

The Seafood Industry

A Self-Study Guide

Processing Finfish



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PROCESSING FINFISH

Within the past forty years, consumers have made major changes in their food purchasing habits. For centuries, fresh fish and shellfish were purchased at retail markets and converted into tasty menu dishes at home. As social patterns changed and disposable income increased, consumers began to purchase partially or fully prepared seafoods. These convenience dishes, while more expensive than the raw product, provided consumers a convenience at a reasonable price. As we approach the twenty-first century, fabricated and further processed seafood products are a commonplace retail food store item. The majority of the traditional convenience products were coated (battered or breaded) while the new items are based on minced fish (surimi) as the primary ingredient. Coated product sales have not experienced substantial growth in recent years, however, the consumption of surimi products has increased at a rapid rate. This chapter discusses both coated and mince-based products and should provide the reader with sufficient information to obtain an in-depth knowledge on further processed seafoods. The first part of the chapter discusses mince and the second part on the use of mince in kamaboko or analog products. The final section is devoted to seafood coatings.

MINCE

INTRODUCTION

The world's consumption of fish could be more than doubled if its great unused resources were fully exploited. These resources remain unused not through a lack of catching technology, but through an inability to transform the raw materials into stable, acceptable products and to distribute these products at an affordable price to people who need them. Developments in minced fish technology could make a major contribution to increased exploitation.

Minced fish, which is flesh separated in a comminuted form from the skin, bones, scales and fins, is a versatile but unstable commodity. To a large extent, its properties are determined by the nature and quality of the raw material. Thus the first part of this section reviews the materials used for mince production. The next part discusses mechanical and non-mechanical separation processes that can be used and notes the effects that non-flesh contaminants can have on the mince quality. The third part reviews the susceptibility of mince to fat, protein, color and microbial degradation and discusses the means available for stabilizing the mince against such effects. The next part shows how these techniques can be used in preparing a wide range of mince-based products. Finally, the current status of mince production is briefly reviewed, and conclusions drawn as to areas needing further development.

Most of the information is drawn from the extensive published literature on minced fish but relates almost exclusively to the resources and technologies available. It is dominated by work in the Japanese surimi and kamaboko industry.

This discussion will be limited to mince from bony fish, omitting the potential for minces from crustacean, mollusk and cartilaginous raw materials. Nevertheless, studies on materials such as krill, whose exploitation will depend on mechanical separation and whose mince products

require extensive stabilization and transformation, may contribute greatly to the exploitation of minced fish.

RAW MATERIALS AND SOURCES

In principle, bone separation processes can be applied to any species of fish, crustacean or mollusk. In practice, these processes can be best justified for those species where significant added value will accrue. Separation techniques can increase the yields obtained from presently utilized commercial species by reclaiming flesh from filleting wastes and other by-products. They can increase the exploitation of presently underutilized species by transforming them into products that are in greater demand, and can upgrade those species that have previously been used for industrial or animal feeding purposes. They can also be used to exploit by-catch materials that otherwise would be discarded at sea.

Different raw materials have different technological properties, and to a large extent, the raw material species or species mix determines both the degradative problems and the potential process and product applications of the mince. Compositional changes due to spawning cycles and seasonal response have a major effect on fat and protein quality. Obviously conditions and handling methods throughout the world generate raw material of widely differing qualities, and most minced fish technologies are more sensitive to raw material qualities than those that use intact flesh.

Commercial Fish

Mince technology is applied to commercial species to obtain a higher yield from whole (headed and gutted) fish and to reclaim additional flesh from filleting wastes. Frozen blocks prepared from both such materials are now major commodities in international commerce.

In the developed world, such trade is based predominantly on the gadoid fish - the cods, hakes, haddocks, polllocks, and croakers. Mince yields are generally high and the microbiological quality good. However, the color, texture and taste of commercial blocks are highly variable. One feature distinguishing these species from other marine and freshwater fish is the presence of trimethylamine oxide (TMAO) as the principal osmo-regulatory agent. The enzymic degradation of TMAO to dimethylamine (DMA) and formaldehyde can cause severe textural damage through formaldehyde cross-linking of the flesh proteins, and this degradation is accelerated in the frozen storage of mince made from these species. (This effect is discussed later.) Protein degradation, the major problem in frozen storage, is accelerated by the mincing process and exacerbated by the presence of blood and several organs. Oxidative rancidity can be evident in minces from the higher fat (1-3 percent) gadoids; this is greatest when dark muscle and blood are present. Color problems arise from skin, blood and ultimately protein degradation.

Despite the predominance of gadoid minces on the world market, minces are prepared from other commercial species. In the West these include several flatfish - the soles (Parophrys and Microstomus spp.) and the flounders (Bothidae and Pleuronectidae). Odor and flavor problems arise from the high skin contamination levels in flatfish minces, however.

Major fisheries are developing for the South Pacific and South Atlantic hakes (Merluccius spp.). A significant proportion of the catch is too small, soft or parasitized for fillet product, and large amounts of block frozen mince are generated at relatively high yield. Hake minces seem particularly susceptible to TMAO breakdown-induced texture problems; frozen stability has been studied intensively. Equipment specifically for the heading and gutting of small hake is being developed, which should facilitate mince production.

Another commercial fishery of particular interest in the Americas is the rockfish (Sebastes spp.), although markets are limited by the short storage life of frozen fillets. Shelf life quality could be extended through the mincing process by the incorporation of anti-oxidants that prevent fat rancidity and cryo-protectants that prevent protein degradation during frozen storage.

Much work has been done on the production of stable minces from Alaska pollock, both by the Japanese and by other nations wanting to develop the Japanese surimi market in addition to their own outlets. As can be seen, mince production from existing commercial species and their by-products have been confined to the developed world. A similar pattern emerges for the world's underutilized species.

Underutilized Fish

The world's consumption of fish could be greatly increased if presently underutilized or unused resources were brought into the human food chain. There is a major incentive to apply mince technology to many of these species, because of the intractable problems in processing and marketing them by other means.

In the developed world, fish resources are underexploited because of difficulties of processing, consumer unfamiliarity, or inherent quality problems. In the early 1970s, studies of the newly discovered Atlantic deep and mid-water resources showed that mincing was the only way of removing the undesirable connotations of species identity from the often grotesque characteristics of the whole fish. Mincing also allowed correction of the high moisture content and soft texture of many species.

Another major resource of great potential includes the lanternfish and bericoid species. The flesh of some deep-water species contains high levels of possibly toxic waxes, but mincing and washing of the mince may reduce the waxes to acceptable levels.

A resource more likely to achieve commercial exploitation through mince production is the blue whiting (Micromesistius poutassou). Extensive studies have been undertaken on the frozen stability of blue whiting mince; stabilization of both protein and the fat fractions is necessary, and mince color is poor. The same considerations probably apply to the large stocks of southern blue whiting (Micromesistius australis).

Much research effort also has been given to the development of mince products from the American mullet (Mugil cephalus). The use of anti-oxidants has overcome the problems of oxidative rancidity experienced in mullet fillet. Other underutilized species studied by American and Canadian workers include the sea trouts (Cynoscion), croaker (Micropogon), ribbonfish (Trichiurus), argentine (Argentina), cusk (Brosme), turbot (Atheresthes), grey cod (Gadus), thorneyhead (Sebastolobus), red hake (Urophycis) and menhaden (Brevoortia). Other underutilized species used for mince production are predominantly temperate species used in the production of frozen mince blocks.

The generation of mince from underutilized tropical and sub-tropical species has received less attention, despite the large tonnage potential in the areas where the need for food protein is greatest. Chemical and sensory tests were performed on minces from six tropical species from the Malaysia Coast: grunt (Pomadasys argyreus), lizardfish (Saurida tumbil), ponyfish (Leiognathus splendens), catfish (Arius spp.), threadfin bream (Nemipterus japonicus) and cutlassfish (Trichiurus lepturus) and another project looked at the relative frozen stability of minces from sixteen underutilized Australian species.

In India, the preparation of frozen mince from anchovies (Thrissoles spp.), croaker (Johnius dussumieri) and other species has been studied. Acceptable products were generated, although some protein and fat degradation was apparent. Indian butter fish (Lactarius lactarius), croakers (Otolithus spp.) and ribbonfish (Trichiurus lepturus) were used in deboned, partially hydrolyzed products. Mince production from croakers and lizardfish also has been studied in the Philippines, and acceptable sausages and cakes have been manufactured.

By-catch

Several million tons of fish are caught and discarded every year in the world's shrimp fisheries, predominantly in tropical and sub-tropical waters. Shrimping is generally conducted by small trawlers with limited hold capacity and few crew members. Thus substantial incentives of added value or government control are needed to induce the landing, sorting, and handling of this wasted resource. While government programs of control and subsidy have had some success in exploitation of by-catch in some countries, full exploitation will only be achieved when the shrimp fisherman can command a higher price for by-catch than is currently realized through "trash fish" industrial applications. By-catch is plentiful, but it should not be regarded as cheap.

Most published work on mince production relates to by-catch from the shrimp fisheries of the Caribbean and the Gulfs of Mexico and California. However, the raw material differs from that encountered in the Caribbean, the Arabian Gulf and elsewhere in that the incidence of fatty pelagic fish is low (relative frequency 0.9), the mean fish length is small (4 inches, 10 cm), the proportion of marketable species is low, and consistency is high (8 species constitute 74 percent of the by-catch). These factors combine to make mince production an attractive option for Mexican by-catch utilization. While the small mean size eases many aspects of handling, it makes evisceration a major problem, so mince products from whole fish are

being studied. The occasional occurrence of toxic pufferfish and possibly scorpion fish will require careful attention to sorting procedures, however.

In Mexico, a main effort of the Instituto Tecnológico program has been in the production of pre-cooked, rapid-salted, dried fish cakes. Consumer acceptance is high, and the technology should be applicable elsewhere. Other applications include frozen, canned and smoked mince, dried mince flour, and silage from mincing waste. A frozen mince product called Pepez has been commercialized in Mexico by Productos Pesqueros Mexicanos. The low levels of fatty pelagics and DMA/formaldehyde-producing gadoids allow frozen mince of good storage stability to be produced.

In the Gulf of Mexico and the Caribbean, by-catch is of a larger mean size and contains a higher proportion of commercial species. This has led to research into the production of frozen mince blocks from sorted by-catch. Indeed the advent of mince technology has increased the potential viability of establishing these fish as target species. Mince has been successfully produced from Caribbean sheepshead (Archosargus), black drum (Pogonias), tilapia (Tilapia), croaker (Micropogon), sand trout (Cynoscion), mullet (Mugil), cutlassfish (Trichiurus), spot (Leiostomus), kingfish (Menticirrhus), robins (Carangidae), flying fish (Exocoetidae) and catfish (Anarhichas spp.).

Programs for mince production from by-catch are under way in Guayan, India, Thailand and Indonesia, and similar programs are planned elsewhere. The major technological problems probably will be in the maintenance of raw material quality under tropical conditions and in the generation of products that can be afforded by consumers, while offering the shrimp fisherman a sufficient price to encourage landing. This illustrates the challenge for mince technology in the developing world -- to generate acceptable value for money products at a minimum of added cost.

Small Pelagics

The world catch of small pelagic species exceeds twenty million tons annually, but half the landings are reduced to fish meal. This quantity could be more than doubled, given suitable handling and utilization technology. The inherent instability of these materials and the high catch rates require fast, mechanized systems for optimal utilization. Mince technology may offer the best potential for increased exploitation. Several major drawbacks can be overcome by mincing: fat degradation can be minimized by the intimate incorporation of protective additives; proteolytic degradation can be reduced by washing the mince; protein functionality can be better manipulated in the minced form; and undesirable connotations of species identity can be removed. However, of all the materials studied for mince production, the small pelagics seem the most difficult. These problems arise mainly from the high (but variable) levels of poly-unsaturated fats, the effects of fat-degradation products on taste and texture, and the contamination of minces by the highly proteolytic gut contents.

Major species studied for mince production include the mackerels (Scomber), horse mackerels (Trachurus), herring (Clupea harengus),

sardines (Sardina and Sardinops), sardinella (Sardinella), sprats (Sprattus), anchovies (Engraulis and Thrissocles) and menhadens (Brevoortia spp.). Oily, non-pelagic industrial fish also have been studied, including capelin (Mallotus), sand eel (Ammodyte) and Norway pout (Trisopterus spp.). Most research has centered on the problems of oxidative and enzymic fat degradation and has generally found that in all but canned applications such reactions are accelerated by the mincing process. However, it is also evident that mince from some species is less susceptible to oxidative rancidity than would be expected, and that proper handling and storage combined with appropriate treatment can produce stable materials. (In some countries a certain degree of rancidity may be acceptable).

It is apparent that, apart from proteolysis (protein breakdown) by gut enzymes, the protein stability of pelagic minces is generally good. Several studies indicate that the texture of pelagic flesh is not damaged by mincing as much as marine demersal materials. Color problems may prove more limiting in the applications of pelagic minces. These materials can suffer toxicological problems arising from microbial contamination from the gut-in whole fish minces, from histamine formation in scombroid (tuna or tuna-related fish) minces, and from the concentration of pesticides and other toxins in larger pelagic fish taken in polluted waters.

There is much active research into producing minces from the major under-utilized pelagic resources of the Northern hemisphere, including the European horse mackerel, the Baltic herrings and sprats, and the Black Sea sardine. Research in the Southern hemisphere seems less evident, despite the majority of the underutilized pelagic resources lying in those waters.

Freshwater and Aquaculture

Freshwater species contribute more than ten million tons to the annual world fish catch, yet there is the potential for several million tons more and the potential productivity from aquaculture is limited only by investment and profitability. Commercially significant freshwater species are generally more consistent in their properties than the marine resources. Technology for producing mince from these species should be widely applicable.

The delicate bone structures of most freshwater fish make filleting difficult, and mincing can markedly improve recovery. With the exception of the freshwater pelagics -- the shads (Alosa, Dorosoma and Brevoortia spp.) -- fat contents are low and their bland taste allow minces to be used in non-fish products and as meat extenders. However, the highly unsaturated fatty acids require particular attention to storage conditions.

Extensive studies have been undertaken on mince from the mullet or sucker of the Great Lakes (Catostomus commersoni). Stable frozen and canned products have achieved good consumer acceptance and are preferred to products from marine species. Carp (Cyprinus carpio) minces have also been produced in the United States, from both cultured and natural sources, together with a wide range of other farmed species.

Again, less work has been done on minces from tropical and sub-tropical species, although acceptable products have been made from the ubiquitous tilapia.

SEPARATION PROCESS

Fish mince quality depends on the raw material and also on the separation process. The process sequence, the equipment used and the operating conditions can influence the potential usefulness of the final product. This section reviews recent work on the reactivity of various raw material constituents, discusses the development of separation technologies, and considers these processes' effects on the mince product.

Anatomy and Biochemistry

Mincing is not a simple separation of flesh from bone. Separation processes effectively fractionate the raw material into a range of anatomically and physiologically distinct components which can affect the mince's texture, flavor and appearance. The criteria for a separation process cannot be established until the desirable and undesirable components are identified.

Most apparent is, of course, the bone fraction. This can be up to 15 percent of whole or gutted fish, or more than 30 percent of filleting wastes. There are several problems associated with bone contamination of minces:

1. Physical injury can result from the consumption of sharp, hard or pointed bone fragments.
2. The visible presence of even soft or harmless bone is considered aesthetically undesirable in most parts of the world.
3. Smaller bone particles can cause a gritty texture.
4. Bone contents over 2-3 percent can approach threshold toxicity levels for fluoride content.
5. Bone marrow exudate has been implicated in the development of oxidative fat rancidity.

Bone is not, however, a constant material. The skull and vertebrae are more highly calcified than the spines, ribs and pin bones. Thus the mincing of heads and frames can give a higher proportion of hard, brittle fragments than is obtained in mincing whole fish or fillets. Calcification varies between species - most notably between pelagic and demersal fish - and increases with age. Most commercial and national quality specifications for minced fish define limits for bone content based on weight, number or size distribution.

A variety of mince contaminants can damage texture or texture stability. Degradation by the cross-linking of proteins with formaldehyde from the breakdown of TMAO has been mentioned. The reaction is enzymic, seems to be limited to certain species, and occurs predominantly

in frozen storage. (In other systems, TMAO is degraded to trimethylamine). The major enzyme source is the kidney. This enzyme is heat labile but is reactivated by an unidentified compound in the muscle. Thus localized heat treatment is not sufficient to prevent texture degradation. Other sources of the enzyme include the blood and blood clots; the pyloric caeca; the dark brown, lateral muscle; and possibly the skin. Mincing these species, reportedly, can accelerate formaldehyde mediated denaturation, presumably by the mixing of the source organs with the flesh. Apparently preparing minces from mixed species (e.g., by-catch) that contain these formaldehyde-producing species can cause degradation of the flesh of non-producing species also.

Significant texture degradation can arise through enzymic proteolysis (protein breakdown) of the minced fish. This is most apparent when whole fish are used, and gut proteases (protein that breaks down muscle tissue) are dispersed through the muscle tissue. Even low levels of contamination by visceral materials from gutted fish can cause extensive proteolysis of the mince. Other active proteases include the catheptic enzymes of the muscle tissue itself and those generated by microbial spoilage.

Minces from both demersal and pelagic species are susceptible to extensive fat degradation, therefore separation methods should aim to reduce both the source of the fat and the materials catalysing the fat decomposition. High levels of unstable, poly-unsaturated lipids are found in the skin, in the subcutaneous and dark lateral tissue, in the viscera, and in the brain and nerve tissues. Contaminating minces with these materials may cause flavor and oxidative rancidity. The mincing process can accelerate the degradation by dispersion of the fat-degrading enzymes, by acceleration of non-enzymic oxidation through increased surface area, and by dispersion of organic and inorganic oxidation catalysts. The enzymes are found mainly in contamination by visceral material and in the dark muscle. Non-enzymic degradation is catalyzed mainly by the hemoproteins (hemoglobin, myoglobin and oxyhemoglobin) in the bone marrow, in blood vessels, and in the flesh itself. Skin also contains pro-oxidant components.

Mincing frequently results in a darker-colored product than the raw material, because of the contamination by melanoid skin pigments, by the black belly membrane, by blood, and by heads and gut contents. On longer term storage, browning and yellowing reactions of the proteins and lipids also become apparent. (Color standards have been developed for frozen mince blocks.)

The problems of visceral contamination are mainly associated with the aesthetic aspects of taste, texture, and color, but consideration also must be given to possible toxicological and microbiological factors. These can only be assessed by examination of the specific raw material. Despite the presence of food poisoning organisms in the guts of several species used for mince production, no instances of disease causing bacterial spoilage have been reported. Similarly, while many species concentrate pollutant heavy metals and pesticides, no problems have been reported in commercial mince products. Problems may occur, however, with parasite contamination. Many species used for mince production - particularly the

underutilized marine resources - can be heavily parasitized. Worms and larvae in the flesh will be transferred to the mince, many surviving intact.

Although, in general, parasites from marine fish are aesthetically unappealing rather than harmful, there are technological problems associated with the rapid proteolysis caused by myxosporidia. On the other hand, there are potential dangers to human health associated with some parasites of fresh-water fish. The risk of nitrosamine formation in nitrite-treated DMA-producing species is well known. These reactions are accelerated in mince products by the dispersion of hemoglobin, which acts as a catalyst. While washing and antioxidant treatment can reduce the effect, DMA-producing species should not be used for nitrite-cured mince products.

Toxins can arise in mince from contamination by certain fat products--notably high levels of sphingomyelins and other complex lipids from nerve tissue and the brain, and the reaction products from advanced oxidative fat degradation. Potent neurotoxins can arise from visceral contamination of the mince from certain tropical species; again raw material sorting is the only effective method of control.

Lastly, consideration should be given to the distribution of non-poisoning bacteria in the raw material. In whole fish, the highest bacterial counts are found in the viscera and on the skin and gills. However, the mincing of whole (gut-in) fish gives a mince with counts similar to that obtained from degutted fish. More significant are the differences in filleting fractions, where it is generally found that frames give higher counts than minces from fillets, V-cuts or frame trimmings. The mincing process itself also will increase bacterial counts.

Mechanical Separation

Most separation techniques use a perforated filter to screen the flesh from non-flesh components. Early separation devices were adapted from those used in the fruit and meat processing industries, but now a wide range of machinery specifically designed for fish separation is available (Figure 1). Three operating principles are used. A belt and perforated drum system is used by Baaer, Bibun, Prince, Seffelaar and Looyen, Yanigiya and Yieldmaster. A variation of this system has been developed where the belt and drum surface move at different speeds, thus increasing the shear rate and consequent yield. A screw feed and perforated cylinder system is used by Beehive. Two concentric cylinders - the inner perforated and rotating - are used by Paoli. Similar systems are used by Aburanoto, Arenco and Iwema. All have their advantages and disadvantages. The belt-and-drum systems benefit from readily adjustable pressure and easy cleaning, although belt wear can be high when using raw materials with large or hard bone particles. Some of the residual bones from fillets or gutted whole fish are needle shaped and the mince may consequently exceed some specifications for limits of bone. Some bone particles in mince made from skeletons of whole fish that have had fillets removed but still carry some flesh are blunt and irregular in shape. These might not meet specifications limiting the permitted weight of bone present. Use of a drum with smaller perforations reduces bone content, but also yields a mince of poorer texture; perforations from 1/25 to 1/4

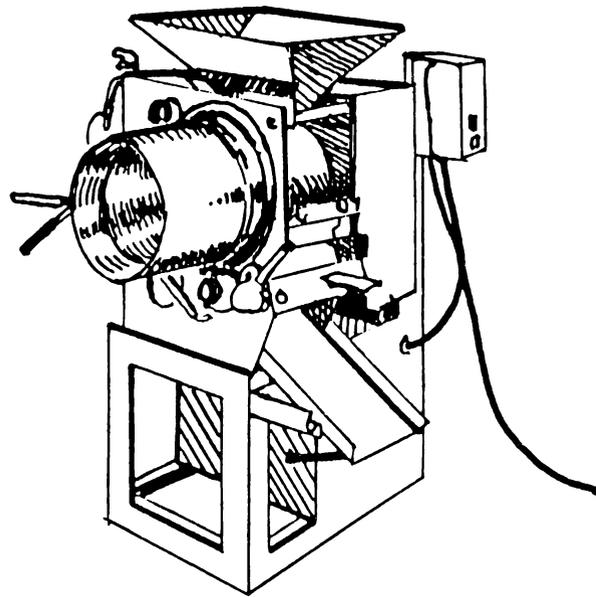


Fig. 1. An example of a roll-type meat separator.

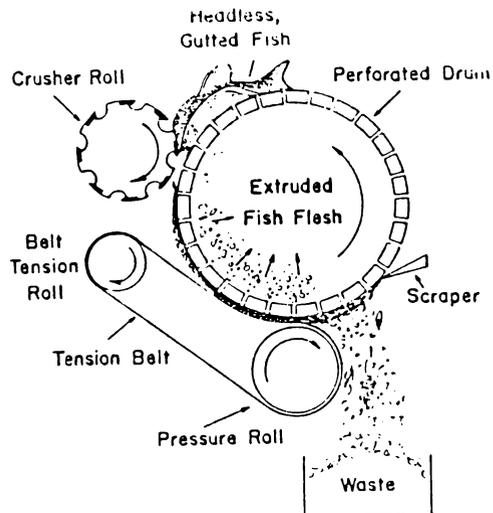


Fig. 2. The interior workings of a meat or flesh separator.

inches (1 to 7 mm) are available commercially, but a 1/8 inch (3 mm) drum generally offers the most reasonable compromise. Screw cylinder systems do not have the same wear problems, but generate higher shear rates and

consequent textural damage. In general these latter systems are more expensive, but all systems give similar yields - 60-80 percent for whole fish and 30-70 percent for fillet wastes. Despite their apparently simple operating principles, however, the relationships between pressure, perforation size and perforation area with yield, contaminant levels and shear damage are complex. These are discussed in more detail later.

As problems have developed, machine designs have been adjusted. The high spoilage rates of minces have led manufacturers to remove dead spaces from the fish-carrying areas. Recognizing that ferric contamination from machinery can accelerate oxidative fat degradation, stainless steel and non-metallic materials have been used for components in contact with the mince. Oxidation can be further reduced by separation under water or under washing solutions.

Mechanical filters that screen bone from untreated raw material are now the most widely used. However, several alternative methods are evolving. Fine pastes can be obtained by grinding and filtering; bone-free minces can be obtained by tumbling and screening; and pre-cooking can be used to weaken connective tissue. Traditionally such techniques have been used prior to manual picking or deboning, but now mechanical systems have been developed. These have the advantages of reducing non-protein contamination, softening bones and reducing texture and flavor degradation; however protein functionality is lost. Mince, of course, can be generated by the comminution of bone-free flesh obtained by traditional filleting methods.

Although filleting machines are available for many species, hand filleting is widely used because yields are higher. The pinbones in the anterior portion of the fillet are removed by V-cutting or the simpler but more extravagant J-cutting. The proportion of fillet removed in V-cutting varies according to the degree of skill exercised and ranges from 4 to 15 percent. Current development effort is aimed at the design of whole lines rather than the separation processes in isolation. The method of preparing the raw material can have a greater effect on final product quality than the separation process. Bone cutting machines can separate the spinal column and belly membranes from filleting waste, thus reducing the major sources of protein, fat and color degrading agents. Feeding devices have been developed that present the raw material at controlled rates and with skin surfaces away from the separation screen--again minimizing contamination from skin-associated and subcutaneous components and increasing the maintenance of the natural fibre structure of the muscle.

Many operators now use multi-pass systems, whereby high-quality mince is generated by low pressure and intermediate perforation size. Extra yield is obtained by generating lower quality minces at higher pressure and lower perforation sizes on subsequent separation steps. Machines are also available for the heading, gutting, dressing and pre-breaking of many species that can be used whole for mince production, notably for consistent catches of small pelagics. However, a major need for mechanical heading and gutting systems for mixed material, such as by-catch, remains. Consideration is also being given to mechanization of

bone separation systems suitable for some developing countries. For example, mechanized separation in the production of Yu-sone (a dry, spiced mince product of the Far East) is under development in the United States, and manually powered separators are being considered by the Tropical Products Institute in London.

Physical Quality Effects

Mechanical deboning systems obviously have a major effect on mince quality, therefore understanding these effects is vital for the optimization of the product.

A strong positive correlation is found between screen perforation size and bone content in the mince. Similar relationships are found between both the degree of pre-processing size reduction and separation pressure with final bone content. Increasing perforation size also increases the proportion of thin, sharp bones in the mince.

More difficult to establish are the relationships between the shear and pressure conditions of the separator and the damage to texture and storage stability. It is important to distinguish between direct pressure effects and the effects of increased dispersion of degradative enzymes.

There is increasing evidence that high shear rates damage protein functionality. Increasing pressure can lead to a reduction in water binding capacity and to an actual loss of water content. Conversely, increasing water content in the raw material has been found to correlate with increasing susceptibility to shear damage during mincing. Extremes of pressure can have dramatic effects on mince; above 4,200 psi (300 kg/cm²) significant fat separation occurs and rancidity development is accelerated; above 21,000 psi (1,500 kg/cm²) a large proportion of the protein is solubilized and denatured--although yields are substantially improved. Excessive protein denaturation is damaging to most mince applications.

Increasing pressure and shear may increase mince discoloration and susceptibility to protein degradation on storage. Shear has less effect on immediate lipid degradation, although the effects of pressure on temperature and subcutaneous fat release can damage longer term lipid stability.

For mechanical separators, the effects of pressure, perforation size and perforation area on bone content, protein functionality, discoloration and lipid stability can only result in a compromise for optimal machine conditions.

Non-mechanical Separators

In addition to mechanical deboning systems, several chemical and biochemical techniques have been developed. Protein can be recovered from both whole fish and filleting waste by enzymic or acid proteolysis followed by centrifugal or filtration bone separation. Yields are high but protein functionality and integrity are generally low. These materials are best suited as inert extenders in composite products.

Washing

Many mince processes employ a post-separation washing stage to remove inorganic salts, water-soluble proteins, pigments, visceral contamination, bacteria and decomposition products. In some species, fat content also can be reduced, and the washing of minces from whole fish can provide products of similar quality to those obtained from gutted material. Washing of gadoid mince can completely eliminate formaldehyde production from TMAO, and washing is essential in applications such as kamaboko production where acceptable products cannot otherwise be produced. It is generally achieved by multiple washes in chilled, preferably chlorinated, water followed by pressing, centrifugation or rotary sieving. Alkaline washes can inhibit protein hydrolysis by acid proteases, although fish flesh may contain alkaline proteases that will be activated by such treatment. Washing with ascorbic or citric acids may inhibit degradation of flounder minces. Reduction of washwater pH also can reduce color, water uptake, protein loss and TMAO levels.

While washing improves the texture of finely minced gel products, it has less effect on coarse textured minces. Similarly, while washing may be necessary for minces heavily contaminated with pigment or visceral material, it has little effect on the flavor or appearance of minces from higher quality raw materials. Washing has little effect on muscle tissue that is inherently colored, such as the grey flesh of saithe and blue whiting, the dark flesh of pelagic species, and the green flesh of certain tropical by-catch species. Discolored minces may be acceptable for incorporation into meat products, as discussed later.

The need for a washing step should be carefully considered, as it can have many undesirable effects. Gross protein yield loss can be substantial, up to 25 percent, and soluble micronutrients including vitamins, minerals and free fatty acids are also lost. This can lead to the secondary problem of effluent disposal. Washing with hard water can damage texture and catalyze fat degradation; washing with sea water or brine can further increase protein loss. Despite the availability of effective dewatering machinery, it is difficult to control the final water content of the washed mince. In many situations, washing of the raw material prior to mincing is more appropriate and is a good manufacturing practice.

MINCE STABILIZATION

As has been seen, mincing can accelerate the degradation of fats, proteins, color and bacteriological quality. This section reviews work on the stabilization of fish minces, and the next section discusses the product applications of these technologies.

Fat Stability

Fat degradation is a major problem in minces from both fatty and low fat species. It occurs in all product applications except canned systems.

Fish fats in mince are characterized by their high levels of long-chain poly-unsaturated fatty acids. While these may be nutritionally desirable, they are highly susceptible to enzyme hydrolysis and non-enzymic oxidation. Undoubtedly, the mincing process accelerates these reactions -- through physical surface effects and through the dispersion of catalytic contaminants. However, measuring fat degradation is extremely difficult, and it is less clear which reactions are increased by mincing and what effects they have on sensory quality.

Fat stabilization

Several approaches are available for the stabilization of fats in fish minces. Most widely studied is the use of antioxidants.

Polyphosphates are added to minces mainly to enhance protein functionality and water binding. They, particularly when in combination with other additives, have been found to have antioxidative properties.

Several process techniques can inhibit fat degradation in mince. Glazing and oxygen impermeable packaging inhibit the oxidative deterioration of frozen mince blocks. Studies have confirmed that oxidation is a surface effect, that impermeable packaging has a greater protective effect than degassing and elimination of occluded air, and that slow frozen glazes are more effective than rapidly frozen glazes. Impermeable packaging is also one of the most effective means of protecting dried mince product.

Rapid heat treatment of minces at temperatures above about 120 - 140° F (49°-60°C) deactivates lipolytic enzymes, thus protecting the mince against free fatty acid formation. However, cooking tends to enhance oxidative deterioration. An effective way to prevent oxidation is to hydrolyze the fats with added lipase and then wash out the free fatty acids. Washing also can remove other oxidation catalysis from the mince, although careful control of wash-water temperature is needed to prevent acceleration of oxidative degradation.

Much work has been done on understanding and controlling fat degradation in minced fish. However, fat stability remains a major factor limiting the use of many small pelagic and underutilized species for mince production.

Protein Stability

Much recent work has been done on the nature, stability and enhancement of fish protein functionality. The proteins of deboned mince are both particularly susceptible to degradation and yet of high inherent functionality. Minced fish has particular problems of protein stability; but it is also a versatile material in terms of the wide range of technological properties that can be exploited in process and product development. The functional properties of major interest are heat-setting capacity, gel-forming ability and water-binding capacity. Maintaining these properties requires that the myofibrillar proteins are preserved in their native, non-denatured form. This, in turn, requires a minimization of a range of degradative reactions.

Color Stability

As with fillet materials, the color and appearance of mince products are vital consumer attributes. In the developed world, whiteness and homogeneity of color are major parameters in products such as mince blocks and kamaboko. In the developing world also, products such as the fish balls of South East Asia must be white or a uniform grey; in other products such as spiced or dried mince, color is less important.

The mincing process itself generally has the greatest effect on color, however, further degradation can occur during storage. Yellow/brown discoloration occurs in frozen minces; and bacterial and non-enzymic browning occurs in non-frozen materials. Oxidative discoloration of fats and blood pigments also can be extensive. Color assessment and specification can be by subjective or instrumental methods.

Several techniques are available for improving mince color. Most commonly used is water washing, which can be effective for whole fish, frame and mixed by-catch minces.

The alternative to whitening is color masking, achieved by incorporating fish mince into products where there is an expectation of a darker color. Such products include those where mince is used as a meat extender or in smoked, spiced or curried minces.

Bacteriological Stability

The major determination of mince's microbiological quality is the quality of the raw material. Thus protracted holding of filleting wastes before mincing or poor storage of whole fish raw materials increase total counts in the minced product and increase the risk of spoilage. "Dustbin" practices of stockpiling prior to mincing should be avoided. Under good hygienic conditions, pre-processing treatment of the raw material by scaling, heading and evisceration has very little effect on the mince's final quality. Even the mincing of gut-in materials leads to only small increases in counts, and no pathogenic species are found in the viscera of most raw materials. Similarly, if temperature and cross contamination are controlled, the mincing process itself should not lead to more than one log cycle ^{1/} increase in counts. Standards of process hygiene have been defined by FAO (Food and Agriculture Organization of the United Nations). The bacteriology of commercial frozen mince blocks produced under such conditions has been extensively studied and reviewed, and the large majority fell within international trading standards.

^{1/} an increase by a factor of 10. eg. 100 in a log increase over 10 and 100,000 in a log increase over 10,000.

However, in many countries, potential raw materials for mince production are spoiled or semi-spoiled. Despite the fact that most of these materials occur in the tropics and thus contain thermophilic spoilers highly amenable to chill or iced stabilization, many current practices generate raw materials of high initial counts, which has several implications. Under such conditions, mincing will lead to substantial increases in microbial counts by dispersion of high levels of surface contamination throughout the muscle tissue. Minces prepared under even the most controlled conditions are extremely susceptible to post-mincing contamination. Thus minces with high levels of initial contamination have an extreme risk of spoilage in handling, storage and further processing.

In wet minces, initial spoilage is predominantly putrefactive and the product becomes inedible before there is any risk of toxicity. However, poor handling practices can lead to contamination by food poisoning organisms. The presence of scombrotoxic (e.g. tuna and bonito) and certain other species in the raw material can also introduce toxin producers into the mince.

MINCE PRODUCTS

The range of mince products established in the world market is limited and is dominated by block frozen materials in the West and surimi in Japan. These are discussed briefly here, but more emphasis is given to product technology currently under development.

Frozen Products

The annual production of frozen blocks probably amounts to well over 500,000 metric tons ^{2/}, although the statistics are inadequate. Blocks can be produced wholly from minces or from mixtures of mince and fillet in various proportions. Production methods are, as for fillet blocks, generally in moulds in plate freezers, and often with the incorporation of salt, phosphate, sugars and other additives. Manufacturing practices and standards are suggested by FAO/Codex Alimentarius and have been adopted by most producing countries. The primary aim of manufacturing is to produce frozen blocks of uniform shape that can be cut, with little or no waste, into a large number of small portions of specific size, shape and weight.

Requirements for the rectangular block are:

1. skinless, boneless fish flesh composition,
2. absence of foreign bodies,
3. reproducible weight,
4. no voids or ice pockets,
5. specified dimensions with sharp edges and
6. smooth surfaces,
7. protection from physical damage, and
8. protection from dehydration.

^{2/} a metric ton is the international standard for reporting fishery statistics and it contains 2000 kilograms. One metric ton is equal to 2,205 pounds.

Headed and gutted fish, fillets, V-cuts and frames are all used as raw materials in commercial mince block production. These mainly come from established white fish sources, but increasingly, also from underutilized white fish, pelagic and mixed by-catch species. Thus blocks of a wide range of composition and sensory properties are produced. It has been common practice to confine the proportion of mince added to fillet blocks to about 15 percent of the total mixture.

While mince blocks are a major commodity in international trade, they are only intermediates in the manufacture of final retail products, such as battered fingers, sticks, steaks and cakes. A retail trade is also developing in the U.S. and Japan for bulk packs of frozen mince for further preparation by the consumer. This concept could be extended to chilled and intermediate moisture products.

Mince should be frozen as soon as it is made or immediately incorporated into products and then frozen within 5 hours of manufacture; products should be kept chilled while awaiting freezing. The storage life of frozen mince made from good quality cod and haddock flesh is at least six months at -20°F (-29°C) or three months at 0°F (-18°C) without any significant loss of quality, but mince from hake and Alaska pollack apparently have a shorter cold storage life as do minces that include kidney or gut. Minces made from fatty fish require protection against oxidation in cold storage.

Frames and cartons

In the normal procedure for making the block, the appropriate weight of material is hand-packed into a waxed cardboard carton fitted into a frame contained in a shallow, light metal tray. The tray collects drip, preventing it freezing on the freezer plates. The frames, often divided to accommodate two cartons, should be constructed strongly of aluminum or galvanized steel channel section in order to withstand the considerable pressures from within the block when the fish expand during freezing. Aluminum frames are preferred because they are less likely to damage the plates of the horizontal plate freezer, although deformation can occur more easily during handling and during freezing if the carton is overfilled. The length and width of the frame space should be accurate to (1 mm) 1/25 inch to provide a block of precise dimensions.

The carton is formed by a folded, one-piece waxed and scored card of food grade quality with either a smooth or dimpled surface. It helps maintain fish quality by providing protection from dehydration in storage and transportation, from damage in handling and from dirt and bacteriological contamination. It also allows easy release from the frame and from the frozen block of fish. Some processors believe dimpled surfaces make release easier and give a smoother block surface with few voids. Much of the protection afforded by the carton is lost if it is opened, for example to inspect the block in quality control, because the intimate seal between fish block and carton is broken.

The folded cartons are fitted in the frames on trays, with all the carton tabs overlapped on the outsides to prevent them from being embedded

in the fish block. The space formed by the carton can be termed a mold.

Packing the mold

The mold must be filled with the correct amount of fish because underfilling results in voids; overfilling results in some material being squeezed out on the freezer plates, bulging of the surfaces, uneven contact with the freezer plates and possibly fracture of welded joints on the frame. Allowance must be made for the expansion of the fish during freezing. The weight of fish will vary slightly with species; the amount of mince required for a given volume is less than the amount of fillet. After weighing, the fish should be transferred quickly to the mold because delays can result in drip loss. The balance pan should be kept free of drip and residue. By strict control, the block weight can be kept within 5 percent of the desired value.

Mince added to fillet blocks should be distributed throughout the block to avoid a sandwich effect of a layer of mince in the middle and to avoid concentrations of mince. Usually the mixture of fillets and mince is spread from the center and pressed into the corners to form a block with random packing.

After the mold is filled, the surface is smoothed and the carton closed so that the overlapping cover edge fits between the side of the carton and the frame to prevent the edge from being embedded in the block. Normally the trays and frames containing the filled molds are stacked on a pallet to accumulate a full load for the horizontal plate freezer. In handling the loaded trays, care should be taken to ensure the mold does not slip through the frame and become trapped between the base of the frame and the tray. If frozen in this position, contact with the freezer plate will be poor and it may be difficult to remove the frozen block from the frame. Long delays in accumulating a freezer load should be avoided. If considerable drip accumulates before freezing and it can be foreseen, some compensation for weight loss before freezing should be made when the mold is filled in order to prevent the incidence of voids. Accumulation of drip also results in ice pockets in the frozen block.

Freezing and storage

Before loading the freezer, the freezer plates should be clean and free from residues of frozen fish and ice which might cause indentations on the blocks or damage to the cartons. Any drip accumulated in the tray can be poured off to prevent it slopping on the plates. The freezer should be loaded evenly to maintain good contact between blocks and plates and to prevent warping of the plates themselves. Spacers should be inserted where there are no blocks, and frames of different thicknesses must never be stacked on the same plate.

Given good contact and efficient heat transfer with a refrigeration temperature of -40°F (-40°C), blocks up to 2.5 inches (6.4 cm) thick can be frozen to a mean temperature of -20°F (-29°C) in less than 2 hours. If the practices outlined above are followed, one defrost of the freezer in 24 hours will be sufficient for cleaning.

The frozen blocks are removed from the frames by mechanical or hydraulic means, using an apparatus consisting of a ram and a simple metal plate slightly smaller in size than the surface of block to eject the block from the frame. The block should be pushed evenly from the bottom surface to avoid damage to the carton; the cover or lid tends to be torn if the blocks are pushed out from the top surface.

The blocks are packed in corrugated cardboard master cartons for added protection and ease of handling during cold storage and distribution. To obtain maximum storage life, the frozen blocks should be transferred immediately to cold storage at -20°F (-29°C).

Reformed, Transformed and Textured Products

As they come off the separator, fish minces are amorphous granular slurries. Coarse minces may have a perceptible structure of fibres and fiber bundles; fine minces and minces from soft textured species have a homogeneous pasty consistency. Thus some forming or structuring process is needed to achieve higher levels of textural integrity.

Intact fillets have three levels of texture - fibrosity, flakiness and gross bulk structure. If fillet simulation is required, forming techniques can achieve some or all of these. Frozen mince blocks achieve fibrosity from the inherent characteristics of the mince and gross structure from compaction in the freezer mould. Mixed mince and fillet blocks also have some degree of flakiness similar to the structure of an intact fillet.

Flakiness can be achieved in all mince products by several reforming techniques. Most widely studied has been the use of alginate gels to set the mince into a sheet structure, followed by layering and compaction of the sheets to simulate the myotome flakes.

Fibrosity can be enhanced by the incorporation of spun vegetable protein fibers, extrusion-textured vegetable protein, pre-cooked fish muscle, alkali/acid-precipitated mince protein fibres.

Few of these flake or fibre forming processes are practiced commercially. Extensively used, however, are techniques for the forming of individual portions from mince. Regular portions are obtained from frozen mince blocks by the use of band saws and circular saws. Blocks can also be portioned by frozen extrusion forming; this eliminates yield loss in sawdust but can cause shear damage to the muscle proteins. A wide range of machinery is available for the low pressure extrusion forming of fresh minces. An infinite variety of shapes and sizes can be produced, including fillets, shrimp tails, balls and regular geometric portions. Additives such as salt, phosphate, soy protein and gums are used to obtain the optimal characteristics for extrusion and to control the final product texture. Colors, flavors and seasonings can also be used. A range of high quality products aimed mainly at developed Western markets are manufactured using extrusion forming techniques. The firm, elastic textures are particularly suited to shellfish and mollusk analogues. The incorporation of shrimp into mince portion can markedly improve acceptability and oxidative stability.

Traditional formed products such as sausages, cakes, patties, balls, loaves and burgers are well established in many countries. Although their forms vary widely with cultural preferences, many of these products are ideal vehicles for minced fish. The use of mince in sausage products is the most extensive, an industry dominated by Japanese kamaboko production. Outside Japan, most mince sausage products are fine-textured, heat-set emulsion products rather than heat-set protein gels.

Mince is used as an extender in meat-based sausages in the USA. The color of frame mince and pelagic mince is effectively masked in products such as frankfurters; usage levels are limited by flavor effects. Mince has also been used as a meat extender in patties and burgers.

Other emulsified mince products include highly comminuted, soft textured pastes -- for use as such or as spreads and dips; and coarsely chopped products such as fishburgers and loaves. The formation of oil-in-water emulsions may be an effective way of reducing contact between the fish fat and ambient oxygen.

Mince can be used as an ingredient in many composite products. The ubiquitous fish cakes, rissoles and croquettes are generally bonded with cereal flours or starches. They are seasoned to local preference and are preserved chilled or frozen. Higher levels of mince are used in traditional products such as fish balls (South East Asia and Scandinavia) and Gefilte fish (Israel, Europe and the U.S.). Such products are being further developed in the U.S. and elsewhere. In the U.S. high levels of mince are used in fish patties; which are structured by using functional additives such as salt, phosphate and alginate.

Other formed products studied for mince utilization include fried or extrusion-expanded, starch-based snack products, sliced salmon or saithe analogues and filled products.

Surimi and Kamaboko

The production of kneaded mince products in Japan exceeds one million metric tons annually. The manufacturing technology for kamaboko, chikuwa and satsumaage and for the intermediate surimi has been unique to Japan for centuries. However, extensive fundamental studies into the properties of mince proteins and the more recent expansion of the industry into foreign markets suggest that the Japanese experience may be of value in the development of mince technologies elsewhere.

Surimi is the semi-processed intermediate mince material used in the preparation of a wide range of finished products. This product is discussed in depth later in this lesson.

PRODUCTION AND MARKETING

A wide range of technologies are available for manufacturing of mince products, although information on the degree of commercial exploitation is limited. This section briefly reviews the state of development of the mince industry.

Japan's surimi industry is well established, with rigorously defined standards for materials, manufacturing practice and finished product quality. In the West also, trade in frozen mince blocks is well advanced. Canada and Western European countries are major producing and exporting nations; the USA is the largest importer, although its domestic production is increasing. Australia also imports mince blocks. Large tonnages are produced by Eastern bloc nations for internal consumption.

Extensive work has been undertaken to define standards for mince block production and utilization. FAO and participating countries have contributed to the development of the Codex Alimentarius Draft Standard for minced and mixed blocks, and to the Proposed Draft Code of Practice for Minced Fish. These detail the range of minimum product quality standards required for international trade and the associated standards for raw material quality and manufacturing practice. Discussions continue, however, on the problems of product identity, description and labeling. Agreement will have to be reached on the nature and extent of classification needed for the infinite variety of raw material species, mince-to-fillet ratios and bone content found in commercial mince blocks and finished products.

Less advanced is the commercial development of minces from underutilized raw materials and their use in novel technologies. The potential supply of mince and minced products greatly exceeds the present demand. Consumption will be increased by the use of mince as an extender in existing products -- both fish and meat -- but the greatest potential may be in the manufacture of new product forms that exploit the natural advantages of the material. This type of diversification requires careful process and product development, thorough acceptability and market testing, and rigorous quality standards. Every effort should be made to prevent poor quality products from jeopardizing the potential and future of minced fish. Unfortunately, some damage was done in Europe and the U.S. when insufficient knowledge on the stabilization of minces led to consumer dissatisfaction with poor quality products and when ill-conceived publicity on alternative species caused suspicion with the consumer and within the trade. With a few notable exceptions, there has been insufficient investment in acceptability and market testing of mince products.

In the developed world, a successful example of mince technology has been developed. Some twenty products have been developed, including frankfurters, balls, chowders, and untreated mince. The intention was to transform a range of unfamiliar or underutilized species and filleting wastes into mince products acceptable as such and with demonstrable market potential. After basic studies into stabilization and structuring of the raw materials, processes and formulations were developed, screened and market tested in supermarkets, restaurants and schools. Unprocessed frozen minces seem particularly successful in the U.S., Japan and elsewhere. In the developed world, however, the cost advantage of mince is confounded by the consumer perception of price as an indicator of quality.

In the developing world, a good example is the Mexican by-catch program. A detailed study to characterize the resource was followed by the development of salt dried, canned, frozen and smoked product technologies. Most emphasis has been given to the rapid salt-dried cake and to Pepepez' frozen portion reformulated into fish shapes. Extensive market testing indicated the products were highly acceptable and price competitive. An industrial model demonstrated that manufacture would give satisfactory returns to the shrimp fishermen and to the processor, while allowing this wasted resource to contribute to the nutritional needs of developing nations.

SUMMARY AND CONCLUSIONS

Mince separation techniques have been applied to a range of raw materials, including commercial and underutilized species, whole fish and filleting waste, by-catch, pelagic and freshwater sources. For many of these, the problems of traditional processing and marketing are so intractable that mincing is the only viable means of utilization. While the greatest tonnages of mince are presently generated from commercial gadoid species, the greatest potential is seen in the by-catch and small pelagic resources of the developing world.

Development of separation processes is now highly advanced, with a wide range of separators available commercially. Current development efforts are aimed at designing whole process lines, in the realization that methods of preparation and handling have a greater effect on final product quality than the actual separation stage. While mechanical separators are highly effective at removing bone, skin and connective tissue, they are less efficient in the removal of other contaminants. Combined chemical and physical methods may be preferred for the removal of fat, guts and pigment from small pelagic and industrial fish. This is an area that merits further development.

All minces are inherently unstable. Fat degradation is a major problem in materials from both fatty and low-fat species. Oxidation and rancidity occur in dried and frozen minces; fat hydrolysis occurs in fresh materials. Canned minces are relatively stable. Several chemical and natural antioxidants have been identified, together with physical methods of limiting oxidation. However, fat stability is still the major factor limiting the use of many small pelagic and other underutilized species in mince production. Further work is needed in the elimination of oxidation catalysis, in the removal of fat by washing or lipolysis, and in the development of inherently stable products such as oil-in-water emulsions and Maillard-reacted intermediate moisture products.

Mince proteins are both highly functional and highly unstable. Frozen denaturation can be minimized by a wide range of cryoprotectants, although their use can cause excessive rubberiness and other sensory defects. Less work has been done on protein degradation in non-frozen systems. Even mild drying processes cause extensive mince denaturation, although this can be advantageous in accelerating drying rates. A large number of functionality-enhancing additives and ingredients are used in mince products, although in many instances more use could be made of the inherent properties of the mince itself.

Mince whiteness is a major consumer attribute in most countries. Color degradation occurs by pigment contamination at the separating stage and during storage. Color can be controlled by pre-treatment of the raw material, by washing or bleaching the mince, or by incorporation of whitening of the mince.

The range of commercial mince products established in the world market is limited and is dominated by block frozen materials in the West and by surimi in Japan. Recent developments of mince product technology in the developed countries are mainly frozen and canned. They include extrusion-formed portions, sausages, balls, pastes and extended meat products. Of particular interest are unprocessed minces for further preparation by the consumer. The industry will continue to expand, taking fuller advantage of underutilized resources.

With the exception of a few traditional products such as fish balls and fermented pastes, mince technology in the developing world has yet to be fully exploited. The reasons for this are several and indicate areas where further development is needed:

- The major resources of by-catch and small pelagics are well suited to mechanical separation. However, there are often insufficient facilities and incentives to land them with the high quality required for mince production.
- Electrically powered mechanical separators are suitable for many situations, however, less costly mechanical separators with a higher quality and output than manual picking are more appropriate elsewhere.
- Many products require mince from gutted, dressed fish. There are no machines available for the gutting of mixed materials such as by-catch, and it's unlikely they will be developed. Machines are available for the gutting of small pelagics, but they are expensive and restricted to fish of basically the small size. More appropriate would be non-mechanical techniques for removing the viscera and other contaminants, and the continued development of gut-in products.
- Most successful have been dried products from low-fat minces, particularly the rapid salt dried materials. These have shown high acceptability in Mexico and elsewhere. Further investment in acceptability and market testing should be encouraged.
- Canning, one of the most effective means of mince stabilization, would be particularly appropriate in those countries with excess canning capacity. However, little work has been reported in these areas.
- While it is likely that the greatest potential is in new product forms that exploit the natural advantages of the mince, more effort is needed to match the major advances in mince technology in the developed world to the resources and food preferences of the developing countries.

As little as ten years ago, technology availability was the major factor limiting the enormous potential of minced fish utilization. Many solutions have been found and the requirement now is for energetic investment in their implementation.

SURIMI

INTRODUCTION

Surimi is a refined form of minced fish meat. It is not in itself a food stuff; rather 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 3.). 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, which is an irreversible change in the protein resulting in a reduction in gel strength. 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 percent 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 4).

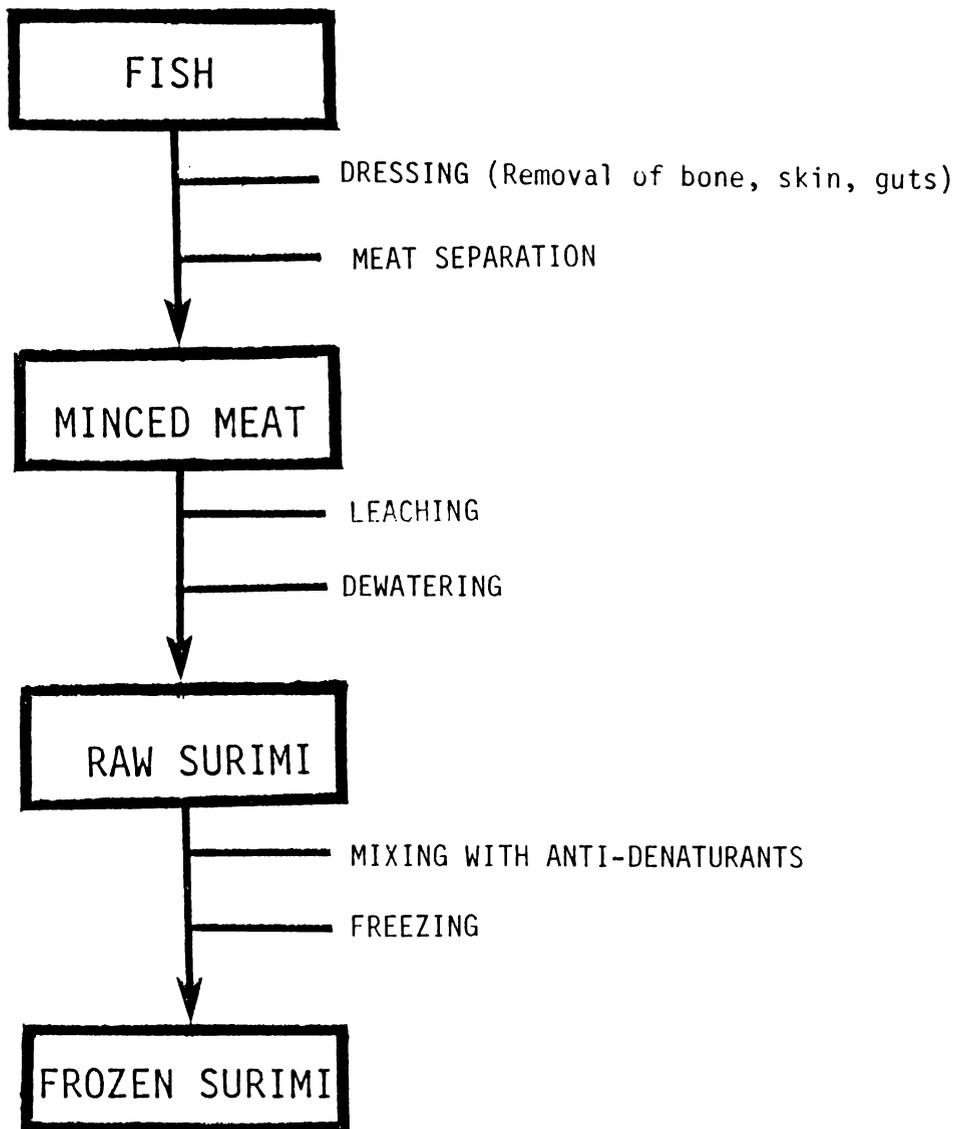


Fig. 3. Definition of Surimi.

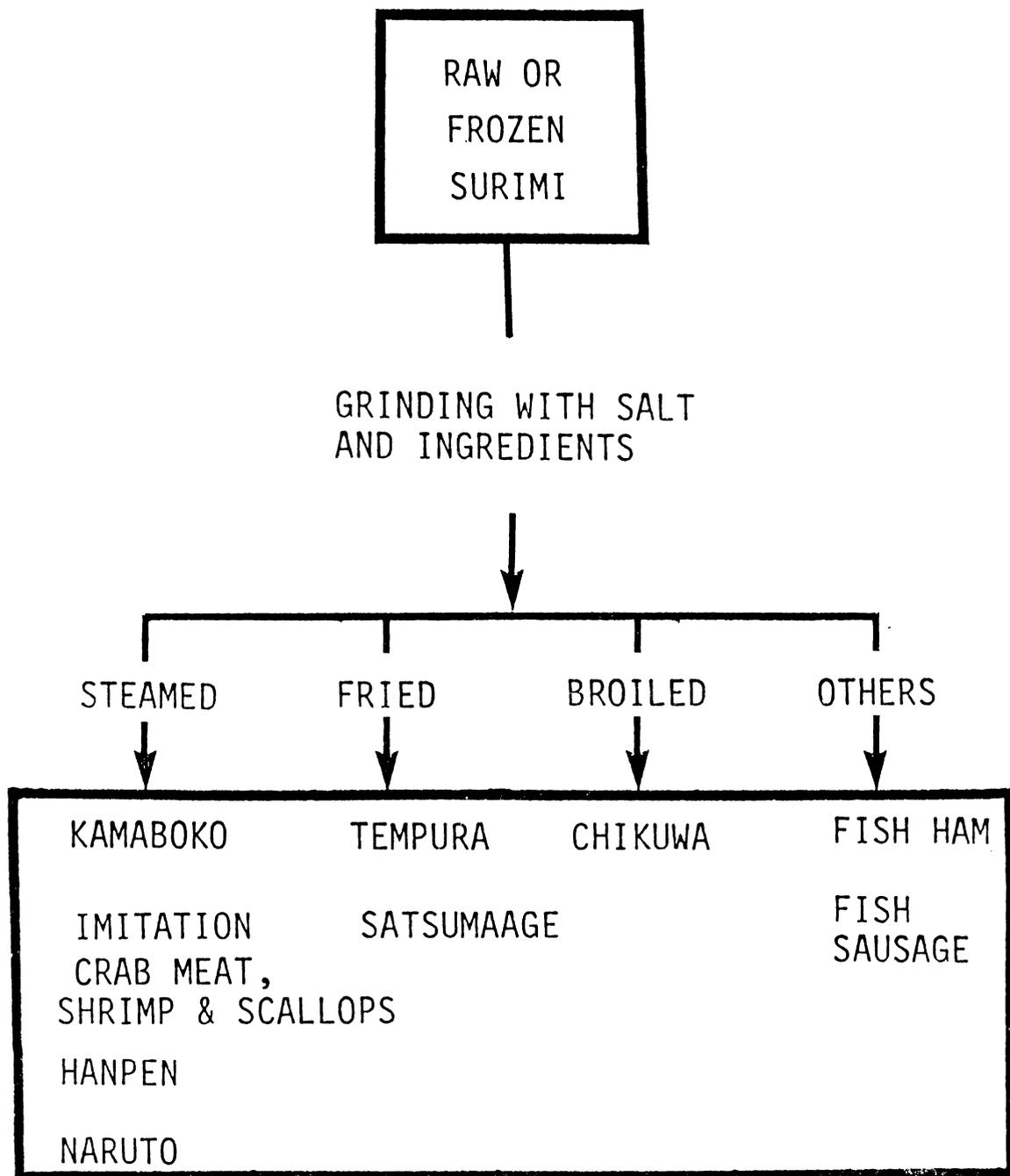


Fig. 4. Definition of Surimi-based Products.

For approximately 1,500 years, the Japanese have practiced the art of manufacturing surimi-based products. Traditional methods consisted of processing the fish into raw 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 soon after the fish was landed.

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 surimi. Tremendous expansion of the surimi-based product industry was made possible by this important change in the nature of its raw material. The 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 1960s. Within thirteen years from its introduction of frozen surimi in 1960, the Japanese surimi-based product industry doubled in size, producing 355,000 metric tons annually. By 1984 the surimi industry had grown into 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 matches the combination of abundance, economy, and quality. 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 percent of all the raw material fish used for surimi during that time.

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 a decade of 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. Before this press was developed the dewatering process was accomplished by a basket-type centrifuge, into which the washed minced meat was fed batch by batch.

Because the centrifuge's efficiency was limited, it became the major bottleneck in surimi production operations. A centrifuge could process only about 0.5 metric tons 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.

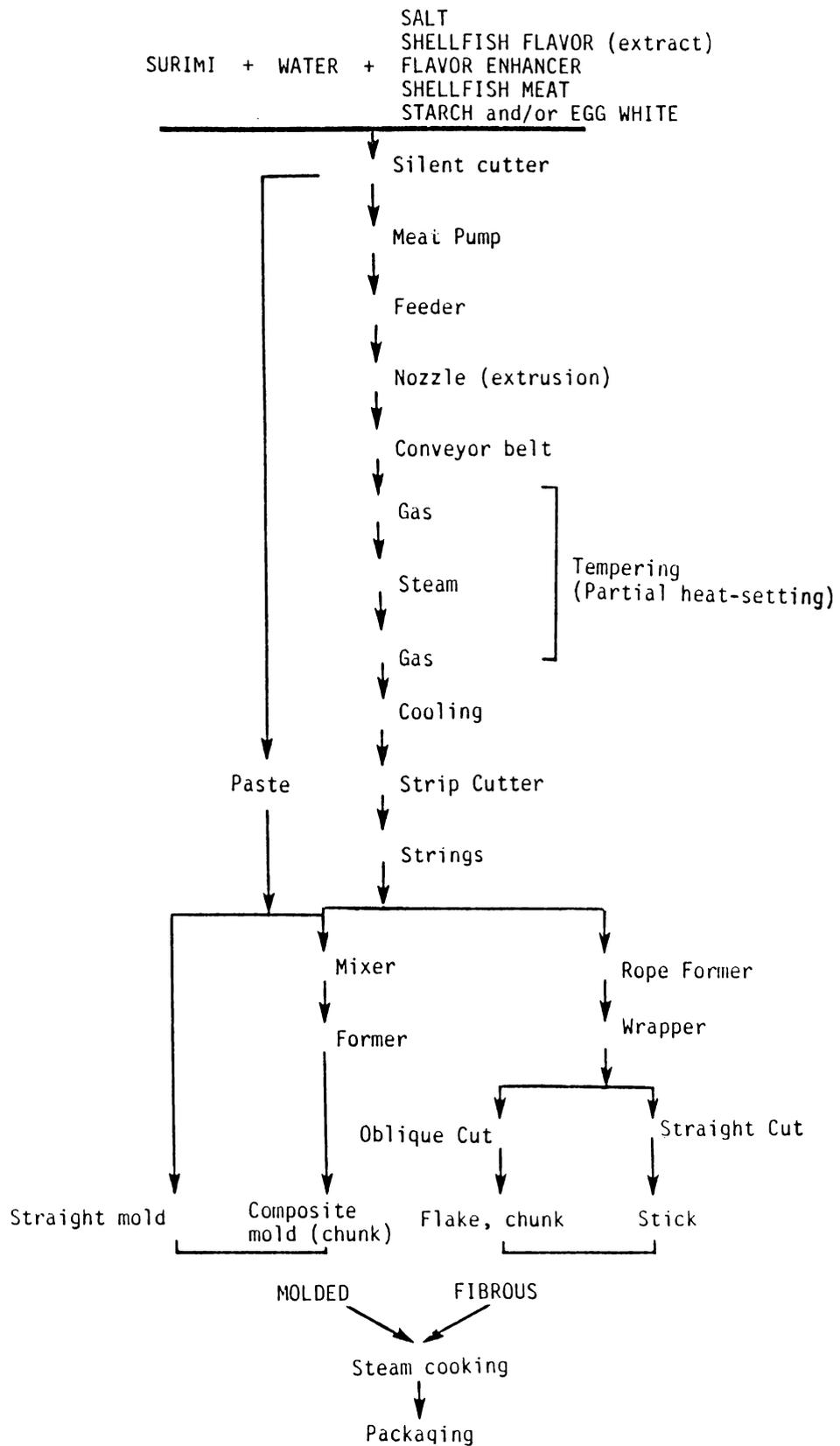


Fig. 5. Process for making fibrous, flake, chunk and composite-molded products.

Surimi production was further streamlined by the 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.

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. 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. 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 percent 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.

SURIMI FROM UNDERUTILIZED SPECIES

Since about 1970, Japan has carried out extensive tests aimed at using 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.

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 Japanese government-funded research effort. 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 in 1982. A method for producing high-grade surimi from shark meat is believed to have been found.

In 1977, the Japanese government launched an \$8.5 million, 5-year program to develop surimi from the dark meat of sardine and Pacific mackerel, abundant domestic species. If their meat could be converted to surimi, the rapidly growing landings of these species would more than offset the impact of declining Alaska pollock catches.

A new method had to be developed to achieve this objective because the dark fish muscle of sardine and Pacific mackerel 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.

Research in this area is still continuing and appears to be the greatest challenge facing surimi producers. Unless dark fleshed fish can be used to produce surimi of analog production quality, the price and product availability will experience substantial changes.

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 percent, are various types of fish cake called "kamaboko". Less than 10 percent 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, broiled and fried. Typical steamed kamaboko is called itatsuki (board-mounted) kamaboko, but the variety also includes imitation seafood, naruto and hapen, spongy marshmallow-like products which contain 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 (whirled 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 and egg whites. Example formulations for typical kamaboko products are shown in Tables 1 and 2.

TABLE 1. TYPICAL INGREDIENTS IN KAMABOKO

INGREDIENTS	ODAWARA KAMABOKO	TOYOHASHI CHIKUWA
Percent.....	
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

TABLE 2. TYPICAL INGREDIENTS IN IMITATION SEAFOOD PRODUCTS

Ingredients	Crab	Scallop	Shrimp
Percent.....		
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

Surimi-based products are prepared by extruding the surimi paste into various shapes, resembling such shellfish meat as king or snow crab legs, crab claws, lobster tails, scallops, or shrimp. The closer the analog resembles the natural product, the greater the extrusion sophistication. The product may be divided to four major categories according to their fabrication and structural features: molded; fiberized, composition-molded, and emulsified.

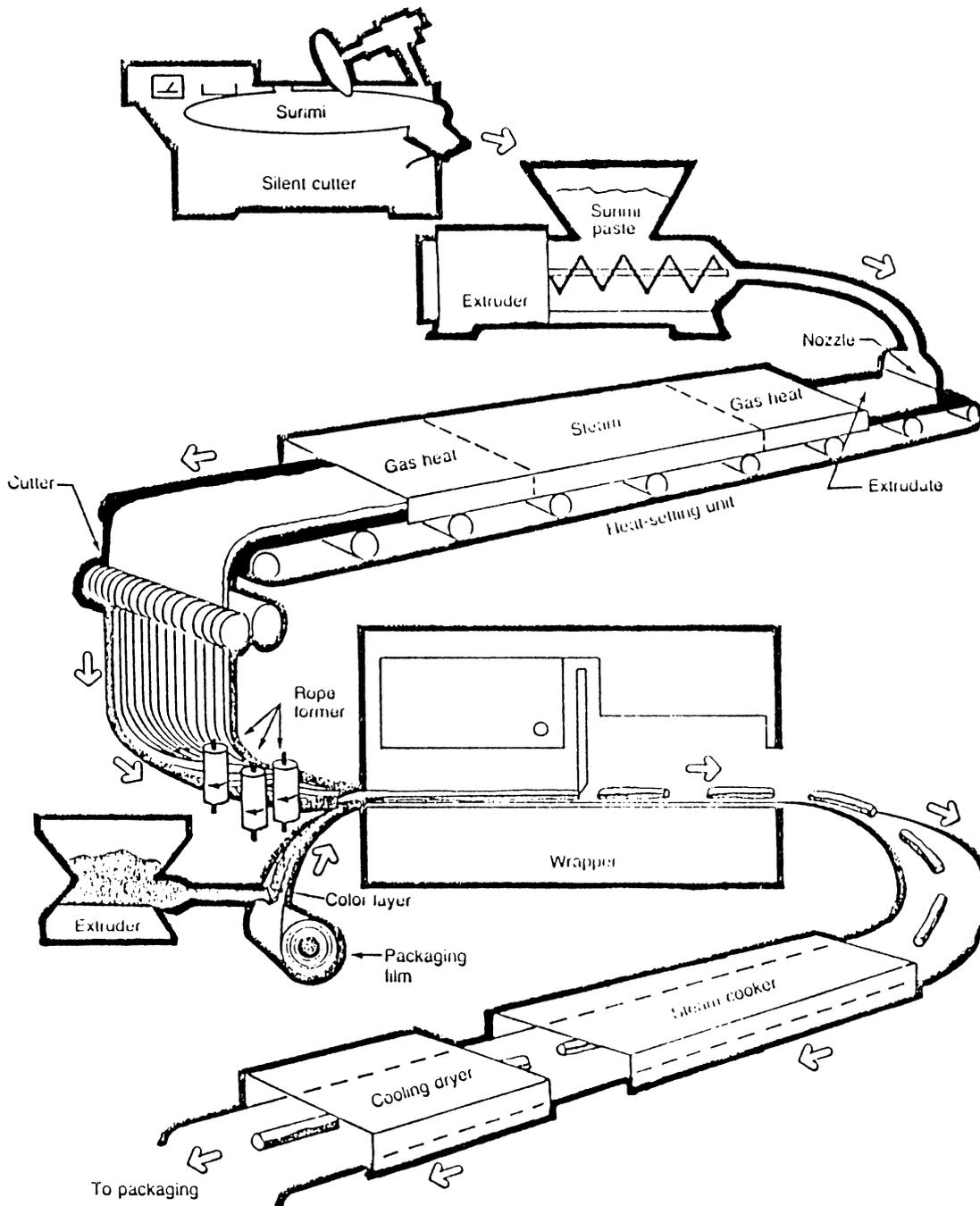


Fig. 6. Small-scale Crab-Leg Processing Line: The color layer is transferred from the film to the meat surface during steam heating.

Molded: These products are produced by molding the chopped surimi into the desired shape and allowing it to set and form an elastic gel (Figure 5). Molding may be accomplished by either a single extrusion or a coextrusion.

For the former, the paste is extruded through a single opening of the nozzle without concurrent texturization. For the latter, the paste is extruded through a nozzle having many separate openings such that strings of extrudate are laid over one another during forming. Coextrusion therefore gives a meat-like texture, whereas the single extrusion results in a uniform and rather rubbery mouthfeel. Restructured shrimp from broken or odd-shaped shrimp of low value and shrimp-flavored surimi-based products are in this category.

Fiberized: These products are produced by extruding the paste into a thin sheet through a rectangular nozzle having a narrow opening 1/25 to 1/8 inch, (1 to 3 mm high). The extruded sheet is then partially heat set and cut into strips of desired width by a cutter, similar to a noodle cutter, having a clearance which allows only partial cutting (4/5 of the thickness), so that a sheet of strips results (Figure 6). The surimi used in this process should be of top grade so that the paste remains sufficiently cohesive and elastic while it is stretched, cut and pulled. The greatest pulling tension occurs between the cutter and wrapper. Strip width is determined by the type of finished product desired. Fine strips are preferred for the fibrous crab-leg product, whereas wider strips are more suitable for the simulated shellfish in the form of sea flake and chunk.

The resulting sheet of strips is folded into a rope (a bundle of fibers) by a simple narrowing device called a rope former. The rope is then colored, wrapped, and cut into a desired length by a wrapping machine. The crab-leg product is produced by a straight cut, while the flake and chunk types are formed by an oblique cut. The oblique cut is evidenced by the zig-zag pattern that is shown when the rope is unfolded. During the folding process, the finished products' texture can be further altered by manipulating the adhesion between the folded layers.

In recent years, substantial improvement has been made in these fiberized products. As a result, consumer acceptance has greatly increased. Nonetheless, there is still plenty of room for improvement, particularly in texturization techniques, flavor, and color.

Composite-molded: For these products, the strings of desired length are mixed with or without surimi paste and extruded into a desired shape. Strings are produced either by a method described above or by slicing a block of surimi gel (approximately 3-4 cm thick) into thin rectangular sheet (about 1/25 inch or 1-2 mm thick), followed by stripping into a desired width. This type of product gives a better bite than the strictly molded variety, which often tend to be rubbery and uniform in texture. Composite-molded products are found in chunk form and sold mixed with fiberized products. Another type of composite-molded product called "fish ham" is prepared by mixing the dice of cured tuna and pork into the fish paste before extrusion.

Emulsified: To make this type of product, surimi is treated in a manner similar to that used when meat is processed for emulsion products. The level of fat added is usually less than 10 percent, and the type of fat used is not limited to animal fat. In fact, vegetable oil is often added, because, unlike mammal and bird meat, fish meat readily produces a stable emulsion with oil. For wiener-type products, the resulting paste is stuffed into casings and steam- or smoke-cooked. A variety of these products have been developed and successfully marketed in Japan for more than 20 years. Sausage-type products can be produced by a method similar to our composite-molded products, as illustrated in Figure 7. The sausage-type products are still in an experimental stage in the U.S. but have been successfully marketed in Japan.

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 3 and 4, 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 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 important raw materials for some name-brand surimi-based products in Japan. For instance, the famous Odawara kamaboko uses croaker only; the Osaka yak-kamaboko uses croaker and sharptoothed eel; the Uwajima yakinuki kamaboko uses some lizard fish; and the Toyohashi chikuwa uses croaker with some blending of sharptoothed eel and lizard fish.

The fish species with relatively high gel-strengths accounted for only a small portion of all the surimi produced annually in Japan, averaging only 12.8 percent 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.

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

TABLE 3. GEL-FORMING CAPACITY OF WHITE-FLESHED FISH

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

Note: Gel-strength is expressed in gm/cm² after heating fish muscle for 20 minutes at 140°F (60°C), unless otherwise specified as follows:

- ^{1/} Heating temperature 122°F (50°C).
- ^{2/} Heating temperature 104°F (40°C).
- ^{3/} Frozen fish.

TABLE 4. GEL-FORMING CAPABILITY OF DARK-FLESHED FISH, SHARK AND FRESH-WATER FISH

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

Note: Gel-strength is expressed in gm/cm^2 after heating fish muscle for 20 minutes at 140°F. (160°C), unless otherwise specified as follows:

- 1/ Heating temperature 122°F (50°C).
- 2/ Heating temperature 104°F (40°C).
- 3/ Frozen Fish.

SURIMI MANUFACTURING PROCEDURES FOR WHITE-FLESHED FISH

EVOLUTION OF SURIMI

Surimi technology has evolved largely through the refinement of manufacturing procedures based on trial-and-error experience. Scientific understanding of these procedures has lagged behind practical advancements.

The most important progress has come 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.

HANDLING OF RAW MATERIAL FISH

The methods used in handling the raw material fish prior to 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.

Freshness 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.

Table 5 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 on 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 5. GEL-STRENGTH IN KAMABOKO DUE TO VARYING DEGREES OF FRESHNESS IN RAW MATERIAL FISH.

	<u>Extremely Fresh</u>	<u>Fish Condition</u>		
		<u>Quite Fresh</u>	<u>Fairly Fresh</u>	<u>Not Fresh</u>
Gel-strength of Kamaboko made from:				
Unleached surimi	1,100	600	350	150
Leached surimi	1,200	850	650	400

Units: g.cm.

A top grade surimi is made aboard factory ships by using very fresh fish, although their manufacturing procedures employ no more than two cycles of washing. 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 Japan Surimi Association has the following recommendations on the handling of the raw material fish following delivery to the plant:

- o The fish must be stored in the (wooden) fish box surrounded by crushed ice.
- o The fish may be stored in a tiled circulating tank approximately one meter deep, filled with water and floating ice. The fish stored in the tank should not be piled higher than about (20-24 inches or 51-61 cm) from the tank floor.
- o When stockpiling the fish in the open air, place the fish on a permeable mattress about (4 inches or 10 cm) above ground level. The fish may be piled about (20 inches or 51 cm) high and covered with crushed ice, and the arrangement may be repeated to create layers of fish.
- o Care must be taken not to allow the fish to freeze under any circumstances.

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 cleanliness, 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 7 shows a typical fish washing machine used in Japan.

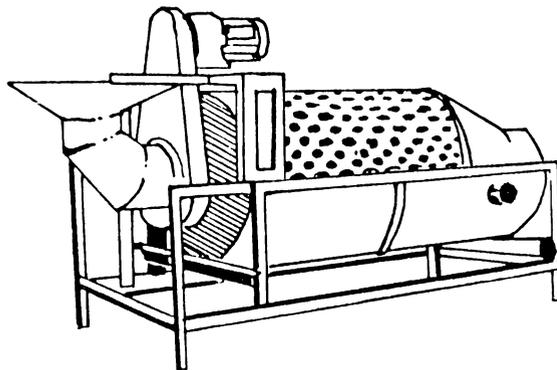


Fig. 7. An example of a fish washing machine.

Surimi producers try to avoid processing fish while they are in rigor and employ systems that handle fish gently at all times. Physical and chemical properties of fish muscle undergo major post-mortem changes that significantly affect functional properties. 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 common practice is 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.

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. This process was discussed in the mince section, only a brief review will be included here. An example of a roll-type meat separator was seen in Figure 1. Many models of various capacities are available, some capable of handling as much as 15,400 lbs (7,000 kg) of fish per hour. The advent of an efficient roll-type meat separator was one reason for the rapid development of Japan's surimi industry.

The roll-type 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 which has numerous holes of $1/8 - 3/16$ in (3 to 5 millimeters) in diameter. A series of rollers press the belt against the drum. 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 that 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. Some impurities are allowed in the minced meat, as these can be removed subsequently with a refiner or a strainer.

Mixing of blood in the minced meat cannot be avoided. If left exposed to air the blood would oxidize rapidly and discolor the meat, so the minced meat is immersed in chilled water immediately after leaving the separator. 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.

LEACHING

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

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

Mechanical Separation of Impurities:

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.

Washing:

The washing dilutes blood, pigments, and other impurities in the minced meat which may cause discoloration to the product or catalyze denaturation of protein.

Leaching:

Contact with fresh water leaches out water-soluble components of the muscle tissue, and inorganic salts believed to contribute to freeze denaturation of surimi. The leaching of water-soluble components in turn isolate the muscle contractile protein, which is responsible for surimi's gel-forming capacity.

Repeated washing reduces residual water-soluble proteins in the meat, which in turn reduces the rate of contractile muscle protein denaturation.

While scientific understanding is still incomplete as to why and how the washing accomplishes these results, it has been established that the greater the number of washing cycles, the stronger the gel-forming capability of the surimi. 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, as much as 30 to 40 times the weight of the meat being processed. The minced meat was stirred in water about seven times its weight, and the supernatant was drained after the mixture was allowed to stand. The cycle was usually repeated five times to complete the process.

About 75 percent of the water used in a surimi plant is expended on the washing process. The water is costly by itself and 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.

PROPERTIES OF LEACHING WATER

Principal factors determining the effectiveness of the leaching water are the hardness and the acidity or alkalinity.

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

DEGREES OF LEACHING

As much as 50 percent of all water-soluble components in the fish muscle are removed after the first leaching cycle. 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.

The gel-forming capacity is proportional to the number of leaching cycles to which the fish meat is subjected.

In general, a duration of 30 to 40 minutes is sufficient to achieve the objectives of leaching. The amount of water 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 seven times the output. Surimi prepared with the leaching water five times its weight deteriorates rather distinctly while in cold storage. Aboard the factory ship where very fresh fish are processed, the leaching water volume can be as little as three times the amount of surimi produced.

EFFECTS OF SALT CONCENTRATION

The gel-forming component of fish protein exhibits wide variability in water holding characteristics as a function of the salt concentration. A very low salt content causes the water holding tendency of the fish meat to rise. Under this condition, frequently caused by the washing cycle that removes the water-soluble salts from the meat, the meat tends to hydrate and swell. Such meat is difficult to dewater, so it is advisable to add sodium chloride prior to the dewatering process.

EFFECTS OF WATER TEMPERATURE

Warm wash water is more conducive to dewatering than cold water. While the cold water is desirable from the standpoint of preserving product quality, 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 50°F (10°C) in order to achieve a reasonable dewatering efficiency.

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 5, somewhat alleviated but did not eliminate the heat problem.

A better solution to this heat problem was the introduction of a refiner, a straining machine which could work on a wet slurry. As shown in Figure 8 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 aboard factory ships beginning around 1975.

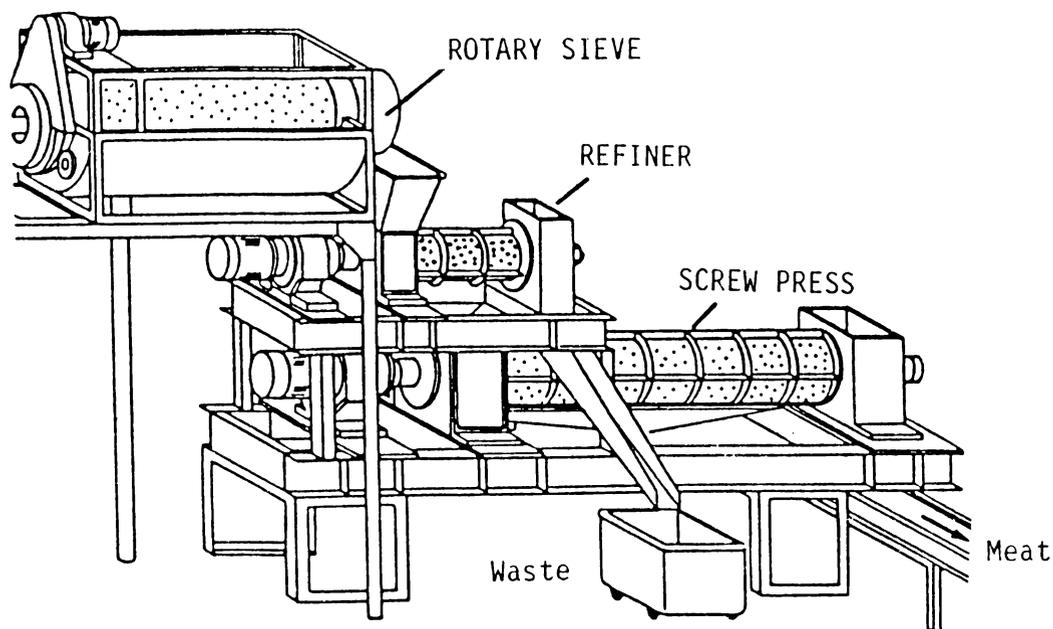


Fig. 8. Arrangement of a refiner.

The introduction of a screw press as the standard dewatering machine was 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. On the other hand, the product could flow continuously through the screw press 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.

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

ADDITIVES

The minced fish meat, a raw surimi, contains as its chief ingredient the muscle contractile protein that provides an elastic property when processed into surimi-based products. Elasticity is closely correlated with the sensory (taste and odor) quality of the product and is considered in Japan to be one of the most prized properties of kamaboko.

A surimi which can be stored while retaining its gel-forming capability became a reality only with the discovery of additives that 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.

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. A silent cutter can also be used for mixing the cryoprotectant additives into raw surimi.

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 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 also have been found to be effective anti-denaturants.

How certain chemicals protect fish protein from freeze denaturation remains unanswered. Accordingly, the prescription of the anti-denaturant additives being used today is experimental (trial and error) in nature, virtually unchanged since their discovery in 1960.

Tables 6 and 7 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 6. FOOD ADDITIVES FOR LAND-PROCESSED FROZEN SURIMI

Raw Material Fish	Grade	Puribesuto*		
		SucrosePercent.....	TP433	TP423
Alaska Pollock	Special	4.0	4.6	0
	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 7. FOOD ADDITIVES FOR SHIP-PROCESSED FROZEN SURIMI

Alaska pollock	Surimi Type	SucrosePercent.....	Sorbitol	PolyPhosphate	Salt
	Salt-free	4	4	0.3	0
	Salt-added	5	5	0	2.5

Sugar, the most important component, comprises 8 percent of the salt-free surimi and 10 percent of the salt-added surimi. Half the sugar is provided by sorbitol in order to avoid an excessively sweet taste and a brownish tint in the kamaboko that could result from a high sugar content. The content of polyphosphates ranges between 0.2 and 0.3 percent of frozen surimi. While a higher content is 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 percent. Glyceride reduces the size of ice crystals in frozen surimi through its emulsifying action and provides a soft, fine texture to kamaboko.

Puribesuto is a prescribed additive developed in 1978. Puribesuto TP 433 contains 87 percent D-sorbitol, 6.5 percent polyphosphate and 6.5 percent glyceride. Puribesuto TP 423 contains 89 percent D-sorbitol, 4.4 percent polyphosphate, and 6.6 percent 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. Other studies indicate that polyphosphates play little, if any, role in providing anti-denaturant protection to surimi but help reinforce the gel-strength. Because 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.

FREEZING AND COLD STORAGE

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

The secret of good freezing is avoiding the formation of large ice crystals, which occurs in the critical temperature range of between 30-23°F (-1°C and -5°C.) This is accomplished by freezing the product quickly or minimizing the time the product remains exposed to the critical temperatures. Comparing three commonly used freezers--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 ability. The important conclusion is that the storage temperature should remain below -4°F (-20°C) with minimum fluctuation.

THE SURIMI PRODUCTION PLANT

Figure 9 shows a typical flow diagram for manufacturing 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 is minced fish meat. A rinsing procedure is normally sandwiched between these two steps in order to remove remnants of intestinal tracts and dark belly membranes, which are difficult to remove by any subsequent procedures. The protease from the digestive organs

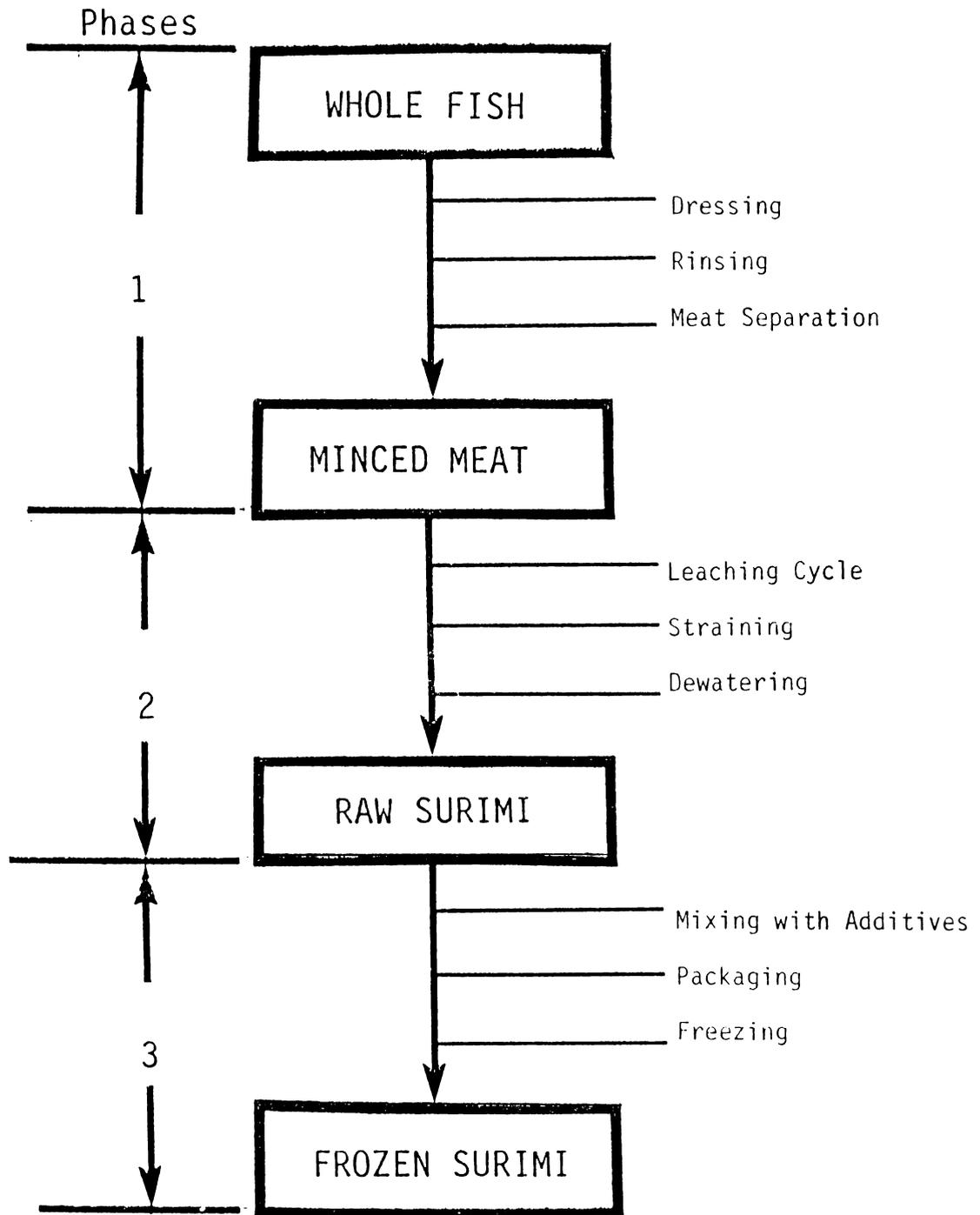


Fig. 9. Typical surimi manufacturing procedures for white-fleshed fish.

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 washing steps: first in an agitating water tank and subsequently in a rotating sieve. 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 fish's freshness. 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 merging from the leaching cycles is a mixture of surimi in a slurry form and an assortment of impurities such as bone fragments, ligaments and scales. The product must be strained and dewatered in order to isolate the surimi.

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. The mixing procedure is performed in a silent cutter or ribbon blender. The product is then weighed, frozen and cartoned.

PROCEDURES AT SHORE PLANTS

Figure 10 shows an example of an equipment arrangement in a land-based plant. While this example represents some of the most current technology, some old methods are still practiced by a number of manufacturers. The practice of dewatering the wet mince before applying a strainer is widely followed.

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

Maximum fish yield, the conservation of energy and effluent disposal are major concerns. To reach these objectives 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.

PLANT LAYOUT

A selected example of plant layout is described in this section.

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 was dated July 30, 1984 and the corresponding flow diagram in Figure 9.

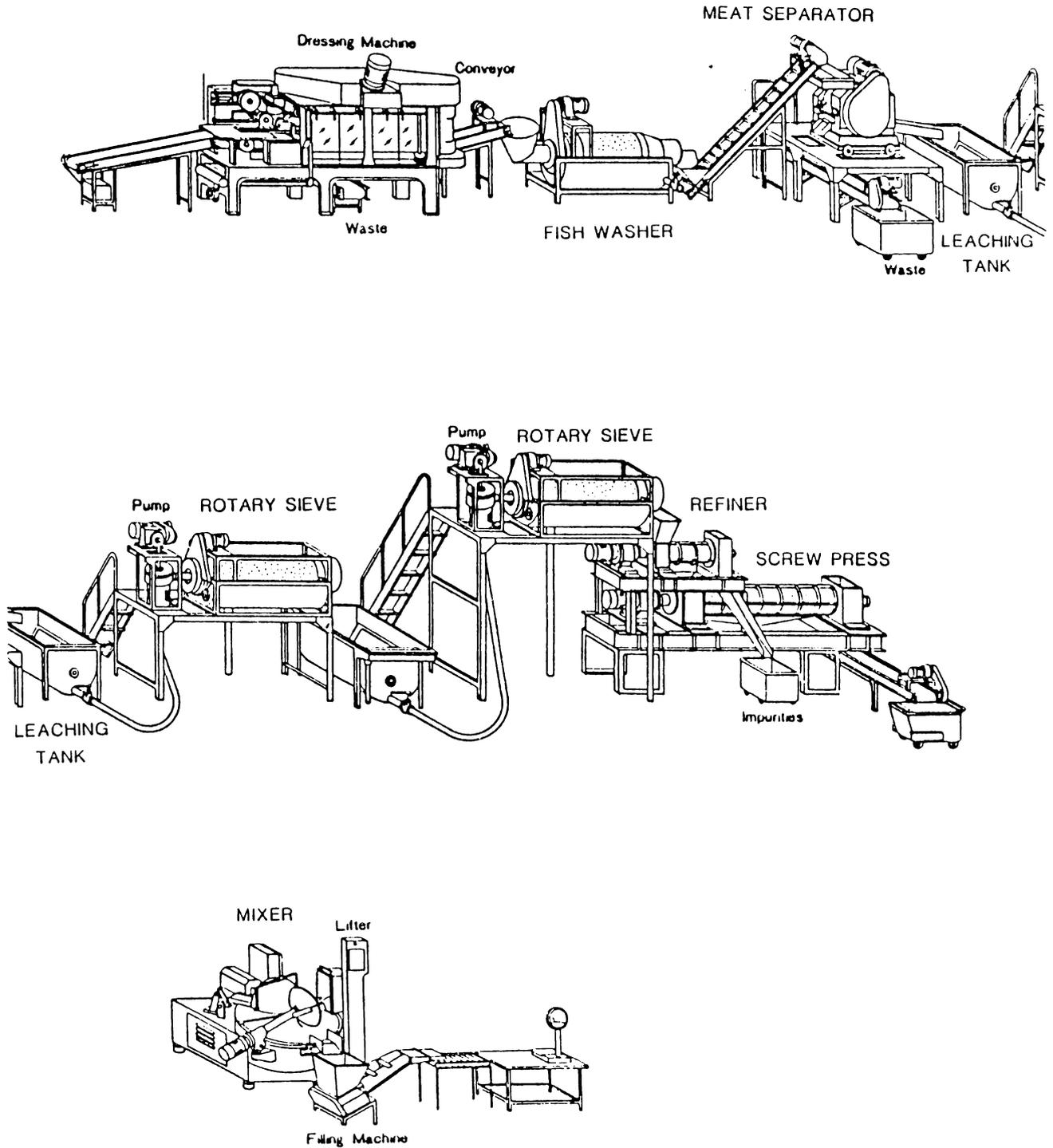


Fig. 10. An example of the equipment arrangement in land-based surimi plant.

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, which essentially repeats the same procedures.

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 secondary grade surimi. Optionally, 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; an alternative procedure routes the waste to a separate rotary sieve connected to an independent screw press. (A different manufacturing procedure is represented by Figure 11, next page.)

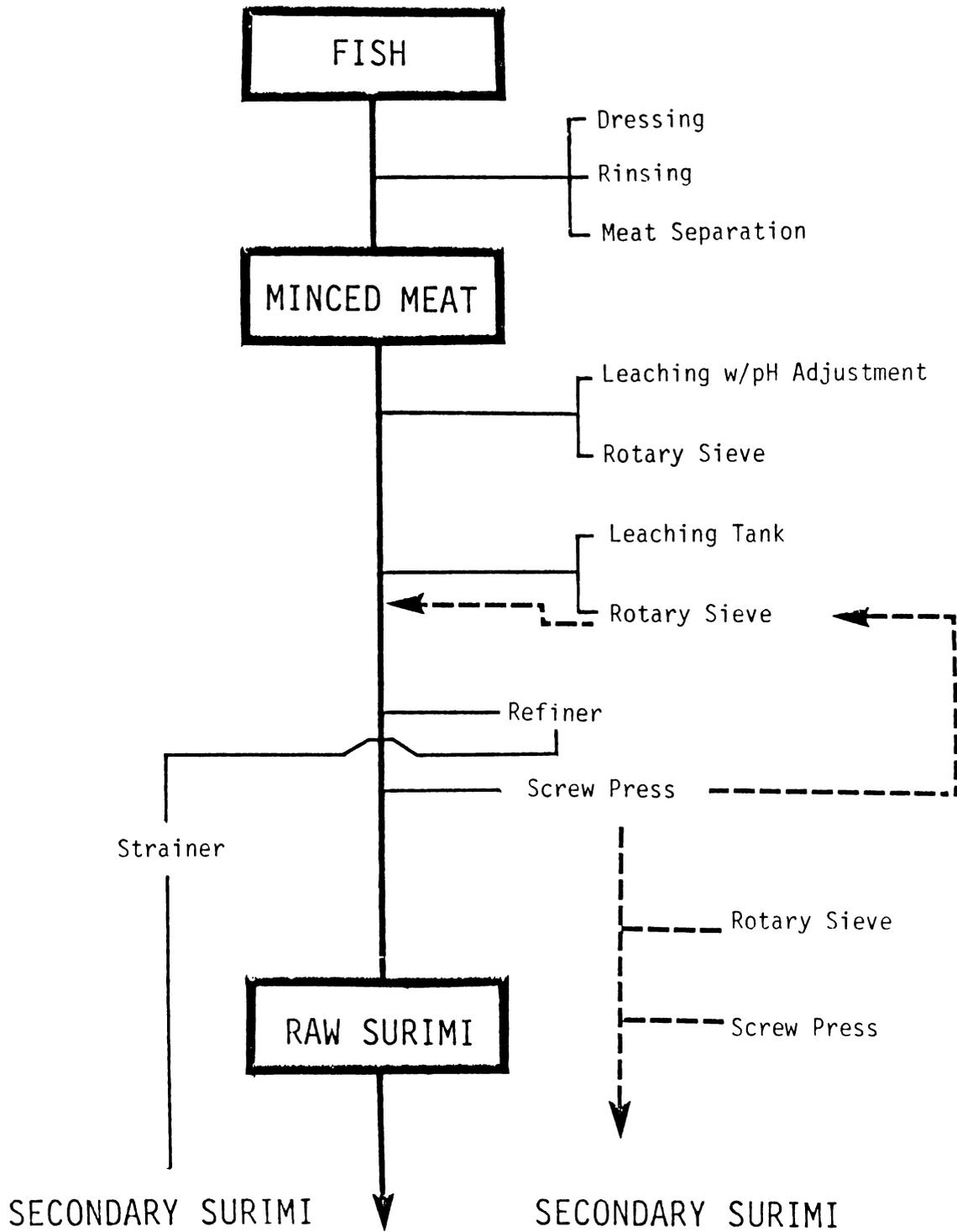


Fig. 11. One example of procedures in a surimi-manufacturing plant.

SURIMI BASED ON DARK-FLESHED FISH

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, surimi-based products based on these dark-fleshed fish have not received a significant level of consumer acceptance because of its weak gel-strength and the product's dark color and fishy aroma.

Developing an improved fish-cake product from dark-fleshed fish, particularly from sardine and Pacific mackerel, began to receive industry attention in the late 1960s when the harvest of bottom fish in the western Japan and the East China Seas, the traditional raw material for "kamaboko", began to decline sharply. By 1965, a method of leaching the dark fish meat in an alkali salt solution to improve gel-strength had been patented.

Efforts to develop a commercially viable surimi technology using dark-fleshed fish species began in earnest in 1977 when the Japanese Fisheries Agency launched a five-year program to develop the technology. The major impetus to this national program was the uncertain future of the supply of Alaska pollock, which had already declined considerably. The catches of sardine and Pacific mackerel in Japan's home waters, on the other hand, had shown a dramatic rise, with combined catch of both species of 1.25 million metric tons in 1972 and 3.26 million metric tons in 1978.

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 problems made it difficult to apply the frozen surimi technology that had been developed for white-fleshed fish such as Alaska pollock.

Products based on two methods developed during the Fisheries Agency Program have exhibited an excellent capacity for cold storage as well as a high level of consumer acceptance. Sardine surimi manufactured by the Nagasaki Fishery Processors Cooperative has been reported to have a cold storage capacity for up to 2 years with little evidence of denaturation. A Pacific mackerel surimi exhibited virtually no deterioration after 14 months in cold storage.

TECHNICAL PROBLEMS 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.

Rapid Protein Deterioration

Migratory fish species such as sardine and Pacific mackerel contain a large amount of glycogen (a type of sugar somewhat similar to starch) in their muscle in order to support their energetic life style. When the fish die, glycogen in the muscle degrades into lactic acid, which affects the gel-forming capabilities.

Freshness is extremely short-lived in sardine and Pacific mackerel. The gel-strength drops rapidly in surimi products, particularly during the early period of storage. Defining "critical" freshness of the fish as where the surimi made from it is capable of showing a minimum acceptable gel-strength of 300 to 400 gram.cm, 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, smaller fish lost freshness more rapidly than large ones.

Other factors affecting gel-strength in kamaboko products from dark-fleshed fish include the age, the fish school, and the season of landing. In particular, summer sardines are known to have less gel-strength than winter sardines, partly because of the greater fat content in summer fish and because of the greater difficulty in preserving fish in summer.

Large Content of Water Soluble Protein

The dark flesh of sardine and Pacific mackerel contains a distinctly large amount of water soluble protein, a component which must be removed through the leaching process because of its suspected role in thwarting acceptable gel-forming. The large amount of soluble protein, which will wash out in the waste water, requires additional effort for waste treatment in surimi production from dark-fleshed fish. Soluble protein in the dark flesh dissolves very slowly in normal fresh water, therefore, a special leaching method must be used to maintain a reasonable speed in the leaching treatment.

Large Content of Dark Muscle Tissue

Dark muscle tissue comprises as much as 10 to 20 percent of the muscle in sardine and Pacific mackerel. By comparison, it constitutes only a few percent in white-fleshed fish. The dark muscle tissue, because of its large content of fat and hemoglobin pigment and a proportionally lower content of gel-forming 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 an important step in the production of surimi from dark-fleshed fish.

Large Content of Fat

While dark-fleshed fish generally contain larger amounts of fat than 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 percent, and that in Pacific mackerel

between 2.1 and 28.7 percent. 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 the 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.

MANUFACTURING PROCEDURES

Four different surimi manufacturing procedures have 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.

Japan Surimi Association (JSA) Method

This method is intended to allow maximum utilization of the existing surimi production facilities built for Alaska pollock. The resulting product has numerous advantages, including 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 been launched in some areas. Disadvantages of this method lie in its dark appearance, weak gel-strength and fishy odor, as the mechanical fish dressing procedure and the subsequent processing procedures employed are unable to completely remove dark muscle tissues of the fish.

Figure 12 illustrates the flow diagram of the JSA method.

Because sardines are generally small and because only small Pacific mackerel are 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 sardines or 300 to 400 Pacific mackerel per minute.

The highlight of the JSA method is the leaching process, which, as shown in Figure 12, is performed in three cycles:

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 maintains a neutral pH level during the leaching process which enhances the products' gel-strength. Salt solution is used in the third leaching cycle to facilitate the dewatering process.

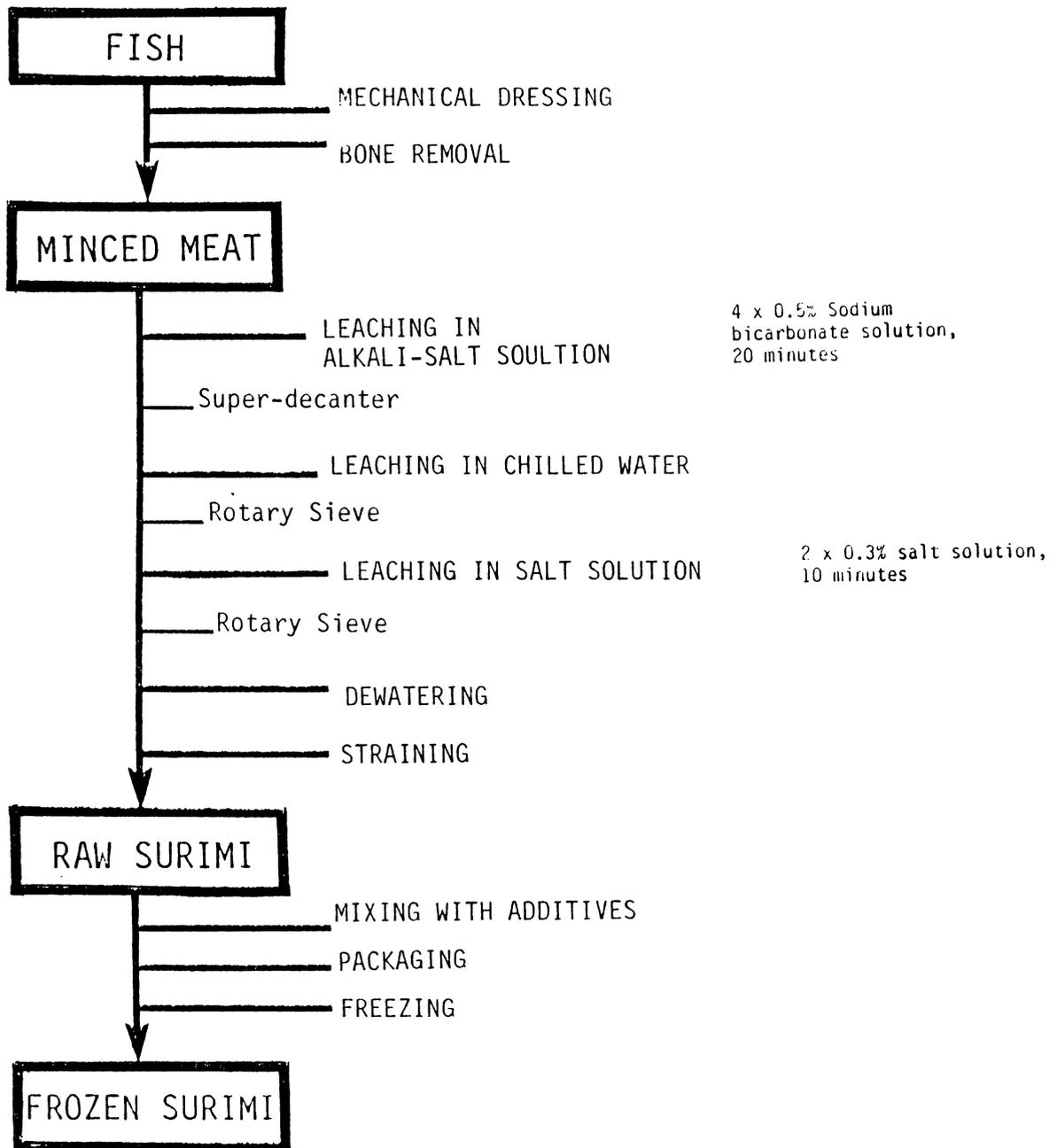


Fig. 12. Flow diagram of JSA Method for manufacturing surimi from dark-fleshed fish.

The JSA recommends three leaching cycles for dark-fleshed mince. 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 recommended for dark-fleshed meat, as the mixture of fat, water and protein can cause the formation of an emulsion, which is extremely difficult to dewater.

Jet Method

This method 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, which also provides some degree of leaching. The method almost completely removes the dark-muscle tissue and fat, giving the product 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 13 illustrates the flow diagram for this method.

The fish is passed through the head cutter and the fillet machine, then rinsed to remove scale. The filleted fish is 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 about 140 to 280 psi (10 to 20 kg/cm²). 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 meat separation process is dewatered in a screw press before passing through the leaching cycles. The first cycle is performed in 0.05-0.1 percent 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 thorough removal of suspended fat.

Other Methods

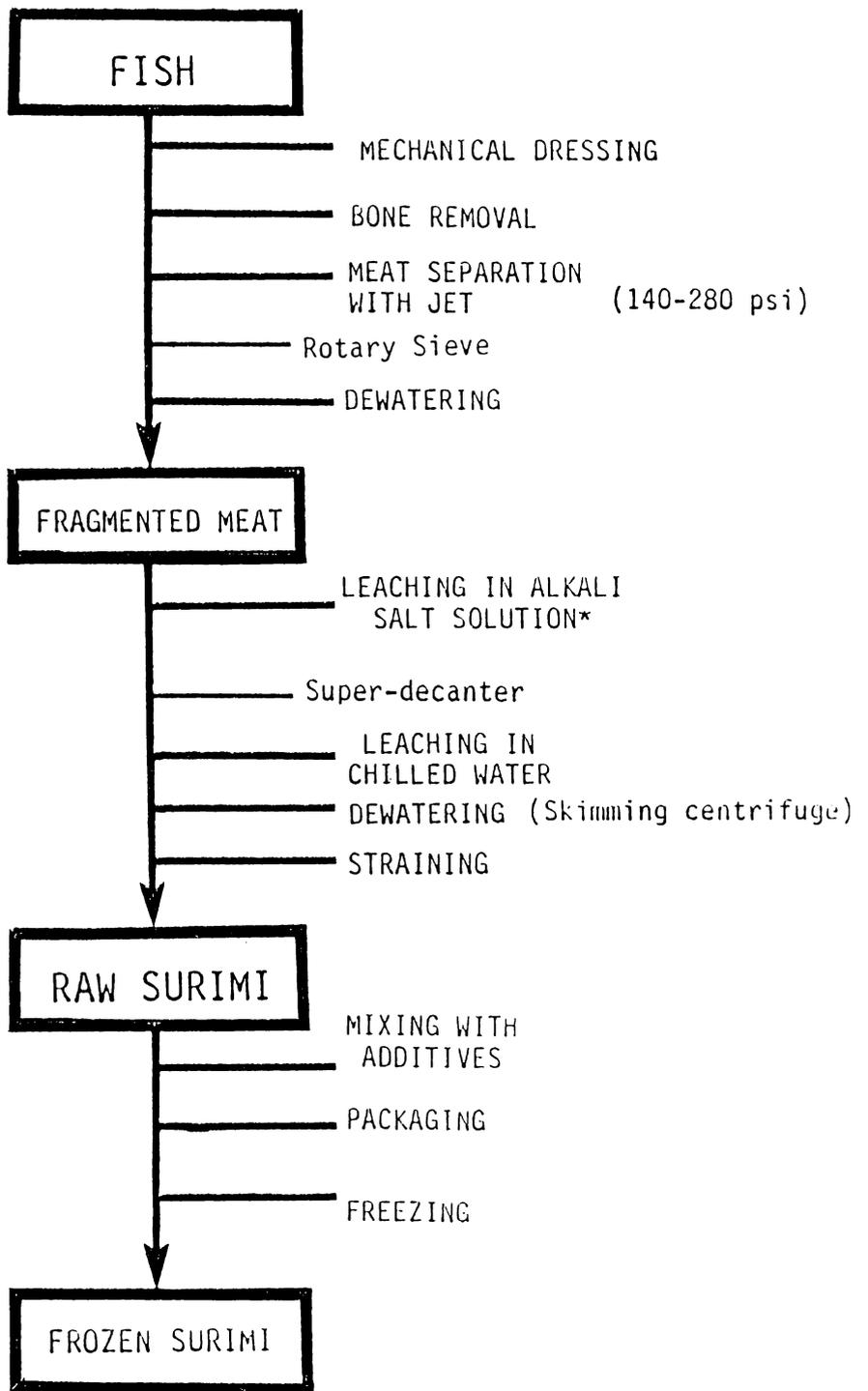
Two other methods were introduced during the national program between 1977 and 1981. Both methods aimed to reduce the water requirement in the production process and would cut water use by one half as compared with the previous two methods described. One of these methods consisted of micronizing the minced meat before leaching and the other of recycling the waste water between successive leaching cycles.

Figures 14 and 15 illustrate the flow diagrams of these methods.

In the micronization method, minced meat is brought to a neutral pH level by soaking in an equal amount of 0.8 percent 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 a yield from this method of about 17 percent, 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 fat content. 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.



* (5 x 0.05-0.1% Sodium Bicarbonate Solution, 20 minutes)

Fig. 13. Flow Diagram of Jet Method for manufacturing surimi from dark-fleshed fish.

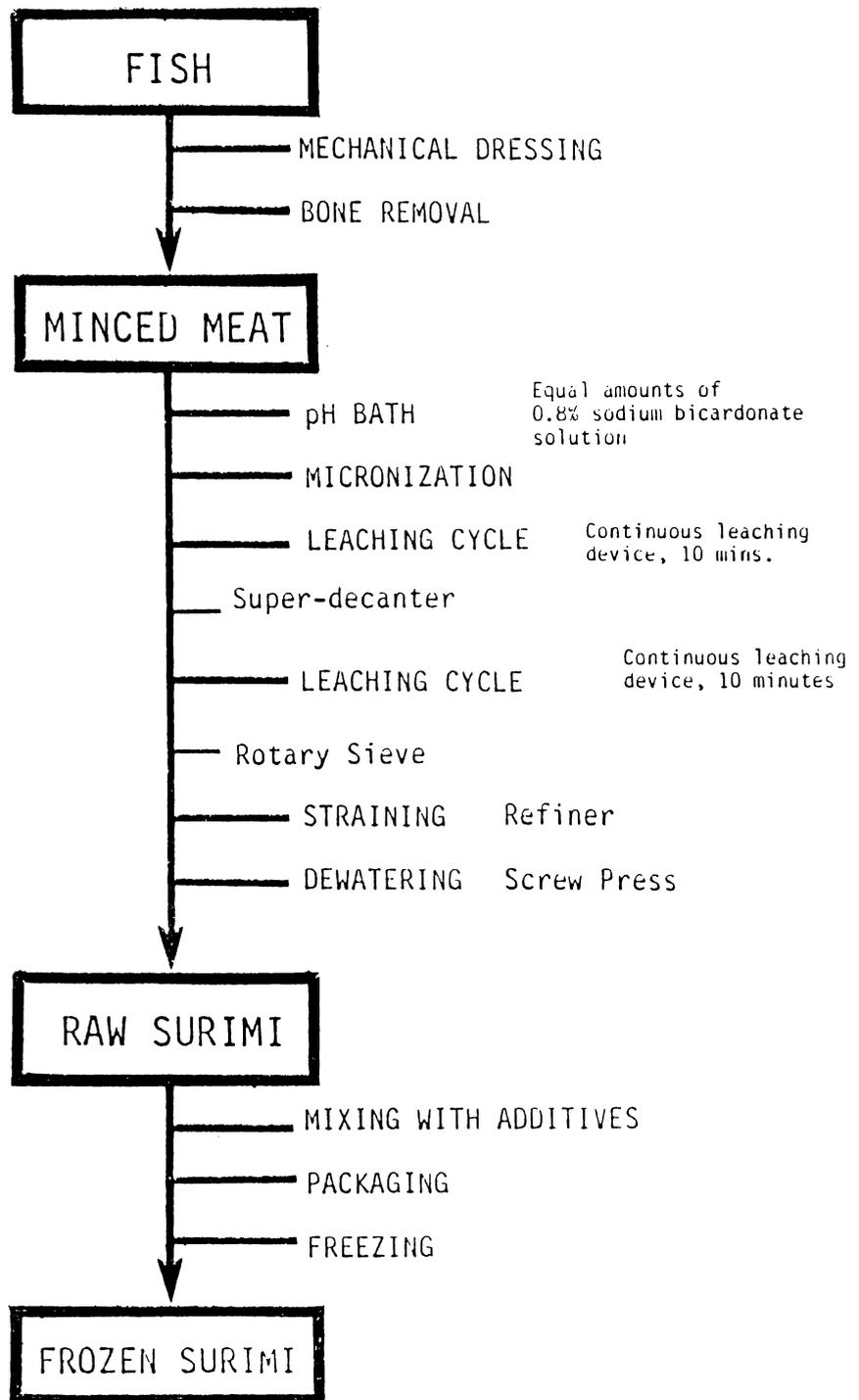


Fig. 14. Flow Diagram of Micronizing Method for manufacturing surimi from dark-fleshed fish.

SURIMI QUALITY

QUALITY STANDARDS

Methods for defining the quality of land-processed frozen surimi have been revised numerous times since standards were introduced in 1964. Unlike ship-processed surimi, for which quality is relatively uniform and consistent, quality of land-processed surimi varies widely largely due to the freshness of the fish used as raw material.

Although the Japan Surimi Association (JSA) quality standards for surimi were 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", first, 2nd, and "off-grade". A new requirement for acceptable gel-strength was incorporated in the 1974 revision. As shown in Tables 8 and 9 the current grade standards incorporate four major criteria: water content, additives, the folding test for elasticity, and gel-strength.

The 1978 revision (Table 10) was intended to enhance the sugar content allowance from 5 percent to about 8 percent 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 percent of Japan's land-processed surimi is classified as grade 2, although a wide variability exists among these products. This situation has resulted partly from the insufficiency of the existing quality standards and partly from a lack of compliance with the quality standards, which are essentially voluntary. Inconsistent quality in grade 2 products has caused a considerable number of claims from users. In January 1985, the Japanese Fisheries Agency announced a plan for a feasibility study aimed at government-regulated quality standards for land-processed surimi in place of the existing industry-regulated standards.

In factoryship operations in which the fish is processed into surimi as soon as it is caught, freshness is not an issue. Table 11 shows the composition standards for ship-processed surimi. 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 8. Industry Quality Standards for Ship-Processed Frozen Surimi

<u>Fish</u>	<u>Surimi Type</u>	<u>Sucrose</u>Percent.....	<u>Sorbitol</u>	<u>Poly-Phosphate</u>	<u>Salt</u>
Alaska pollock	Salt-free	4	4	0.3	0
	Salt-added	5	5	0	2.5

TABLE 9. 1974 JSA* QUALITY STANDARDS FOR SALT-FREE, LAND-PROCESSED FROZEN SURIMI

Fish	Grade	Water Content (%)	Additives (%)		Folding Test***	Yield Stress (g)
			Sugar**	Phosphate		
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 10. 1974 JSA* QUALITY STANDARDS FOR SALT-ADDED, LAND-PROCESSED FROZEN SURIMI

Fish	Grade	Water Content (%)	Additives (%)		Folding Test***	Yield Stress (g)
			Sugar**	Phosphate		
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 11. 1978 JSA* QUALITY STANDARDS FOR SALT-FREE, LAND-PROCESSED FROZEN SURIMI

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

* JSA - Japan Surimi Association

** Puribesuto TP 433-Consists of D-sorbitol 87%, glyceride 6.5% and polyphosphate 65.%.
Puribesuto TP 432-Consists of D-sorbitol 88.9%, glyceride 6.7% and polyphosphate 4.4%

*** () - Potato Starch Content

BATTERS AND BREADING

Ingredients used in batter and breading formulations fall into two groups: Those that comprise the bulk of the formula and those that are present in relatively small quantities. The first group would include: flour, eggs, milk, while the second would contain greens, spices, whey, leavening agents, starch, salt, and sugar. These ingredients, from a quantitative perspective, determine the physical differences in batters and breadings.

Consumer appeal and texture of a coating vary among the types of products such as red and white meat, fish and shellfish, and vegetables. Even within a group, as fish and shellfish, the physical characteristics may vary depending on consumer preference within a market area. For example, corn breading might be preferred in the South while four coating would be used in the Northeast.

Flour in a dry batter mix constitutes approximately 80-90 percent of the total weight. In a breading mixture, flour is included in a lower amount and normally ranges between 70-80 percent. Major flour sources include corn, rice, soy and barley. Wheat flour differs from the others in that it has the ability to form a cohesive mass when hydrated and subjected to mixing. There are also differences in the wheat flour depending on whether soft or hard wheat is used.

Several major characteristics or functional properties can be used to distinguish between breadings. These are as follows:

Mesh

The particle size of breadings can range from half-inch cubes to fine particles that will pass through a 80-mesh standard sieve. Typical breadings, however, will pass between a No. 5 U.S. and a No. 80 U.S. sieve. Particle size is the major factor affecting the appearance and texture of the coated food. If fine mesh is used, the batter's ability to absorb liquid is increased. A coarse coating can result in a loosely adhering product that will fall off during handling or transportation. Consequently, breadings are chosen that usually range between a U.S. No. 20 and 60 screen.

Browning Rate

The browning rate depends largely upon the amount of sugars in the coating. A fast browning rate provides for high processing rates, which could permit either the use of a lower frying time *or* temperature. The ability to use shorter frying time and lower temperatures reduces shrink while the faster processing time increases efficiency and reduces labor and capital equipment expenditures. In some applications, the ability to reduce the sugar content and retard the browning rate is highly desirable. This is particularly true with large or thick foods which require long frying times. Consequently the ability to vary browning rates permits the balancing of color, texture, and cooking time.

Moisture and Oil Absorption

The rate at which a particular breading absorbs moisture and oil depends on several factors, including particle size and porosity. A coating with a porous structure will absorb and release moisture and frying oil much more quickly than a more dense product.

There are various types of prepared breadings which are applied to battered foods to enhance their appearance or sensory qualities, Table 12. These include:

Cracker Meal is made by manufacturing a dough from flour, sugars and salt, drying to approximately 35 percent moisture; and crumbling the product through a mill or grinder. This is the product most extensively used on fish and seafood products.

Bread Crumb is more porous than the cracker meal and tends to absorb more oil and moisture. It also tends to darken more quickly. The crumbs cannot tolerate long frying times but they do have a more friable or tender texture than cracker meals. This product differs from the previous in that the dough mixing operation is followed by a fermentation time.

Oriental or Japanese Crumb has a splinter-like shape, low density, and is very porous. The dough is baked in a special electrical oven which requires less than half the time of the conventional oven system. The result is a product that has low density and a low moisture content.

Battered and Breaded Seafoods

Seafood accounts for approximately 50 percent of all frozen battered and breaded products in the United States. Precooked and raw fish portions are the most frequently coated products followed in order by speciality products such as shrimp, fish sticks, and scallops. Breadings have been long used in the seafood industry, but the application of batters did not come into prominence until the 1960s. In the mid-1960s, a relatively new concept called "batter frying" became prevalent within the seafood industry. In this process, the food is usually given a predest with flour or dry battermix, coated with a batter, and prefried to set the batter and impart the desired frying oil content for enhanced texture and quality. Figure 1 diagrams the four basic types of coating systems that duplicate traditional methods of preparing products manually. The batters can be either tempura (leavened) or non-leavened (Table 2). Production rates for batter fried products are half that for a breaded product due to the space between products on the conveyor belt and additional time required for coating and draining. One of the biggest challenges limiting the expanded consumption of battered products is the inability to produce a microwavable product that retains crispiness.

One problem associated with battered products has been the uneven distribution of coating on the product. In some instances the batter fails

Table 12. Basic Machining Characteristics of Breadings ^{1/}

BREADING TYPE	GENERAL CHARACTERISTICS	MACHINE HANDLING	MACHINE TO BE USED
Free-flowing breadings	Fine, uniform granulation, not fragile	Easy to handle, flow without problems in machinery	Can be run on every machine
Coarse breadings (Japanese, Pandora, Panko, Oriental)	Non-uniform granulation, fine and coarse particles, fragile	Extremely difficult to handle, presents two challenges to the processor: ..Breeding must be prevented from grinding up ..Product must be uniformly coated on top and bottom with the same ratio of fine and coarse crumbs	Only special type machine can be used. Usually can run free-flowing coatings too.
Flour type breadings	Usually raw flour; can be a dry batter mix, for example.	Difficult to handle, material packs and bridges easily. This type of breadings must be driven (pushed) through the machine.	Special type machine must be used. Usually can run free-flowing coatings too.

^{1/} Stein Associates, Inc.

Table 13. Basic Machining Characteristics of Batters ^{1/}

BATTER TYPE	MIXING	TEMPERATURE	VISCOSITY CONTROL
Non-Leavened (Conventional)	Can be pumped. Batters are mixed continuously to keep batter solids in solution. Viscometer cup reading to 25 seconds.	Preferably under 10°C (40-50°F)	It is possible to obtain a continuous viscosity control. The Stein ABC unit automatically mixes dry batter mix with water to a pre-set thickness (viscosity) and maintains that thickness continuously. It also controls the batter temperature.
Leavened (Tempura)	Cannot be pumped. Mixing must be done quickly and then stopped. Mixing is not done continuously after that. Batter should be transferred quickly to the applicator.	"Cold Batter" 4-7°C (40-45°F) "Warm Batter" 18-24°C (65-75°C)	There is no continuous viscosity control. Identical batches only.

^{1/} Stein Associates, Inc.

to coat the entire product leaving large void areas. Also, the coating can be applied too thin so that it loses flakes or chips off. A third problem occurs when too heavy a coating is applied.

It is important that an effective quality assurance program be initiated to insure the production of high quality battered and breaded food products. The program should include all incoming fish blocks and other frozen seafood products. Quality control examinations are important to insure that the block adheres to purchase specifications such as block dimensions and weight, microbial counts, foreign matter, water content, additives, evidence of decomposition, or quality determination (freeze-thaw cycling), and species. Quality assurance is important to the production of high quality products since seemingly minor compositional properties, such as water, can have a direct affect on batter adhesion or cooking time. A high water content can cause an ice glaze on a surface during the sawing operation in block subdivision. The glaze will result in poor batter adhesion to the fish stick or portion. Even without sawing and glazing, however, blocks with a higher water content can have a high incidence of batter adhesion problems. The main problem is "blow-off" which is the loss of batter when the product leaves the frying oil.

All quality assurance programs should include an examination of batter mixes, breading, and batter ingredients. The quality program also should extend to storage conditions because experience has shown that products stored in a dry, cool environment produce higher quality batter coatings.

An important step in monitoring quality is proper batter mixing. Cold water increases batter adhesions, consequently most processors maintain water temperature at 50°F (10°C) or lower.

The batter mix is hydrated by adding water either in a mixing bowl with a large whip or an automatic batter mixing machine. The batter should be mixed past the point where no unwanted lumps remain. In most cases, a batter will perform better if mixed for a longer, rather than shorter, period of time. Too short a mixing time will result in a partially hydrated batter with poor preparation characteristics, lumps and gummy textures.

It is important that batter viscosity be monitored and closely regulated during production. There are several methods of measuring viscosity, and it is recommended that measurements be taken on the production line and the laboratory. All adjustments to the batter should be made as soon as possible.

Prior to battering, seafood products are generally given a predusting step to create a product surface that will increase batter adhesion. Salt has sometimes been used as an additive to increase adhesion since it melts the ice on the product surface and the resulting liquid can hydrate the produce, thereby improving adhesion. It is sometimes appropriate to include taste and odor ingredients in the predusting since their inclusion in the batter can affect product characteristics, such as browning.

After predusting, the product is placed on a conveyor belt and moved through the batter applicator. Batter applicators are usually of two types: (1) the product being coated completely submerged in batter and (2) the batter is poured on in a continuous cascade. The amount of batter pick-up is affected by several factors including line speed or degree of bacteria hydration. Incomplete product coverage can be caused by line speed, product shape, faulty or lack of predusting material, and the degree of glazing on the product surface.

The final operation is the prefrying is to set the batter coating and to facilitate further processing. Prefrying is important; it produces a desirable color, provides a crunch texture, and improves sensory characteristics. Proper prefrying depends on maintaining frying oil temperatures at the desired temperature, insuring that the oil is replaced or filtered as necessary, and insuring that frying time is properly maintained. The customary prefrying time of 30 seconds is usually employed.

After cooking the product is usually frozen. Care should be exercised to insure that product does not cover or touch during frying as this can cause the batter coating to be removed when the product is separated at packaging. All products should be frozen as quickly as possible to insure the coating adheres to the product.

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1. T F Mince Technology is applied to commercial species to obtain a higher yield from whole (headed and gutted) fish and to reclaim additional flesh from filleting wastes.
2. T F Mince technology may offer the best potential for increased exploitation of small pelagic fish species whose annual catch exceeds 20 million tons.
3. T F The major problems in using small pelagics are: high levels of polyunsaturated fats; the effects of fat degradation on taste and texture; and the contamination of the minces by highly proteolytic gut contents.
4. T F A problem in mince technology is the bone fraction which can consist of 50 percent of whole or gutted fish, or more than 30 percent of filleting wastes.
5. T F Commercially significant freshwater fish are generally less consistent in their properties than marine resources and consequently have limited potential for commercial mince production.
6. T F Protein degradation can occur during mince frozen storage through the action of chemicals that are produced by the fish tissue.
7. T F Minced fish usually have a darker color than the natural material because of skin pigments and blood.
8. T F While many fish species can be heavily parasitized, the worms and larvae in the flesh are not transferred to the mince. Consequently parasites are not a potential danger.
9. T F The mince from some species of fish should not be nitrite-cured as there is a risk of nitrosamine formation.
10. T F The contamination of mince by visceral contents from certain tropical species can result in a mince with potent neurotoxins.
11. T F It is possible to produce a high-quality mince by using low pressures, intermediate perforation sizes, and multi-pass systems.
12. T F Producing mince with high belt pressures and shear may increase discoloration, cause protein degradation and affect long term lipid stability.
13. T F Washing improves the texture of fine and coarse minced gel products.

14. T F The color and appearance of mince products are vital consumer attributes, however, in the developing world color is unimportant.
15. T F When processing a fish of the scombroid family and other species to mince, there is an inherent danger of toxin introduction.
16. T F The storage life of frozen mince made from good quality cod flesh is at least 6 months when stored at 0°F (-18°C).
17. T F Texture characteristics of minced fish tissue can be improved through the incorporation of spun vegetable protein fibers or extrusion-textured vegetable protein.
18. T F Surimi is not in itself a food stuff but an intermediate raw material from which the traditional Japanese kneaded foods called "kamaboko" are manufactured.
19. T F The Japanese word "surimi" literally means "raw fish".
20. T F Sugar is added to surimi to improve its taste characteristics.
21. T F The most important mechanical innovations that led to the automation of surimi manufacturing were the screw press and automatic filleting machine.
22. T F The refiner was an improvement over the strainer in surimi production because it was more efficient in removing impurities and also did not have a heat problem.
23. T F The main ingredient of kamaboko is a homogenous gel of ground fish muscle, obtained by kneading the thawed frozen surimi or raw surimi into a paste with salt.
24. T F Surimi analogs may be divided into three major categories according to their fabrications and structured factors.
25. T F The predominance of Alaska pollack as the raw material fish for surimi indicates that quantity and economy have largely replaced gel-strength as the main qualifications for the raw material for surimi.
26. T F New technology in the manufacture of surimi has permitted high-grade surimi to be manufactured from fish lacking freshness.
27. T F It is common practice to process fish into surimi within about five hours after death.

28. T F The Japanese have long known that the greater the number of washing cycles, the less the gel-forming capability of the surimi.
29. T F About 50 percent of the water used in a surimi plant is used in the washing process.
30. T F In washing surimi the amount of water used is approximately 20 times the amount of surimi product.
31. T F A typical surimi mixture contains 10 percent sugar and 2.5 percent salt.
32. T F Many migratory fish species, such as sardines and mackerel, produce an acid in their muscle tissue after death which affects the gel-forming capabilities.
33. T F Flour in a batter mix constitutes approximately 80-90 percent of the total weight, while in a breading mixture it normally ranges between 70-80 percent.
34. T F The browning rate of battered and breaded products is primarily dependent on frying time.
35. T F Seafood accounts for approximately 50 percent of all frozen battered and breaded products in the United States.
36. T F One of the major problems associated with battered products has been the uneven distribution of coating on the product.
37. T F Predusting formulations sometimes contain salt to increase coating adhesion since it melts the ice on the product surface and the resulting liquid can hydrate the product thereby improving adhesion.
38. T F Pre-frying a coated product produces a desirable color but reduces texture and sensory characteristics.
39. T F Oriental or Japanese crumbs is the breading most extensively used on fish and seafood products.
40. T F Imitation crab and other surimi-based shellfish analogs are correctly called Kamaboko because surimi is one of the raw materials.