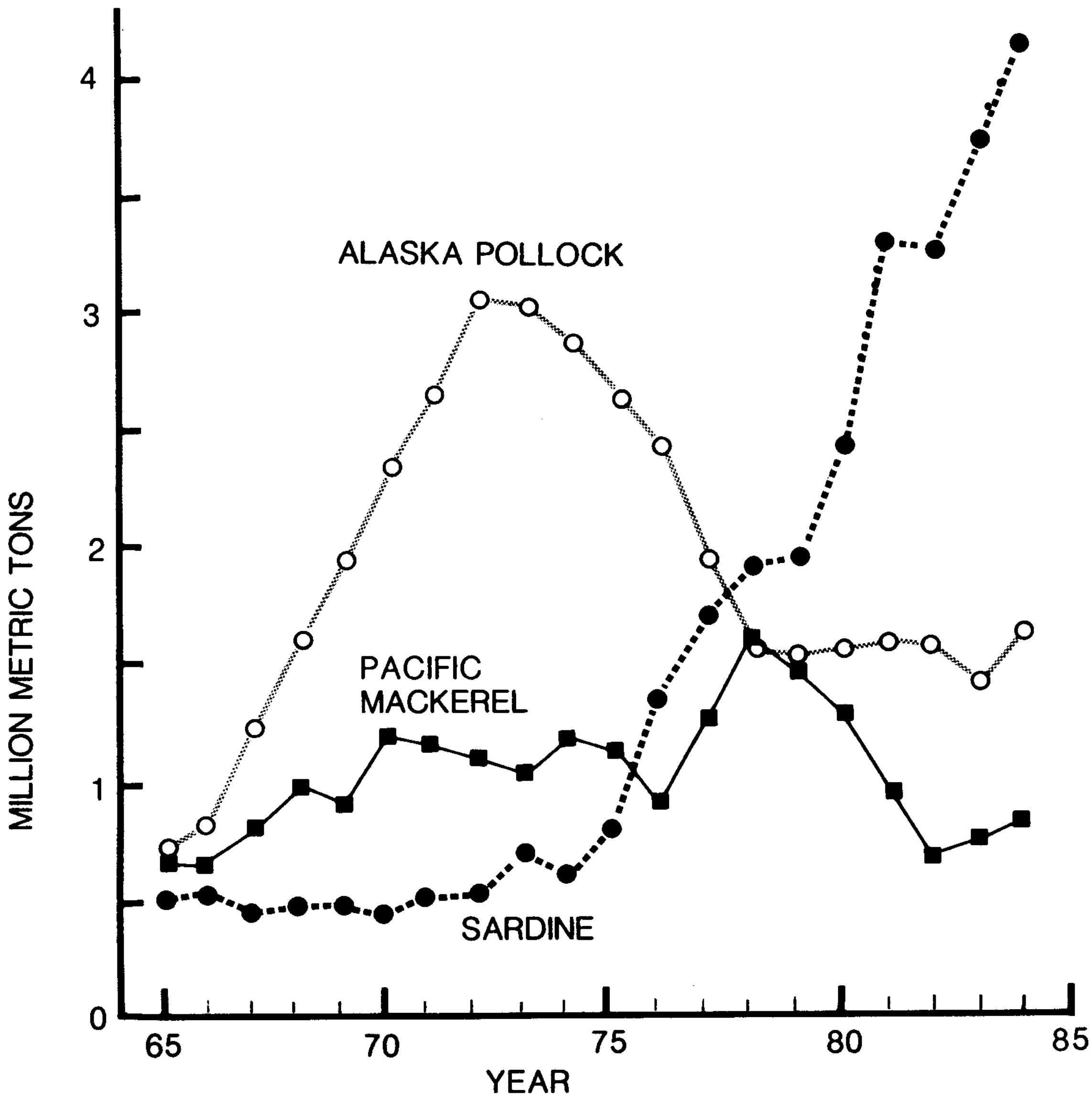


FIGURE 1-8. JAPAN'S ANNUAL CATCHES OF ABUNDANT SPECIES, 1965-84

1.3. JAPANESE SURIMI INDUSTRY

A. DOMESTIC PRODUCTION

The history of frozen surimi production in Japan from 1960 to 1984 is illustrated in Figure 1-9 and in Table 1-4. The 25-year history of frozen surimi in Japan consists of two distinct periods: an expansion phase until 1973, and a period from 1974 to the present, during which the production has hovered around 300,000 to 400,000 metric tons per year.

The dramatic rise in surimi production was particularly evident during a 6-year period between 1967 and 1973. This trend was facilitated by the advent of automated facilities for surimi production and by the introduction of factoryship operations. By 1973, total annual output of surimi rose to 382,744 metric tons, more than quadrupling the 1967 figure.

The number of surimi production facilities also registered a rapid rise during this period. From 1967 to 1973, land-based plants increased from 58 to 103, and the count of factoryships rose from 6 to 22. Factory trawler operations became the dominant mode of surimi production during this period. By 1973, the annual production of ship-processed surimi by a total of 22 factoryships climbed to 223,599 metric tons, accounting for

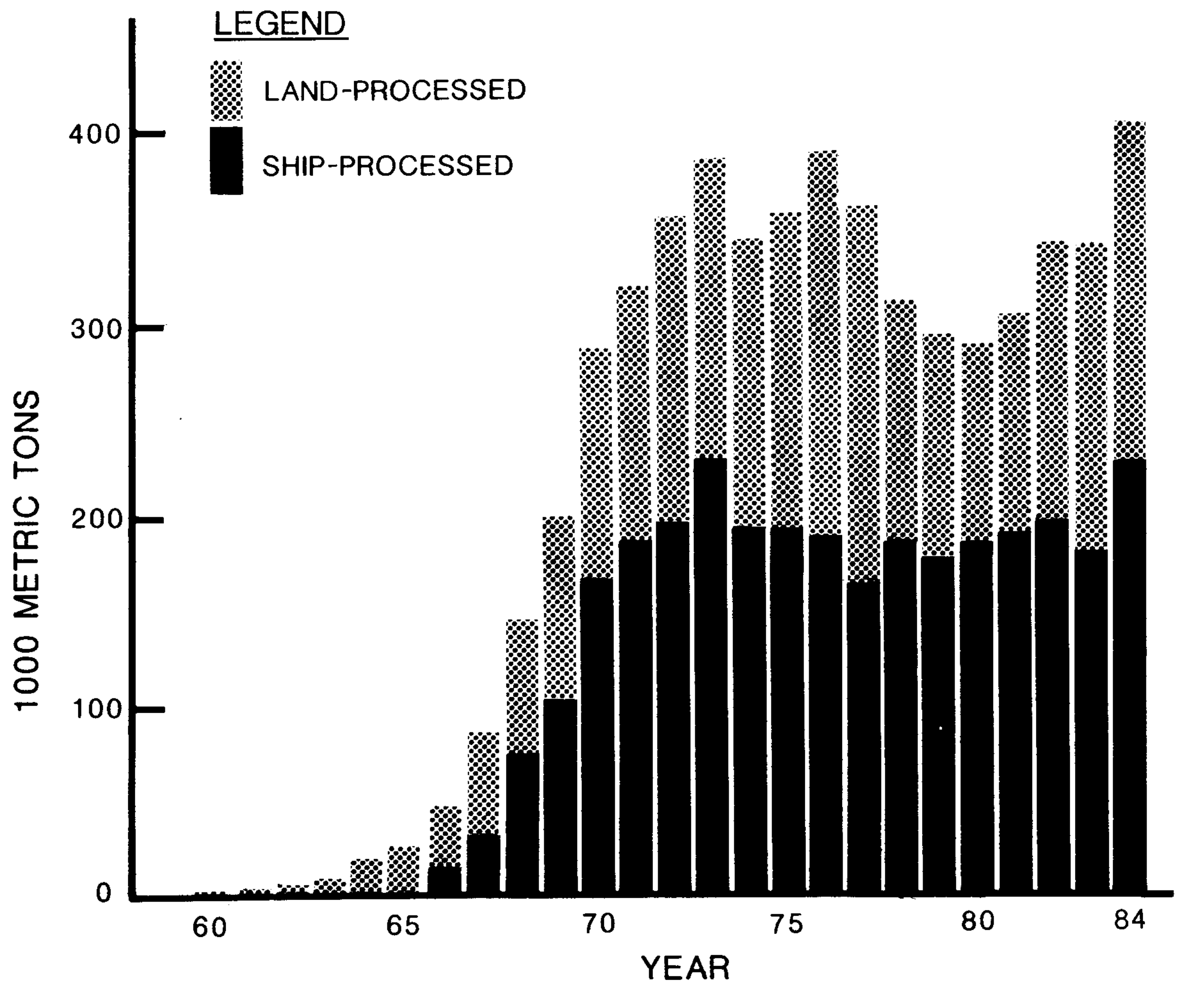


FIGURE 1-9. JAPAN'S SURIMI PRODUCTION, 1960-84

TABLE 1-4. JAPAN'S SURIMI PRODUCTION AND PRODUCTION FACILITIES, 1960-1984

Year	Production Volume (Metric Ton)			Production Facilities	
	Land-Processed	Ship-Processed	Total	Land-Based Plant	Factory-Ship
1960	250	0	250	4	0
61	2,500	0	2,500	9	0
62	4,500	0	4,500	14	0
63	9,283	0	9,283	28	0
64	18,060	0	18,060	39	0
65	23,639	8,184	31,823	41	2
66	29,912	13,014	42,927	54	5
67	44,869	37,550	82,419	58	6
68	69,635	73,625	143,260	121	12
69	92,719	103,610	196,329	110	14
70	118,249	142,802	261,051	100	15
71	137,848	183,535	321,383	110	15
72	161,308	193,548	354,856	105	19
73	159,145	223,599	382,744	103	22
74	152,829	195,297	348,126	100	23
75	169,034	191,730	360,764	97	23
76	197,560	187,806	385,366	125	22
77	193,123	168,823	361,946	111	22
78	132,432	183,012	315,444	89	19
79	114,426	180,402	294,828	85	20
80	105,669	183,232	288,901	76	20
81	114,393	192,264	306,657	66	22
82	142,000	198,534	340,535	61	22
83	160,000	180,000	340,000	61	22
84	183,314	224,444	407,758	61	22

Source: Japan Surimi Association

58 per cent of the total output for the year. For the last several years the shore plants, although their number is declining, have retained about a 40 per cent share of the total surimi production.

In terms of value, the factoryship contributions were much greater than indicated by volume. For instance, in 1973, the price of high-grade ship-processed surimi averaged ¥178.33/kg, whereas the land-surimi averaged ¥137.83/kg for grade-A product.

Thus, the ship-processed surimi comprising 58 per cent of the total production volume was worth at least 66 per cent of the total value. Multiplying prices by volumes, it can be shown that the ship-processed surimi was almost twice as important economically as the land-based surimi.

During the period from 1974 to the present, a series of events occurred which helped brake the unbridled growth of the Japanese surimi industry. There was fear that the Alaska pollock resource might be overfished. The average size of the fish being caught was obviously dwindling, an indicator of heavy fishing pressure. In the peak harvest year of 1972, Japan had landed a total of 3,035,000 metric tons of Alaska pollock, an astounding catch figure for a single species.

Mounting international pressure led to catch regulations in U.S. and Soviet waters, institutionalized by the proclamation of Fishery Conservation Zones by both countries in 1977. By the following year, Japan's total catch of Alaska pollock in the North Pacific Ocean had dropped to 1,546,000 metric tons, about half of her peak harvest in 1972. Japan's annual harvest of Alaska pollock since that year has remained at similar levels.

The oil crisis in 1974 also had a major influence on the surimi industry, hitting particularly hard the factoryship operations which were heavily dependent on fuel oil. These events, i.e., catch regulations and the oil crisis, were responsible for two quantum jumps in the price of surimi that occurred during the period between 1974 and the present. The prices of surimi approximately doubled during this period of time.

Although the production of surimi did decline after 1974, its drop was not as precipitous as the collapse in the supply of Alaska pollock. Annual production over the recent five years from 1980 to 1984 averaged 88 per cent of the peak 1973 level. Considering the rise in surimi prices during the same period, the value of surimi production has risen about 90 per cent over 1973 without inflationary adjustment. Today, annual production of frozen surimi in Japan is worth approximately $500 million at the wholesale level.

B. IMPORTS AND EXPORTS

In recent years, Japan has been importing annually between 4,000 and 5,000 metric tons of frozen surimi from Taiwan and Thailand, but the supply from these sources is expected to decline in the years ahead.

Taiwan manufactures frozen surimi at about 60 land-based plants using croaker and sharp-tooth eel. Landings of these species have been declining, so her ability to boost the supply of this product is suspect. Demand for imitation crab legs has risen sharply in Taiwan, so that she may begin to import high-grade frozen surimi from Japan.

Thailand exports between 2,000 and 2,500 metric tons of surimi to Japan. It is doubtful that the quantity will increase, since landings of croaker and butterfly-bream, the raw material species, are thought to have reached their maxima.

South Korea once exported frozen croaker surimi to Japan, but the supply from this source has ceased since about 1975, due in part to the declining catch of croaker and in part to the rising demand for surimi-based products in South Korea's own domestic market. In light of her strong interest in enhancing her own frozen surimi manufacturing capability, South Korea may resume her role as an exporter of this product to Japan in the future. She maintains three factory trawlers in the North Pacific Ocean and has begun manufacturing imitation crab meat from her own Alaska pollock frozen surimi.

Table 1-5 summarizes the history of Japanese exports of Alaska pollock frozen surimi since 1974. Figure 1-10 and Table 1-6 illustrate the exports of surimi from Japan to the U.S. as compared to total Japanese surimi exports.

As shown in Table 1-5, Japan's export of Alaska pollock frozen surimi hovered near a meager 700 metric tons a year until about 1980. As evident in Table 1-6, the U.S. has been the dominant destination for surimi throughout its export history. Exports began to rise sharply in 1981 and have continued the trend through 1984. Over this period of time, total exports of surimi have almost quadrupled, from about 700 to 2,600 metric tons a year. The U.S. share of the exports was about 90 per cent in 1984.

The sudden surge in the Japanese sale of frozen surimi to the U.S. since 1981 stems from the interest shown by the U.S. food industry in producing imitation crab meat in this country. Nearly 27,000 metric tons of Japanese-made imitation crab meat was purchased by U.S. consumers in 1984 (Table 1-7), which was worth about $190 million on the retail level. Since the imitation crab meat contains frozen surimi for about half its weight, a sale of 27,000 metric tons of this product means that there exists a confirmed demand for frozen surimi in this county amounting to at least about 13,500 metric tons, more than five times the amount imported from Japan in 1984. At the current price of about $1.10/lb CIF west coast, this demand for high quality surimi is worth about $33 million. It is not surprising that more than half a dozen new plants will begin producing imitation crab in the U.S. in 1985 or early 1986, and several surimi plants in Alaska are planned to follow.

TABLE 1-5. JAPAN'S EXPORTS OF ALASKA POLLOCK FROZEN SURIMI, 1974-1984

Year	U.S.A. East Coast	U.S.A. West Coast	U.S.A. Subtotal	Canada	Europe	Total*
	........................Metric Tons......................					
1974	55.0	544.0	599.0	---	---	603.0
75	2.2	683.9	686.1	---	8.8	694.9
76	2.2	485.9	488.1	---	---	489.2
77	---	771.1	771.1	14.8	6.0	793.3
78	6.5	648.8	655.3	6.0	---	661.3
79	---	681.1	681.1	7.5	4.0	692.6
80	---	703.0	703.0	6.0	---	709.0
81	13.5	815.6	829.1	20.4	7.0	928.0
82	18.1	1,095.6	1,113.7	55.0	4.6	1,276.3
83	33.2	1,675.1	1,708.3	69.2	3.6	1,962.8
84	247.8	2,058.6	2,306.4	55.0	6.4	2,579.8

* Total also includes other countries
Source: Japan Frozen Foods Inspection Corporation

TABLE 1-6. U.S. SHARE OF JAPAN'S SURIMI EXPORTS, 1974-1984

Year	Total Exports	U.S. Share East Coast	U.S. Share West Coast	U.S. Share Subtotal
	..Metric Tons..	...............Per Cent.............		
1974	603	9.1	90.2	99.3
75	695	0.3	98.4	98.7
76	489	0.5	99.3	99.8
77	793	0	97.3	97.3
78	661	1.0	98.1	99.1
79	692	0	98.4	98.4
80	709	0	99.2	99.2
81	928	1.4	87.9	89.3
82	1,276	1.4	85.8	87.2
83	1,963	1.7	85.3	87.0
84	2,579	9.6	79.8	89.4

Source: Japan Frozen Foods Inspection Corporation

TABLE 1-7. JAPAN'S EXPORTS OF IMITATION CRAB MEAT*

EXPORTS BY DESTINATION, 1982-1984

Country	1982	1983	1984
	..............Metric Tons............		
U.S.A., East Coast	2,231	3,921	12,572
U.S.A., West Coast	4,518	9,902	14,184
New Zealand	114	309	428
Australia	1,751	1,580	1,641
Canada	26	210	778
United Kingdom	348	2,139	1,602
Belgium	43	157	216
France	5	44	9
Netherlands	117	241	269
Italy	N.A.	5	10
Norway	N.A.	84	248
Sweden	43	67	197
Middle East	N.A.	1	3
Southeast Asia	29	49	146
South Africa	64	104	63
Other Countries	41	15	96
Total	9,330	18,828	32,462

EXPORTS BY YEAR, 1978-1984

Year	Quantity
	Metric Tons
1978	405
1979	442
1980	1,472
1981	4,044
1982	9,330
1983	18,828
1984	32,462

* Made with Alaska pollock surimi (50-60%), crab meat or crab paste (some companies claim to have up to 20%) and other ingredients.

Source: Japan Frozen Foods Inspection Corporation.

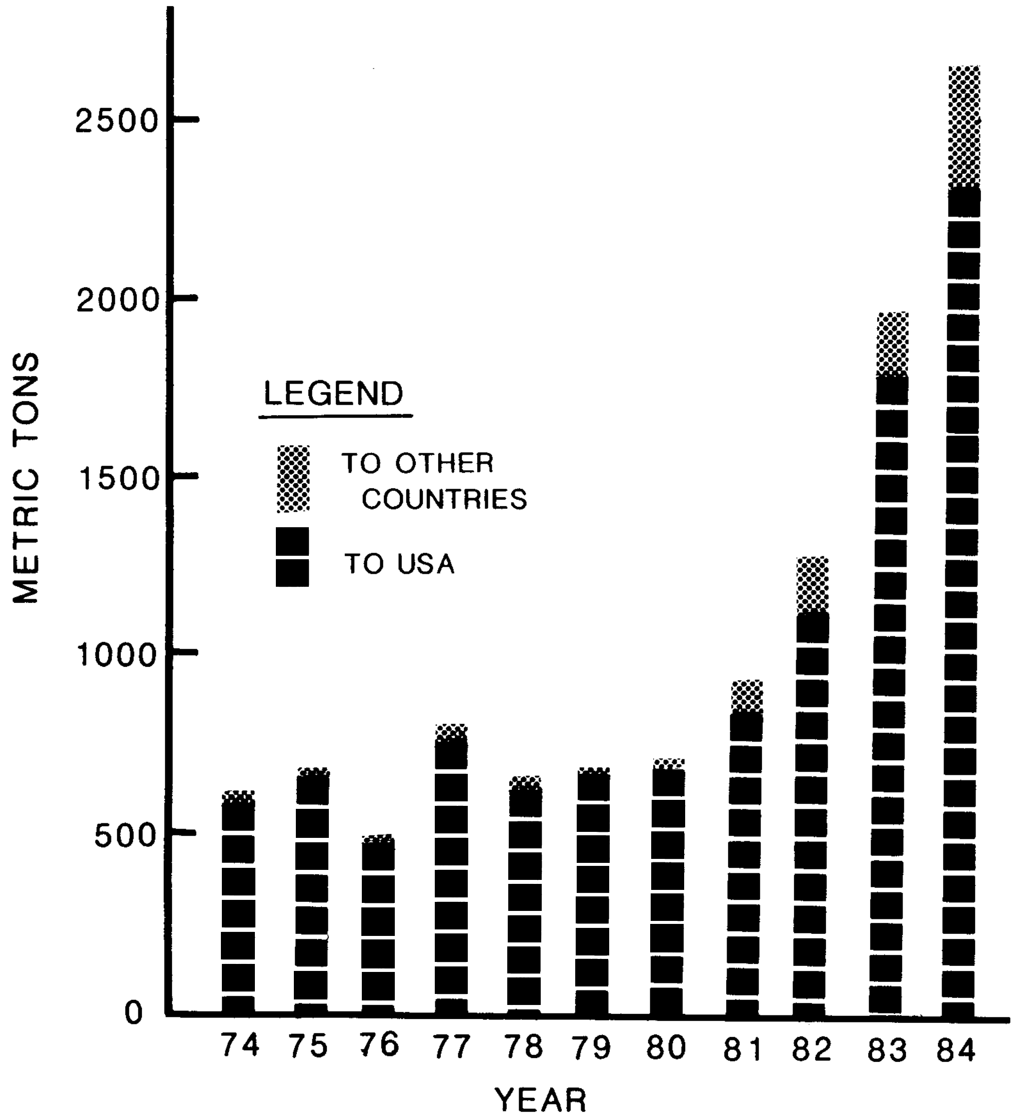


FIGURE 1-10. JAPAN'S EXPORTS OF ALASKA POLLOCK FROZEN SURIMI, 1974-84

C. PRICES OF FROZEN SURIMI

Figure 1-11 and Table 1-8 summarize the history of surimi prices in Japan since 1972. Comparing the prices between 1972 and 1984, one finds that the prices for both ship-processed and land-processed surimi approximately doubled during this period. Also during the same time, the price difference between ship-processed and land-processed surimi widened considerably. For example, in 1972, prices for ship-processed surimi were approximately ¥173/kg ($0.33/lb at ¥240 = U.S. $1) and those for land-based grade 2 surimi approximately ¥94/kg ($0.18/lb). By 1984, the prices had risen to about ¥412/kg ($0.78/lb) and ¥204/kg ($0.39/lb), respectively. The difference in prices between ship-processed and land-processed surimi has widened from ¥79/kg ($0.15/lb) in 1972 to ¥208/kg ($0.39/lb) in 1984.

As mentioned previously, the two major increases in surimi prices occurring in 1974-1976 and in 1977 may be attributed respectively to the oil crisis and to the establishment of catch restrictions in U.S. and Soviet waters. Another important factor that affected surimi price fluctuations was the quantities held in cold storage (Z.S.K., 1984). As shown in Figure 1-12, cold storage holdings reached a 100,000 metric ton level by 1977 and began to impact the prices of surimi.

TABLE 1-8-A. MONTHLY AVERAGE WHOLESALE PRICES OF FROZEN SURIMI, FACTORYSHIP PROCESSED, TOP GRADE, 1972-1984*

Year	1	2	3	4	5	6	7	8	9	10	11	12**
						¥/kg						
1972	175	175	170	170	170	170	170	170	170	180	180	180
73	180	175	170	170	170	170	175	180	185	185	190	190
74	225	225	240	255	255	255	255	255	255	265	275	295
75	285	270	270	270	280	280	280	285	295	300	310	310
76	270	255	260	260	265	265	265	260	260	270	280	290
77	290	300	300	310	320	390	390	420	420	420	430	430
78	430	430	430	430	430	430	425	425	425	425	425	425
79	425	425	425	435	438	440	440	445	440	440	440	440
80	435	440	430	430	430	430	430	430	430	430	430	430
81	370	360	320	320	320	320	330	340	340	340	340	340
82	350	360	360	370	370	370	375	375	375	380	390	390
83	390	390	390	390	390	390	410	410	400	400	410	410
84	410	410	410	410	410	410	410	410	415	415	415	420

TABLE 1-8-B. MONTHLY AVERAGE WHOLESALE PRICES OF FROZEN SURIMI, LAND-PROCESSED GRADE 1, 1971-1984*

Year	1	2	3	4	5	6	7	8	9	10	11	12**
						¥/kg						
1971	105	107	109	108	108	105	89	90	104	114	114	109
72	113	113	108	105	106	106	111	115	125	120	115	120
73	118	125	130	134	135	135	135	140	130	120	125	138
74	148	148	137	135	135	133	125	128	130	130	145	160
75	140	135	135	138	138	137	138	145	153	155	160	160
76	155	155	155	155	160	160	165	170	165	170	180	200
77	180	180	183	225	275	390	380	360	335	320	320	325
78	300	310	313	320	300	270	245	230	210	230	215	210
79	200	205	230	255	260	275	300	315	349	280	260	258
80	300	300	295	310	315	325	330	305	260	275	295	285
81	267	---	250	250	230	---	210	240	240	230	220	210
82	225	235	245	240	240	235	230	220	225	---	---	230
83	240	235	230	230	240	345	345	300	280	240	220	210
84	210	220	250	260	240	220	220	205	200	210	220	220

TABLE 1-8-C. MONTHLY AVERAGE WHOLESALE PRICES OF FROZEN SURIMI, LAND-PROCESSED GRADE 2, 1970-1984*

Year	1	2	3	4	5	6	7	8	9	10	11	12**
						¥/kg						
1970	105	105	105	110	105	98	98	104	110	113	115	113
71	81	82	85	82	81	78	72	80	84	94	94	89
72	94	88	93	79	79	81	94	105	115	100	100	100
73	105	115	114	115	115	116	121	115	100	90	95	105
74	130	126	114	110	106	102	90	91	98	110	138	140
75	122	115	115	118	115	106	115	125	140	143	145	143
76	128	135	136	138	138	142	147	153	150	153	172	180
77	165	165	173	210	260	370	370	345	320	300	290	280
78	270	280	290	285	260	225	210	180	180	180	180	175
79	175	170	185	230	235	240	280	300	320	250	240	240
80	275	280	285	285	305	315	315	280	255	257	275	265
81	257	245	225	225	210	200	190	215	210	215	210	208
82	215	225	230	230	220	215	210	190	195	215	215	210
83	215	210	208	210	220	245	325	280	260	220	200	180
84	190	200	220	240	220	200	200	195	190	195	200	200

* Wholesale prices delivered to wholesalers in Western Japan.
** Numbers 1-12 denote months.

Source: Japan Surimi Association

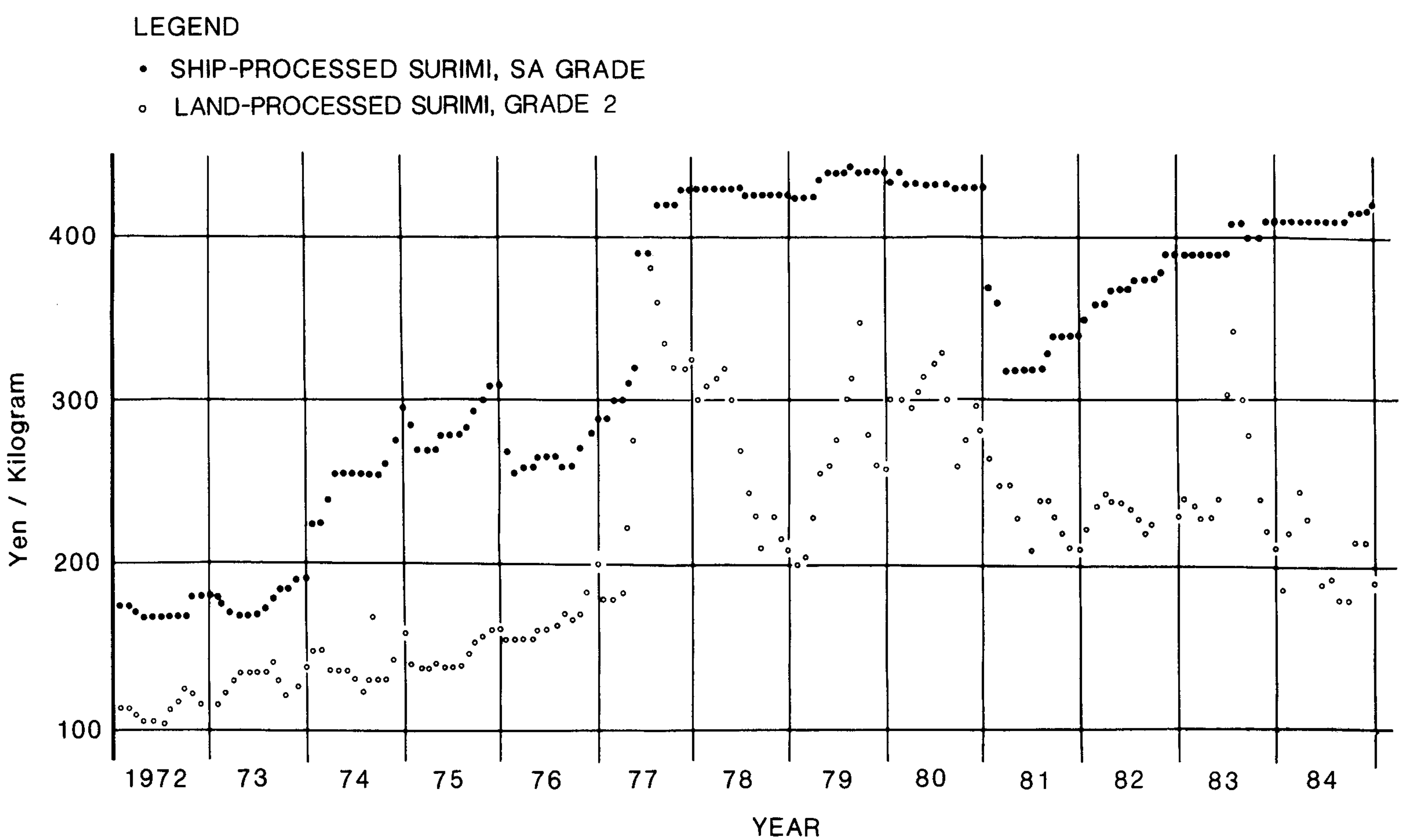


FIGURE 1-11. MONTHLY AVERAGE WHOLESALE PRICES OF SURIMI, 1972-84

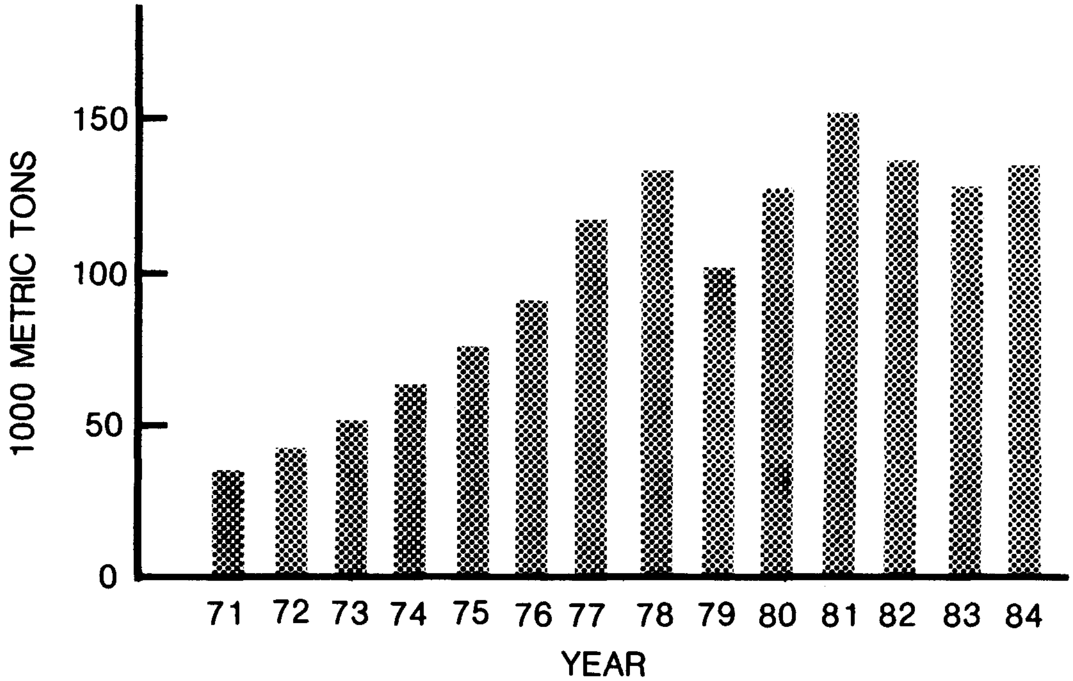


FIGURE 1-12. YEAR-END COLD STORAGE HOLDINGS OF SURIMI IN JAPAN, 1971-84

Figure 1-13 shows a comparison between cold storage holdings and prices of land-processed surimi (grade 2) by month during 1978 through 1984. Obviously, these two factors correlate inversely with each other, so that the greater the cold storage holdings, the lower the prices, and vice versa.

As shown in Figure 1-14, the prices of ship-processed surimi have been much more stable than those of land-processed surimi, although they are not entirely free from major fluctuations. The drastic drop in prices that occurred from January through March, 1981 (see also Figure 1-11) was due to pressure from overstocked cold storage holdings of ship-processed surimi.

Grade 2 surimi represents about 80 per cent of all the land-processed surimi being produced in Japan. Therefore, the relationship shown in Figure 1-15 shows similar price fluctuations for both grade 1 and grade 2 land-processed surimi. Patterns have varied from year to year, often drastically. Informed sources cite landings and prices of Alaska pollock as additional important factors affecting the prices of land-processed surimi.

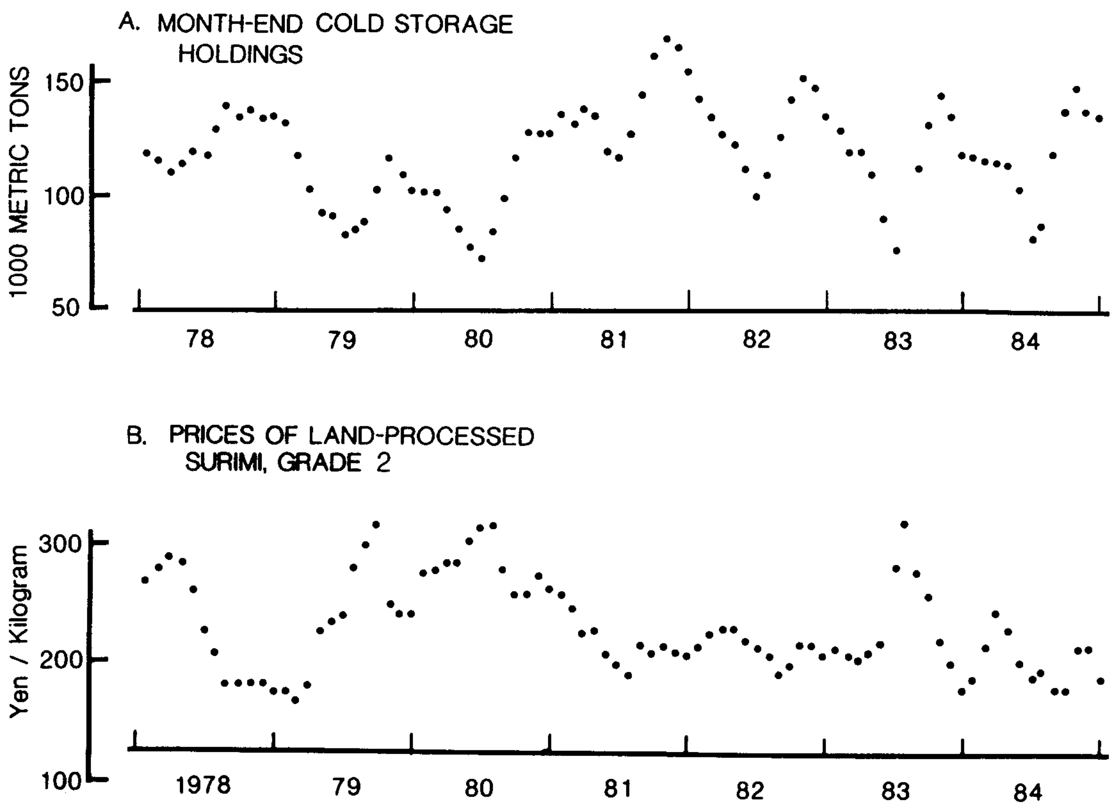


FIGURE 1-13. COLD STORAGE HOLDINGS VERSUS PRICES FOR LAND-PROCESSED SURIMI, 1978-84

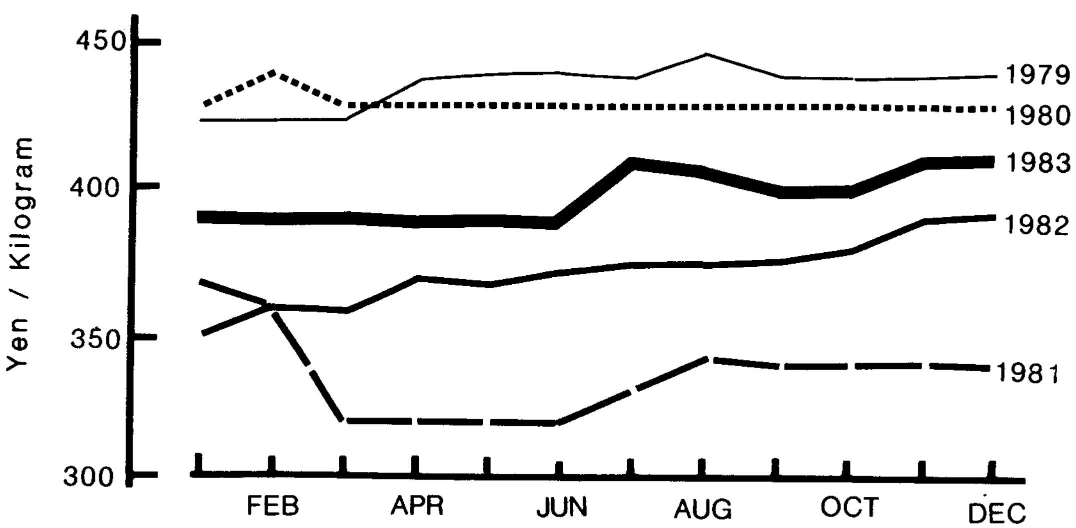


FIGURE 1-14. PRICE FLUCTUATIONS OF SHIP-PROCESSED SURIMI, 1979 - 83

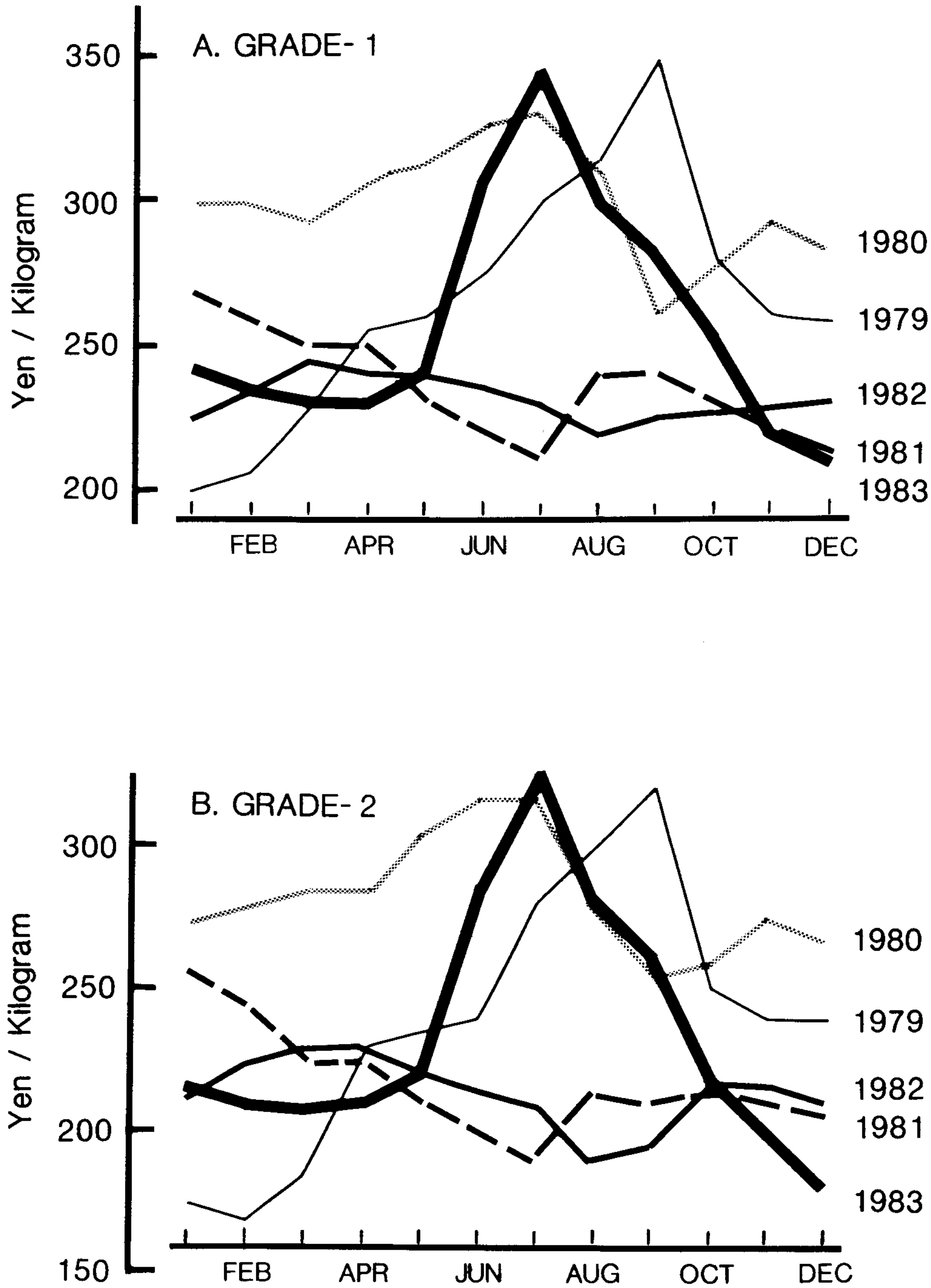


FIGURE 1-15. PRICE FLUCTUATIONS OF LAND-PROCESSED SURIMI, 1979-83

D. END PRODUCTS OF SURIMI: SURIMI-BASED PRODUCTS

Surimi is the intermediate raw material from which the end products called "neri-seihin" (surimi-based products) are manufactured. The majority of surimi-based products, approximately 90 per cent, are comprised of various types of fish cake called "kamaboko". Less than 10 per cent of surimi-based products are represented by fish sausage, fish ham and fish-burgers. The imitation crab and other surimi-based shellfish analogs may be included as kamaboko.

Kamaboko products are divided among three major categories: steamed kamaboko, broiled kamaboko and fried kamaboko. Typical steamed kamaboko is called itatsuki (board-mounted) kamaboko, but the variety also includes imitation seafood, naruto and hampen, a spongy marshmallow-like product which contains entrapped air. The typical broiled kamaboko is chikuwa, which has the shape of a hollow bamboo stem. Typical fried kamaboko (age-kamaboko) products are satsuma age and tempura. Kamaboko is also given various names depending on product shapes, such as sasa (bamboo-leaf shaped), soba (noodle-shaped), date-maki (swirled or rolled), etc.

The main ingredient of kamaboko is a homogeneous gel of ground fish muscle, obtained by kneading the thawed frozen surimi or raw surimi into a paste with salt. It also contains other ingredients such as sugar, starch, sweet sake, sodium glutamate, etc. Example formulations for typical kamaboko products are shown in Tables 1-9 and 1-10.

Table 1-11 summarizes annual production of surimi-based products by Japan since 1970. The production peaked at 1,185,100 metric tons in 1973, but decreased continuously for the subsequent seven years, reaching an historical low of 913,186 metric tons in 1980. Annual output since 1981 has increased to nearly 1 million metric tons.

In Table 1-11 the production of imitation crab meat has been listed under the category of "others" of the kamaboko family only since 1978. Until that time, it was included in the category of steamed kamaboko.

TABLE 1-9. TYPICAL INGREDIENTS IN KAMABOKO

INGREDIENTS	ODAWARA KAMABOKO	TOYOHASHI CHIKUWA
	.... Per cent	....
Surimi	76 - 84	80.2
Additives:		
Salt	4.2 - 5.3	2.6
Sugar	11.9 - 19.5	6.4
Sodium glutamate	1.2 - 2.0	1.2
Potato starch	0 - 6.5	---
Wheat starch	---	5.6
Sweet sake	4.8 - 6.5	4.0
Egg white	Small Amount	Small Amount
Total	100	100

Source: Adapted from Okada (1981a)

TABLE 1-10. TYPICAL INGREDIENTS IN IMITATION SEAFOOD PRODUCTS

Ingredients	Crab	Scallop	Shrimp
	.............Per	cent........	....
Surimi	55.0	60.0	68.0
Egg white	8.0	5.0	4.0
Starch	5.0	4.3	11.0
Sorbitol	0	0	0.2
Salt	1.5	1.0	1.0
Sugar	0.6	0	0
Sweet sake	1.0	0.5	0
Chemical seasoning	2.3	2.7	0.4
Natural coloring	0.1	0	0.08
Water	25.0	25.0	11.32
Crab essence	2.5	0	0
Scallop essence	0	1.5	0
Vegetable oil	0	0	2.5
Seasoning	0	0	1.5

Source: Overseas Fishery Cooperation Foundation and Japan Deep Sea Trawlers Association, 1984.

TABLE 1-11. JAPAN'S ANNUAL PRODUCTION OF SURIMI-BASED PRODUCTS, 1970-1984

Year	Steamed	Broiled	Fried	Others*	Ham & Sausage	Total
	....................Metric Tons..........................					
1970	356,397	221,484	313,552	6,381	183,516	1,081,331
71	379,814	238,539	322,151	6,381	180,107	1,127,105
72	399,782	244,615	326,623	6,381	178,801	1,156,205
73	425,057	249,172	329,692	1,589	179,586	1,185,100
74	437,638	250,946	324,149	3,271	132,693	1,148,701
75	446,988	258,882	327,058	1,324	120,708	1,154,970
76	451,495	235,278	316,929	9,931	123,114	1,136,747
77	428,171	214,393	303,224	16,086	124,088	1,086,962
78	427,100	190,911	289,481	16,615	113,109	1,037,216
79	404,420	177,192	272,175	17,589	106,815	976,191
80	362,104	174,377	269,211	18,037	89,457	913,186
81	359,577	180,678	291,412	25,350	91,865	948,882
82	352,074	187,734	289,361	36,555	95,152	960,876
83	346,557	194,931	297,257	59,328	98,098	996,171
84	330,154	196,221	298,063	71,323	94,688	990,449

* Includes surimi-based imitation shrimp, scallop and crab meats, since 1978.

Source: Kamaboko Nenkan (N.S.K., 1985)

1.4. RAW MATERIAL RESOURCES

A. DESIRABLE PROPERTIES FOR RAW MATERIAL

Important qualifications desired for the raw material fish for surimi are:

* Strong gel-forming capability when processed into surimi-based products;
* Good organoleptic quality (taste, odor, appearance);
* White flesh;
* Year-round availability;
* Abundance; and
* Reasonable price.

Unfortunately, none of the existing fish species would meet the full set of these qualifications. As shown in Tables 1-12 and 1-13 the gel-forming capability, traditionally the most important characteristic, varies widely from species to species. 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.

If gel-strength is deemed the major criterion of interest, croaker ranks very high among the white-fleshed fish. Lizard fish and cutlass fish, two other species that have been favored as raw material for surimi, also exhibit high gel-strengths. It is noteworthy that the gel-strengths of these species are more than twice that of the most widely used species, Alaska pollock. Croaker, lizard fish, cutlass fish and sharptoothed eel are still the important raw materials for some name-brand surimi-based products in Japan. For instance, the famous Odawara kamaboko uses croaker only; the Osaka yaki-kamaboko uses croaker and sharptoothed eel; the Uwajima yakinuki kamaboko uses lizard fish; and the Toyohashi chikuwa uses croaker with some blending of sharptoothed eel and lizard fish.

As shown in Table 1-14, the fish species with relatively high gel-strengths accounted for only a small portion of all the surimi produced annually in Japan, namely an average of only 12.8 per cent between 1980 and 1984. In particular, Japan's catch of croaker decreased sharply from 39,000 metric tons in 1976 to 24,000 metric tons in 1984, reflecting the declining harvests of this species in the East China Sea due to overfishing for a number of years.

The predominance of Alaska pollock as the raw material fish for surimi, as seen in Table 1-14, indicates that the virtues of quantity and economy have largely replaced that of gel-strength as the main qualifications for the raw material for surimi. Even the bland taste of the Alaska pollock meat is probably no longer a drawback, since it allows imitation flavors to be incorporated readily into the kamaboko, as has been demonstrated by the imitation crab meat, scallops and shrimps.

TABLE 1-12. GEL-FORMING CAPACITY OF WHITE-FLESHED FISH

White-Fleshed Fish	Gel-Strength
Croaker (Nibea mitsukurii)	1,560
Barracuda (Sphyraena schlegeli Steindachner)	1,560
Yellow-belly threadfin bream (Nemipterus bathybius Snyder)	1,536
Lizardfish (Saurida undosquamis)	1,430
Cutlassfish (Trichiurus lepturus Linne)	1,334 1/
Jarbua therapon (Therapon jarbua)	1,317
Striped mullet (Mugil cephalus Linne)	1,293
Unicorn leatherjacket (Aluterus monoceros)	1,273
Leatherjacket (Navodon medestus)	1,164
Red seabream (Chrysophrys auratus)	1,158 1/
Frigate mackerel (Auxis thazard)	1,110
Brill (Pseudorhombus cinnamoneus)	1,083
Puffer (Labocephalus lunaris spadiceus)	1,020
Red bigeye (Priacanthus macracanthus Cuvier)	918
Sharptoothed eel (Muraenesox cinereus)	792 1/
Red gurnard (Chelidonichthys kumu)	616
Needlefish (Ablennes anastomella)	612
Alaska pollock (Theragra chalcogrammus)	555 2/3/
Cuttlefish (Sepia esculenta)	543 1/
Hoki (Macrourus novaezelandiae)	477 3/
Angler (Lophius litulon)	438

Note: Gel-strength is expressed in gm/cm^2 after heating fish muscle for 20 minutes at 60°C, unless otherwise specified as follows:

1/ Heating temperature 50°C.
2/ Heating temperature 40°C.
3/ Frozen fish.

Source: Shimizu (1984b)

TABLE 1-13. GEL-FORMING CAPABILITY OF DARK-FLESHED FISH, SHARK AND FRESH-WATER FISH

Dark-Fleshed Fish	Gel-Strength
Pacific blue marlin (Makaira mazara)	2,937
Flying fish (Prognichthys agoo)	1,470
Dolphin-fish (Coryphaena hipprus Linne)	1,431
Purse-eyed scad (Selar crumenophthalmus)	1,078
Horse mackerel (Trachurus japonicus Temmink & Schlegel)	1,023
Japanese sardine (Etrumeus micropus)	933 1/
Pacific saury (Colorabis saira)	624
Yellowfin tuna (Thunnus albacares)	561 2/,3/
Pacific mackerel (Scomber japonicus Houttuyn)	543 1/
Sardine (Sardinops melanosticta)	447 2/
Skipjack tuna (Katsuwonus pelamis)	321 3/
Wavyback skipjack (Euthynnus affinis yaito Kishinoue)	222 1/,3/
Sharks	
Dog-shark (Scoliodon walbeehmi)	1,143 1/
Smooth dog-fish (Mustelus manazo Bleeker)	690
Whiptail-ray (Dasyatis akajei)	540 1/
Smooth dogfish (Mustelus griseus Pietschmann)	540
Fresh-water fish	
Tilapia (Tilapia mossambica Peters)	867
Common carp (Cyprinus carpio Linne)	600 1/,3/
Snakehead (Channa argus)	423 1/

Note: Gel-strength is expressed in gm/cm^2 after heating fish muscle for 20 minutes at 60°C., unless otherwise specified as follows:

1/ Heating temperature 50°C.
2/ Heating temperature 40°C.
3/ Frozen Fish.

Source: Shimizu (1984b)

TABLE 1-14. JAPAN'S CATCH OF FISH SPECIES THAT ARE USED PRIMARILY TO MANUFACTURE SURIMI, 1976-1984

Species	1976	1977	1978	1979	1980	1981
	...............1,000 Metric Tons.............					
Alaska pollock	2,445	1,928	1,546	1,551	1,552	1,595
Atka mackerel	229	235	135	119	117	125
Croaker	39	40	37	39	32	33
Sharp-toothed eel	17	19	18	16	17	16
Lizard fish	20	22	21	22	25	24
Cutlass fish	31	28	28	31	38	35
Shark	44	49	42	42	42	38
Total	2,825	2,321	1,827	1,820	1,823	1,866

Species	1982	1983	1984	1980-84 Average	
	...1,000 Metric Tons..............				Per Cent
Alaska pollock	1,567	1,434	1,621	1,554	87.2
Atka mackerel	103	56	66	93	5.2
Croaker	30	27	24	29	1.6
Sharp-toothed eel	14	12	11	14	0.8
Lizard fish	18	15	14	19	1.1
Cutlass fish	36	35	34	36	2.0
Shark	35	36	35	37	2.1
Total	1,803	1,615	1,805	1,782	100.0

Source: Ministry of Agriculture, Forestry and Fisheries, Japan.

B. ALASKA POLLOCK RESOURCES

Alaska pollock feeds on plankton, the abundant microscopic plants and animals that support all marine ecosystems. The fish grows relatively quickly, attaining a harvestable size by about three years of age. Sexual maturity is reached at the age of three or four, with a prolific yield of roe per spawning. The pollock schools are found at all levels in the water column between the sea floor and the surface, beyond as well as over the continental shelf.

The U.S. waters in the Bering Sea and around the Aleutian Islands are believed to contain the largest resources of Alaska pollock in the world, estimated to exceed 8 million tons (Yamamoto, 1974).

The abundance in resources and the opportunity to produce a high-grade surimi from fresh fish made the Japanese factoryship operations in the Bering Sea a highly attractive proposition as early as the mid-1960's. Japan's pollock catches in the Bering Sea off Alaska increased rapidly, reaching an historical high of 1.67 million metric tons in 1972, about 55 per cent of her total landings of pollock for that year. Since then, Japanese catches in U.S. waters including high-seas purchases have declined more than 30 per cent. Catches by Japan in U.S.S.R. waters off Kamchatka and the Siberian coast have declined even more drastically, by as much as 80 per cent since 1972.

In recent years, Japan has maintained an average of five mothership fleets and a total of 14 factory trawlers every year in the Bering Sea region (Table 1-15). Each mothership fleet is

TABLE 1-15. JAPANESE SURIMI FACTORYSHIPS CURRENTLY IN OPERATION

A. Factory Trawlers

Gross Tonnage	Number of Vessels
Below 3,000 tons	3
3,000-4,000 tons	6
4,000-5,000 tons	7
Over 5,000 tons	1
Total	17

B. Motherships

Gross Tonnage	Number of Vessels
Below 10,000 tons	1
10,000-20,000 tons	2
Over 20,000 tons	2
Total	5

Source: Japan Deep Sea Trawlers Association

comprised of a factoryship and about 14 catcher boats. Because the small catcher boats cannot operate in the stormy weather during the winter in the Bering Sea, the mothership operations are limited to the summer season, while factory trawlers operate year-round. In 1984, the Japanese factory ships in the Bering Sea and in the Gulf of Alaska handled as much as 1.1 million metric tons of Alaska pollock, including direct catches amounting to about 770,000 metric tons and high-seas purchases from U.S. fishermen totaling about 340,000 metric tons. In the same year, Japan procured a total of 335,000 metric tons of Alaska pollock from Soviet waters, much of which was delivered to shore plants in Hokkaido and Northern Honshu.

CHAPTER II. SURIMI MANUFACTURING PROCEDURES FOR WHITE-FLESHED FISH

The evolution of surimi technology has occurred largely through the refinement of manufacturing procedures based on trial-and-error experience. Scientific understanding of the developed procedures has lagged considerably behind the practical advancements (Yamamoto, 1974; Shimizu, 1984a).

The most important progress has occurred in three key areas: (1) how to maximize the leaching effect with the least amount of water; (2) how to separate the meat from impurities; and (3) how to mechanize the manufacturing procedures.

2.1. HANDLING OF RAW MATERIAL FISH

The methods used in handling the raw material fish prior to the mincing are crucial determinants of the quality of surimi. The success of the fish handling methods is judged according to whether or not the fish entering the meat separator are (1) fresh and (2) clean.

The freshness in fish is a principal factor affecting gel-forming capability in the resulting surimi. A high-grade surimi cannot be manufactured from fish lacking in freshness even with the best available technology (Noguchi, 1982).

Table 2-1 shows variations in gel-forming capability in kamaboko (the kneaded fish cake made from surimi) associated with different degrees of freshness of the fish used. Clearly, the freshness of fish has a decisive influence over its gel-forming capability, and the deficiency in gel-forming capability resulting from lack of freshness in the raw material fish cannot be amended with a leaching process.

TABLE 2-1. GEL-STRENGTH IN KAMABOKO DUE TO VARYING DEGREES OF FRESHNESS IN RAW MATERIAL FISH

	Fish Condition			
	Extremely Fresh	Quite Fresh	Fairly Fresh	Not Fresh
Kamaboko made from:				
Unleached surimi	1,100	600	350	150
Leached surimi	1,200	850	650	400

Units: g.cm.
Source: Noguchi, 1982.

A top-grade surimi is made aboard factoryships by using very fresh fish, although their manufacturing procedures employ no more than two cycles of washing. The ship-processed surimi generally exhibits a gel-forming capacity higher than that of land-processed surimi which has gone through several cycles of leaching.

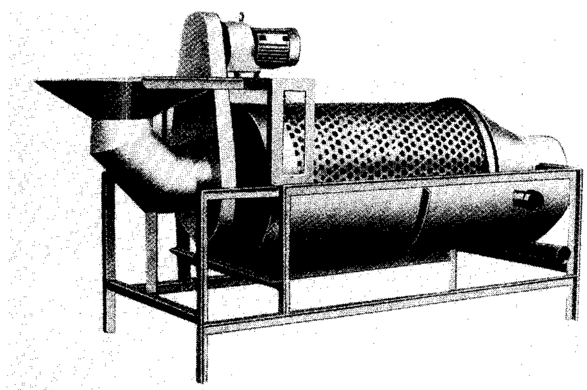
The Technical Institute of the Japan Surimi Association (Yamamoto, 1974) has the following official recommendations on the handling of the raw material fish following delivery to the plant:

> The fish must be stored in the (wooden) fish box surrounded by crushed ice (Figure 2-1).
>
> The fish may be stored in a tiled circulating tank approximately 1 meter deep, filled with water and floating ice. The fish stored in the tank should not be piled higher than about 50 to 60 cm from the tank floor.
>
> When stockpiling the fish in the open air, place the fish on a permeable mattress about 10 cm above the ground level. The fish may be piled about 50 cm high and covered with crushed ice, and the arrangement may be repeated to create layers of fish.
>
> Care must be taken not to allow the fish to freeze under any circumstances.

(PHOTO BY S. C. SONU)

FIGURE 2-1. DRESSED FISH STORED IN BOXES WITH CRUSHED ICE

The dressed fish entering the meat separator must be clean and free of any remnants of intestinal tracts, black belly membranes, blood clots, and other impurities which are difficult to remove in the subsequent procedures. To ensure the cleanliness of the fish, a recommended practice is to wash the fish twice, once immediately after the removal of head and guts, and again immediately before the fish is fed into the meat separator. Use of soft water is recommended for washing fish, instead of a ground water which contains dissolved salts and metals. Figure 2-2 shows a typical fish washing machine used in Japan.



(COURTESY, YANAGIYA MACHINERY WORKS, LTD.)

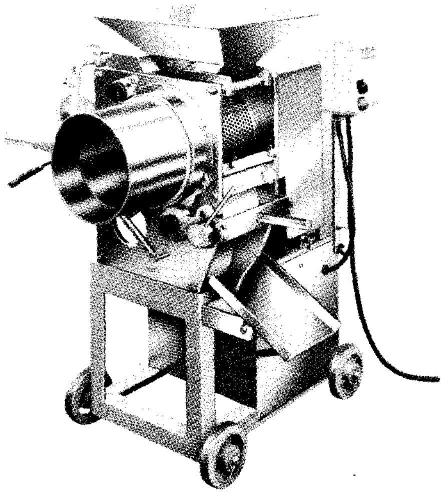
FIGURE 2-2. FISH WASHER

Surimi producers try to avoid processing fish while they are in rigor, and employ systems that handle fish gently at all times. The physical and chemical properties of fish muscle undergo major post-mortem changes that significantly affect functional properties (Shimizu, 1981). Although surimi attains its maximum gel-strength when fish are processed immediately after death, it is impractical to attempt processing all fish before onset of rigor. While in rigor, the fish is difficult to handle and cannot be cleaned readily. In addition, surimi made from fish muscle during rigor mortis tends to have a fishy odor. Therefore it is common practice to begin processing just after rigor mortis fades, about five hours after death. Rough handling of fish can bruise the muscle, which leads to softening of the tissues and an inferior quality in the end product.

2.2. MEAT SEPARATION

It is standard practice for surimi plants, both land-based and ship-based, to use a roll-type meat separator to free the fish meat from bones, scales, fins and other large impurities.

An example of a roll-type meat separator is shown in Figure 2-3. A large number of models of various capacities are available, some capable of handling as much as 7,000 kg of fish per hour. The advent of an efficient roll-type meat separator was one of the reasons for the rapid development of the surimi industry in Japan (Z.S.K., 1984).



(COURTESY, BIBUN MACHINE CONSTRUCTION CO., LTD.)

FIGURE 2-3. MEAT SEPARATOR

The roll-type meat separator reduces fish meat to a minced form. In this machine, the dressed fish is inserted between a traveling rubber belt and a steel drum with numerous holes of 3 to 5 millimeters in diameter. The belt is pressed against the drum by a series of rollers located behind it. The fish meat, minced by the pressure between the belt and the drum, is squeezed through the tiny holes into the interior of the drum, leaving behind bones, skin and other impurities which are too large for the holes. Blood clots, broken bones and small impurities will pass into the interior of the drum to mix with the minced meat, especially when the pressure between the belt and the drum is increased to raise the yield of meat from the fish. It is a common practice to allow some impurities in the minced meat, since these can be removed subsequently with a refiner or a strainer.

Mixing of blood in the minced meat cannot be avoided. Since the blood would oxidize rapidly while exposed to the air and discolor the meat, the minced meat is immersed in chilled water immediately after leaving the separator (Z.S.K., 1984). Because commonly a certain ratio of water to mince is sought, the tank that receives mince from the separator is often called a ratio tank.

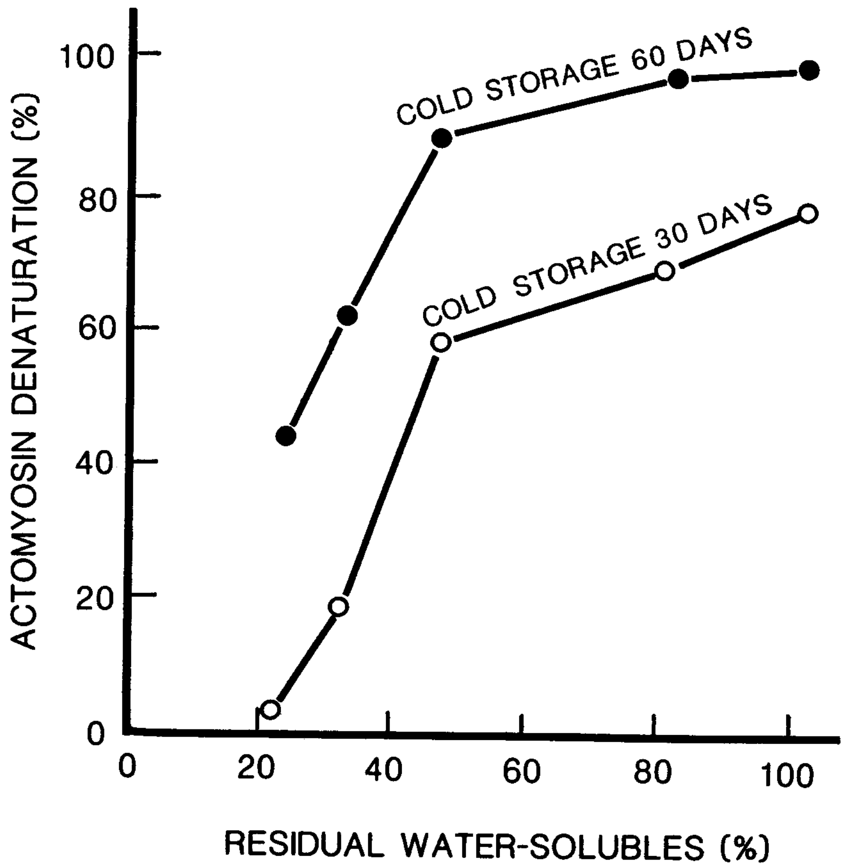
2.3. LEACHING

The practice of washing the minced fish meat in the process of manufacturing kamaboko (surimi-based product) was begun in Japan during the 1910's as a means of removing fats, oils and fishy odor as well as providing a white tint to the product (Shimizu, 1979). It soon became clear that the washing also resulted in reinforcing the product's gel-strength (Nishioka, 1984).

The Japanese word for the washing process, "mizusarashi", literally means "leaching with water". Several functions are performed by this process:

> <u>Mechanical Separation of Impurities</u>:
>
> The mechanical stirring of the mixture of minced meat and water releases the fat and oil from the muscle tissue and floats them out as the supernatant, which is readily removed by draining. Also separated from the meat by mild agitation are the remnants of digestive organs, which tend to float out along with the fatty substances.
>
> <u>Washing</u>:
>
> The washing dilutes blood, pigments, and other impurities in the minced meat which may cause discoloration to the product or catalyze denaturation of protein.
>
> <u>Leaching</u>:
>
> Contact with fresh water leaches out water-soluble components of the muscle tissue, particularly sarcoplasmic protein which is believed to impede the gel-forming potential of the fish muscle, and inorganic salts believed to contribute to freeze denaturation of surimi. Sarcoplasmic proteins occur in the fluids inside and between muscle fibers, and include many of the fish's metabolic enzymes, which might act to break down the functional proteins of surimi if they were not removed. The leaching of water-soluble components in turn isolates myofibrillar protein, which is responsible for surimi's gel-forming capacity.

Figure 2-4 shows the effect of washing on the reduction of freeze denaturation in the fish muscle (Nishiya et al., 1960). Repeated washing reduces residual water-soluble proteins in the meat, which in turn reduces the rate of actomyosin denaturation. Actomyosin, a combination of the proteins actin and myosin, is the principal constituent of myofibrillar (muscle fiber) protein. It is what allows surimi to gel and living muscles to contract; in short, it endows surimi with its functionality. Residual water-soluble protein must be reduced to less than 50 per cent of its original level in order to curtail the rate of denaturation to a meaningful extent.



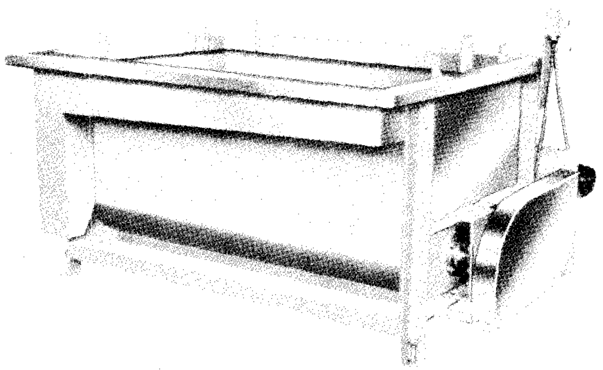
(NISHIYA ET AL., 1960)

FIGURE 2-4. EFFECT OF RESIDUAL WATER SOLUBLES ON ACTOMYOSIN DENATURATION AT DIFFERENT STORAGE DAYS

While scientific understanding is still incomplete as to why and how the washing accomplishes these results, it has been established through experience that the greater the number of washing cycles applied to the fish muscle, the stronger the gel-forming capability of the surimi made from it (Nishioka, 1984). In the early days of the surimi industry, washing was performed by what was known as the "batch tank" method, a brute approach using a large amount of water, namely as much as 30 to 40 times the weight of meat being processed. The minced meat was stirred in water about 7 times its weight, and the supernatant was drained after the mixture was allowed to stand. The cycle was usually repeated 5 times to complete the process (Z.S.K., 1984).

About 75 per cent of the water used in a surimi plant is expended on the washing process (Z.S.K., 1984). The water is not only costly by itself, but also results in additional expenses for waste water treatment. The current method of washing is designed to minimize the use of water by combining a washing (or leaching) tank and a rotary sieve in succession. This is called a "continuous washing" system, and the meat travels between the two via a vacuum pump. A survey by Japan Surimi Association revealed that a plant employing the continuous washing system would normally use water at a rate of about 25 times the weight of the surimi it produces.

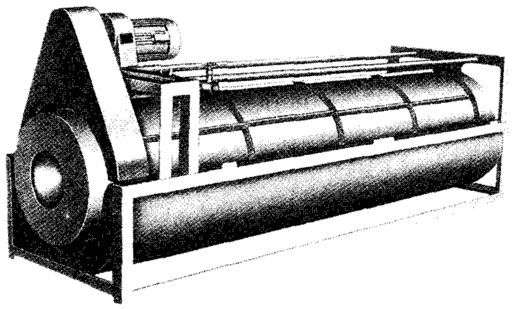
Figure 2-5 shows a typical washing (or leaching) tank. Usually, the tank has built-in paddles which are automatically activated when the tank is filled to 80 per cent of its capacity. The supernatant can be drained by adjusting the height of a drain port inside the tank (Figure 2-25, scenes (11) and (12)), or by tilting the tank itself.



(COURTESY, BIBUN MACHINE CONSTRUCTION CO., LTD.)

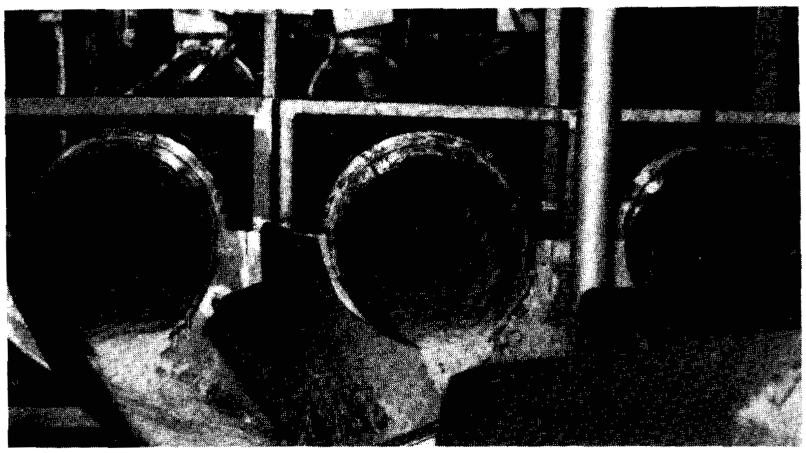
FIGURE 2-5. LEACHING TANK

Figure 2-6 shows a rotary sieve or screen. The washed and partially drained minced meat emerges from the open end of the rotary sieve, as shown in Figure 2-7. In both Figures 2-6 and 2-7, notice the traveling nozzles applying a spray on the exterior of the sieve, enhancing the rinsing effect of this device.



(COURTESY, YANAGIYA MACHINERY WORKS, LTD.)

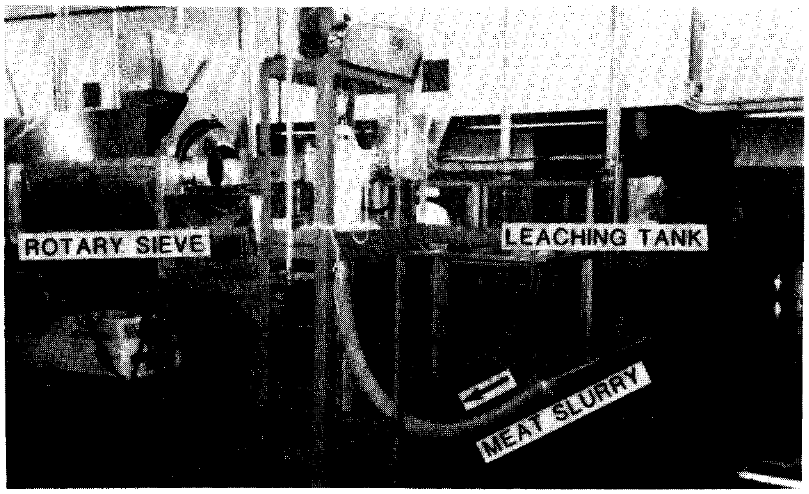
FIGURE 2-6. ROTARY SCREEN



(COURTESY, YANAGIYA MACHINERY WORKS, LTD.)

FIGURE 2-7. MEAT SLURRY EMERGING FROM ROTARY SIEVES

Figure 2-8 shows a continuous washing system consisting of a washing (or leaching) tank and a rotary sieve in a serial arrangement. The minced meat slurry travels via meat pump, such as that shown in Figure 2-9. Rotary sieves may also be used in a stacked arrangement where a thorough washing of the minced meat is desirable.



(COURTESY, BIBUN MACHINE CONSTRUCTION CO., LTD.)

FIGURE 2-8. CONTINUOUS LEACHING AND WASHING SYSTEM

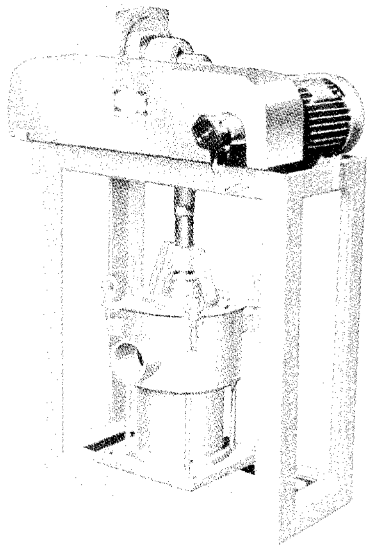
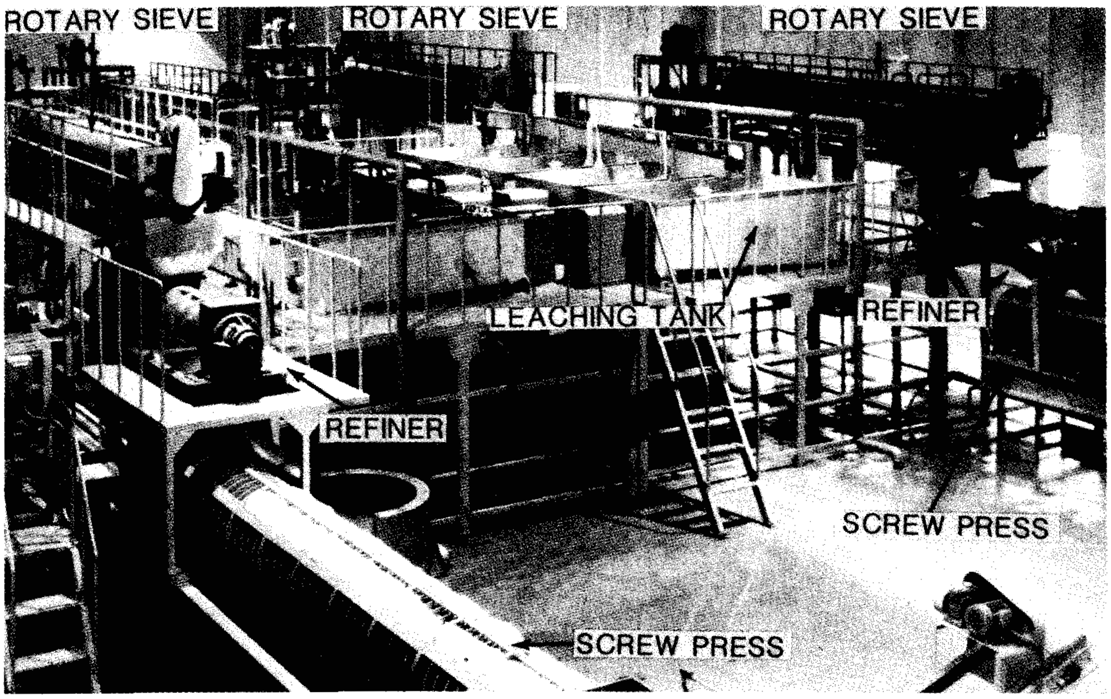


FIGURE 2-9. MEAT PUMP

Figure 2-10 shows the layout of a continuous washing system in a plant. This example presents an arrangement in which a set of four leaching tanks is connected to a single rotary sieve to comprise a single washing cycle. Notice in the foreground of the photo that the exit end of the rotary sieve leads to a refiner, which is followed by a screw press.



(COURTESY, YANAGIYA MACHINERY WORKS, LTD.)

FIGURE 2-10. EXAMPLE OF EQUIPMENT LAYOUT IN LAND-BASED SURIMI PLANT

A. PROPERTIES OF LEACHING WATER

Principal factors determining the effectiveness of the leaching water are the hardness and the pH.

The hardness of the leaching water affects the swelling tendency of the meat and, consequently, the gel-strength of the surimi. As the leaching continues, the meat in the leaching tank becomes hydrophilic (water-loving) and swells by absorbing increasing amounts of water. The hydrophilic tendency in a meat is proportional to the declining hardness of the leaching water (Nishioka, 1984; Okada, 1981c).

The swollen meat presents a dual problem. First, the swollen meat cannot be readily separated from impurities, because it does not settle readily to the bottom of the tank to be separated from the supernatant. Secondly, the water cannot be removed satisfactorily from the swollen meat, resulting in a surimi with high water content and hence low gel-strength.

Figure 2-11 shows the relationship between the hardness of the leaching water and the water content in the leached meat. The softer the leaching water, the greater the water content and the lower the gel-strength in the surimi. Use of a medium hard water should therefore not only facilitate the leaching process, but also improve the gel-strength in the product.

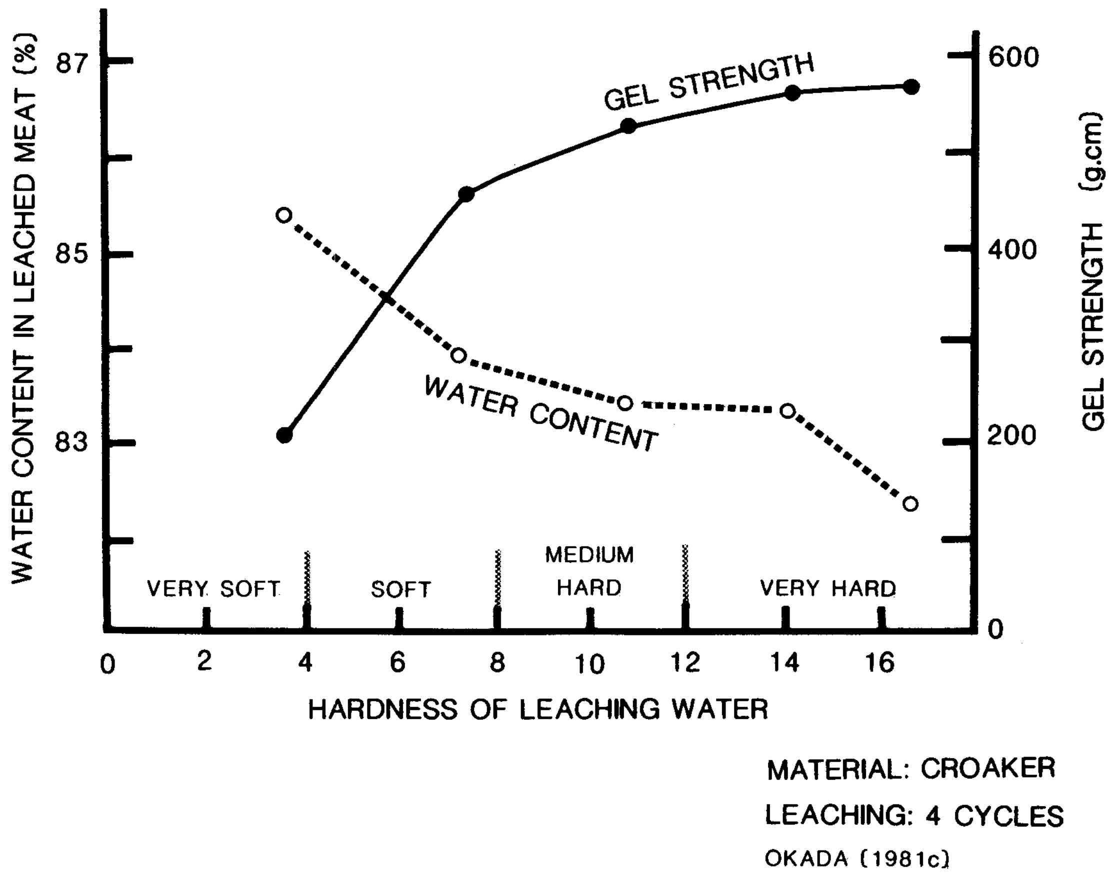


FIGURE 2-11. EFFECTS OF HARDNESS OF LEACHING WATER ON SWELLING OF LEACHED MEAT AND GEL STRENGTH OF SURIMI

The good surimi-based products in Japan have been traditionally attributed to the superior quality of the water of the region where they are manufactured (Okada, 1981a). Namely, the water at Odawara, a place well known for its excellent kamaboko, has a medium hardness with a calcium content of 20 to 40 mg% (Okada, 1981a). Water of medium hardness will make a good leaching water, since it replenishes the loss of hardness as the washing cycles are repeated, preempting the development of hydrophilic tendency in the meat. Since meat swelling is likely to occur more readily in the latter part of the washing process, it is a good practice to perform the last washing cycle with water containing 0.1 to 0.3 per cent sodium chloride. Magnesium chloride or calcium chloride may also be used.

Figure 2-12 shows the dependence of the gel-strength and water content in the leached meat on pH (Okada et al., 1965). While the pH level of white-fleshed fish meat is between 6.5 to 7.0, the isoelectric point (pH of minimum solubility) of the myofibrillar protein is 5.3.

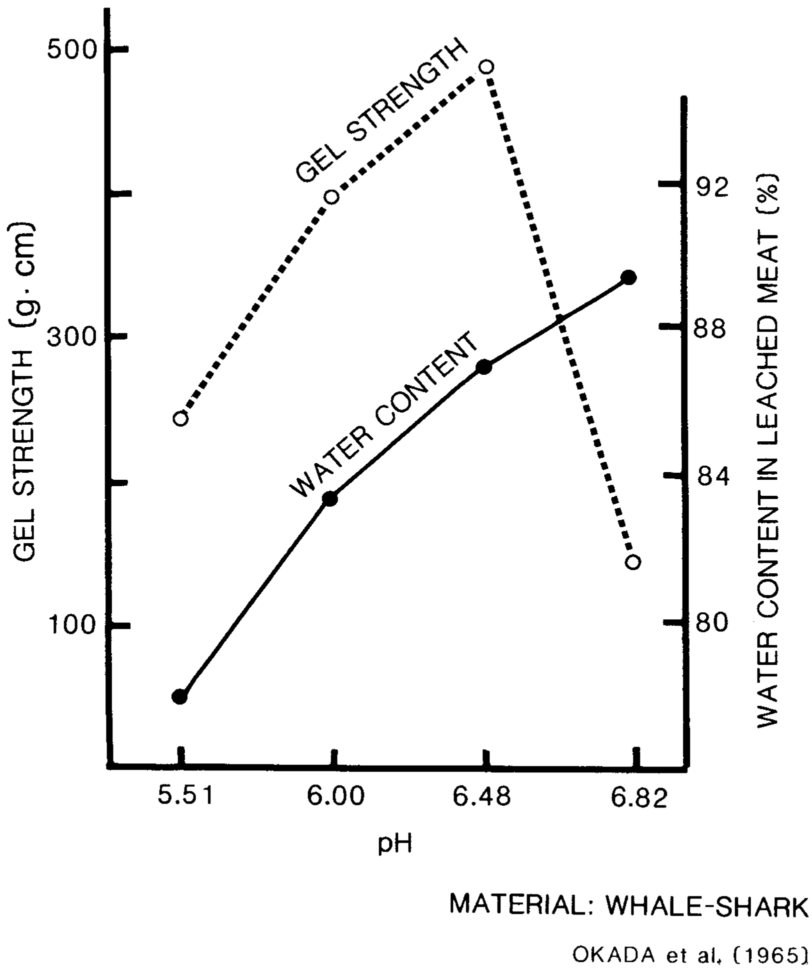


FIGURE 2-12. EFFECTS OF pH OF LEACHING WATER ON SWELLING OF LEACHED MEAT AND GEL STRENGTH OF SURIMI

Since the water content in the leached meat is expected to be very low in the vicinity of the isoelectric point, it would appear advantageous to perform the leaching process at a low pH value so that problems associated with meat swelling could be avoided. However, the gel-strength undergoes a sharp decline for pH values less than about 6, due presumably to instability of the myofibrillar protein caused by low pH values (Nishioka, 1984). In consideration of both desired gel-strength in the surimi and an adequate efficiency of washing, the optimum pH value to be used in the leaching water is said to be about 6.5 (Okada, 1981c).

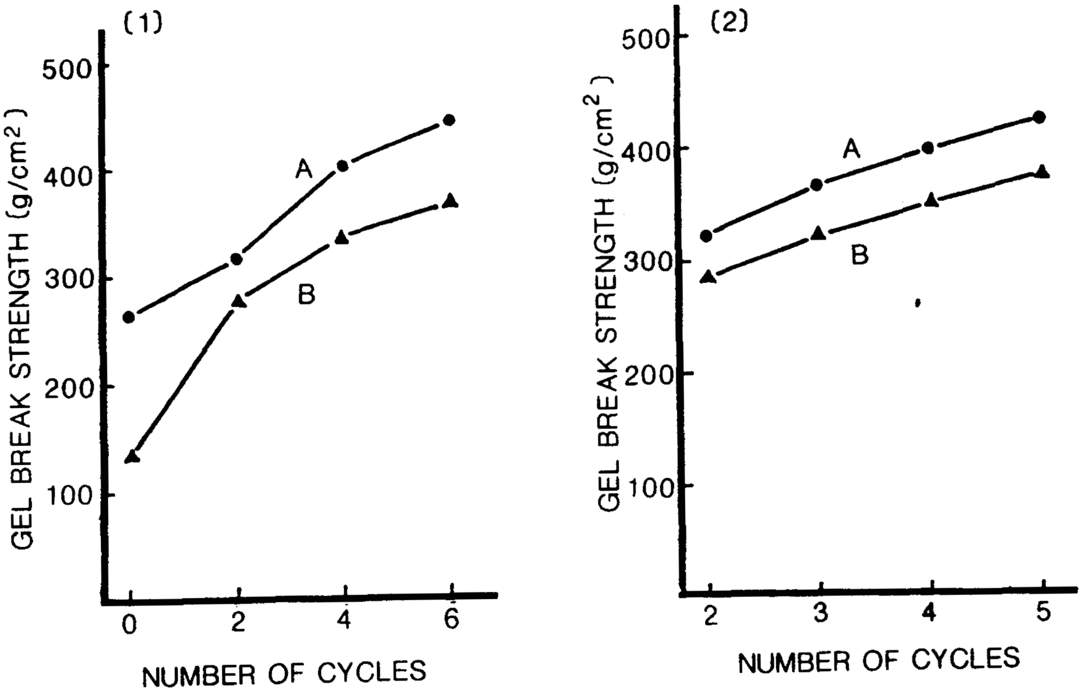
Dark-fleshed fish meat possesses pH values less than 6, closer to the isoelectric point of the myofibrillar protein. This presents a special problem in selecting an optimum pH level in the leaching water for the dark fish meat, which will be discussed in detail in a later chapter.

B. DEGREES OF LEACHING

It is well known that as much as 50 per cent of all the water-soluble components in the fish muscle are removed after the first leaching cycle (Yamamoto, 1974). Additional leaching cycles, while removing progressively diminishing amounts of water-soluble components, serve to remove blood, dark pigments (melanin), black membranes and other impurities as well as bleaching the product. One additional important benefit arising from repeated leaching cycles is the reinforcement of gel-strength in the kamaboko. It has long been established that the gel-forming capacity is proportional to the number of leaching cycles to which the fish meat is subjected.

Figure 2-13 (1) shows the results of a test in which gel-strengths were measured on the kamaboko made from surimi that received up to six cycles of washing (Nishioka, 1984). It is obvious that in the test the gel-strength continued to improve as the number of leaching cycles was increased. The test samples were prepared to have a constant actomyosin content relative to water soluble protein. Thus, the test results indicate that the enhanced gel-strength occurred due to the larger number of washing cycles, not due to the increased relative concentration of actomyosin in the product as some researchers have proposed.

Figure 2-13 (2) shows the result of a similar test in which the meat was allowed to swell as the leaching was repeated (Nishioka, 1984). The leached meat swelled to 1.7 times its original volume after the third leaching cycle, to 2.7 times after the fourth, and to 3.6 times after the fifth. The gel-strengths were measured on kamaboko made from the surimi, whose water content was reduced to 85 per cent in a centrifuge. The test results show that even in these swollen meats, if an adequate dewatering is performed, the gel-strength is improved by increasing the number of leaching cycles.



(1)
Samples containing equal amounts of actomyosin with water contents of 83 - 86%.

(2)
Samples allowed to swell but dewatered to 85% water content.

LEGEND: A. Heated at 50°C
B. Heated at 85°C

NISHIOKA (1984)

FIGURE 2-13. IMPROVEMENT IN GEL STRENGTH WITH INCREASE IN LEACHING CYCLES

In general, a duration of 30 to 40 minutes is sufficient to achieve the objectives of the leaching (Z.S.K., 1984). The total amount of water to be used in the leaching may be about 10 times the amount of the surimi produced, and this amount may be divided into three cycles. The water requirement may be reduced somewhat, but not below 7 times the output. Surimi prepared with the leaching water 5 times its weight deteriorates rather distinctly while in cold storage. Aboard the factoryship where very fresh fish is processed, the leaching water volume can be as little as only 3 times the amount of surimi produced.

C. EFFECTS OF SALT CONCENTRATION

Myofibrillar protein, the gel-forming component of fish protein, exhibits wide variability in hydrophilic characteristics as a function of the salt concentration. A schematic representation of its behavior is shown in Figure 2-14 (Okada, 1981c). A very low salt content causes the hydrophilic tendency to rise. Under this condition which is frequently caused due to the washing cycle which removes the water-soluble salts from the meat, the meat tends to hydrate and swell. Such meat is difficult to dewater, and it is advisable to add sodium chloride prior to the dewatering process.

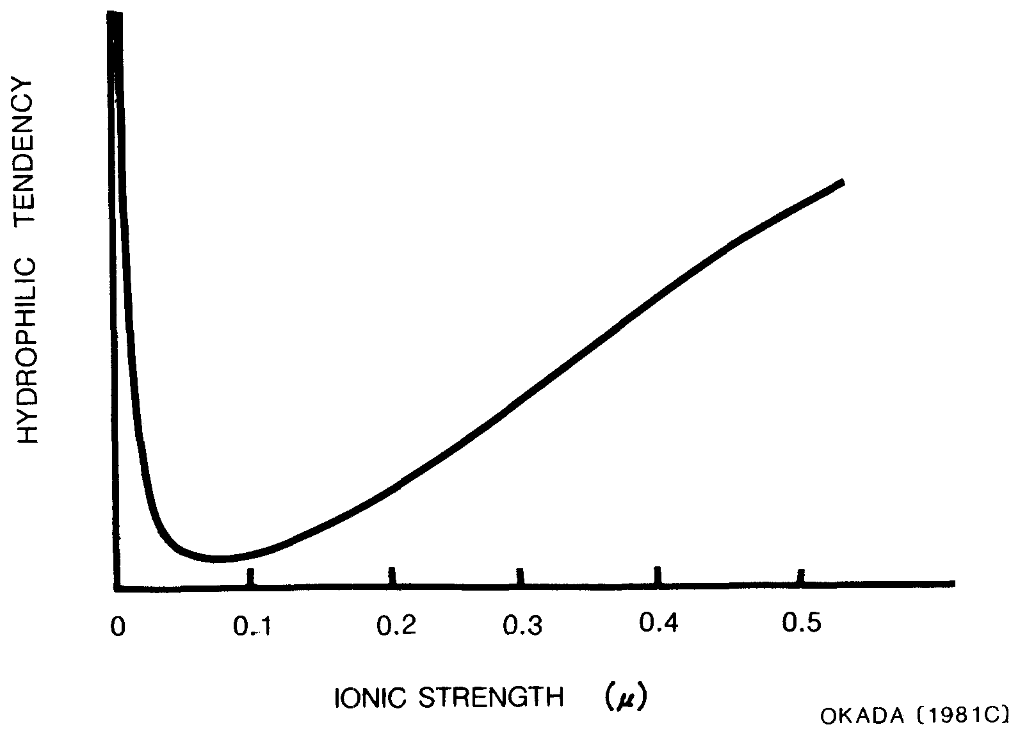


FIGURE 2-14. HYDROPHILIC TENDENCY VERSUS IONIC STRENGTH OF MYOFIBRILLAR PROTEIN

A minimum hydrophilic condition is realized at an ionic strength between 0.005 and 0.1 (the corresponding salt concentration is between 0.03 and 0.6%). At ionic strengths higher than about 0.1, the hydrophilic tendency of the meat increases. Therefore, the addition of sodium chloride should be carefully controlled so as not to exceed a concentration of 0.6%.

D. EFFECTS OF PH

The pH level of the meat also affects its hydrophilic characteristics (Shimizu, 1981). Figure 2-15 shows the hydrophilic characteristics of jack mackerel as a function of pH (Okada and Tada, 1953). The ordinate denotes dewatered volume of a meat and water mixture after it has been subjected to dewatering in a centrifuge, expressed in per cent of the initial volume which contained 1 part meat and 3 parts water. It is obvious from Figure 2-15 that a maximum dewatering efficiency is achieved at a pH value of 5.3, which corresponds to the isoelectric point of the myofibrillar protein. At this pH value, the swelling of the meat is at its minimum, so that it can be dewatered efficiently.

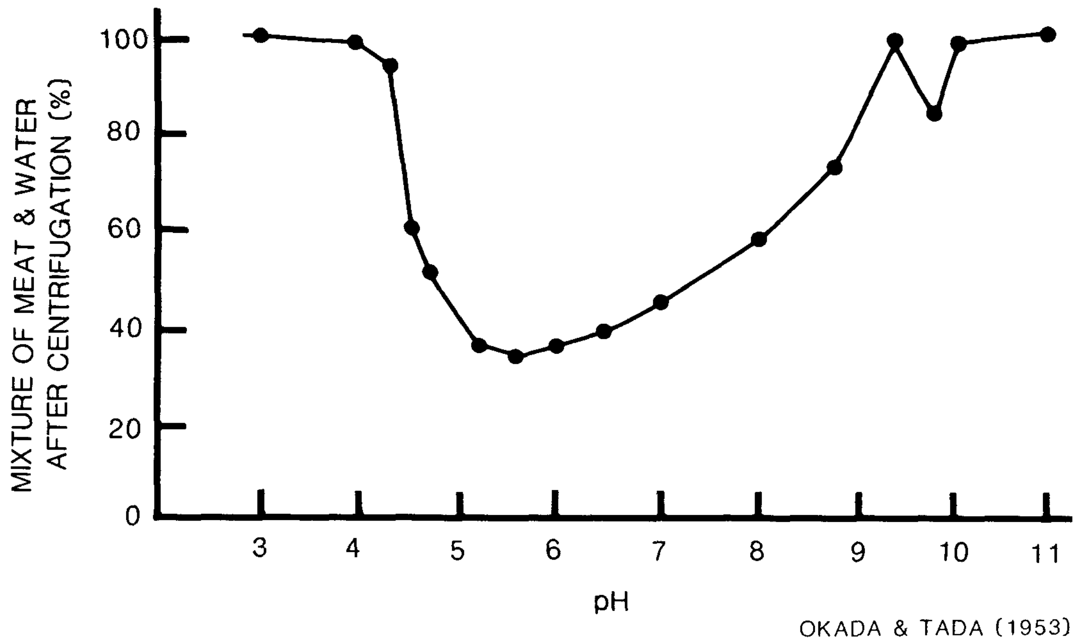


FIGURE 2-15. EFFECT OF pH ON SWELLING OF JACK MACKEREL MEAT

This result would seem to suggest that the minced meat of Alaska pollock, whose pH value lies between 7.0 and 7.3, should be treated to bring its pH value closer to the isoelectric point so as to improve its dewatering performance. However, the Alaska pollock meat is highly unstable at low pH values. In particular, the gel-forming ability declines sharply for pH values less than about 6. Also to be considered is the fact that actomyosin, the principal component of the myofibrillar protein, exhibits its highest resistance to freeze denaturation at pH values slightly higher than 7.0 (Arai, 1974). Consequently, it is advised that the pH values in the minced meat may be adjusted to between 6.2 and 7.0 (Noguchi, 1982).

E. EFFECTS OF WATER TEMPERATURE

Warm wash water is more conducive to dewatering than cold water. For example, Figure 2-16 shows that not only the amounts of water but also the speed at which the water separates from the meat and water mixture increase with the rising water temperature (Z.S.K., 1980). In this example, mixtures were prepared with a

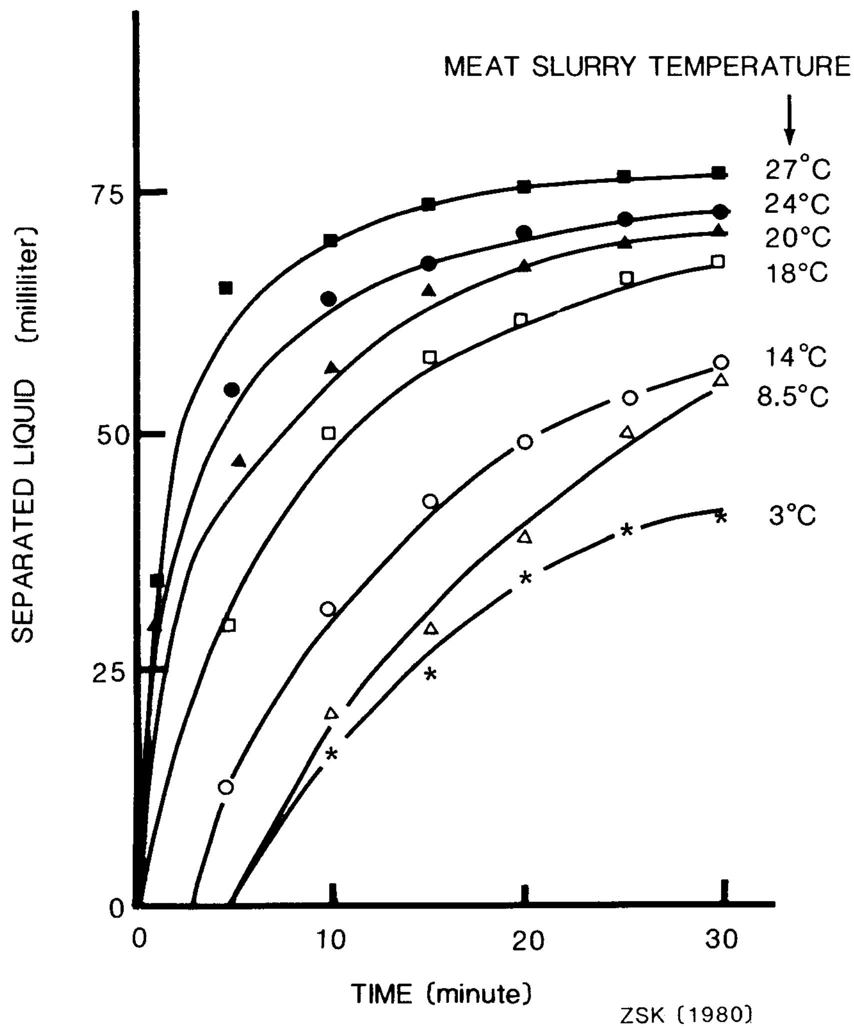


FIGURE 2-16. DEPENDENCE OF DEWATERING EFFICIENCY ON TEMPERATURE OF MEAT SLURRY

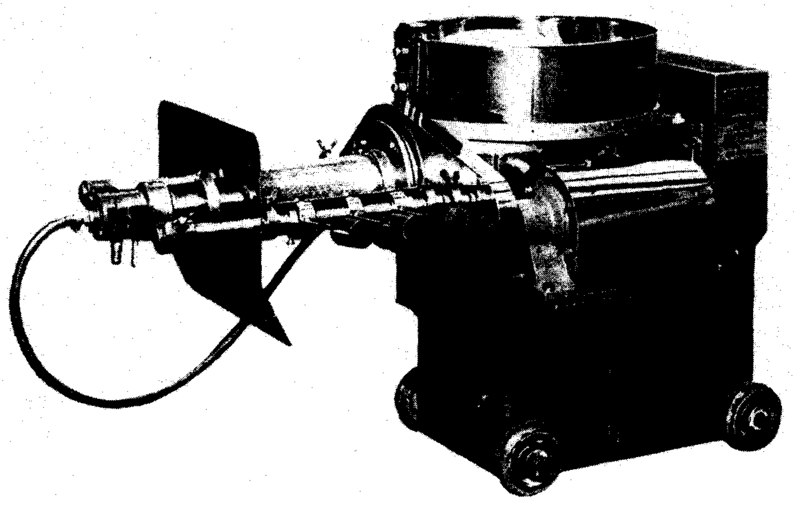
uniform combination of 100 grams of minced and leached Alaska pollock meat and 100 milliliters of 0.025M sodium chloride solution. The mixture was homogenized and allowed to separate while standing in a cylinder.

Comparing between the amounts of separated water after the elapsed time of 30 minutes in Figure 2-16, one finds that the amount of separation at 8.5 - 14°C drops to about 80 per cent of that at 20°C, and that the amount of separation at 3°C drops to 57 per cent of that at 20°C.

While the cold water is desirable from the point of view of preserving the quality of the product, this benefit may be outweighed by the loss of efficiency in the dewatering procedure when the water temperature is very low. Japan Surimi Association recommends that where the seasonal water temperature falls very low, the temperature of the water being used for the last washing cycle may be raised to about 10°C in order to achieve a reasonable dewatering efficiency (Z.S.K., 1984).

2.4. STRAINING AND DEWATERING

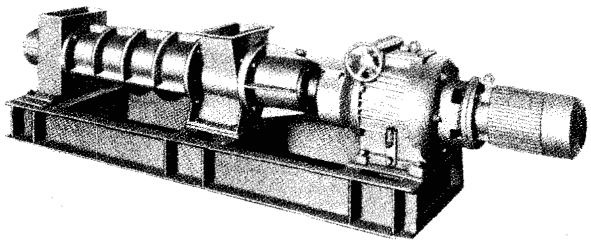
The minced, washed and leached fish meat is a wet slurry containing fragments of bones, ligaments, and scales as well as a large amount of water, which must be removed before the product can be called surimi. In the old procedure, the meat slurry was first dewatered before subjecting it to a strainer. As the dewatered meat was strained by being forced through tiny holes in a strainer, heat was generated in the meat being processed, causing harm to the protein. Use of a self-cooling strainer, such as the one shown in Figure 2-17, somewhat alleviated, but did not eliminate, the heat problem.



(COURTESY, BIBUN MACHINE CONSTRUCTION CO., LTD.)

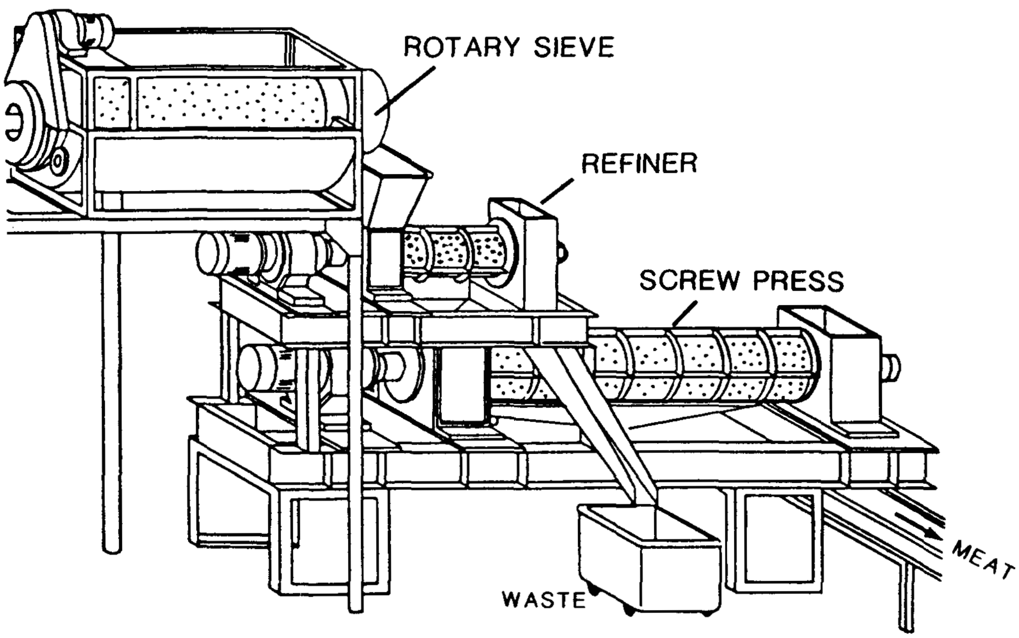
FIGURE 2-17. MEAT STRAINER

A better solution to the heat problem associated with the straining process was introduced in the form of a refiner (Figure 2-18), a straining machine which could work on a wet slurry (Noguchi, 1984). As shown in Figure 2-19 a refiner is placed ahead of a dewatering machine, or screw press, so that the wet but drip-free meat emerging from the rotary sieve in the last washing cycle is strained first in a refiner and dewatered later in a screw press. The use of a refiner began about 1972 at shore plants, and was employed aboard factoryships beginning around 1975 (Z.S.K., 1984).



(COURTESY, YANAGIYA MACHINERY WORKS, LTD.)

FIGURE 2-18. REFINER



(COURTESY, YANAGIYA MACHINERY WORKS, LTD.)

FIGURE 2-19. ARRANGEMENT OF REFINER

The introduction of a screw press as the standard dewatering machine represented one of the most significant breakthroughs in surimi production methods. For about 10 years following the invention of frozen surimi technology, the standard dewatering machine was the basket centrifuge, an extremely inefficient device requiring a batch operation. The screw press, on the other hand, allowed the product to flow through it continuously, hence the name "continuous dewatering machine" used by some manufacturers. It purges water from the meat slurry by squeezing the product into a progressively reducing chamber with the aid of a rotating screw, while allowing the pressurized water to escape through tiny drain holes in the chamber wall. Since its first appearance around 1967, the device has been vastly renovated both in quality and capacity. A single unit today can turn out more than 20 tons of product a day (Yamamoto, 1981).

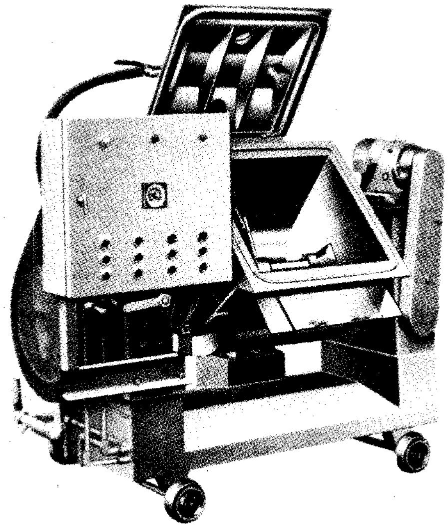
While the screw press is universally used as the dewatering machine in surimi plants today, the refiner has not become as predominant. A substantial number of surimi plants still use a self-cooling strainer, and some adhere to the old practice of dewatering first and straining later.

2.5. ADDITIVES

The minced, leached fish meat, a raw surimi, contains as its chief ingredient the myofibrillar protein that will provide an elastic property when processed into kamaboko (surimi-based products). Elasticity is closely correlated with the organoleptic quality of the product and is considered in Japan to be one of the most prized properties of kamaboko. The water-soluble inorganic constituents as well as the sarcoplasmic protein in the fish muscle, which are believed to thwart the gel-forming capability of the myofibrillar protein, have been removed through the washing and leaching process to produce raw surimi. However, when frozen, the myofibrillar protein becomes denatured and loses its gel-forming capability. The raw surimi develops a spongy texture and is useless as the raw material for kamaboko.

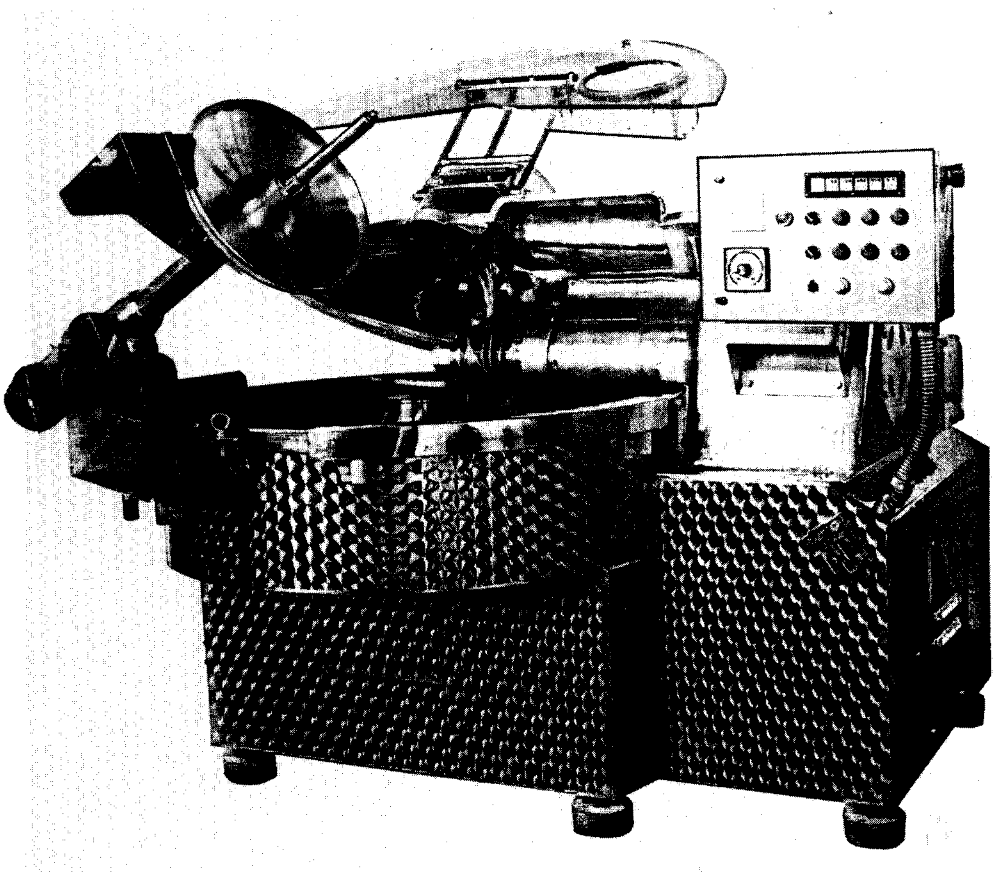
A surimi which can be stored while retaining its gel-forming capability became a reality only with the discovery of additives which can be mixed into the raw surimi to protect the myofibrillar protein from freeze denaturation. Consequently, surimi that is destined for cold storage is mixed with anti-denaturant additives before being frozen.

Figure 2-20 shows a mixer used for blending additives into surimi. Since the mixing procedure may generate heat, the mixer may be equipped with a self-cooling device. A vacuum mixing chamber may help purge air bubbles from the product. Figure 2-21 shows a silent cutter, which can also be used for mixing the cryoprotectant additives into raw surimi.



(COURTESY, YANAGIYA MACHINERY WORKS, LTD.)

FIGURE 2-20. MIXER WITH COOLING AND VACUUM DEVICES



(COURTESY, YANAGIYA MACHINERY WORKS, LTD.)

FIGURE 2-21. SILENT CUTTER

The anti-denaturant additives introduced in 1960 involved only sucrose, glucose, sorbitol, and polyphosphates (pyrophosphate and tripolyphosphate). Since then, a number of other chemicals have been identified as possessing similar functions. There are at least nine different varieties of sugar, including among them galactose and lactose, known to be as effective as sucrose, glucose and sorbitol as anti-denaturants for fish protein. Some amino acids and carboxylic acids have also been found to be effective anti-denaturants.

The scientific question of how certain chemicals function as protectors of fish protein from freeze denaturation still remains unanswered (Noguchi, 1984). Accordingly, the prescription of the anti-denaturant additives being used today is empirical in nature, virtually unchanged since their first discovery in 1960.

Tables 2-2 and 2-3 summarize the recent standards for surimi additives. The components in the additives are sugar, polyphosphate, salt, and glyceride. Additives for salt-free surimi, which represents virtually all the land-processed surimi and most of the ship-processed surimi, include all the components except salt. Additives for salt-added surimi do without polyphosphate, but contain salt.

TABLE 2-2. FOOD ADDITIVES FOR LAND-PROCESSED FROZEN SURIMI

Raw Material Fish	Grade	Sucrose	Puribesuto* TP 433	Puribesuto* TP423
		.... Per cent..........		
	Special	4.0	4.6	0
Alaska pollock	1	4.0	4.6	0
	2	4.0	4.6	0
	Off-grade	4.0	4.6	0
Atka mackerel	1	4.0	0	4.5
	2	4.0	0	4.5
Blenny	Special	4.0	4.6	0
	1	4.0	4.6	0

* TP 433: D-sorbitol 87%, polyphosphate 6.5%, glyceride 6.5%
TP 423: D-sorbitol 89%, polyphosphate 4.4%, glyceride 6.6%

TABLE 2-3. FOOD ADDITIVES FOR SHIP-PROCESSED FROZEN SURIMI

Alaska pollock	Surimi Type	Sucrose	Sorbitol	Poly-Phosphate	Salt
		..............Per	cent.............		
	Salt-free	4	4	0.3	0
	Salt-added	5	5	0	2.5

Source: Z.S.K., 1984

Sugar, the most important component, comprises 8 per cent of the salt-free surimi and 10 per cent of the salt-added surimi. Half of the sugar is provided by sorbitol in order to avoid an excessively sweet taste and a brownish tint in the kamaboko that may result from a high sugar content. The content of polyphosphates ranges between 0.2 and 0.3 per cent of frozen surimi. While a higher content is known to be more effective in preserving water-retaining and gel-forming capabilities of surimi, polyphosphates adversely affect the taste of kamaboko and must be held below 0.3 per cent. Glyceride serves the purpose of reducing the size of ice crystals in frozen surimi through its emulsifying action, and provides a soft, fine texture to kamaboko (Noguchi, 1971).

Puribesuto is a prescribed additive developed jointly by Japan Surimi Association and a pharmaceutical manufacturer in 1978. Puribesuto TP 433 contains 87 per cent D-sorbitol, 6.5 per cent polyphosphate and 6.5 per cent glyceride. Puribesuto TP 423 contains 89 per cent D-sorbitol, 4.4 per cent polyphosphate, and 6.6 per cent glyceride.

The role of polyphosphates as an anti-denaturant has long been questioned, whereas the role of sugars has been well documented. Some studies suggest that polyphosphates enhance the anti-denaturant function of sugar when the two are used together (Okada, 1967). Other studies indicate that polyphosphates play little, if any, role in providing anti-denaturant protection to surimi, but help to reinforce the gel-strength (Noguchi, 1984). Mentioning that the safety of polyphosphates as food additives has not been fully ascertained, some researchers have suggested that the Alaska pollock salt-free surimi may be prepared without polyphosphates as additive (Noguchi, 1984).

Table 2-4 summarizes various compounds which have been confirmed to exhibit various degrees of anti-denaturant effect on protein during frozen storage (Matsumoto, 1978; Shimizu, 1981).

TABLE 2-4. ANTI-DENATURANT EFFECTS OF VARIOUS COMPOUNDS ON PROTEIN DURING FROZEN STORAGE

Distinctly effective:

Sugars:
Xylite, Sorbitol, Glucose, Galactose, Lactose, Sucrose, Maltose, Fructose

Amino Acids:
Aspartic acid, Glutamic acid, Cysteine, Glutathione

Carboxylic Acids:
Malonic acid, Methyl malonic acid, Maleic acid, Glutaric acid, Lactic acid, L-malic acid, Tartaric acid, Gluconic acid, Citric acid, Alpha-amino-butyric acid

Others:
Ethylene diamine tetra-acetic acid (EDTA)

Moderately effective:

Sugars:
Glycerine, Propylene glycol, Ribose, Xylose, Raffinose

Amino Acids:
Lysine, Histidine, Serine, Alanine, Hydroxyproline

Carboxylic acids:
D, L-malic acid, Adipic acid

Others:
Triphosphoric acid

Slightly or not effective:

Sugars:
Starch, Mannite, Erythritol

Amino Acids:
Glycine, Leucine, Isoleucine, Phenylalanine, Tryptophane, Threonine, Glutamine, Asparagine, Ornithine

Carboxylic Acids:
Fumaric acid, Succinic acid, Oxalic acid, Pimelic acid

Others:
Ethylene diamine, Creatine, Pyrophosphoric acid

Source: Matsumoto, 1978; Shimizu, 1981

2.6. FREEZING AND COLD STORAGE

The surimi which has been dewatered and mixed with anti-denaturant additives is ready for freezing. The product is weighed into blocks of 10 kg (22 lbs) each in polyethylene bags, and placed in freezer pans.

The secret of good freezing lies in avoiding the formation of large ice crystals in the frozen surimi, which occurs in the critical temperature range of between -1°C and -5°C (Z.S.K., 1984). This is accomplished by freezing the product quickly or minimizing the time the product remains exposed to the critical temperatures. Comparing among three commonly used freezers such as the contact freezer, semi-air-blast freezer and air-blast freezer, the contact freezer is reported to be preferable, although other freezers could be made to perform as well by controlling carefully the amount of load relative to the freezing capability.

The dominant factors that affect the quality of surimi in cold storage are the temperature and the steadiness of temperature. Figure 2-22 shows ashi-strength (springiness) of Alaska pollock surimi samples which were stored at -35°, -20° and -10°C for up to 7 months (Okada, 1967). The ashi value remains quite stable at -35°C, but is less so at -20°C. At a storage temperature of -10°C, the value exhibits a steep decline in 2 months. The decline in ashi is even faster in the product whose storage temperature was raised from -20°C to -10°C than in the product which has been kept at a constant -10°C.

The important conclusion is that the storage temperature should remain below -20°C with minimum fluctuation.

Among other factors affecting the quality preservation of frozen surimi in cold storage are quality of product and pH. It has been well established from experience that quality deterioration in frozen surimi in cold storage is more noticeable with low-grade than high-grade surimi.

Surimi containing remnants of intestinal tracts of fish will suffer from the enzymic spoilage of muscle protein which remains active during cold storage. A low pH, which may result from insufficient leaching, causes rapid denaturation of surimi in cold storage. In the case of Alaska pollock surimi, the pH can be brought to a neutral level by ensuring a satisfactory leaching; in the case of dark meat of sardine and Pacific mackerel, leaching in an alkaline water has the effect of raising the pH toward a neutral level.

The question as to which of salt-free or salt-added surimi is better able to preserve its gel-strength in cold storage has long been a controversial issue. Although there are indications that salt-free surimi is a better performer, the controversy remains essentially unsettled today. According to Shimizu

(1981), the mechanism by which anti-denaturant additives protect surimi's gel-strength in cold storage has yet to receive an acceptable theoretical explanation.

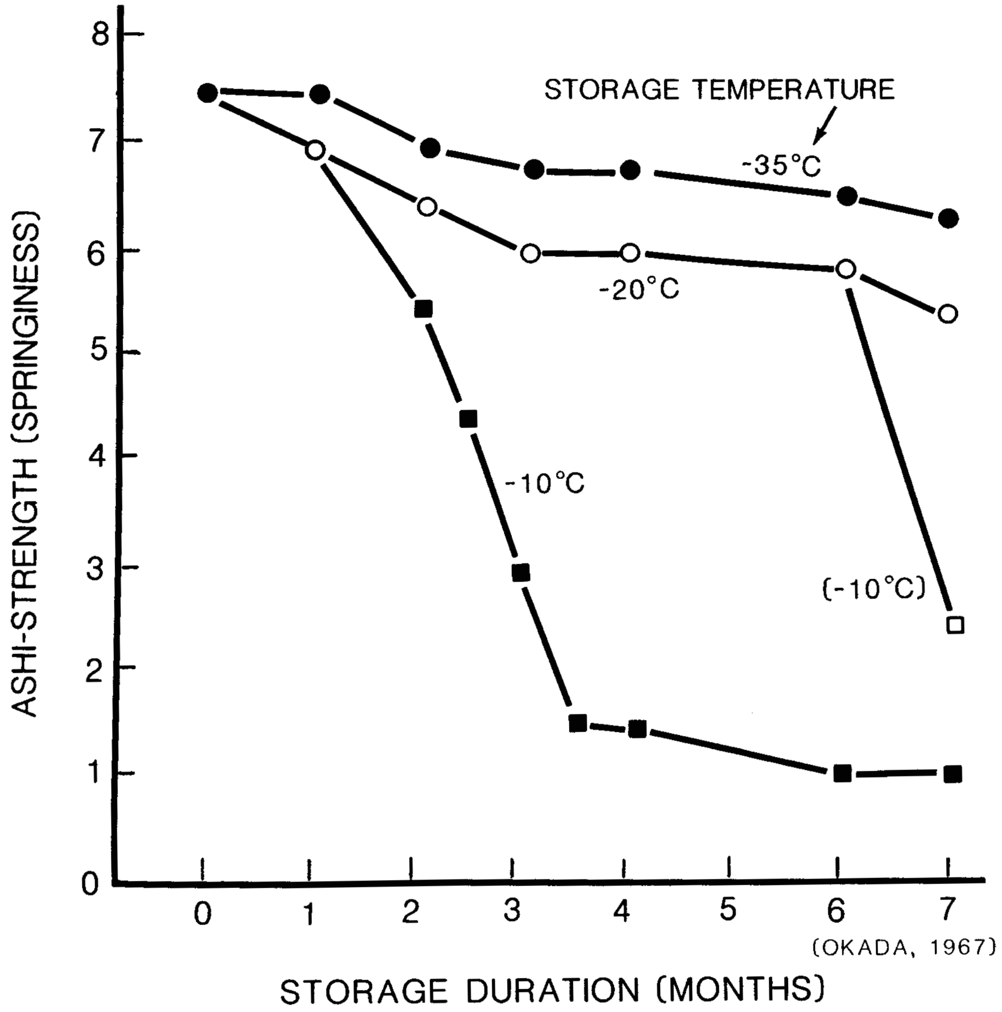


FIGURE 2-22. EFFECT OF COLD STORAGE TEMPERATURE ON ASHI-STRENGTH DETERIORATION IN ALASKA POLLOCK SURIMI

2.7. THE SURIMI PRODUCTION PLANT

A. FLOW DIAGRAM

Figure 2-23 shows a typical flow diagram for the manufacture of frozen surimi from white-fleshed fish. The frozen surimi is essentially a minced, water-washed, stabilized, frozen fish paste. The manufacturing procedures feature mincing, water-washing and stabilizing steps as essential components. Thus, the process flow diagram may be considered to consist of three phases:

Phase 1. Mincing	The whole round fish is transformed into minced meat after the removal of head, guts, bones, and skin.
Phase 2. Leaching	The minced meat acquires gel-forming capability after being leached with cold water. It has now become a surimi.
Phase 3. Stabilizing	The surimi acquires resistance to freeze denaturation by addition of anti-denaturants.

In Phase 1, the transformation of the fish occurs in two steps: first, heads and guts are removed in a dressing machine or manually, and secondly, the meat is separated from bones and skins in a meat separator. The end product of these two steps is minced fish meat. A rinsing procedure is normally sandwiched between these two steps in order to remove the remnants of intestinal tracts and dark belly membranes which are difficult to remove by any subsequent procedures. The protease from the digestive organs can cause enzymatic spoilage of surimi even in cold storage, and the dark membranes are an undesirable blemish in the end product of surimi.

In Phase 2, the leaching cycle consists of two consecutive steps of washing: first, in an agitating water tank and subsequently in a rotating sieve. The washing in a rotary sieve combines the functions of leaching and partial dewatering. The leaching cycles are repeated as often as judged necessary, depending upon the degree of freshness of the fish. At a shore plant where the fish is delivered with some delay after it was caught, the leaching must be more thorough, requiring up to four cycles.

The product emerging from the leaching cycles is a mixture of surimi in a slurry form and an assortment of impurities such as bone fragments, ligaments, scales, etc. The product must be strained and dewatered in order to isolate the surimi.

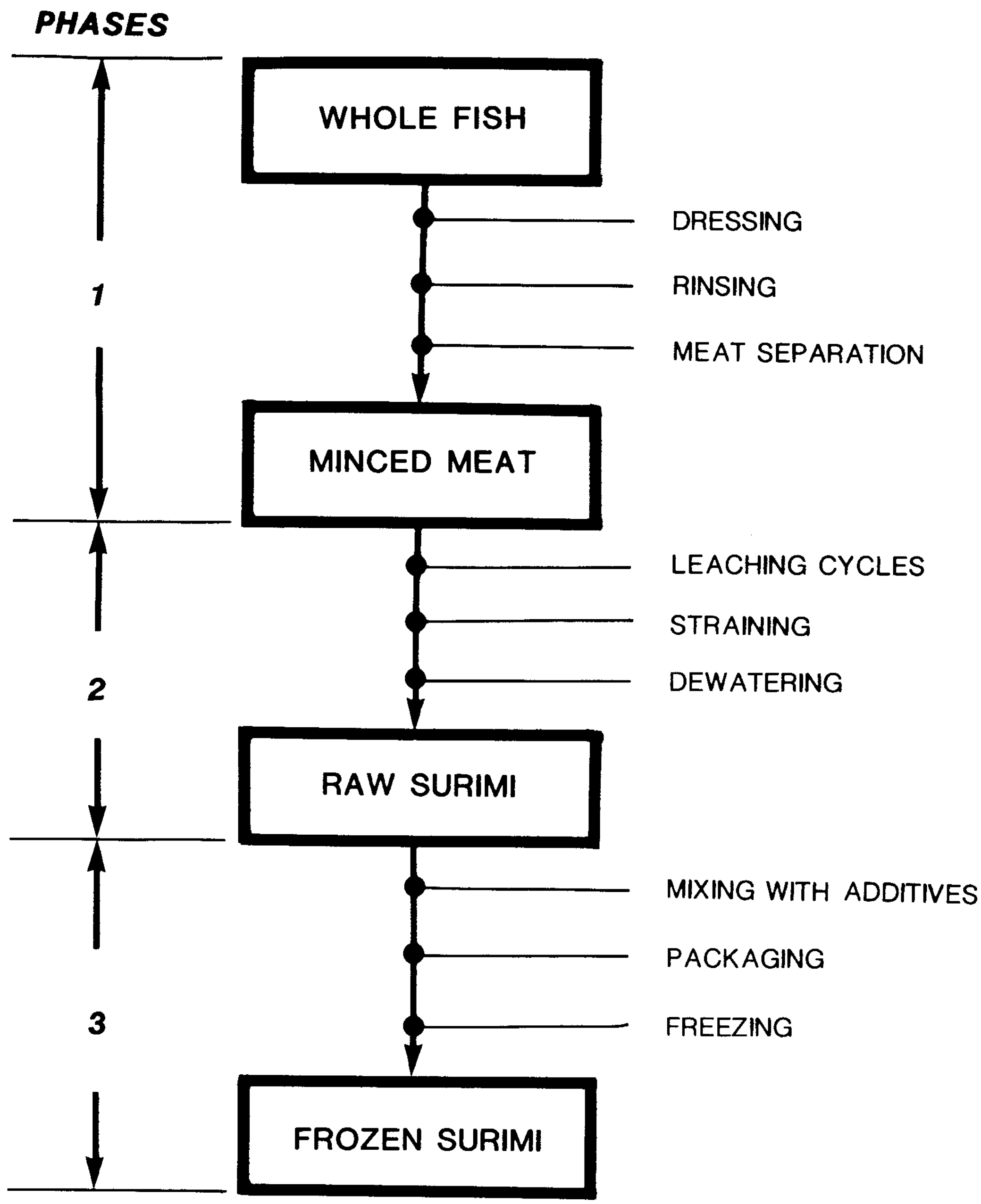


FIGURE 2-23. TYPICAL SURIMI MANUFACTURING PROCEDURES FOR WHITE-FLESHED FISH

The procedures in Phase 1 and 2 result in a surimi which has no capability to resist freeze denaturation. The product is called raw surimi. When used immediately, this product is fit as the intermediate raw material for kamaboko and imitation seafoods. The most important step in Phase 3 is the mixing of cryoprotectant additives into the raw surimi to convert it into a product which can be stored in frozen form without the risk of freeze denaturation, called frozen surimi. The mixing procedure is performed in a silent cutter or ribbon blender. The product is then weighed, frozen and cartoned.

B. PROCEDURES AT SHORE PLANTS

Figure 2-24 shows an example of equipment arrangement in a land-based plant. While this example represents the most current state of technology, some old methods are still being practiced by a fair number of manufacturers, since they still have not caught up with the progress of the technology. Namely, the practice of dewatering the wet mince ahead of applying a strainer is being followed quite widely.

Whereas the fish dressing machine is standard equipment aboard a factoryship since it helps minimize the labor requirement, even the most automated shore plants often depend upon manual labor for fish dressing since it serves best the needs for maximizing the yield and roe extraction.

Since the fish yield, the conservation of energy and effluent disposal are major concerns, a number of plants have incorporated steps designed to recycle the wastes emerging from the meat separator, the leaching cycles, and the straining and dewatering processes in order to recover protein of secondary quality.

Figure 2-25, scenes (1) through (18), depicts actual procedures used in land-based surimi plants in Japan. Scenes (1) through (8) represent Phase 1, in which the fish is converted into minced meat. Scenes (9) through (16) represent Phase 2, in which the minced meat is leached, strained and dewatered enroute to becoming raw surimi. Two scenes, (17) and (18), show freezing and cartoning procedures in Phase 3, where the production of frozen surimi is completed.

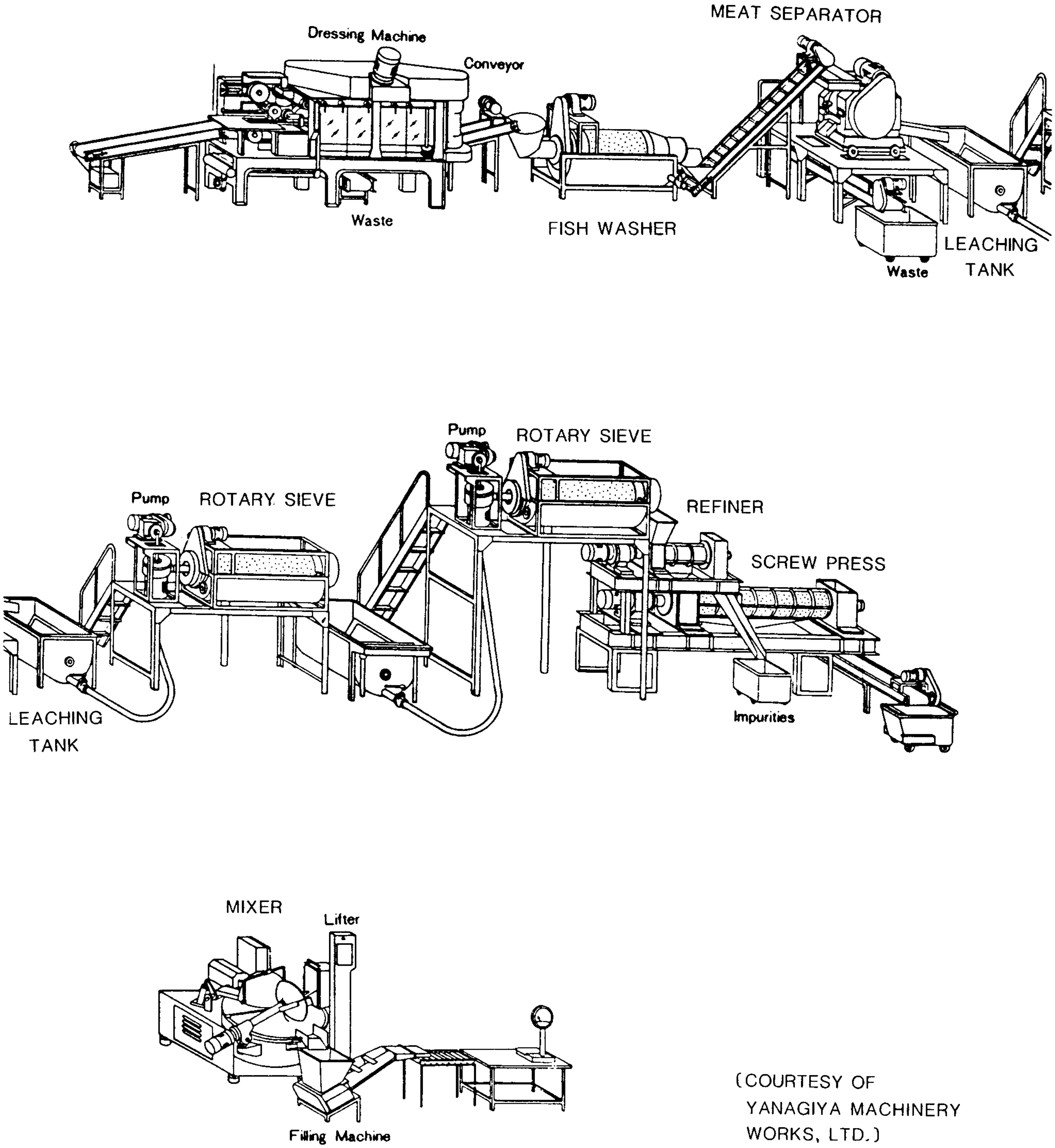


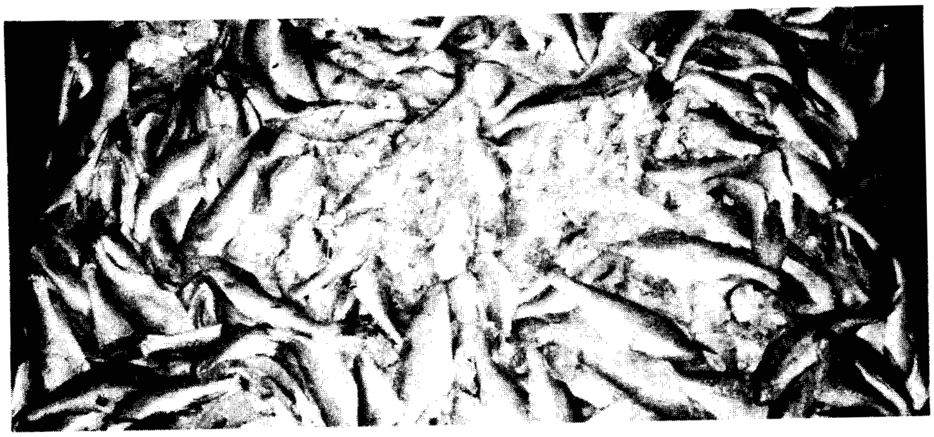
FIGURE 2-24. EXAMPLE OF EQUIPMENT ARRANGEMENT IN LAND-BASED SURIMI PLANT

1) The raw material fish, Alaska pollock, is stockpiled next to the fish dressing aisles.

(COURTESY, KUSHIRO-MARUSUI, LTD.)

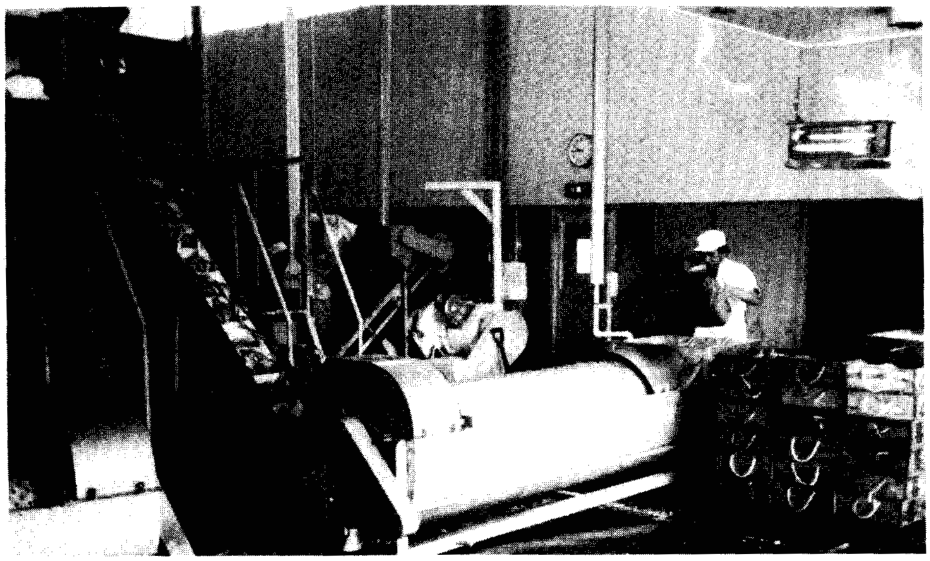
(2) Manual labor is the primary form of fish dressing work at the shore plant. Workers remove the head and guts while extracting the roe at the same time. The fish dressing work is the most labor intensive part of the surimi manufacturing process.

FIGURE 2-25. SCENES OF VARIOUS PROCEDURES IN LAND-BASED SURIMI PLANT



(PHOTO BY S. C. SONU)

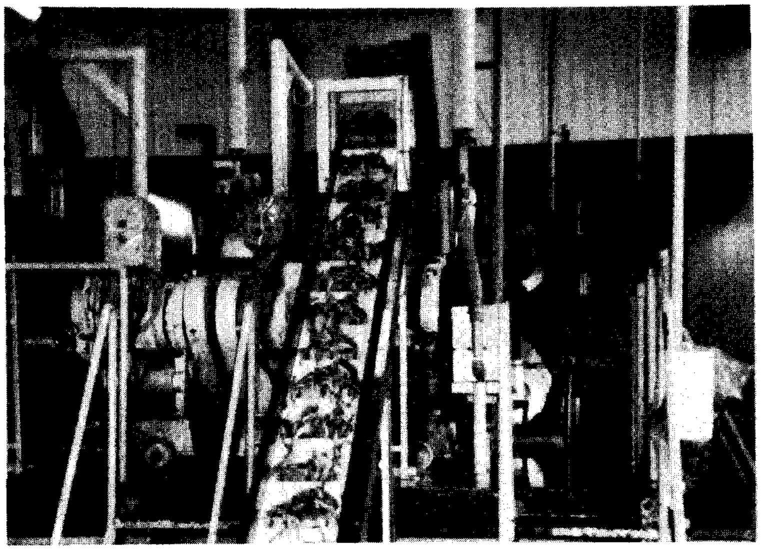
(3) The dressed fish (croaker without head and guts as shown) are kept chilled in layers of crushed ice, taking care to avoid freezing the fish.



(PHOTO BY S. C. SONU)

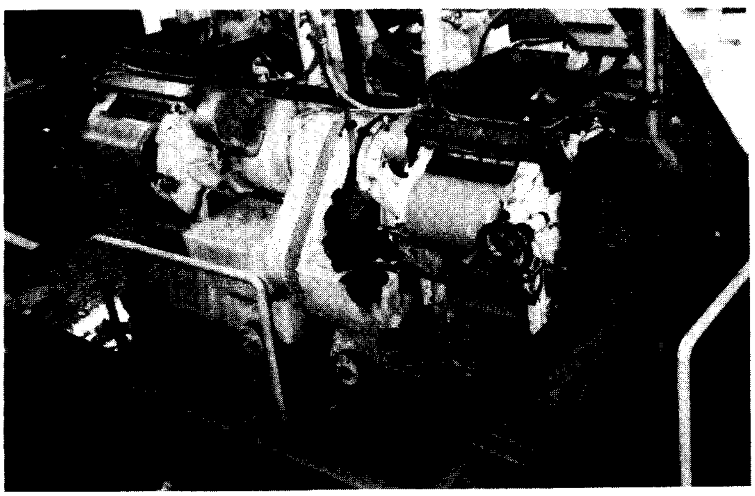
(4) Boxes of dressed fish delivered to the surimi plant bear the names of the fish processors who performed the dressing work for this plant. In this scene a laborer has just emptied a boxful of dressed fish into the fish washer. The washed fish emerge at the other end of the rotary washer to ride the ladder conveyor to the elevated meat separator.

FIGURE 2-25. (CONT'D)



(PHOTO BY S. C. SONU)

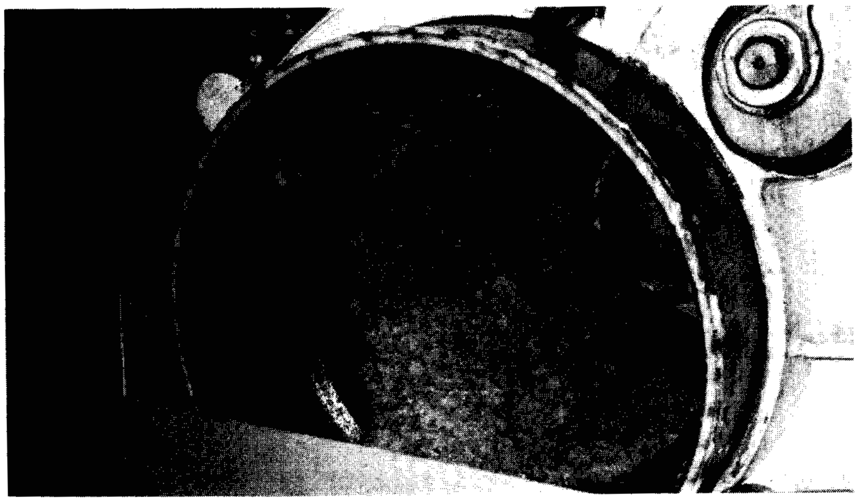
(5) The dressed and washed fish are being transferred to the meat separator located at the upper end of the ladder conveyor.



(PHOTO BY S. C. SONU)

(6) The fish go over the end of the ladder conveyor to fall into the receiving bin of the meat separator. This plant employs two meat separators. Scenes (5) and (6) show the opposite sides of the same system.

FIGURE 2-25. (CONT'D)



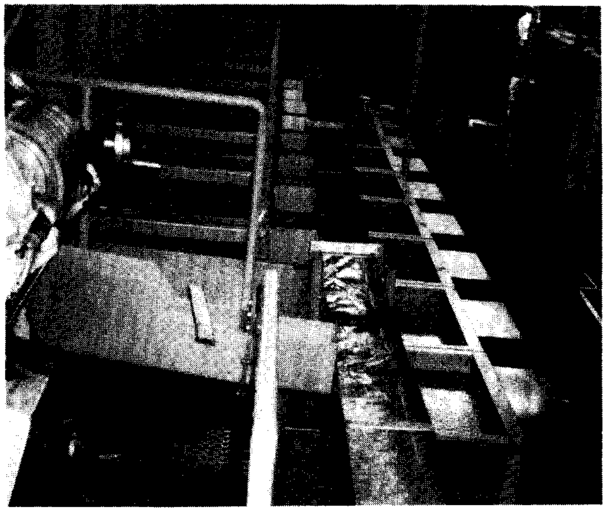
(PHOTO BY S. C. SONU)

(7) The meat separator minces the fish by pressing it against a perforated steel drum. The drum allows the minced meat to pass into its interior, while collecting the bones, skin and scales which cannot pass through the perforations on the outside.

(PHOTO BY S. C. SONU)

(8) The minced meat emerging from the meat separator is fluidized with chilled water. The slurry then flows through the distribution duct toward the leaching tanks.

FIGURE 2-25. (CONT'D)



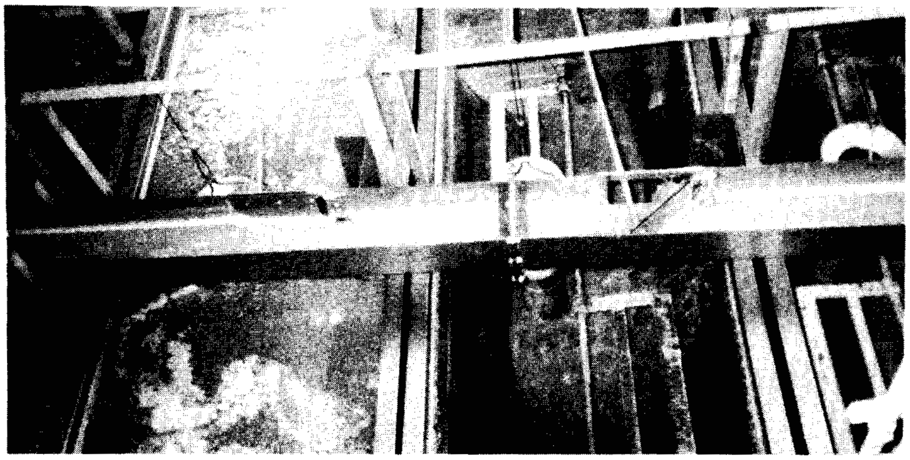
(PHOTO BY S. C. SONU)

(9) The distribution duct is taking the fluidized meat slurry to the leaching tank assembly. The meat separator can be seen on the left of the photo.

(PHOTO BY S. C. SONU)

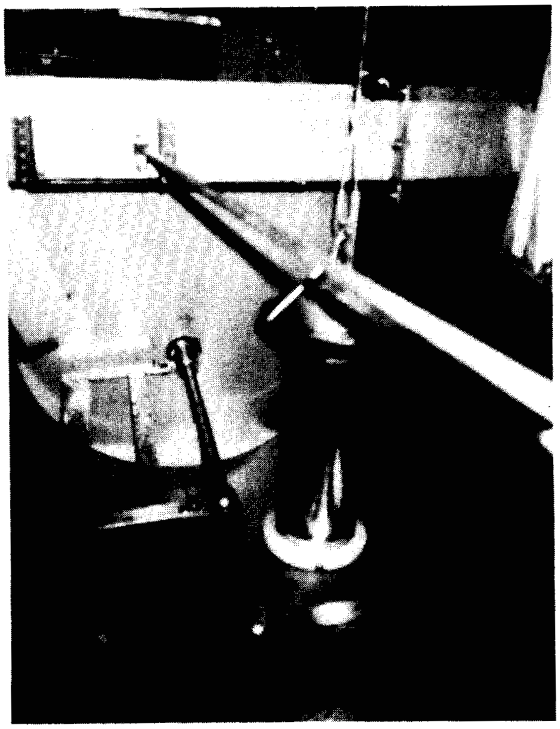
(10) A controlled swing gate blocks the flow of meat slurry, forcing it to spill into the leaching tank below. A vertical pipe supplies chilled water to the tank, automatically adjusting a constant water to meat ratio, usually at 3:1.

FIGURE 2-25. (CONT'D)



(PHOTO BY S. C. SONU)

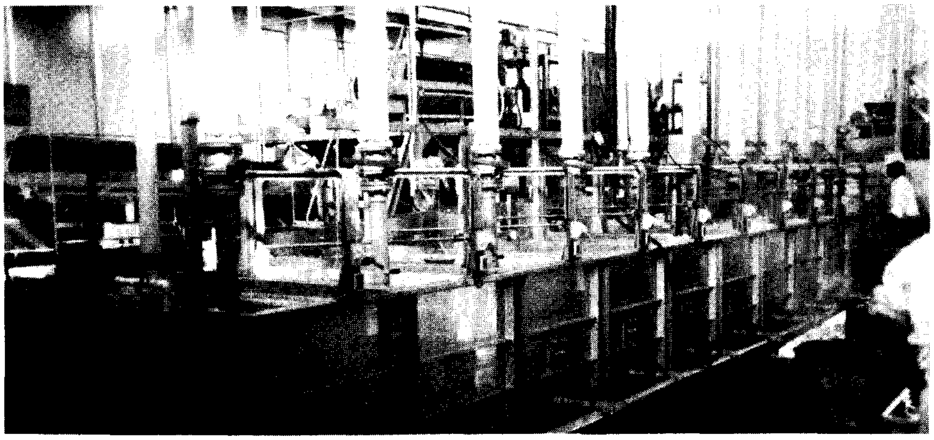
(11) The photo reveals an open swing gate and the control rod. The swing gate is closed when the leaching tank is 80 per cent full, allowing the meat slurry in the distribution duct to proceed to the next open gate.



(12) This interior view of the leaching tank reveals a telescopic drain pipe with a flared port and a pair of stirring paddles. The height of the port is adjusted to changing water levels.

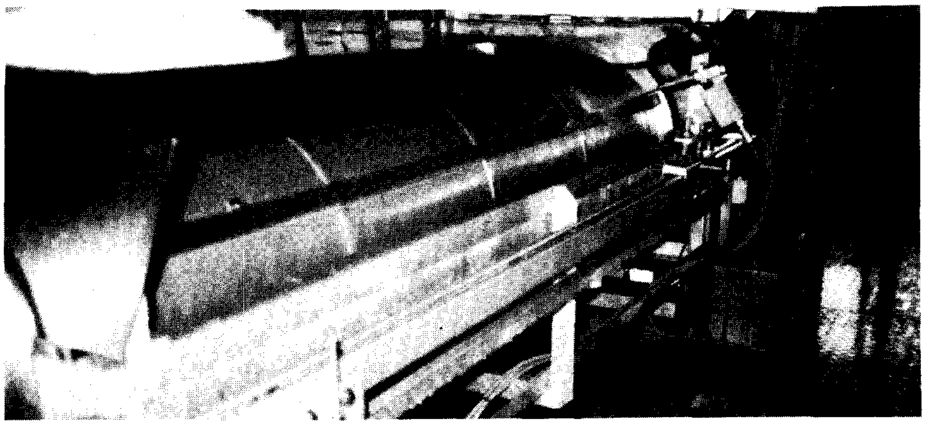
(COURTESY, BIBUN MACHINE CONSTRUCTION CO., LTD.)

FIGURE 2-25. (CONT'D)



(PHOTO BY S. C. SONU)

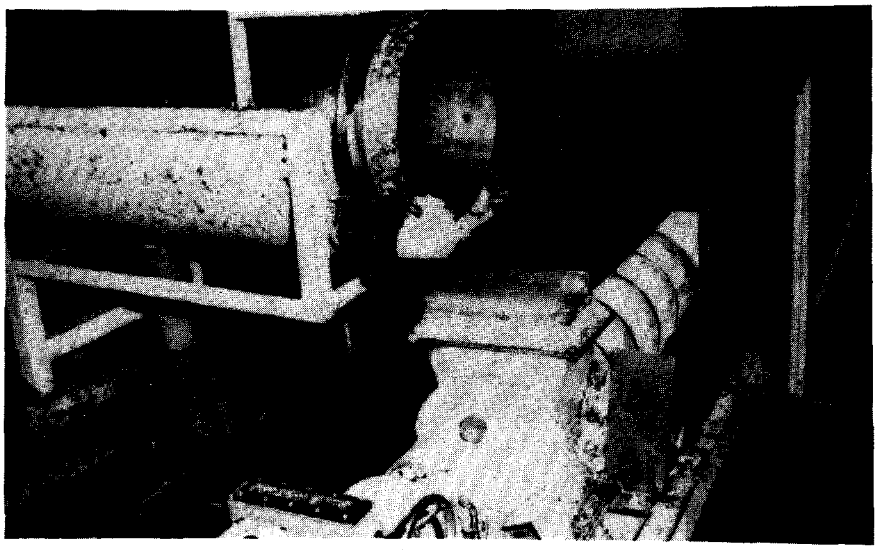
(13) After a period of stirring action by the paddles, the suspended meat slurry is allowed to settle. The supernatant containing grease and water soluble components of the meat is drained into the flared port which stays slightly below the water level. Chilled water is then added and the leaching cycle is repeated. After the last cycle, the leached and washed meat is pumped to rotary sieves through the pipes shown along the side of the tanks in this photo.



(PHOTO BY S. C. SONU)

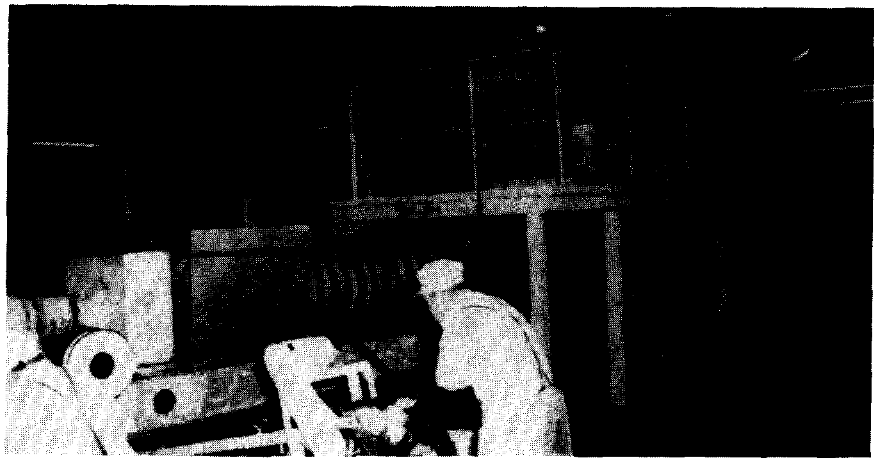
(14) A rotary sieve in action. A jet spray is being applied to the exterior of the rotating sieve from a high-pressure nozzle which travels the length of the system, while the waste water is drained continuously to give the partial dewatering effect. The rotary sieve is particularly effective in removing water soluble impurities such as blood.

FIGURE 2-25. (CONT'D)



(COURTESY, YUZUKI, LTD.)

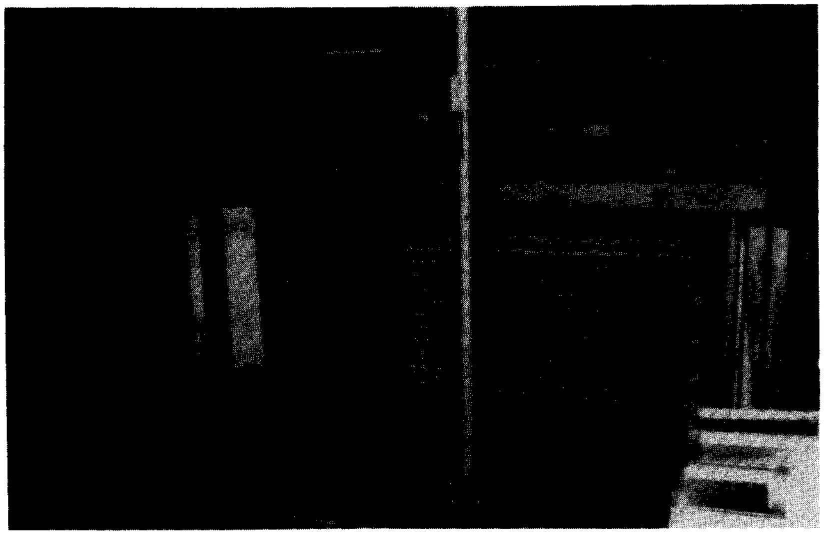
(15) A circular opening in the upper left of the photo is the outlet of the rotary sieve from which the partially dewatered minced meat emerges to enter the refiner below. The refiner is a straining device capable of handling a wet slurry. Working on the wet slurry, heat damage to the surimi is less likely than if the plant uses a strainer, which requires dewatered mince as its feedstock.



(COURTESY, YUZUKI, LTD.)

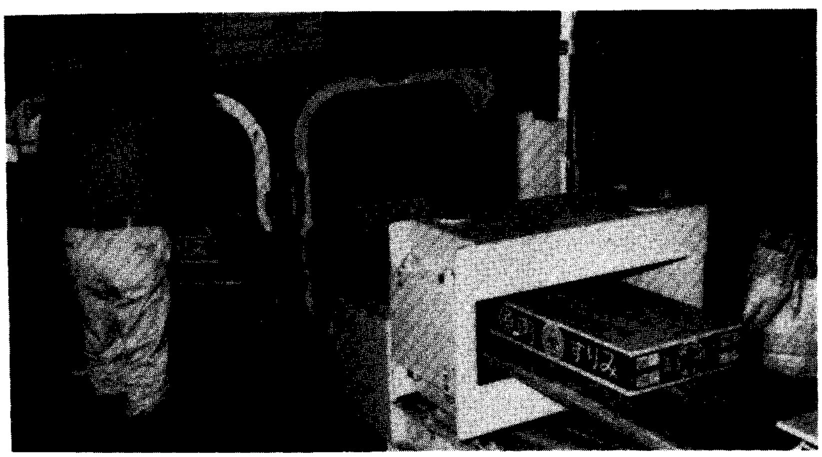
(16) The photo shows a side view of the screw press, a dewatering machine. Notice also the refiner above the screw press.

FIGURE 2-25. (CONT'D)



(COURTESY, KUSHIRO-MARUSUI, LTD.)

(17) Weighed bags of surimi, 10 kg each, are being placed into the contact freezer in metal pans.



(COURTESY, KUSHIRO-MARUSUI, LTD.)

(18) The frozen surimi is cartoned and is being readied for shipment.

FIGURE 2-25. (CONT'D)

C. PLANT LAYOUT

Four selected examples of plant layouts are described in this section.

PLANT A

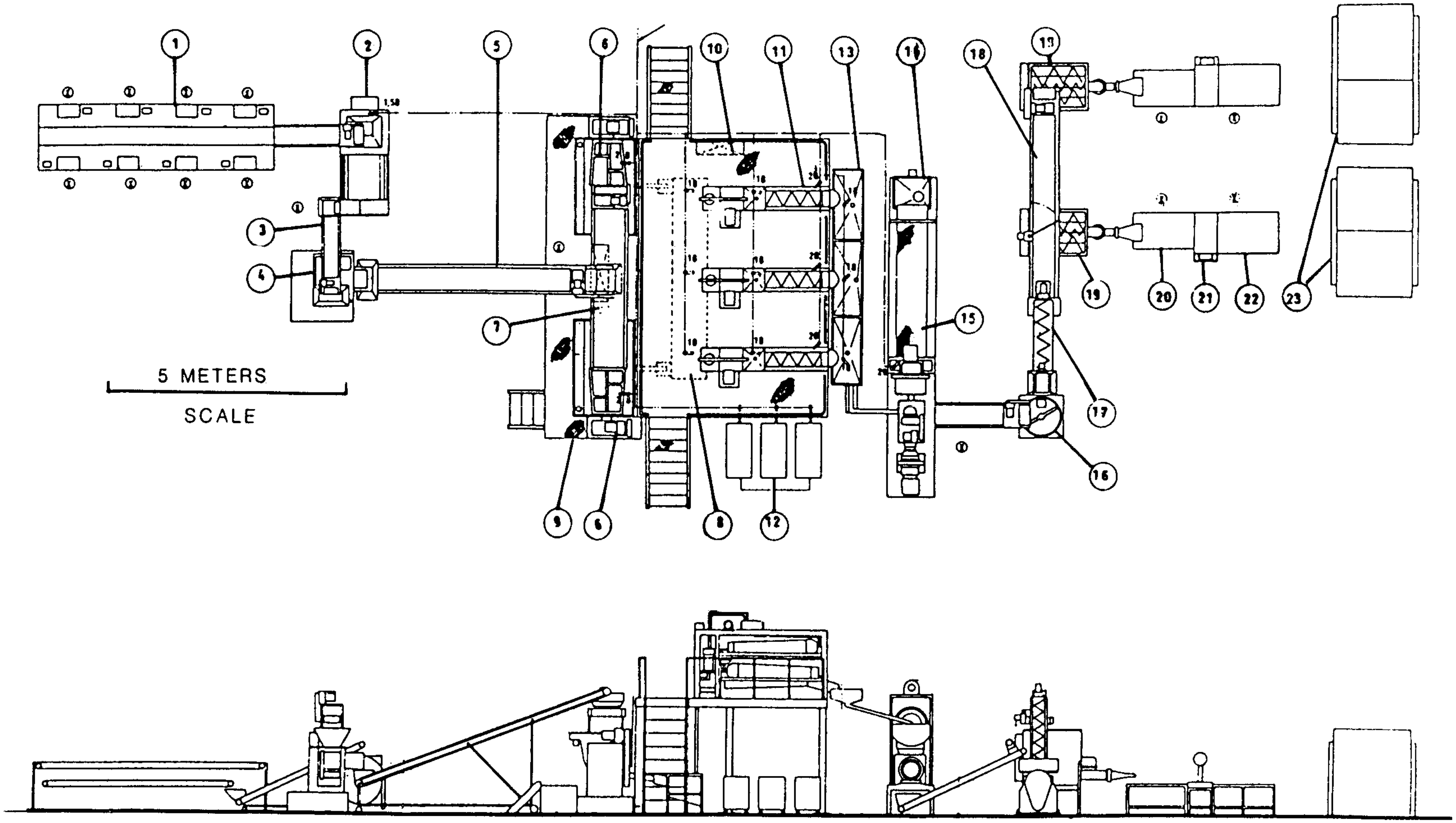
This plant has a production capacity of 7.2 tons of frozen surimi on an 8-hour day basis. It employs 14 laborers, eight of whom perform fish dressing details. Daily water use includes 30 to 40 tons of chilled water and 10 tons of tap water. Figure 2-26 shows the layout of the plant dated January 8, 1981. The Phase 1 and Phase 2 operations at this plant follow standard procedures. However, procedures in Phase 2 are somewhat unusual, as can be seen in the flow diagram in Figure 2-27.

The fish dressing work is performed by an in-house team of eight laborers. The dressed fish is washed in a 2-HP rinsing tank and transferred to a single meat separator to produce minced meat.

The minced meat is leached in two successive steps: first in a tank and then in a succession of three rotary sieves. In the tank, also called the grease remover, the mixture of the minced meat and chilled water is stirred by a paddle to extract the floatable grease and impurities. The stirring action is stopped to allow the meat to settle to the tank bottom, before the tank is tilted to drain the supernatant. This cycle is repeated while adding more chilled water each time. Two tanks are operated in turn in order to make the work flow continuous.

The minced meat which has been washed in the tank is collected in a holding tank before being pumped to the continual leaching machine located on an elevated rack. The leaching device (Figure 2-28) consists of three serial rotary sieves. The minced meat is advanced through them by a built-in screw conveyor, while continually being washed by sprays applied both internally and externally. Once through all three rotary sieves, the leaching process is completed.

The product emerging from the leaching process, essentially a wet surimi, is drained in a rotary screen device prior to full dewatering in a screw press. The product is then passed through a strainer. An improved method reverses this order, first straining the wet surimi with a refiner before the use of a screw press.



PLANT LAYOUT DATED: January 8, 1981

PRODUCTION CAPACITY: 900 kg/hour
EMPLOYEES: 14

WATER REQUIREMENTS:
FOR LEACHING 30-40 T/8 hours
FOR CLEANING 10 T/8 hours

POWER REQUIREMENTS: 68.5 HP

NO.	NAME	QTY	HP
1	DRESSING CONVEYOR	1	0.5x2
2	FISH WASHER	1	2
3	BELT CONVEYOR	1	0.5
4	DEBONER	1	5
5	BELT CONVEYOR	1	0.5
6	CREASE REMOVER	2	7x2
7	BELT CONVEYOR	1	0.5
8	MIXING TANK	1	2
9	WORK DECK	1	
10	WORK DECK	1	
11	LEACHING TANK	3	2x3
12	WATER CLEANER	3	3x3
13	MEAT COLLECTOR	1	
14	SCREW PRESSS	1	2
15	ROTARY SCREEN	1	1
16	STRAINER	1	8
17	SCREW CONVEYOR	1	0.5
18	BELT CONVEYOR	1	0.5
19	MIXER-STUFFER	2	8x2
20	WORK TABLE	2	
21	SCALE	2	
22	WORK TABLE	2	
23	CONTACT FREEZER	2	

COURTESY OF IKEUCHI TEKKOSHO, LTD.

FIGURE 2-26. LAYOUT OF PLANT A

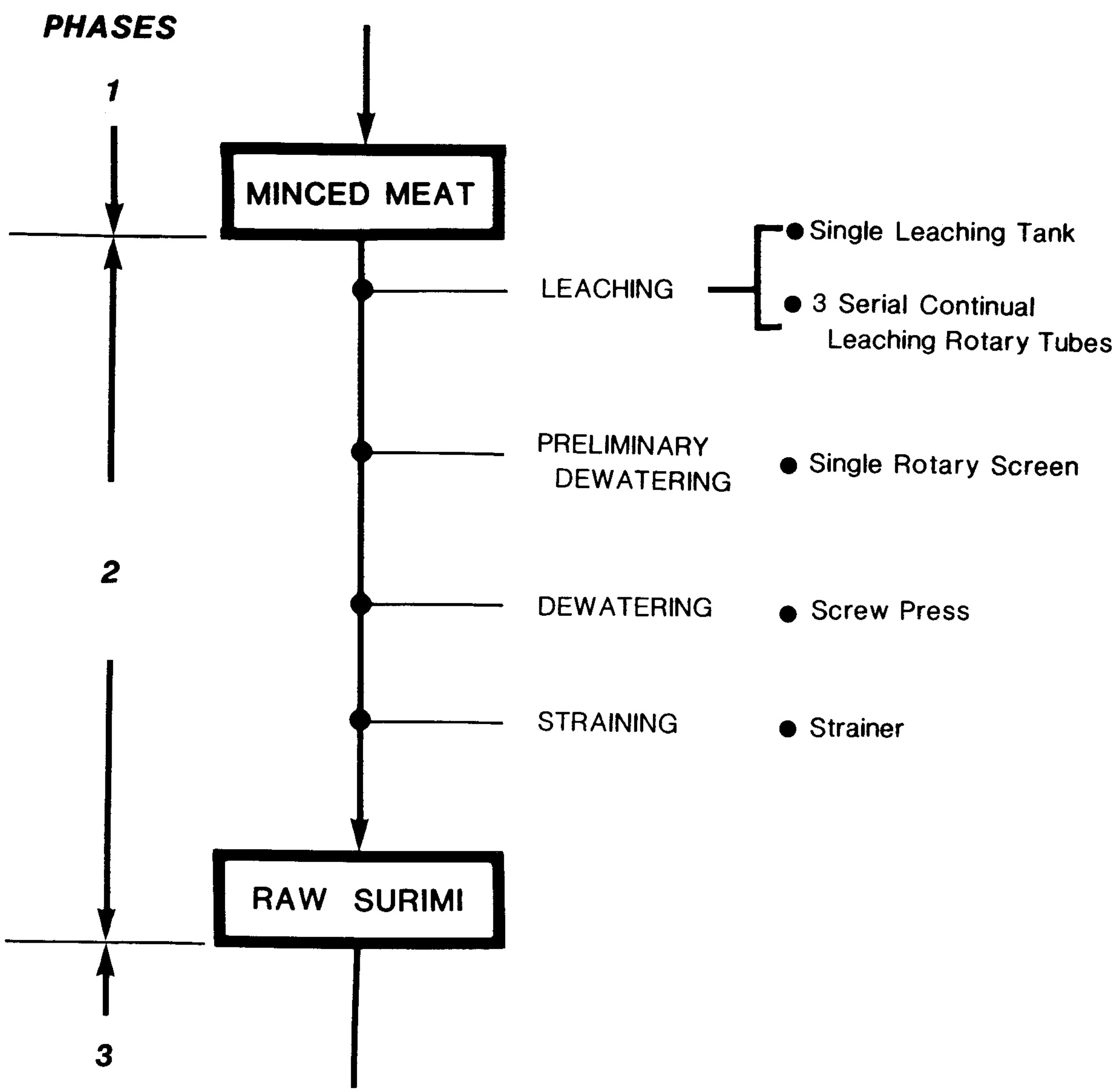
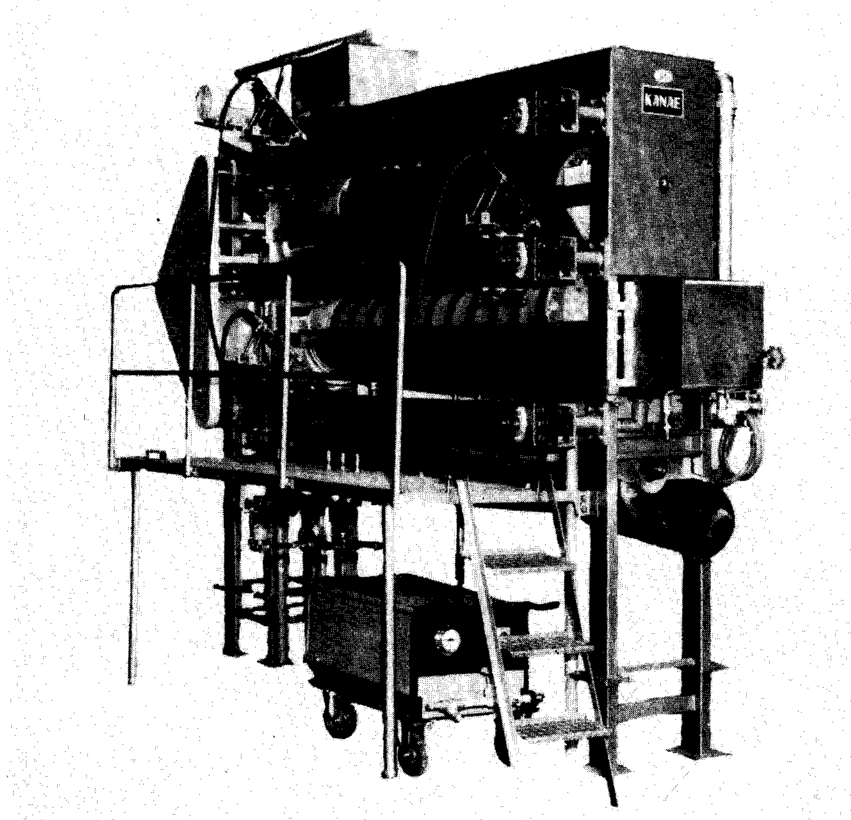


FIGURE 2-27. MANUFACTURING PROCEDURES IN PLANT A



(COURTESY, IKEUCHI TEKKOSHO, LTD.)

SPECIFICATIONS:

PROCESSING CAPACITY	Approx. 300 kg/hour
WATER REQUIREMENT	Approx. 4000 kg/hour
POWER REQUIREMENT	1.5 kw
DIMENSIONS	Height 3,300 mm
	Width 700 mm
	Length 3,270 mm

FIGURE 2-28. CONTINUAL LEACHING DEVICE USED IN PLANT A

PLANT B

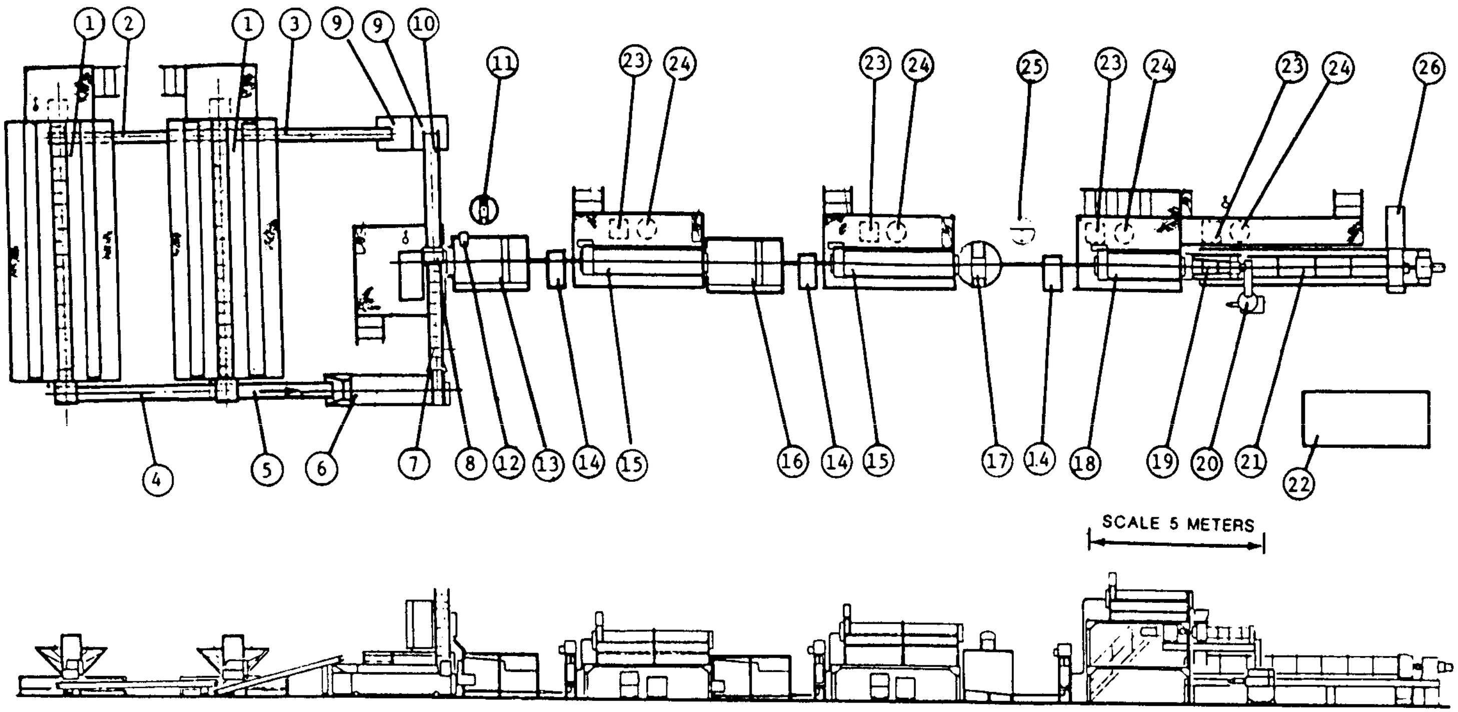
This plant has a production capacity of 10 tons of frozen croaker surimi on an 8-hour day basis. It employs five male and two female workers, plus about 40 laborers in fish dressing detail. Daily use of water includes 200 tons of chilled water (5°-10°C) and 100 tons of tap water. The Phase 1 and 2 portions of the plant layout, dated July 9, 1984, are shown in Figure 2-29 and the corresponding flow diagram in Figure 2-30.

The Phase 1 operations at this plant follow standard procedures. The dressed fish is passed through a single fish rinsing tank and a single meat separator to produce the minced meat. The Phase 2 operations include unique, innovative procedures.

Leaching of the mince is performed by passing the minced meat through three successive cycles of washing, each with a separate set of leaching tank and rotary sieve. The product travels through the cycles with the aid of meat pumps. The first two of these cycles aim to remove impurities in the tank and blood and other soluble impurities in the rotary sieve. The last cycle completes the leaching and provides partial dewatering.

In the first cycle, the minced meat emerging from the meat separator is placed in a tank with the chilled water and stirred. The pH of the mixture is adjusted to facilitate the leaching action of fatty substance from the fish muscle. After the supernatant is drained, the meat slurry in the tank is pumped to the rotary sieve for a shower treatment under high-pressure sprays. The procedures are repeated in the second cycle without an additional pH adjustment.

In the third cycle, the meat is leached in a leaching tank and further in a rotary sieve. The partially dewatered wet surimi emerging from the rotary sieve is placed in a refiner to be strained and the product is dewatered in a screw press as the final step in Phase 2. Additionally, the waste from the refiner is recycled through a strainer to obtain secondary grade surimi.



FISH TYPE: Croaker
PRODUCTION CAPACITY: 10 T/8 hours
PLANT LAYOUT DATED: July 9, 1984

WATER REQUIREMENTS:
Chilled (5-10°C) 200 T/8 hours
Tap Water 100 T/8 hours

POWER REQUIREMENTS:
3-Phase 231 kw
Single-Phase 0.41 kw

LABOR REQUIREMENTS:
Full-time 7
Fish Dressing 40

NO.	NAME	QTY	HP	SPECS
1	DRESSING TABLE	2	0.75x2	
2	CONVEYOR A	1	0.75	
3	CONVEYOR B	1	0.75	
4	CONVEYOR C	1	0.75	
5	CONVEYOR D	1	0.75	
6	FISH WASHER	1	2.2	G3
7	FISH SUPPLY CONVEYOR	1	0.75	
8	MEAT SEPARATOR	1	5.5	NF21
9	WASTE BIN	1		
10	CONVEYOR E	1	0.75	
11	pH ADJUST TANK	1	0.2/0.145	
12	pH ADJUSTER	1	0.2	
13	LEACHING ACCELERATOR	1	0.75	MWFS 2000
14	FISH MEAT PUMP	3	3.7x3	
15	AUTOMATIC LEACHER	2	0.95x2	F53L
16	LEACHING ACCELERATOR	1	0.75	MWFS
17	LEACHING TANK	1	0.75	MWFR 1500
18	AUTOMATIC LEACHER	1	0.95	F52L
19	REFINER	1	7.5	#300
20	STRAINER	1	3.7	SUM 420
21	SCREW PRESS	1	2.2	YS500
22	CONTACT FREEZER	3	55x3	CFA-7.5H
23	HI-PRESSURE JET	4	1.5x4	TE-2DX
24	WASHING TANK	4		
25	SALT WATER TANK	1	0.2/0.06	
26	CONVEYOR	1	0.4	

COURTESY OF BIBUN MACHINE CONSTRUCTION CO., LTD.

FIGURE 2-29. LAYOUT OF PLANT B

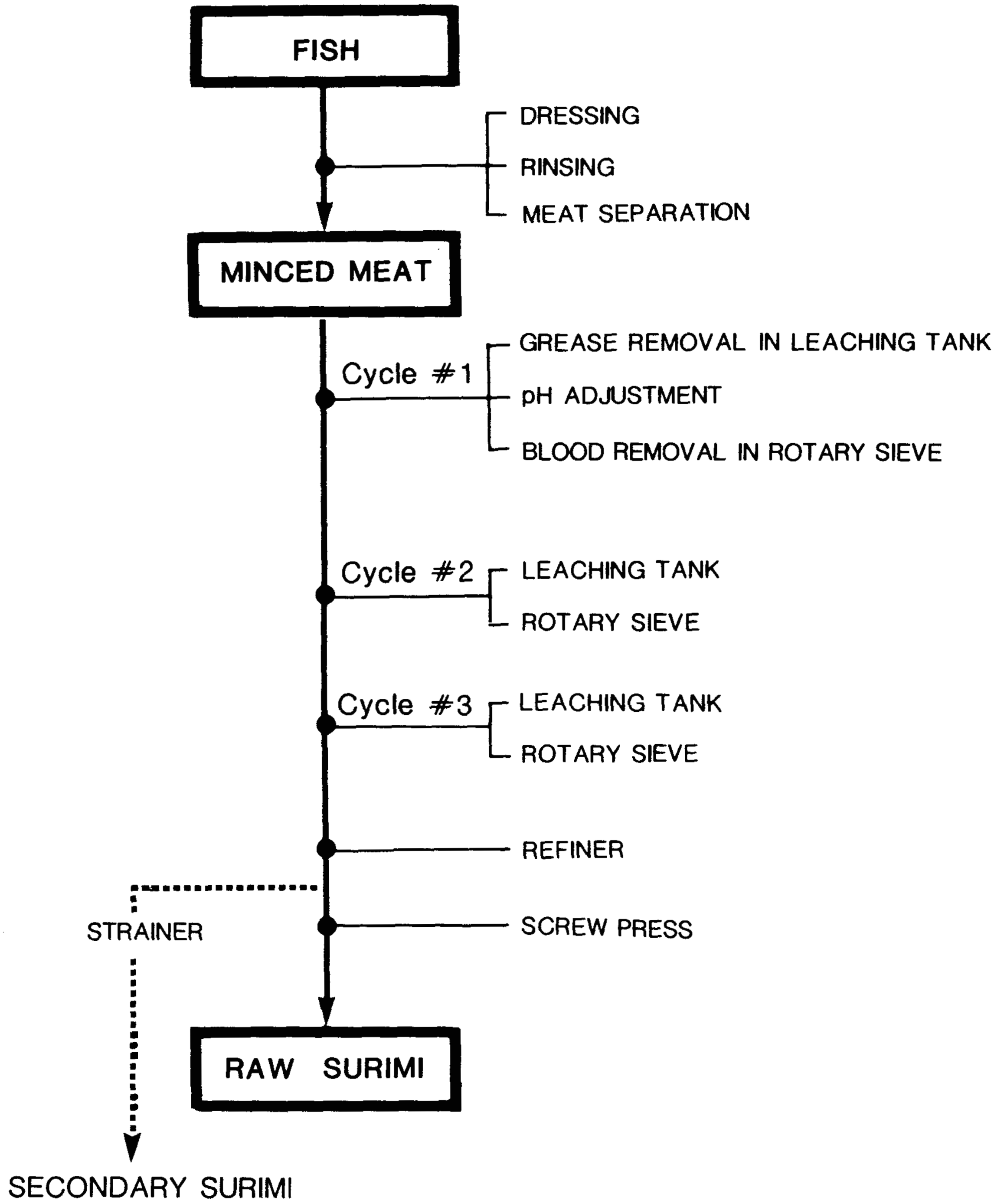


FIGURE 2-30. MANUFACTURING PROCEDURES IN PLANT B

PLANT C

This plant can process 10 tons of raw material fish on an 8-hour day basis. Daily use of water includes 60 tons of chilled water and 20 tons of tap water. The layout of the plant, dated July 30, 1984, is shown in Figure 2-31 and the corresponding flow diagram in Figure 2-32.

The Phase 1 operations at this plant follow standard procedures. The Phase 2 operations include innovative recycling procedures to recover secondary grade surimi.

In the Phase 2 operations, the washing process takes place in two serial cycles each featuring a leaching tank and rotary sieve. In the first cycle, the minced meat is first washed in the stirring tank with an adjusted pH level, and rinsed in a rotary sieve. The meat slurry then proceeds to the second cycle in which essentially the same procedures are repeated.

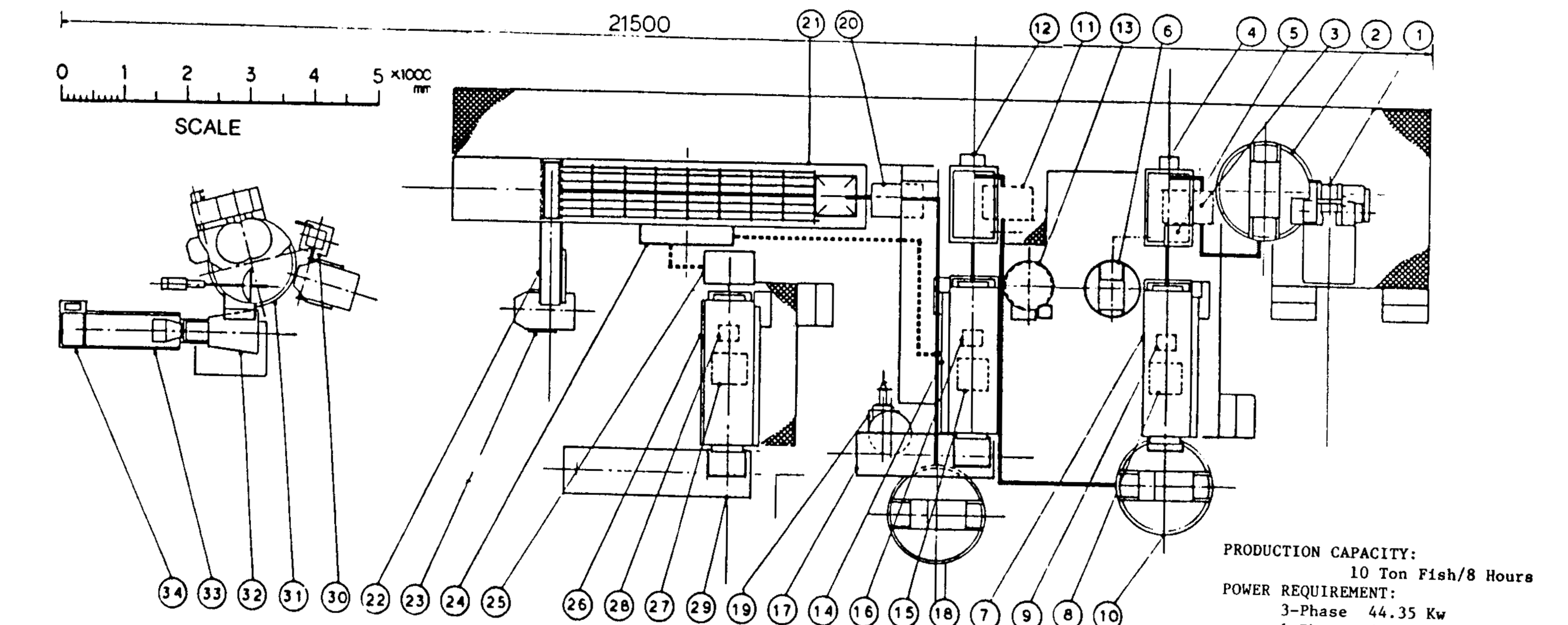
The product emerging from the second washing cycle, a partially dewatered wet surimi, is passed through a refiner to be strained and subsequently through a screw press to be dewatered. The transfer of the product between the cycles is performed by meat pumps, with the aid of holding tanks.

The waste from the refiner is placed in a stand-by strainer to recover the secondary-grade surimi. Optionally, the waste from the screw press may also be recycled. One such procedure takes the waste back through the rotary sieve of the second washing cycle, while an alternative procedure routes the waste to a separate rotary sieve connected to an independent screw press.

PLANT D

This plant produces 5 tons of frozen surimi on an 8-hour day, with daily use of approximately 90 to 100 tons of chilled water and approximately 20 to 30 tons of tap water. The layout of the plant, dated January 1, 1984, is shown in Figures 2-33 and 34, and the corresponding flow diagram in Figure 2-35.

The Phase 1 operations at this plant follow standard procedures. The Phase 2 operations feature three serial cycles of leaching, each consisting of leaching in a tank and preliminary dewatering in a rotary sieve. The meat slurry then is passed through a refiner and a screw press, in that order, to produce raw surimi.



FISH TYPE: HAKE

PLANT LAYOUT DATED : JULY 30, 1984

PRODUCTION CAPACITY:
10 Ton Fish/8 Hours

POWER REQUIREMENT:
3-Phase 44.35 Kw
1-Phase 600 w

WATER REQUIREMENT:
Chilled (4-5°C) 60 Ton/8 Hours
Normal ca. 20 Ton/8 Hours

NO.	NAME	QTY	HP	SPECS
1	MEAT SEPARATOR	1	3.7	SDX 16
2	ACCEPTANCE TANK	1	0.4	MWFR700
3	ROTARY PUMP	1	1.5	
4	LEACHING TANK	1	0.4	MWF500
5	pH CONTROL M/C	1		
6	pH TANK	1		350L
7	ROTARY SIEVE	1	0.95	F52L
8	JET CLEANER	1	1.5	TE-2DX
9	JET CLEANER TANK	1		
10	ACCEPTANCE TANK	1	0.4	MWFR500
11	ROTARY PUMP	1	1.5	
12	LEACHING TANK	1	0.4	MWF500
13	NACL TANK & PUMP	1	0.2	250L
14	ROTARY SIEVE	1	0.95	F52L
15	JET CLEANER	1	1.5	TE-2DX
16	JET CLEANER TANK	1		
17	REFINER	1	3.7	#200
18	ACCEPTANCE TANK	1	0.4	MWFR500
19	MEAT STRAINER	1	3.7	SUM420
20	ROTARY PUMP	1	1.5	
21	SCREW DEHYDRATOR	1	1.5	YS-400x9
22	CONVEYOR	1	0.4	
23	BUCKET	3		
24	RECEIVE TANK	1		
25	ROTARY PUMP	1	1.5	
26	ROTARY SIEVE	1	0.95	F52L
27	JET CLEANER	1	1.5	TE-2DX
28	JET CLEARNER TANK	1		
29	SCREW DEHYDRATOR	1	0.75	SR1000
30	LIFT BOY	1	0.75	
31	BLEND MIXER	1	6.6	BM150
32	FILLING M/C	1	7.5	SF-15
33	ROLLER CONVEYOR	1		
34	SCALE	1		

COURTESY OF BIBUN MACHINE CONSTRUCTION CO., LTD.

FIGURE 2-31. LAYOUT OF PLANT C

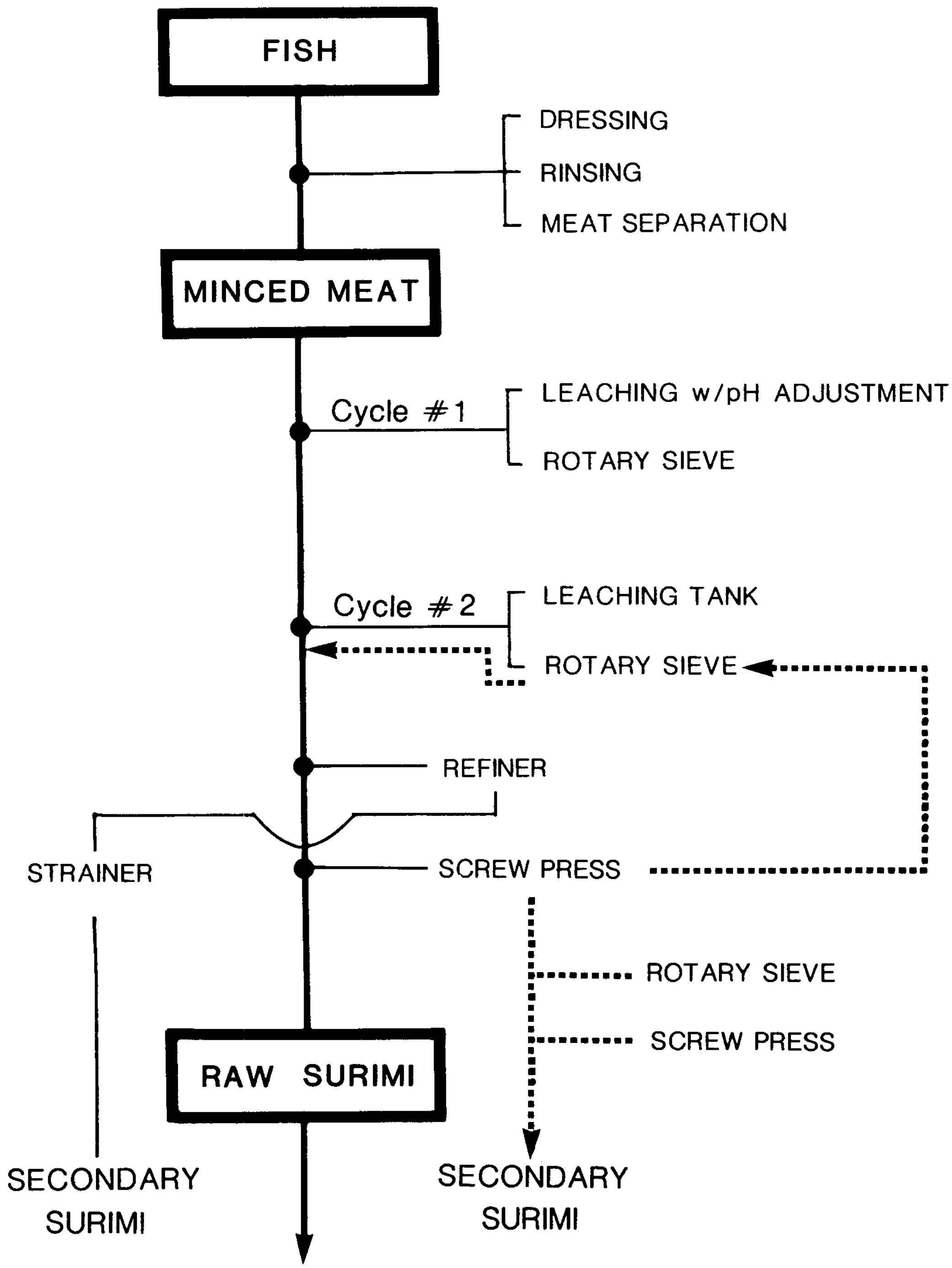
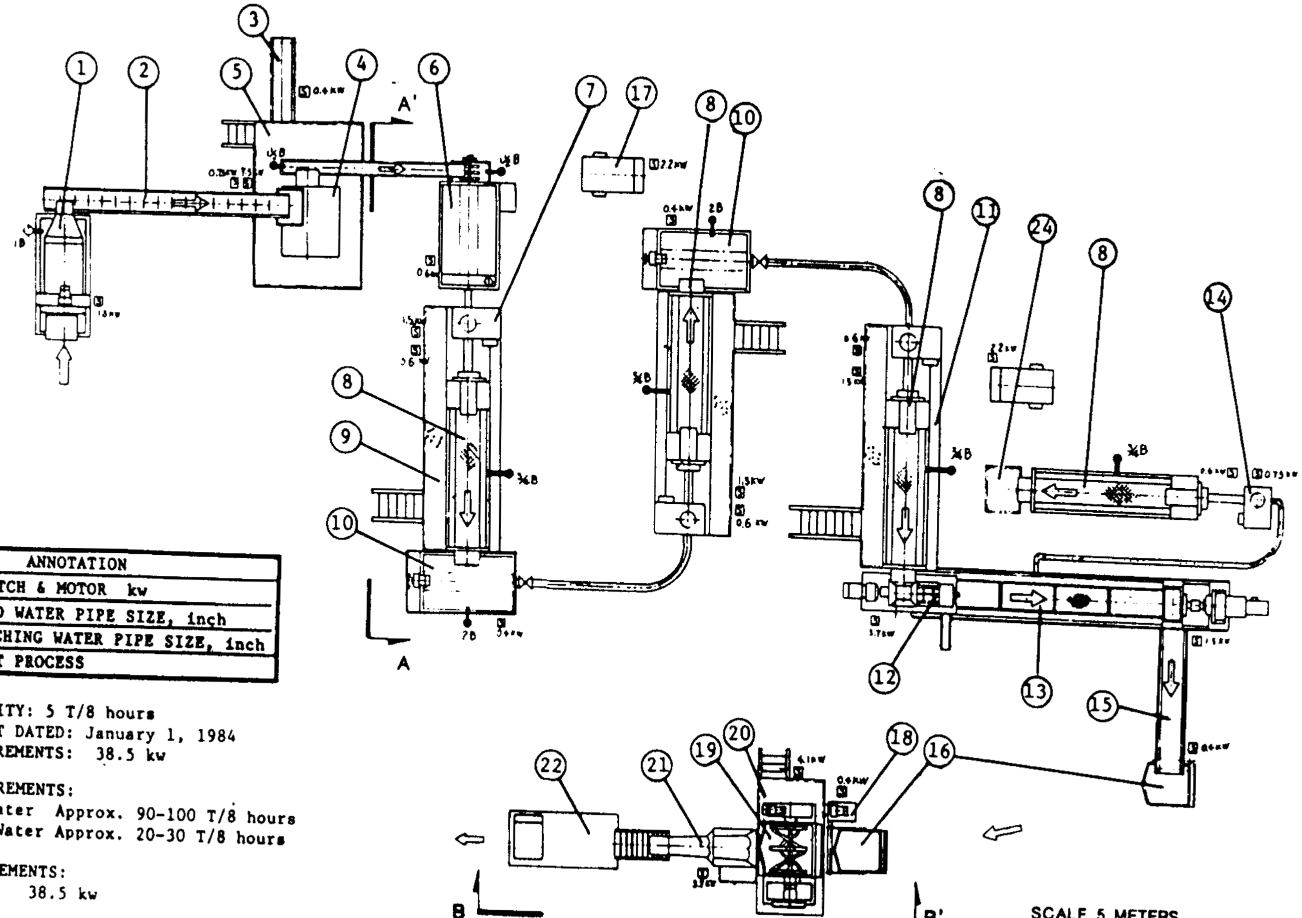


FIGURE 2-32. MANUFACTURING PROCEDURES IN PLANT C



SYMBOL	ANNOTATION
S KW	SWITCH & MOTOR kw
● B	COLD WATER PIPE SIZE, inch
○ B	LEACHING WATER PIPE SIZE, inch
⇨	MEAT PROCESS

PLANT CAPACITY: 5 T/8 hours
PLANT LAYOUT DATED: January 1, 1984
POWER REQUIREMENTS: 38.5 kw

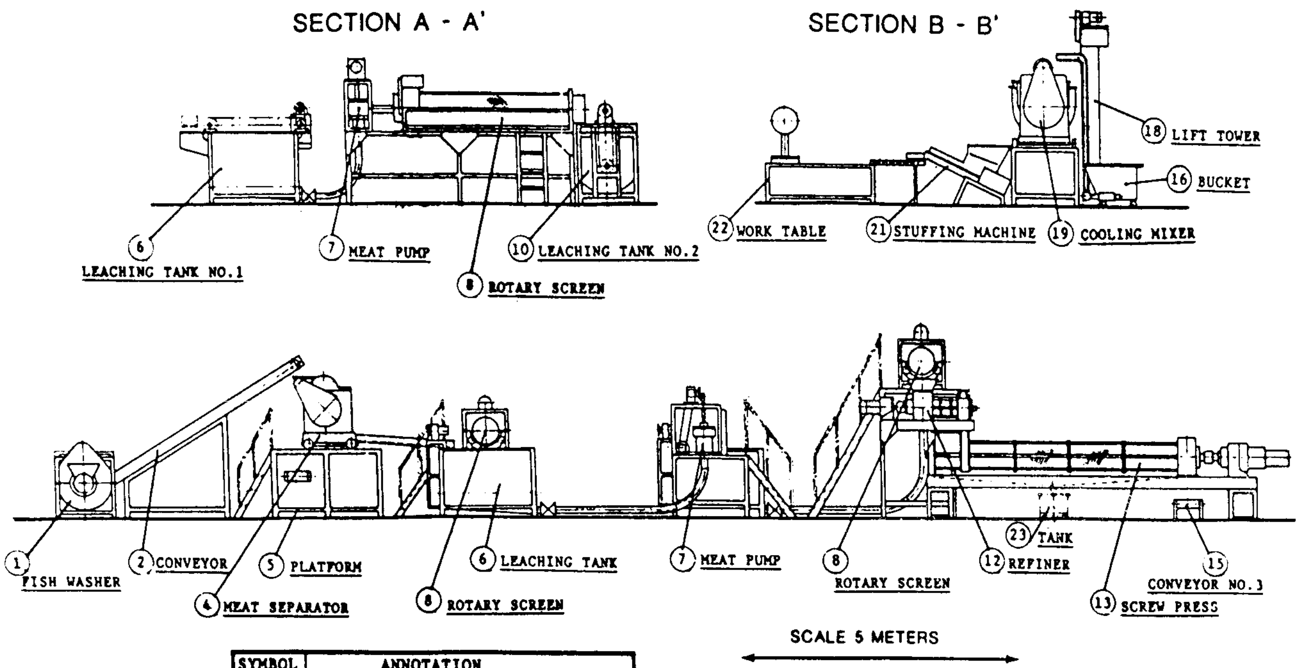
WATER REQUIREMENTS:
Chilled Water Approx. 90-100 T/8 hours
Cleaning Water Approx. 20-30 T/8 hours

POWER REQUIREMENTS:
38.5 kw

NO.	NAME	QTY	HP	SPECS
1	FISH WASHER	1	1.5	TYPE M
2	CONVEYOR	1	0.75	
3	CONVEYOR	1	0.4	
4	MEAT SEPARATOR	1	7.5	Y-400
5	PLATFORM	1		
6	LEACHING TANK	1	0.6	1200 LITRE
7	MEAT PUMP	3	1.5	8- S
8	ROTARY SCREEN	4	0.6	TYPE 3M
9	PLATFORM	2		
10	LEACHING TANK	2	0.4	1000 LITRE
11	PLATFORM	1		
12	REFINER	1	3.7	TYPE 250N
13	SCREW PRESS	1	1.5	HX-400
14	MEAT PUMP	1	0.75	6-S
15	CONVEYOR	1	0.4	
16	BUCKET	4		150 LITRE
17	HI-PRESSURE WASHER	2	2.2	SW-3DX
18	LIFT TOWER	1	1.5	200 Kg
19	COOLING MIXER	1	4.1	200K-CA
20	PLATFORM	1		
21	STUFFING MACHINE	1	3.7	DOUBLE SCREW
22	WORK TABLE	1		
23	TANK	1		300 LITRE
24	TANK	1		200 LITRE

(COURTESY, YANAGIYA MACHINERY WORKS, LTD.)

FIGURE 2-33. LAYOUT OF PLANT D



SYMBOL	ANNOTATION
S KW	SWITCH & MOTOR kw
● B	COLD WATER PIPE SIZE, inch
○ B	LEACHING WATER PIPE SIZE, inch
⇨	MEAT PROCESS

PLANT CAPACITY: 5 T/8 hours
PLANT LAYOUT DATED: January 1, 1984
POWER REQUIREMENTS: 38.5 kw

WATER REQUIREMENTS:
Chilled Water Approx. 90-100 T/8 hours
Cleaning Water Approx. 20-30 T/8 hours

POWER REQUIREMENTS:
38.5 kw

NO.	NAME	QTY	HP	SPECS	NO.	NAME	QTY	HP	SPECS	NO.	NAME	QTY	HP	SPECS
1	FISH WASHER	1	1.5	TYPE M	9	PLATFORM	2			17	HI-PRESSURE WASHER	2	2.2	SW-3DX
2	CONVEYOR	1	0.75		10	LEACHING TANK	2	0.4	1000 LITRE	18	LIFT TOWER	1	1.5	200 Kg
3	CONVEYOR	1	0.4		11	PLATFORM	1			19	COOLING MIXER	1	4.1	200K-CA
4	MEAT SEPARATOR	1	7.5	Y-400	12	REFINER	1	3.7	TYPE 250N	20	PLATFORM	1		
5	PLATFORM	1			13	SCREW PRESS	1	1.5	HX-400	21	STUFFING MACHINE	1	3.7	DOUBLE SCREW
6	LEACHING TANK	1	0.6	1200 LITRE	14	MEAT PUMP	1	0.75	6-S	22	WORK TABLE	1		
7	MEAT PUMP	3	1.5	8- S	15	CONVEYOR	1	0.4		23	TANK	1		300 LITRE
8	ROTARY SCREEN	4	0.6	TYPE 3M	16	BUCKET	4		150 LITRE	24	TANK	1		200 LITRE

(COURTESY OF YANAGIYA MACHINERY WORKS, LTD.)

FIGURE 2-34. ELEVATED VIEW OF PLANT D

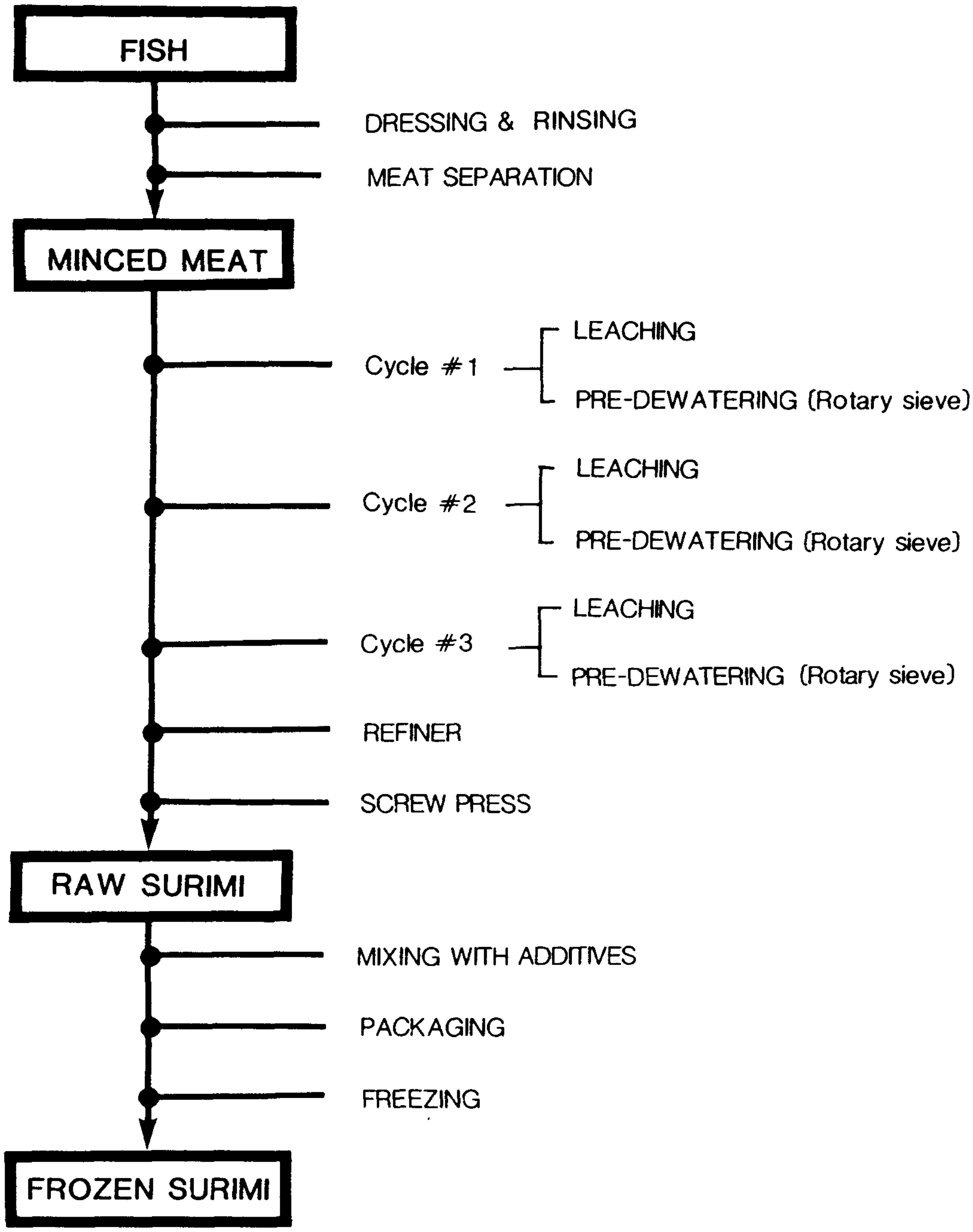


FIGURE 2-35. MANUFACTURING PROCEDURES IN PLANT D

CHAPTER III. SURIMI BASED ON DARK-FLESHED FISH

3.1. HISTORY

Sardine and Pacific mackerel have long been used as the raw material for some special surimi-based products, such as kuro-(black) hampen, a product known for its excellent taste. However, the surimi-based products based on these dark-fleshed fish have failed to secure a significant level of consumer acceptance owing to such drawbacks as weak gel-strength, the dark color of the product, and their fishy aroma.

The idea of developing an improved fish-cake product from dark-fleshed fish, particularly from sardine and Pacific mackerel, began to receive the industry's attention in the latter half of the 1960's when the harvest of bottom fish in the western Japan and the East China Seas, which traditionally had been used as raw material for "kamaboko", began to decline sharply. Already in 1965, a method of leaching the dark fish meat in an alkali salt solution to improve the gel-strength had been discovered and patented (Shimizu, 1965).

An allout effort to develop a commercially viable surimi technology using dark-fleshed fish species was begun in earnest in 1977 when the Fisheries Agency launched a five-year $8 million program to develop the technology as a joint effort among the government laboratories, the industry and the universities. The major impetus to this national program, named "Effective Utilization of Abundant Dark-Fleshed Fish Species", was the uncertain future of the supply of Alaska pollock in foreign waters, which had already declined considerably (Fisheries Agency, 1982b). The catches of sardine and Pacific mackerel in Japan's home waters, on the other hand, had shown a dramatic rise in the mean time. The combined catch of both species was 1.25 million metric tons in 1972; it rose to 3.26 million metric tons in 1978 (Z.S.K., 1984).

Key problems associated with the dark-fleshed fish as the raw material for frozen surimi were: (1) the relatively high content of fat and its strong affinity to the flesh and skin, (2) the dark meat containing blood streaks and strong pigments, (3) the small size of the fish, (4) rapid loss of freshness, (5) rapid reduction in the pH level after death, (6) the rapid rate of protein denaturation, and (7) the brief landing season of the raw material fish. These unique problems made it difficult to apply the frozen surimi technology that had been developed for white-fleshed fish such as Alaska pollock (Shimizu, 1980).

The products based on two of the methods developed during the Fisheries Agency Program have exhibited an excellent capacity for cold storage as well as a high level of consumer acceptance. The sardine surimi manufactured by the Nagasaki Fishery Processors Cooperative has been reported to have a cold storage capacity for as long as 2 years with little evidence of denaturation (Fujii, 1981). The Pacific mackerel surimi manufactured at the Hachinohe test plant by the Japan Surimi Association exhibited virtually no deterioration after 14 months in cold storage (Japan Society of Scientific Fisheries, 1981).

3.2. TECHNICAL PROBLEMS ASSOCIATED WITH DARK-FLESHED FISH

The difficulty of manufacturing frozen surimi equipped with anti-denaturant properties is compounded in the case of dark-fleshed fish because of a host of chemical, physical, physiological and biological characteristics unique to these fish species.

A. RAPID PROTEIN DETERIORATION

Migratory fish species such as sardine and Pacific mackerel contain a large amount of glycogen in their muscle in order to support their energetic life style (Fujii, 1981). Following the death of the fish, glycogen in the fish muscle degrades into lactic acid, which in turn causes rapid reduction of pH in the flesh to as low as 5.6 to 5.8 (Ishikawa et al., 1977 and 1979). This poses a serious problem because myofibrillar protein in the fish muscle, which gives surimi its gel-forming and hydrophilic capabilities, has the tendency to deteriorate rapidly at a pH level near or below 6. It is extremely important, therefore, to restore pH of the fish muscle to a neutral level at the earliest opportunity following the death of the fish.

Freshness is extremely short-lived in sardine and Pacific mackerel. Figure 3-1 demonstrates the rapid decline in gel-strength in the fish cakes ("kamaboko") manufactured with either the unfrozen fish which was kept in an ice-water bath, or the same fish which was subsequently frozen at -27°C for 30 days (Matsumori et al., 1979). The gel-strength dropped rapidly in both samples, particularly during the early period of storage. Defining "critical" freshness of the fish as the case where the surimi made from it is capable of showing a minimum acceptable gel-strength of 300 to 400 gram-cm, it has been found that the critical freshness is reached after 1 day of storage for unfrozen sardine, after 2 days of storage for unfrozen Pacific mackerel, within 1 day for frozen sardines, and in less than 1 day for frozen Pacific mackerel. In both sardines and Pacific mackerels, the small fish lost freshness more rapidly than the large ones.

Other factors affecting gel-strength in kamaboko products based on dark-fleshed fish include the age, the fish school, and the season of landing (Fujii, 1981). In particular, summer sardines are known to have less gel-strength than winter

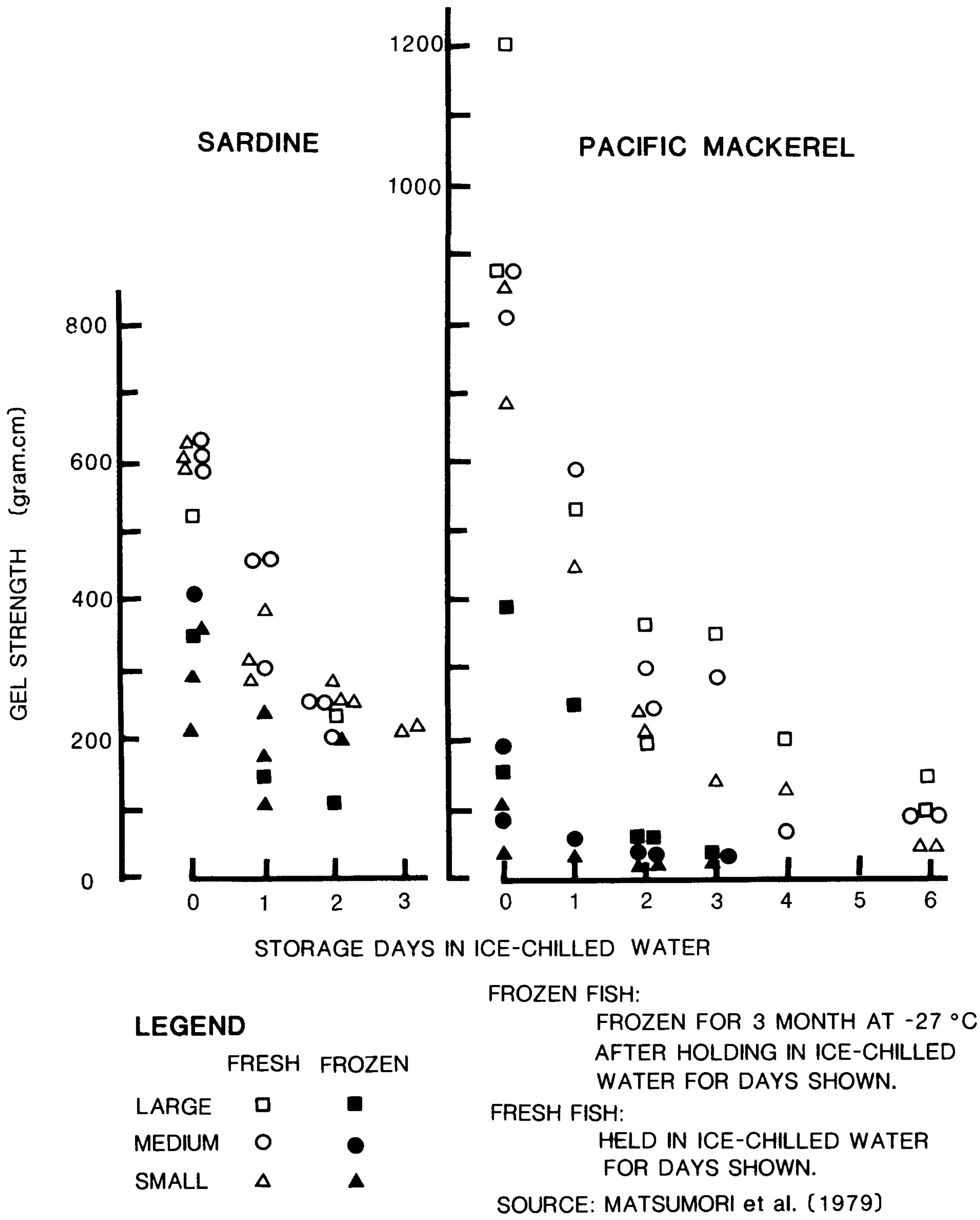


FIGURE 3-1. DECLINE IN GEL STRENGTH OF SURIMI-BASED PRODUCTS MADE FROM UNFROZEN AND FROZEN SARDINE AND PACIFIC MACKEREL

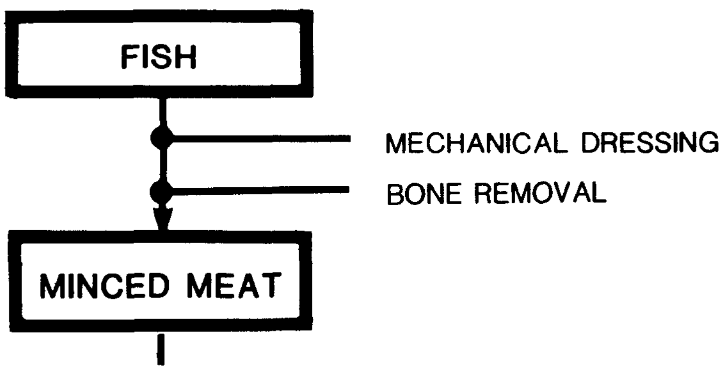
sardines, due partly to the greater fat content in the summer fish and partly to the greater difficulty of preserving the fish in summer.

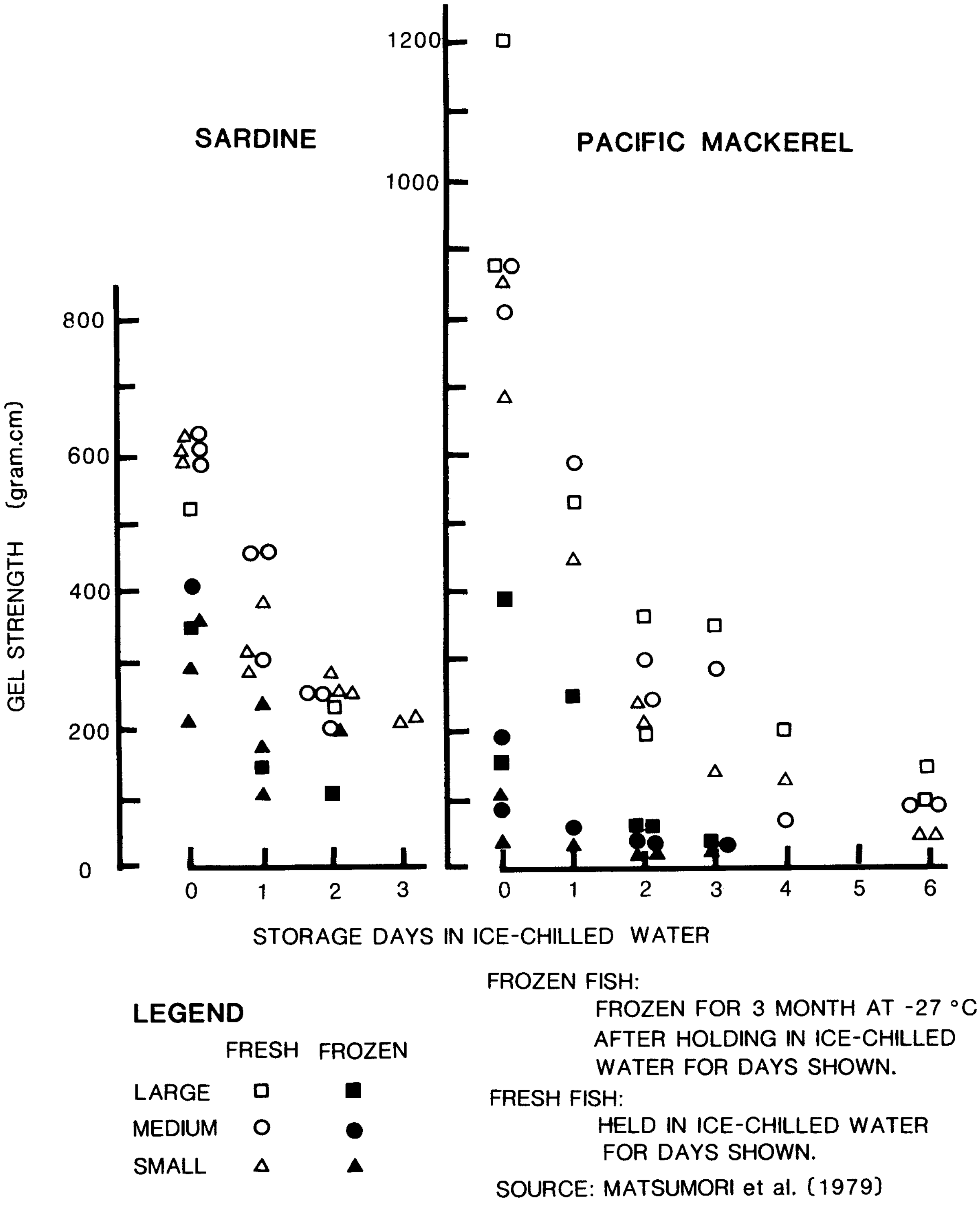
B. LARGE CONTENT OF SARCOPLASMIC PROTEIN

The dark flesh of sardine and Pacific mackerel contains a distinctly large amount of sarcoplasmic protein, a component which must be removed through the leaching process because of its alleged role in thwarting the gel-forming function of myofibrillar protein. The large amount of sarcoplasmic protein which will wash out in the waste water then requires additional effort for waste treatment in surimi production using dark-fleshed fish. Sarcoplasmic protein in the dark flesh dissolves very slowly in normal fresh water (at a zero ionic strength). Therefore, a special leaching method must be used to maintain a reasonable speed in leaching treatment given to the dark-fleshed fish (Shimizu, 1965).

C. LARGE CONTENT OF DARK MUSCLE TISSUE

Dark muscle tissue comprises as much as 10 to 20 per cent of the muscle in sardine and Pacific mackerel. By comparison, it constitutes only a few per cent in the white-fleshed fish (Fujii, 1981). The dark muscle tissue, because of its large content of fat and hemoglobin pigment and a proportionally lower content of myofibrillar protein, could cause a reduction in gel-strength and an increase in the stain and fish odor if mixed into the surimi. A thorough removal of dark muscle tissue during the fish dressing process is one of the important steps in the production of surimi based on dark-fleshed fish.





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Dark muscle tissue comprises as much as 10 to 20 per cent of the muscle in sardine and Pacific mackerel. By comparison, it constitutes only a few per cent in the white-fleshed fish (Fujii, 1981). The dark muscle tissue, because of its large content of fat and hemoglobin pigment and a proportionally lower content of myofibrillar protein, could cause a reduction in gel-strength and an increase in the stain and fish odor if mixed into the surimi. A thorough removal of dark muscle tissue during the fish dressing process is one of the important steps in the production of surimi based on dark-fleshed fish.

D. LARGE CONTENT OF FAT

While the dark-fleshed fish generally contain larger amounts of fat than the white-fleshed fish, the fat content in the dark-fleshed fish also undergoes acute seasonal fluctuations. The fat content in sardine is reported to fluctuate between 2.6 and 18.4 per cent, and that in Pacific mackerel between 2.1 and 28.7 per cent (Matsumori et al., 1979). A particularly annoying problem is that the fat that adheres to the underside of the skin in the dark-fleshed fish is liable to oxidation after the death of the fish, causing fishy odor and discoloration to the flesh. During surimi production, this fat mixes into the minced meat after passage through the meat separator, if not removed during the fish dressing process. Consequently, the waste water from the leaching treatment of dark-fleshed fish can contain a large amount of fat, necessitating added effort for waste water treatment.

3.3. MANUFACTURING PROCEDURES

There are four different surimi manufacturing procedures which have so far been developed in Japan specifically for the dark-fleshed species. Two of them have already been applied to commercial production, while the other two are still in experimental stages.

A. JAPAN SURIMI ASSOCIATION (JSA) METHOD

This method, developed by the Japan Surimi Association (JSA), is intended to allow maximum utilization of the existing surimi production facilities built for Alaska pollock (Miyamoto, et al.,1982). The product resulting from this method has numerous advantages, among them inexpensive production facilities, high productivity, high yields, and good taste. Since the product is suitable as the material for fried kamaboko, broiled kamaboko, and fish sausage, commercial-scale production using the JSA method has already been launched in some areas. Disadvantages of the surimi manufactured by the JSA method lie in its dark appearance, weak gel-strength and fishy odor, as the mechanical fish dressing procedure and the subsequent processing procedures employed in the JSA method are unable to completely remove dark muscle tissues of the fish.

Figure 3-2 illustrates the flow diagram of the JSA method.

Because sardine is generally small in size and also because only the small Pacific mackerel is used for surimi production, a mechanical fish dresser is used instead of manual labor to remove bones as well as head and guts. A single dressing machine can handle as many as 500 sardine per minute, or 300 to 400 Pacific mackerel per minute (Z.S.K., 1984).

The highlight of the JSA method is the leaching process. As shown in Figure 3-2, leaching is performed in three cycles, consisting of:

First cycle: In 0.5% sodium bicarbonate solution; amount four times the weight of the meat; duration 20 minutes.

Second cycle: In chilled water; amount four times the weight of the meat; duration 15 minutes.

Third cycle: In 0.3% salt solution; amount twice the weight of the meat; duration 10 minutes.

The sodium bicarbonate solution used in the first cycle serves to maintain a neutral pH level during the leaching process in order to enhance the gel-strength in the product, a method originally developed by Shimizu (1965). Salt solution is used in

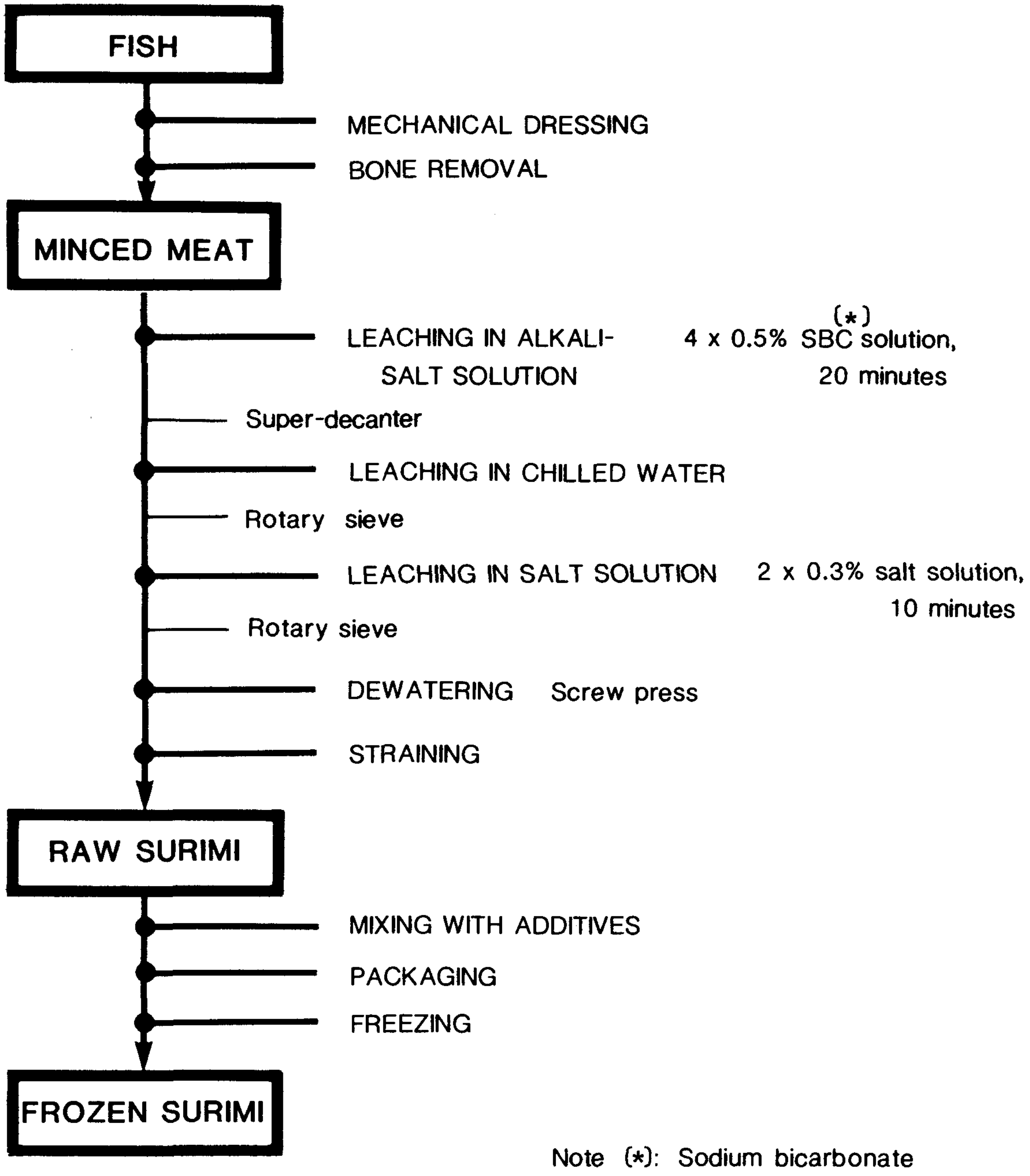


FIGURE 3-2. FLOW DIAGRAM OF JSA METHOD FOR MANUFACTURING SURIMI FROM DARK-FLESHED FISH

the third leaching cycle in order to facilitate the dewatering process.

Japan Surimi Association has developed a special device that performs (1) removal of water-soluble constituents in the fish muscle, (2) separation and removal of fat, and (3) adjustment of pH level during the first leaching cycle. The device, illustrated in Figure 3-3, consists of a pair of leaching tanks each with 2 cubic meters in capacity. In the first tank, fat is shaken loose from the meat through vigorous stirring. In the second tank, fat is allowed to float to the surface through gentle stirring, which is then removed into the collection bin by the directional jet from the overhead shower. Both tanks are serviced by an automatic pH control device programmed to maintain a neutral pH level in the tanks. Using this device, the first leaching cycle reportedly removes about 60 per cent of all the fat in the meat, with fat comprising 20 per cent of the fish's weight.

Japan Surimi Association has experimented with a device called a "super-decanter", a centrifuge designed to improve removal of fat from the leached meat after the first leaching cycle. The super-decanter proved effective in reducing the fat content in surimi, but it also caused a decline in overall yield.

The Japan Surimi Association recommends a total of three leaching cycles for dark-fleshed mince, as shown in Figure 3-2. Additional cycles will give the product a whiter appearance and a higher gel-strength, but will reduce the yield.

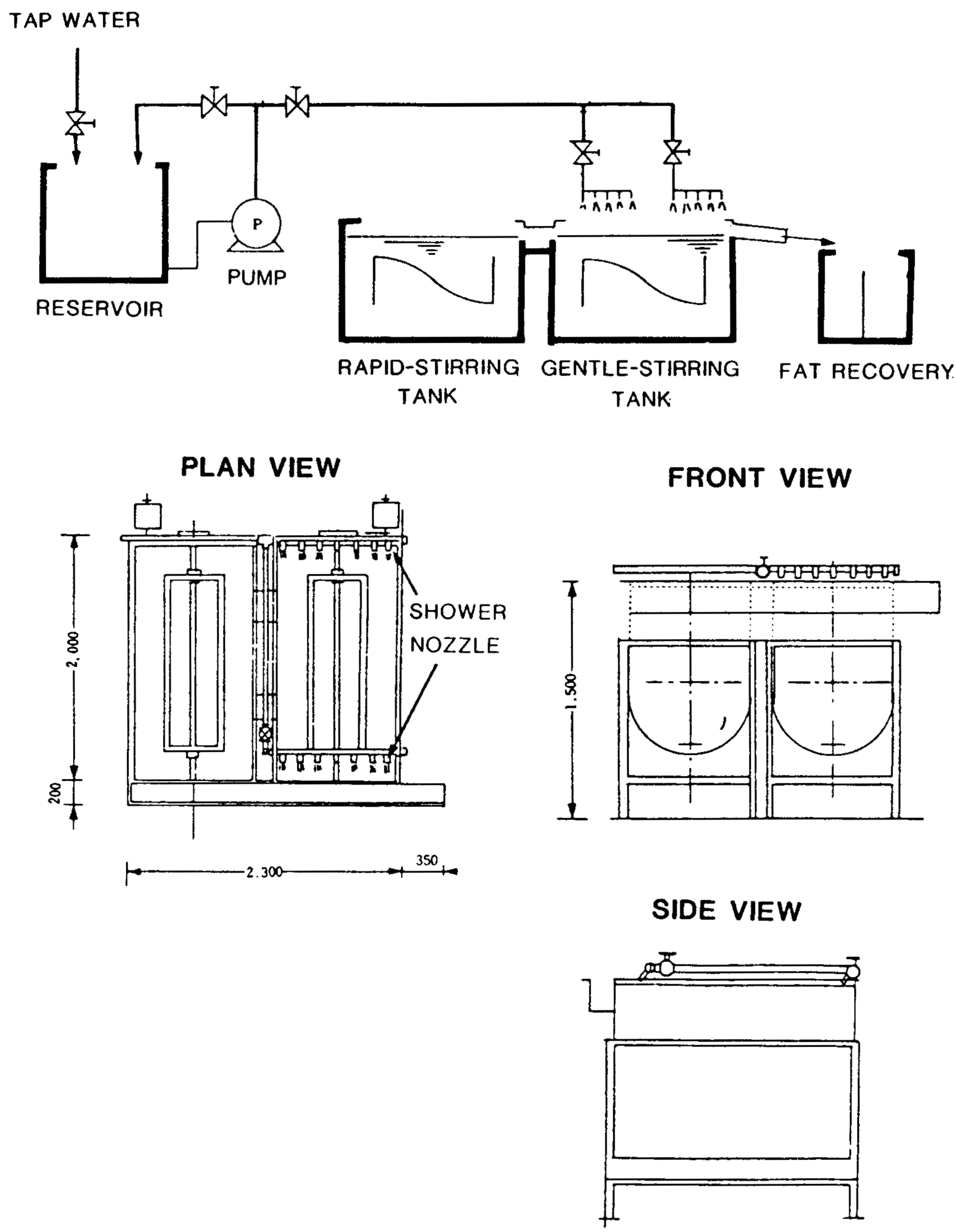
The leached meat is dewatered in the screw press. Use of a refiner on a wet slurry is not a recommended practice for dark-fleshed meat, since it could cause the formation of an emulsion from the mixture of fat, water and protein, which is extremely difficult to dewater.

B. JET METHOD

This method, developed jointly by Chiba Prefecture and Kyokuyo Fisheries Company, features a special meat separation procedure in which light muscle tissue is separated from the rest of the fillet with the aid of a high-pressure jet (Horiguchi and Katayori, 1982). The jet also provides some degree of leaching. The method almost completely removes the dark muscle tissue and fat from the product, giving it a white appearance and high gel-strength with an almost complete lack of fishy odor. Disadvantages of the method are the expensive facilities, low yield, and relatively low productivity.

Figure 3-4 illustrates the flow diagram for this method.

The fish is passed through the head cutter and the fillet machine, and then rinsed to remove scales. The filleted fish is



(MIYAMOTO et al., 1982)

FIGURE 3-3. FAT REMOVING DEVICE USED IN JSA METHOD

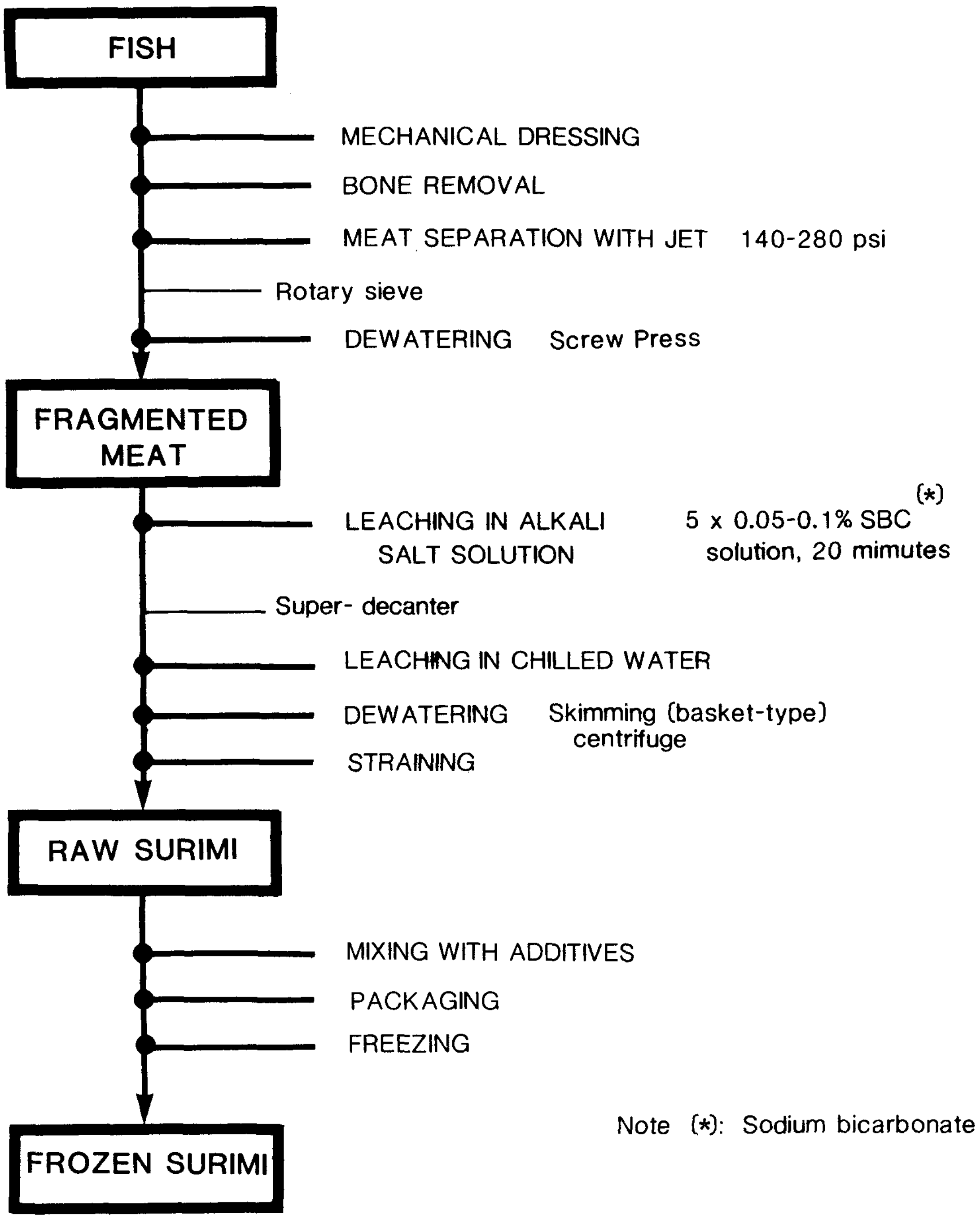


FIGURE 3-4. FLOW DIAGRAM OF JET METHOD FOR MANUFACTURING SURIMI FROM DARK-FLESHED FISH

placed on a net conveyor with the open side up, so that the exposed meat will directly face the overhead jet. The jet is applied to a slowly passing file of fillets, with a pressure of 10 to 20 kg/cm^2 (about 140 to 280 psi). Pressure may be varied depending upon the speed of the conveyor, freshness of the fish, and the desired yield and gel-strength for the product. Light muscle tissue is fragmented by the jet and separates from the fillet, leaving behind the fish skin with its attached fat and dark muscle tissue. The fragmented meat is collected in a rotary sieve where it is rinsed continuously by a shower.

The separated meat, which has already received some degree of leaching in the process of meat separation, is dewatered in a screw press before passing through the leaching cycles. The first cycle is performed in 0.05 - 0.1 per cent sodium bicarbonate solution about 5 times the weight of the meat for 20 minutes, and the second cycle in chilled water 5 times the weight of the meat for 15 minutes. A super-decanter is used following the first leaching cycle to ensure the thorough removal of suspended fat.

Table 3-1 summarizes the specifics of a test plant operation using the jet method (Horiguchi and Katayori, 1982). The yield achieved was only 17 per cent (on the basis of surimi production with 80 per cent water content) in this instance. However, with

TABLE 3-1. SPECIFICS OF TEST PLANT OPERATIONS USING THE JET METHOD

Raw Material (Sardine)	8.4 ton/7 hours
Surimi Production	1.3-1.4 ton/9 hours
Surimi Yield (*)	15 - 17%
Plant Floor Space	200 m^2 (10m x 20m)
Water Requirements:	
Meat Separator	21 m^3/day
Leaching	21 m^3/day
Rotary Sieve	12 m^3/day
Fish Dressing	9 m^3/day
Others	5 m^3/day
Total	68 m^3/day
Labor	3 male, 7 female
Power Requirement	450 kwh

Note (*): Based on surimi with 80% water content.

Source: Horiguchi and Katayori, 1982

improvements in the fish dressing work and addition of secondary meat recovery processes, the overall yield could be raised to about 20 per cent without difficulty. Use of the water could be trimmed by recycling the water from the rotary sieve to the jet.

C. OTHER METHODS

Two other methods were introduced during the national program between 1977 and 1981. Both methods aimed to reduce the water requirement in the production process, and would cut water use by one half as compared with the other two methods already described. One of these methods consisted of micronizing the minced meat before leaching (Takahashi et al., 1982), and the other of recycling the waste water between successive leaching cycles. Figures 3-5 and 3-6 illustrate the flow diagrams of these methods.

In the micronization method, developed jointly by Toyo Food Machine Co. and Taiyo Fisheries Co. (Takahashi et al., 1982), minced meat is brought to a neutral pH level by soaking in an equal amount of 0.8 per cent sodium bicarbonate solution. The minced meat is then micronized and passed through a leaching device which consists of three serially connected drums containing agitated water. A small test plant program showed that the yield from this method was about 17 per cent, but it will vary widely depending upon the meat recovery procedures used following the leaching process. The product exhibited a white appearance and a markedly low content of fat. The expensive facilities required and the low yield are the main drawbacks of this method.

The multiple recycle method was developed by Nitto Engineering Service Company (Kouda, 1982).

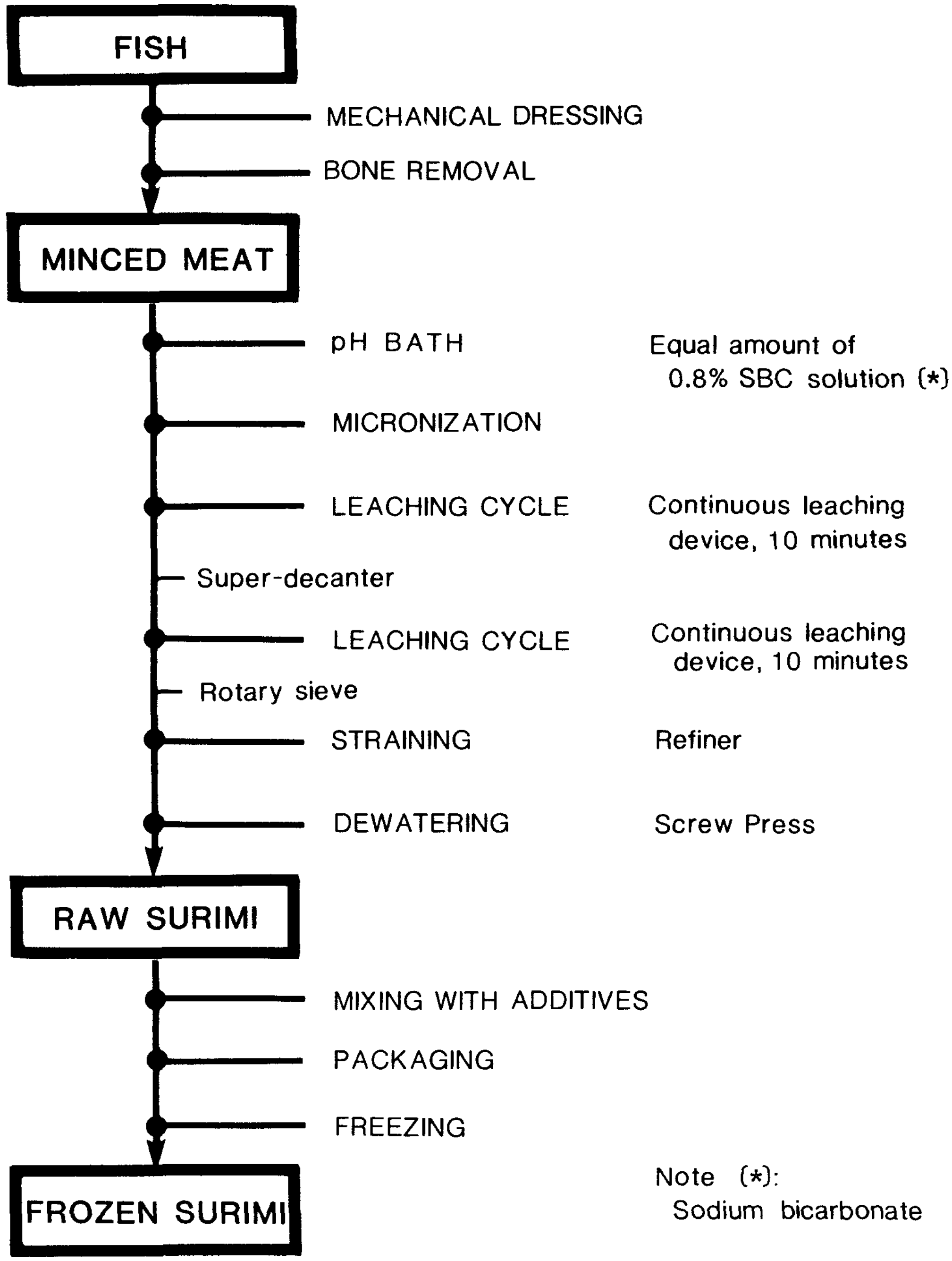


FIGURE 3-5. FLOW DIAGRAM OF MICRONIZING METHOD FOR MANUFACTURING SURIMI FROM DARK-FLESHED FISH

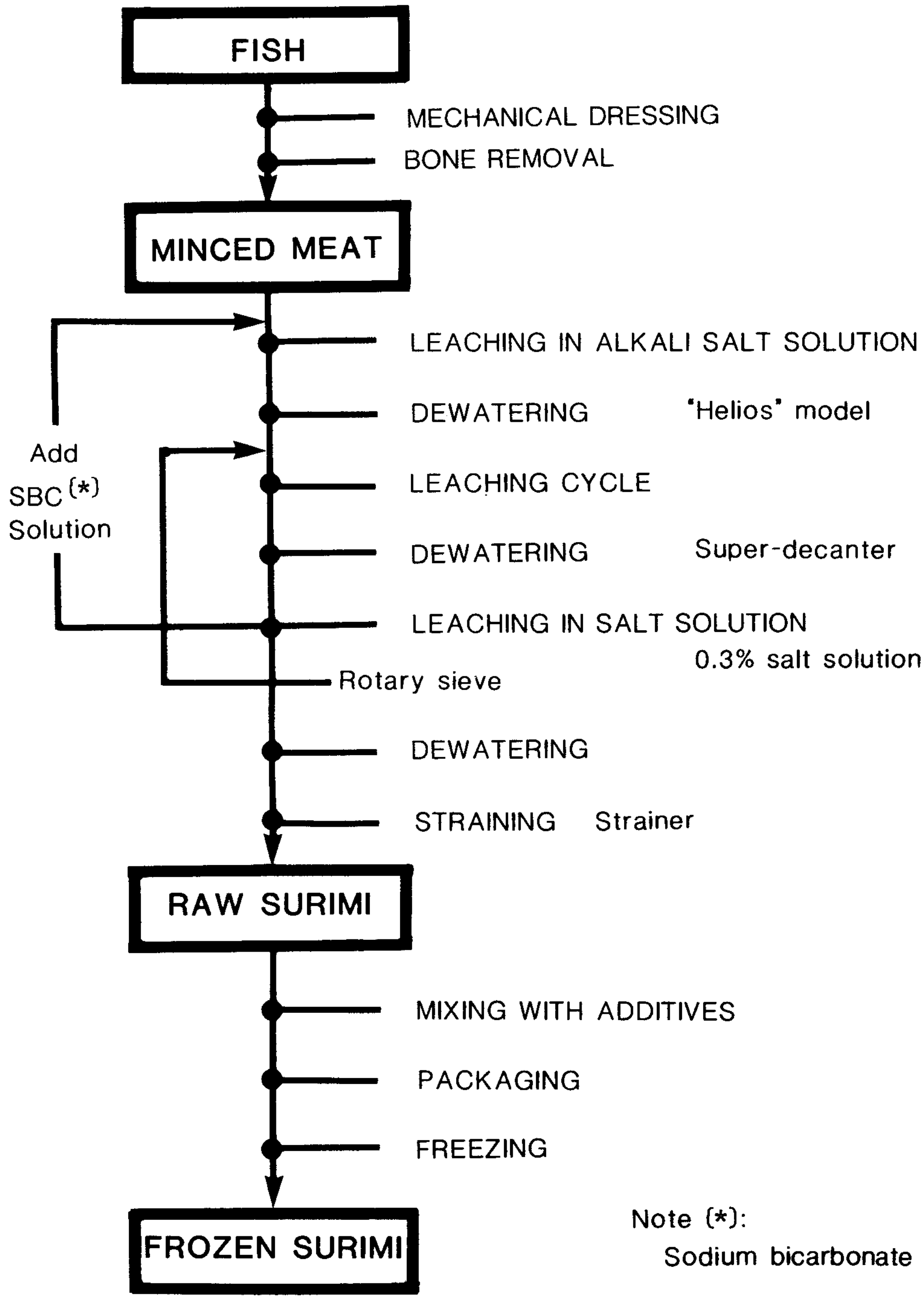


FIGURE 3-6. FLOW DIAGRAM OF WASTE WATER RECYCLING METHOD FOR MANUFACTURING SURIMI FROM DARK-FLESHED FISH

CHAPTER IV. SURIMI QUALITY

4.1. QUALITY STANDARDS

Methods for defining the quality of land-processed frozen surimi have gone through a number of revisions since the first introduction of standards in 1964. Unlike ship-processed surimi, for which quality is relatively uniform and consistent, quality of land-processed surimi varies widely due largely to the degree of freshness of the fish used as raw material (Z.S.K., 1984).

Although the Japan Surimi Association (JSA) quality standards for surimi have been revised as recently as 1978, in practice, the 1974 standards continue to be influential among the majority of surimi manufacturers in Japan.

In 1974, the old grade rankings of "special", A, B, and C were renamed as "special", 1st, 2nd, and "off-grade". A new requirement for acceptable gel-strength was incorporated in the 1974 revision. As shown in Tables 4-1 and 4-2, the current grade standards incorporate four major criteria: water content, additives, the folding test for elasticity, and gel-strength.

The revision in 1978 (Table 4-3) was intended mainly to enhance the sugar content allowance from 5 per cent to about 8 per cent for salt-free frozen surimi, while introducing quality standards for products using Puribesuto as an additive. The revision also tightened the allowable water content while upgrading the quality.

As much as 90 per cent of the land-processed surimi in Japan is classified as grade 2, and there exists wide variability among these products (Z.S.K., 1984). This situation has resulted partly from the insufficiency of the existing quality standards, and partly from the general lack of compliance with the quality standards, which is essentially voluntary. Inconsistent quality in grade 2 products has caused a considerable number of claims from users. In January 1985, the Fisheries Agency of the Japanese government announced a plan for a feasibility study aiming toward government-regulated quality standards for land-processed surimi in place of the existing industry-regulated standards.

In the factoryship operations in which the fish is processed into surimi as soon as it is caught, freshness in raw material is not an issue. Table 4-4 shows the composition standards for ship-processed surimi, which have been in effect since their initial introduction in 1966. Factors other than freshness, such as the size of the fish, location of catch, season of catch, method of catch, and handling of the fish after the catch, also contribute to the quality of the surimi.

TABLE 4-5. MONTHLY AVERAGE TEST RESULTS OF LAND-PROCESSED FROZEN SURIMI FOR 1983 AND 1984

	Jan.	Feb.	Mar.	Apr.	May	June
Surimi Test:						
Water Content (%)	79.43	79.25	79.54	79.23	80.46	79.68
	79.06	78.90	79.58	79.25	79.53	79.30
pH	7.50	7.48	7.43	7.47	7.29	7.32
	7.46	7.45	7.32	7.32	7.16	7.41
Brightness	52.3	51.8	51.6	51.5	53.0	51.7
	53.6	52.3	52.0	49.9	49.1	50.4
Hunter Whiteness	23.1	22.2	21.8	21.3	23.2	22.1
	24.3	22.8	22.3	20.4	19.6	21.1
Kamaboko Test:						
Yield Stress (g)	448	423	432	415	422	408
	480	458	437	406	411	440
Indentation Depth(cm)	1.11	1.05	1.06	1.02	1.02	1.04
	1.14	1.12	1.07	1.00	1.00	1.02
Gel-Strength (g.cm)	498	444	459	425	430	428
	553	515	466	411	411	452
Ashi (Springiness)	7.1	6.3	6.5	6.1	6.3	6.6
	7.3	7.1	6.6	6.0	6.0	6.3
Brightness	68.2	67.4	67.2	66.9	67.9	67.0
	68.8	68.5	68.3	66.8	65.9	67.1
Hunter Whiteness	40.6	39.1	38.8	38.2	39.6	39.2
	41.4	40.6	39.9	38.0	36.6	39.0

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annl.
Surimi Test:							
Water Content (%)	79.92	79.57	79.47	79.43	78.99	78.96	79.42
	79.15	79.13	79.21	79.07	79.18	79.24	79.19
pH	7.37	7.36	7.41	7.42	7.42	7.51	7.45
	7.31	7.43	7.39	7.45	7.55	7.55	7.43
Brightness	53.4	51.0	50.6	52.5	52.4	52.6	51.8
	52.0	51.9	52.2	52.5	53.0	52.3	52.1
Hunter Whiteness	23.1	21.2	20.9	22.9	23.0	23.4	21.5
	21.6	21.7	22.0	22.4	23.2	22.5	22.3
Kamaboko Test:							
Yield Stress (g)	356	384	402	414	478	481	423
	465	460	459	492	481	448	461
Indentation Depth(cm)	0.97	0.93	0.94	1.03	1.10	1.10	1.03
	0.99	1.01	1.00	1.07	1.10	1.12	1.06
Gel-Strength (g.cm)	348	357	380	426	516	532	438
	462	468	452	530	533	503	493
Ashi (Springiness)	5.7	5.5	5.6	6.3	7.3	7.3	6.4
	6.2	6.4	6.2	7.1	7.4	7.4	6.8
Brightness	67.8	67.2	67.5	68.6	68.5	68.6	67.5
	67.8	68.1	68.0	68.4	68.2	68.3	68.0
Hunter Whiteness	38.8	38.2	38.7	40.2	40.7	41.1	39.3
	39.3	39.5	39.3	39.9	42.1	39.9	39.7

Note: Upper figures represent statistics for 1983, and lower figures for 1984.

Source: Japan Surimi Association, Technical Laboratory

TABLE 4-6. TEST RESULTS OF FACTORY TRAWLER PROCESSED, FROZEN SURIMI, TOP GRADE

	Sample Number			
	1	2	3	4
Surimi Test:				
Water Content (%)	75.5	75.1	74.7	74.7
pH	7.20	7.19	7.16	7.18
Impurity Content, Rank	7	8	9	9
Hunter Whiteness	27.9	29.1	28.0	28.0
Brightness	57.0	58.4	56.9	57.2
Kamaboko Test: (3% Potato Starch used in preparing kamaboko gel)				
Yield Stress (g)	548	556	541	526
Indentation (cm)	1.61	1.61	1.41	1.41
Gel-Strength (g.cm)	882	895	763	742
Hunter Whiteness	49.5	50.6	53.0	52.9
Brightness	72.8	73.8	72.8	72.4
Folding Test	5	5	5	5

Source: Japanese factoryship surimi processor

TABLE 4-7. TEST RESULTS OF FACTORY TRAWLER PROCESSED, FROZEN SURIMI, MEDIUM GRADE

	Sample Number			
	1	2	3	4
Surimi Test:				
Water Content (%)	73.1	74.9	74.7	74.5
pH	7.17	7.22	7.16	7.19
Impurity Content, Rank	6	7	5	6
Hunter Whiteness	26.7	26.8	27.7	26.8
Brightness	57.7	58.8	58.4	58.3
Kamaboko Test: (3% Potato Starch used in preparing kamaboko gel)				
Yield Stress (g)	479	527	417	460
Indentation (cm)	1.28	1.27	1.25	1.26
Gel-Strength (g.cm)	613	669	521	580
Hunter Whiteness	46.5	45.4	45.9	45.0
Brightness	72.0	72.2	72.3	71.9
Folding Test	5	5	5	5

Source: Japanese factoryship surimi processor

TABLE 4-1. 1974 JSA* QUALITY STANDARDS FOR SALT-FREE, LAND-PROCESSED FROZEN SURIMI

Fish	Grade	Water Content (%)	Additives (%) Sugar**	Additives (%) Phosphate	Folding Test***	Yield Stress (g)
Alaska pollock	Special	79	5	0.2	AA (0%)	350
	1	80	5	0.2	AA (3%)	330
	2	81.5	5	0.2	AA (5%)	280
	Off-grade	82.5	5	0.2	AA (10%)	
Atka mackerel	1	79	5	0.1-0.2	AA (3%)	350
	2	80	5	0.1-0.2	AA (5%)	300
Blenny	Special	79	5	0.2	AA (0%)	350
	1	80	5	0.2	AA (3%)	350
Flatfish	Special	79	5	0.2	AA (0%)	350
	1	80	5	0.2	AA (3%)	350
Wachna Cod	2	81.5	5	0.2	AA (5%)	300

* JSA - Japan Surimi Association

** Sugar - Sucrose or Sorbitol

*** ( ) - Potato Starch Content

TABLE 4-2. 1974 JSA* QUALITY STANDARDS FOR SALT-ADDED, LAND-PROCESSED FROZEN SURIMI

Fish	Grade	Water Content (%)	Additives (%) Sugar**	Salt	Phosphate	Folding Test***	Yield Stress (g)
Alaska pollock	Special	75	10	1-1.5	0-0.2	AA (0%)	350
	1	76	10	1-1.5	0-0.2	AA (3%)	330
	2	77	10	1-1.5	0-0.2	AA (5%)	280
	Off-grade	78	10	1-1.5	0-0.2	AA (10%)	
Atka mackerel	1	75	10	1-1.5	0-0.2	AA (3%)	350
	2	76	10	1-1.5	0-0.2	AA (5%)	300
Blenny	Special	75	10	1-1.5	0-0.2	AA (0%)	350
	1	76	10	1-1.5	0-0.2	AA (3%)	350
Flatfish	Special	75	10	1-1.5	0-0.2	AA (0%)	350
	1	76	10	1-1.5	0-0.2	AA (3%)	350
Wachna Cod	2	77	10	1-1.5	0-0.2	AA (5%)	300

* JSA - Japan Surimi Association

** Sugar - Sucrose or Sorbitol

*** ( ) - Potato Starch Content

TABLE 4-3. 1978 JSA* QUALITY STANDARDS FOR SALT-FREE, LAND-PROCESSED FROZEN SURIMI

Fish	Grade	Water Content (%)	Additives (%)** Sucrose	Puribesuto TP 433	Puribesuto TP432	Folding Test***	Yield Stress (g)
Alaska pollock	Special	77	4.0	4.6	0	AA (0%)	350
	1	78	4.0	4.6	0	AA (3%)	330
	2	79.5	4.0	4.6	0	AA (5%)	300
	Off-grade	80	4.0	4.6	0	AA (10%)	300
Atka mackerel	1	77	4.0	0	4.5	AA (3%)	330
	2	78	4.0	0	4.5	AA (5%)	300
Blenny	Special	77	4.0	4.6	0	AA (0%)	350
	1	78	4.0	4.6	0	AA (3%)	330

* JSA - Japan Surimi Association

** Puribesuto TP 433-Consists of D-sorbitol 87%, glyceride 6.5% and polyphosphate 6.5%
Puribesuto TP 432-Consists of D-sorbitol 88.9%, glyceride 6.7% and polyphosphate 4.4%

*** ( ) - Potato Starch Content

TABLE 4-4. INDUSTRY QUALITY STANDARDS FOR SHIP-PROCESSED FROZEN SURIMI

Fish	Surimi Type	Sucrose	Sorbitol	Poly-Phosphate	Salt
		....	Per	cent	....
Alaska pollock	Salt-free	4	4	0.3	0
	Salt-added	5	5	0	2.5

4.2. TEST PROCEDURES

In 1980, procedures to be employed in testing the quality of surimi were unified in Japan under "Frozen Surimi Quality Test Criteria", a result of joint efforts during the preceding year among the Tokai Regional Fisheries Research Laboratory, various fisheries industry groups and companies, under the initiative of the Fisheries Agency of the Japanese government (Z.S.K., 1984). The test criteria consist of two parts: Part 1 deals with test procedures for surimi, and Part 2 with "kamaboko", the end product of surimi. Following is a complete translation of the Frozen Surimi Quality Test Criteria.

PART 1. SURIMI TEST

The tests undertaken under this category are concerned partly with compulsory test items such as water content, pH and impurity content, and partly with elective test items such as Hunter whiteness, brightness, drip, and viscosity. The test procedures for the items listed in the latter category are unable to yield reproducible results; therefore, a compulsory requirement cannot be imposed on these items. Efforts are being made to improve the reliability of the test procedures on elective test items, so that the tests on them could be made compulsory in the future.

1. COMPULSORY TESTS:

All items listed under this category constitute the essential requirements for the certification of the quality grade of surimi.

A. WATER CONTENT

Either a whole block of frozen surimi in its original polyethylene bag or an appropriate portion of this block, placed in a new polyethylene bag, is brought to a partially thawed state. The surimi must remain in the bag while being tempered, so as to avoid loss of its water content by evaporation. A test sample is then taken from any area of the tempered surimi block.

When a hot air convection oven is used, the test sample is brought to above 0°C while remaining in an airtight polyethylene bag. A test piece weighing between 5 and 10 grams is secured and dried in a beaker at 100 to 150°C until its weight becomes constant. Drying frozen surimi directly in a beaker is not advisable, since this may cause dews to form on the exterior wall of the beaker, biasing the measurement.

When the IR (infrared) moisture meter is used, a thin slice of tempered surimi weighing between 5 to 10 grams is dried directly on a tray.

In either case, the test should be performed on more than 3 samples and the results averaged. The water content is expressed in per cent by weight, as follows:

$$\text{Water Content (\%)} = \frac{(\text{Weight before drying (g)} - \text{Weight after drying (g)})}{\text{Weight before drying (g)}} \times 100$$

B. pH

A 5-gram sample of thawed surimi is added to 45 ml of distilled water or a 10-gram sample of surimi is added to 90 ml of distilled water. The mixture is then homogenized in a blender and its pH measured with a pH meter. A BTB test paper may be used in lieu of a pH meter when the latter is not available. The measurement should be repeated on at least two samples and their results averaged.

C. IMPURITY CONTENT (SOMETIMES CALLED "DEFECTS" OR "CONTAMINATION")

A 10-gram piece of thawed surimi is spread into a thin sheet less than 1 mm thick. Impurities in the test piece, such as black skin and bone, are counted visually. An impurity larger than 2 mm in any dimension is counted as one, and an impurity less than 2 mm as 1/2. Impurities less than 1 mm in size are ignored as insignificant. The impurity content is ranked in accordance with the ranking scale of 1 to 10, as follows:

Rank	Impurity Content
10	0
9	1 - 2
8	3 - 4
7	5 - 7
6	8 - 11
5	12 - 15
4	16 - 19
3	20 - 25
2	26 - 30
1	Over 31

2. ELECTIVE TESTS:

A. HUNTER WHITENESS

An appropriate amount of thawed surimi is packed into a glass measuring vessel, densely enough to avoid formation of air bubbles. Whiteness is measured with the whiteness meter to obtain the Z value in the tri-stimulus XYZ system, as described in the International Commission of Illumination standards. The test is performed at least in triplicate and the results averaged.

B. BRIGHTNESS

The sample is prepared as in the procedures for the Hunter whiteness test. A whiteness meter is used to obtain the L reading in the L, a and b system of the USC standard. The test is performed at least in triplicate and the results averaged.

C. DRIP

A 50-gram sample of naturally thawed surimi is placed in a tube 33 mm in diameter and 150 mm long, and subjected to a vertical load of 500 grams for 5 to 10 minutes, followed by an additional load of 500 grams for about 20 minutes. The tube has a number of 3-mm holes on its bottom to allow the moisture to drain. The drip is expressed as a ratio between the weight of the liquid which has drained and the total weight of the test sample, expressed in per cent.

D. VISCOSITY

A 143-gram sample of thawed salt-free surimi is mixed into 857 grams of a 3.5 per cent salt solution which has been kept at a temperature below 10°C. The salt concentration in the mixture is 3 per cent. When using salt-added surimi, the sample weight should be adjusted in order to achieve a salt concentration of 3 per cent in the mixture. The mixture is then blended in a special-order mixer (a JM 310-model by Mitsubishi Electric Co., Ltd.) which is equipped with self-cooling and anti-foaming capabilities. The mixer is operated at the setting of 1 for 8 minutes at 8 to 10°C. After allowing the blended mixture to sit for 40 minutes, viscosity is measured with a Brookfield viscometer (Model C, made by Tokyo Keiki Co., Ltd.) at a rotor revolution rate of 4/sec and a liquid temperature of 10 $\pm$ 0.5°C.

PART 2. KAMABOKO TEST

The purpose of these tests is to measure gel forming capacity based on a kamaboko sample prepared from a given surimi to be evaluated.

1. PREPARATION OF KAMABOKO TEST SAMPLES

A-1. SAMPLE WITHOUT STARCH

A semi-thawed sample of surimi of between 3 and 5 kilograms is chopped in a stone mortar or a silent cutter for about 5 minutes. Salt in the amount of 3 per cent by weight to the surimi sample is added to the chopped surimi, and the mixture is ground into a paste in a stone mortar for no more 30 minutes, or in a silent cutter for no more than 15 minutes. The duration of grinding must be recorded in the test result. The temperature of the mixture at the end of the grinding must be less than 10°C.

A-2. SAMPLE WITH STARCH

A surimi paste is prepared as per the procedures just described. Potato starch at a level of between 3 to 5 per cent by weight is added to the surimi paste and mixed for an appropriate duration. Only the potato starch may be used, and its amount must be recorded in the test result.

B. CASING

The surimi paste is stuffed into a polyvinylidene chloride sausage casing, in amount of 150 grams to each 20-cm length of the casing, and both ends of the casing are tied. In principle, the cased sample is not allowed to undergo a suwari (low-temperature setting) process. When it was, then a note of the setting condition must appear in the record of the test results.

C. COOKING

The sample in the casing is cooked in a hot-water bath at 90°C for 30 to 40 minutes. The sample has now become a kamaboko.

D. COOLING

The sample is cooled sufficiently in chilled water immediately after the cooking, and is then allowed to stand at room temperature to cool.

2. QUALITY EVALUATION

The test sample is subjected to evaluation within 48 hours after its preparation. The sample should be kept at 20 to 30°C, preferably near 20°C, during the test.

A. GEL-STRENGTH

The gel-strength is measured with an Okada-type gel-strength meter or a rheometer, equipped with a plunger of 5 mm in diameter. The test pieces are sliced out in thicknesses of 25 mm from the cased kamaboko sample, and its casing removed. The diameter of the test piece is about 30 mm. The test piece is placed on the measuring device with its center directly beneath the plunger. The plunger is thrust into the test piece at a constant speed. The vertical loading on the plunger and the depth of indentation forming on the test piece are recorded when the test piece is broken. The yield stress, denoted W, is expressed in grams, and the identation depth, denoted L, is expressed in cm. The gel-strength is expressed as W X L (g.cm). The test result must list the measuring device used, along with the gel-strength, yield stress and indentation depth. The test must be conducted on at least 3 samples, and the results averaged.

B. HUNTER WHITENESS

A test piece is sliced out from the cased kamaboko in appropriate thickness, and the whiteness (Z) on the cut surface is measured with a whiteness meter in accordance with the procedures used for the Hunter whiteness test for the surimi sample. The results should be expressed as the average from at least 3 samples.

C. BRIGHTNESS

A test piece is sliced out from the cased kamaboko in appropriate thickness, and the brightness (L) on the cut surface is measured with a whiteness meter in accordance with the procedures described in the brightness test for the surimi sample. The results should be expressed as the average from at least 3 samples.

D. "ASHI"

The test piece is secured by slicing the cased kamaboko in thicknesses of 3 mm. Evaluation is performed by a panel of at least 3 experts, using a 10-point grade system. "Ashi" is defined as the combined effect of "springiness" (or resilience felt on the biting teeth) and "cohesiveness". The 10-point grade system is as follows:

Grade	Ashi Evaluation
10	Extremely strong
9	Very strong
8	Strong
7	Somewhat strong
6	Average
5	Somewhat weak
4	Weak
3	Very weak
2	Extremely weak
1	Crumbly

E. FOLDING TEST

The test piece is a 3 mm slice cut from the kamaboko column. Evaluation is performed in accordance with a 5-point grading system as follows:

Grade	Evaluation
5	No crack when folded into quadrants.
4	No crack when folded in half.
3	Crack develops gradually when folded in half.
2	Crack develops immediately when folded in half.
1	Crumbles when pressed by finger.

4.3. TEST RESULTS

Table 4-5 summarizes actual test results of land-processed surimi made in Japan. The statistics represent monthly and annual averages of all the tests performed in 1983 and 1984, as reported by the Japan Surimi Association's Technical Laboratory at Abashiri, Hokkaido. In 1984, the total number of tests amounted to 967, of which 854 samples or 90 per cent were on grade 2 Alaska pollock surimi. The number of test samples in 1983 was 660, of which also 90 per cent was comprised of grade 2 Alaska pollock surimi.

The water content of the land-processed surimi for 1983 and 1984 decreased distinctly following the general trend for decline which has continued for the past several years. At no time in 1984 did the monthly average of water content exceed an 80 per cent level. It generally hovered within 79 to 79.5 per cent.

The yield stress of the land-processed surimi also improved during the two-year period, reflecting the effect of the decreased water content which occurred during the same period. So did the indentation depth (strain) and the gel-strength. In general, in 1984, the yield stress remained above 410 grams, the indentation depth above 1.0 cm, and the gel-strength above 410 gram-cm, in terms of monthly averages. The annual average for gel-strength made a quantum jump from 438 to 493 g-cm between 1983 and 1984. Brightness and Hunter whiteness essentially remained the same for these two years.

Tables 4-6, 4-7, 4-8 and 4-9 show examples of the test results of ship-processed surimi during 1984. The grades indicated in the tables are indicative only of relative results within each sample population, and do not necessarily represent the grades being employed by individual manufacturers.

The gel-strength is the most important arbiter for the grade, and it ranges up to almost 900 g-cm in some samples. Even among the surimi samples processed aboard factory trawlers, the gel-strength can be as low as about 200 to 300 g-cm, lower than the 2nd grade land-processed products. Comparing between the factory trawler and mothership products, the products from the factory trawler appear to exceed in gel-strength those from the mothership, as expected.

TABLE 4-5. MONTHLY AVERAGE TEST RESULTS OF LAND-PROCESSED FROZEN SURIMI FOR 1983 AND 1984

	Jan.	Feb.	Mar.	Apr.	May	June
Surimi Test:						
Water Content (%)	79.43	79.25	79.54	79.23	80.46	79.68
	79.06	78.90	79.58	79.25	79.53	79.30
pH	7.50	7.48	7.43	7.47	7.29	7.32
	7.46	7.45	7.32	7.32	7.16	7.41
Brightness	52.3	51.8	51.6	51.5	53.0	51.7
	53.6	52.3	52.0	49.9	49.1	50.4
Hunter Whiteness	23.1	22.2	21.8	21.3	23.2	22.1
	24.3	22.8	22.3	20.4	19.6	21.1
Kamaboko Test:						
Yield Stress (g)	448	423	432	415	422	408
	480	458	437	406	411	440
Indentation Depth(cm)	1.11	1.05	1.06	1.02	1.02	1.04
	1.14	1.12	1.07	1.00	1.00	1.02
Gel-Strength (g.cm)	498	444	459	425	430	428
	553	515	466	411	411	452
Ashi (Springiness)	7.1	6.3	6.5	6.1	6.3	6.6
	7.3	7.1	6.6	6.0	6.0	6.3
Brightness	68.2	67.4	67.2	66.9	67.9	67.0
	68.8	68.5	68.3	66.8	65.9	67.1
Hunter Whiteness	40.6	39.1	38.8	38.2	39.6	39.2
	41.4	40.6	39.9	38.0	36.6	39.0

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annl.
Surimi Test:							
Water Content (%)	79.92	79.57	79.47	79.43	78.99	78.96	79.42
	79.15	79.13	79.21	79.07	79.18	79.24	79.19
pH	7.37	7.36	7.41	7.42	7.42	7.51	7.45
	7.31	7.43	7.39	7.45	7.55	7.55	7.43
Brightness	53.4	51.0	50.6	52.5	52.4	52.6	51.8
	52.0	51.9	52.2	52.5	53.0	52.3	52.1
Hunter Whiteness	23.1	21.2	20.9	22.9	23.0	23.4	21.5
	21.6	21.7	22.0	22.4	23.2	22.5	22.3
Kamaboko Test:							
Yield Stress (g)	356	384	402	414	478	481	423
	465	460	459	492	481	448	461
Indentation Depth(cm)	0.97	0.93	0.94	1.03	1.10	1.10	1.03
	0.99	1.01	1.00	1.07	1.10	1.12	1.06
Gel-Strength (g.cm)	348	357	380	426	516	532	438
	462	468	452	530	533	503	493
Ashi (Springiness)	5.7	5.5	5.6	6.3	7.3	7.3	6.4
	6.2	6.4	6.2	7.1	7.4	7.4	6.8
Brightness	67.8	67.2	67.5	68.6	68.5	68.6	67.5
	67.8	68.1	68.0	68.4	68.2	68.3	68.0
Hunter Whiteness	38.8	38.2	38.7	40.2	40.7	41.1	39.3
	39.3	39.5	39.3	39.9	42.1	39.9	39.7

Note: Upper figures represent statistics for 1983, and lower figures for 1984.

Source: Japan Surimi Association, Technical Laboratory

TABLE 4-6. TEST RESULTS OF FACTORY TRAWLER PROCESSED, FROZEN SURIMI, TOP GRADE

	Sample Number 1	2	3	4
Surimi Test:				
Water Content (%)	75.5	75.1	74.7	74.7
pH	7.20	7.19	7.16	7.18
Impurity Content, Rank	7	8	9	9
Hunter Whiteness	27.9	29.1	28.0	28.0
Brightness	57.0	58.4	56.9	57.2
Kamaboko Test: (3% Potato Starch used in preparing kamaboko gel)				
Yield Stress (g)	548	556	541	526
Indentation (cm)	1.61	1.61	1.41	1.41
Gel-Strength (g.cm)	882	895	763	742
Hunter Whiteness	49.5	50.6	53.0	52.9
Brightness	72.8	73.8	72.8	72.4
Folding Test	5	5	5	5

Source: Japanese factoryship surimi processor

TABLE 4-7. TEST RESULTS OF FACTORY TRAWLER PROCESSED, FROZEN SURIMI, MEDIUM GRADE

	Sample Number 1	2	3	4
Surimi Test:				
Water Content (%)	73.1	74.9	74.7	74.5
pH	7.17	7.22	7.16	7.19
Impurity Content, Rank	6	7	5	6
Hunter Whiteness	26.7	26.8	27.7	26.8
Brightness	57.7	58.8	58.4	58.3
Kamaboko Test: (3% Potato Starch used in preparing kamaboko gel)				
Yield Stress (g)	479	527	417	460
Indentation (cm)	1.28	1.27	1.25	1.26
Gel-Strength (g.cm)	613	669	521	580
Hunter Whiteness	46.5	45.4	45.9	45.0
Brightness	72.0	72.2	72.3	71.9
Folding Test	5	5	5	5

Source: Japanese factoryship surimi processor

TABLE 4-8. TEST RESULTS OF FACTORY TRAWLER PROCESSED, FROZEN SURIMI, LOW GRADE

	Sample Number			
	1	2	3	4
Surimi Test:				
Water Content (%)	74.6	73.4	76.4	74.2
pH	7.13	7.19	7.03	7.10
Impurity Content, Rank	7	8	7	8
Hunter Whiteness	24.5	24.0	28.1	27.1
Brightness	56.5	55.2	59.0	58.8
Kamaboko Test: (3% Potato Starch used in preparing kamaboko gel)				
Yield Stress (g)	245	294	468	406
Indentation (cm)	0.87	1.03	1.17	1.00
Gel-Strength (g.cm)	213	302	548	406
Hunter Whiteness	41.5	40.6	43.9	44.4
Brightness	70.3	69.5	70.8	71.7
Folding Test	5	5	5	5

Source: Japanese factoryship surimi processor

TABLE 4-9. TEST RESULTS OF MOTHERSHIP PROCESSED, FROZEN SURIMI, MEDIUM GRADE

	Sample Number	
	1	2
Surimi Test:		
Water Content (%)	75.0	76.4
pH	7.32	7.38
Impurity Content, Rank	9	10
Brightness	57.6	59.3
Kamaboko Test: (3% Potato starch used in preparing kamaboko gel)		
Yield Stress (g)	590	550
Indentation (cm)	1.11	1.15
Gel-Strength (g.cm)	655	632
Ashi (Springiness)	6.5	6.5

Source: Japanese mothership surimi processor

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