MENHADEN:

SOYBEAN OF THE SEA

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Credits

Written by UNC Sea Grant researcher Tyre Lanier
Department of Food Science, North Carolina State University

Edited and designed by Nancy Davis
UNC Sea Grant College Program

With contributions from Robert Chapoton
National Marine Fisheries Service, Beaufort Laboratory

And research data from David Green and Reino Korhonen
Department of Food Science, North Carolina State University

Introduction

It is not hard to surmise the menhaden's place in nature: swarming our waters in countless myriads, swimming in closely-packed, unwieldly masses, helpless as flocks of sheep, close to the surface and at the mercy of any enemy, destitute of means of defense or offense, their mission is unmistakably to be eaten.

— *George Brown Goode*

Over a century ago, George Goode described the menhaden's ecological niche. Sharks, whales, striped bass, bluefish and countless other fish seek out the menhaden for their next meal. While it's not likely that you've ever eaten a menhaden, this fatty, oily fish has almost assuredly touched your life in some way. The fish's oil may have been added to your cosmetics, and the chickens you eat were probably fed a food with menhaden meal as one of its ingredients.

The early fishery

Menhaden have figured into the history of this country from the beginning. Legend has it that the Indian Squanto saved the Pilgrims from starvation that first winter by showing them how to plant menhaden along with their crops to fertilize the soil. Since that time, the menhaden has never been without a mission.

In the 1700s and 1800s, menhaden were salted and eaten like herring. In John Lawson's *History of North Carolina*, written in 1714, he called menhaden an "excellent sweet food." Later, however, menhaden came to be known as a poor man's fish or a famine food.

During the early 1800s, fishermen discovered the value of menhaden oil as a substitute for the more costly whale oil in lamps, paints and tanning solutions. The fish were allowed to rot in barrels, and the entire contents were pressed in hogsheads so the oil would rise to the surface. Steam cooking eventually replaced the rotting process and, during

National Marine Fisheries Service Photo

A school of menhaden

N.C. Division of Archives and History Photo

An 1889 catch of menhaden from Albemarle Sound

the 1850s, the mechanical screw press was introduced.

After the Civil War, a greater demand for menhaden oil spurred the fishery to expand. Before the war, menhaden were caught only in the North. But Union soldiers stationed in North Carolina noticed the abundance of menhaden in inshore waters. When they returned home with the news of the bounty, several opportunists traveled south to cash in on this oily wealth.

But all the efforts to establish a fishery in North Carolina between 1865 and 1887 failed. George Goode and Howard Clark wrote in an 1887 report that it was doubtful a fishery could be established in this state. They cited problems with spoiling catches, fickle inlets and shallow sounds.

Despite this dire prediction, within two years the menhaden fishery had begun to thrive. By 1889, seven factories were operating near Beaufort. By the turn of the century, the fishery had expanded to include plants near the Cape Fear River. During the 1902 season, more than 18 millions pounds of menhaden, valued at over $30,000, were caught in North Carolina waters.

When the fishery moved south, it brought with it some northern innovations. One of these, the purse seine, allowed fishermen to net large quantities of fish. Before, fishermen caught menhaden in gill nets or haul seines they worked from the beach.

A purse seine is a large "curtain-type" net, hung between surface floats and weights along its base. Two boats, called purse boats, drop the net in a circle. When a school of fish is enclosed, a heavy weight is attached to the purse line and dropped overboard. The purse line is then pulled in, causing the bottom of the seine to close like a purse.

Sailing sloops and schooners were the first boats to use purse seines to catch menhaden; purse boats were oar-driven yawls. After the Civil War, coal-fired steamers were introduced and, during the 1930s, diesel-powered vessels began to replace steamers.

After World War II, the industry grew rapidly and reached peak production between 1953 and 1962. By then spotter planes were used to sight the schools of menhaden from the air. Nylon nets had replaced cotton nets. Pumps sucked the fish from the nets through hoses to the hold. And hydraulic power blocks winched aboard the nets.

With the changes in technology came changes in the market for menhaden. Around the turn of the century, chemicals replaced menhaden as the main ingredient in fertilizers. The dried fish scrap was being mixed into feeds for poultry, swine and cattle. Oil from the fish was used in the manufacture of soaps, paints, linoleum and waterproof fabrics.

Since about 1940, menhaden oil has been used in cosmetics. Dried meal and condensed fish solubles—products rich in protein—were processed from the whole fish. These products have supplied the expanding poultry industry with feed ingredients which stimulate growth and help produce inexpensive meat for human consumption.

N.C. Division of Archives and History Photo

A menhaden scrap-and-oil factory near Beaufort in 1884

The fishery today

In 1983, menhaden landings totaled over 1.3 million metric tons or 2.9 billion pounds, and contributed over 53 percent of all finfish landed by U.S. commercial fishermen. These abundant fish inhabit virtually every bay and cove from the rocky coast of Maine down the Atlantic seaboard to Palm Beach, Fla., and in the Gulf of Mexico from Cape Sable, Fla., to the Yucatan Peninsula.

Although four species of the genus Brevoortia occur along the Atlantic coast of North America, the resource and fishery are dependent upon two species of menhaden. The Atlantic menhaden supports the older Atlantic Coast fishery and the younger, but currently larger, fishery in the Gulf of Mexico is supported by the Gulf menhaden. These fish are known by no less than 30 common names, including bunker, pogy, moss bunker and shad.

Through a cooperative federal, state and industry research program initiated in the mid 1950s, the status of the resource is monitored regularly. Scientists follow the menhaden's spawning, growth, migrations, abundance, distributions, age, size composition and general well-being. This research provides information on safe harvest levels and on the effects of man on the abundance of the resource. Results of these studies show that menhaden distribute themselves by size and age along the coast as the seasons change. Thus the resource provides unusual opportunities for fishermen to select menhaden of specific size ranges, oil content and other properties which are most desirable for their intended use.

Throughout the history of the menhaden fishery, we've used this fish to help us live better, healthier and more efficient lives. The list of products made from menhaden is large and varied—from fertilizer to lamp oil, rust-resistant paints to animal feeds, and from cosmetics to medicines. But the important observation is that a succession of new ideas and products has been developed over the years since man first caught menhaden. Throughout this time, those familiar with the fishery and the traditional end-products have pondered and searched for ways for the protein-rich menhaden to directly benefit the diet of the nation and of the world.

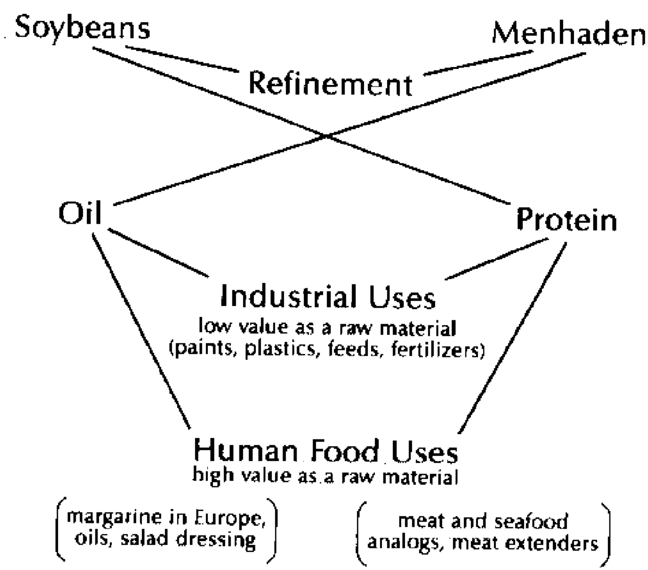
From fertilizer to food

Henry Ford (of automobile fame) faced a similar challenge earlier in the century. When he saw the contribution soybeans were making to the nutrition of Far Eastern populations, he conducted numerous agricultural experiments with the crop in this country. Although he could demonstrate the suitability of U.S. farmlands to grow vast amounts of soybeans, aside from fertilizer and feeds, there were no domestic outlets for the crop. He subsequently initiated research which eventually resulted in edible oils and protein concentrates. Now, one or both of these ingredients can be found in almost every domestically manufactured food product.

The present uses for menhaden are comparable to the utilization of domestic soy at the turn of the century; the oil is not approved for food use domestically, and the protein is used almost entirely for animal feeds. Just as the populations of the Far East were the first to utilize the soybean, the Japanese have for centuries manufactured many food products from fish protein.

More recently they have developed ways to manufacture this protein into a pure form for food ingredient uses—a product they have termed "surimi." Development of a high quality surimi from menhaden, coupled with current efforts to gain approval from the U.S. Food and Drug Administration for domestic food use of menhaden oil, would complete the analogy between the utilization of soybeans and menhaden. The establishment of surimi manufactured from menhaden could form yet another milestone in the long and fruitful history of our use of these abundant fish.

"Soybean of the Sea"



What is surimi?

The word surimi (sir ē' mē) translates from Japanese as "minced fish." But the frozen commodity known by this name bears little resemblance to the mushy, pigmented, strongly flavored product of the mechanical deboner for which many in the American fishing industry have long sought a marketable application. We should have learned from soybean processors that some food materials need refinement to bring out their real potential as a human foodstuff. Soybeans were merely feed and fertilizer until Henry Ford developed a light-colored, bland and functional protein from the meal. Likewise, the Japanese found that mechanically deboned, or minced, fish can be transformed by a simple water-leaching process to yield the light, bland and functional protein material known as surimi.

For centuries, water-washing of mince had been but one step in the process of converting fresh, whole fish into the highly prized kamaboko fish cakes, popular during Japanese celebrations. Later, as the popularity of these products grew and the local supply of fresh fish diminished, Japanese technologists were forced to develop a stable intermediate product in order to tap distant sources of fish such as the Alaska pollock.

This intermediate product was termed "surimi." It was the same mechanically deboned, washed and pressed material made on the premises by kamaboko manufacturers. But now, it was stabilized with the addition of sugars and sugar alcohols so it could endure the long months of frozen storage needed to ship it back to Japan.

Thus the Alaska pollock surimi industry was born. By 1980, Japanese and other foreign fishing fleets dominated the American pollock fishery.

If the market for traditional kamaboko products had not begun to level out in the late seventies, it's likely that surimi would have remained a totally Japanese enterprise. Attempts to expand the market prompted the development of several new surimi-based shellfish analog products such as "kanibo," translated as "kamaboko crab."

A dramatic decline in the American king crab fishery occurred in 1981, resulting in sharp cost increases of natural crab. Kanibo, which had caught the attention of American seafood wholesalers a few years earlier, now seemed a perfect substitute for the scarce natural crab, and imports of the surimi product began in earnest.

In 1982 and 1983, the United States imported more surimi-based simulated crabmeat from Japan than it actually produced real king crab meat. The domestic market for such simulated products has skyrocketed, from only 2 million pounds imported in 1979 to an estimated 70 million pounds in 1984. Japanese entrepreneurs have discovered an untapped American market for one of their products. But the real embarrassment is that the product they are selling us is processed from our fish.

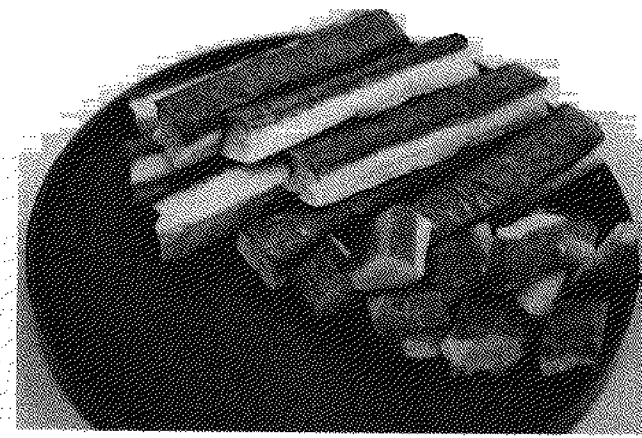
Besides being an essential ingredient in the manufacture of these popular seafood analogs, surimi may prove to be as widely used in other food products as vegetable proteins. Its superior heat-gelling properties make it a potentially useful "glue" in many types of engineered foods and a prime candidate for use in popular processed meat items such as hot dogs and bologna. Its flavor can be blander than soy protein and, like other meats, it is superior in nutritional quality to vegetable proteins.

Why menhaden?

Why make surimi from menhaden? If there ever was a likely candidate for conversion into the "soybean of the sea," this is it. Like soybeans, this fish is low in cost (about 5 cents per pound) and very abundant. Menhaden contain very functional proteins which we already know can be refined into a surimi of a quality comparable in many ways to that prepared from Alaska pollock.

Conversion of the fish into a quality surimi could be the last step toward making menhaden the "soybean of the sea" and the initiation of a new era in this largest of American fisheries. The increasing market for imported surimi-based products apparent by 1982 foretold of a large potential demand for high quality surimi in the United States. This was the impetus for initiating such research at that time.

Photo by Doug Yoder



A surimi-based seafood analog product

Conversion of menhaden into surimi—a progress report

The following is a progress report on current research directed toward production of high-quality surimi from menhaden. It includes summaries of the achievements made to date as well as a look at the challenges that will require further research. At the initiation of this project, we enumerated several potential problem areas which would have to be addressed in order for menhaden to prove feasible as a species for production of a high-quality surimi. These were:

(a) the significant content of dark muscle in menhaden which could cause discoloration of the product;

(b) the high fat content of whole menhaden, especially the Gulf species, which might result in surimi of high fat content, possibly adversely affecting gelling quality, flavor and storage stability of the product; and

(c) the excessive requirement for water and the high percentage of effluent generated by a surimi process which, for menhaden, must be carried out in coastal land-based plants.

As work on the project proceeded, a fourth problem was identified—high proteolytic (protein degrading) enzyme activity in the meat—which could cause textural problems, but only during the processing of the meat in the 50° to 75° C (120° to 170° F) temperature range. At these temperatures, the enzyme will degrade the muscle proteins to the extent that the texture of products will be mushy.

The following briefly summarizes research conducted to date on these and other areas pertinent to surimi manufacture from menhaden.

Handling the fish prior to processing

The strong gel-forming properties in a quality surimi derive from maintaining the fish protein in a state most nearly like that in the live fish—the so-called "native" state. This can be accomplished by rapid chilling of the fish to slow natural enzymatic and microbial degradative processes, coupled with other handling procedures which isolate the muscle proteins from any degradative agents. Such procedures might include gutting to remove digestive enzymes and bacteria, and controlling pH (acidity) and salt-content of the chilling medium to minimize changes in the solubility or other properties of the fish protein.

At present, the handling procedures for menhaden intended for surimi production are still being developed. However, it is certain that the fish must be handled more in the manner of a food fish rather than by present methods as an industrial fish. This will require measures to prevent crushing during transport, as well as proper chilling, possibly some pre-processing at sea, and/or sorting of the catch into sizes to facilitate machine-processing.

Even with proper icing, menhaden may require processing within eight to 12 hours of harvest when a light-colored surimi is desired. Recent experiments suggest that separation of the light and dark muscle can only be accomplished when very fresh fish are used. The use of "by-boats" in the fishery has been suggested to ensure rapid delivery of fish from the harvest grounds. These smaller boats could take on a portion of the haul from a purse seine alongside a traditional menhaden boat, and then chill and possibly pre-process the fish while rushing the catch to the surimi processing plant. Sorting might be accomplished at sea or on land, whichever proves to be most economical.

Processing of menhaden into surimi

Thus far, the washing, or leaching, procedure used to process menhaden into surimi has been about the same as that used for Alaska pollock. (Figure 1, next page) This was a logical starting point for the present work. As work proceeds, the washing procedure may require alteration to optimize the process for this fish and its fishery.

The process begins by either filleting or gutting the fish by machine. Experience has indicated that the primary source of pigments (which must be removed by washing) is the backbone, which is removed by filleting but not by heading and gutting. However, filleting may result in lower meat yields and will likely incorporate more belly tissue, which is higher in fat. Experiments are presently in progress to determine the best method of preparing the fish for deboning.

The cleaned, split fish or fillets are first washed to remove excess blood and other contamination and then fed, meat-side down (skin-side up) into a drum-type meat-bone separator. Proper adjustment of this machine is essential; too much belt pressure will force more bone and scale through the drum orifices along with the meat, while too little pressure will result in low meat yields. Adjustment of the belt pressure will also control the quantity of dark muscle incorporated.

In fresh fish, the dark muscle lies close to the skin to which it is tightly attached (see Figure 2); thus if the belt pressure is not too great, the dark muscle will tend to be separated from the light meat along with the skin and scales. Total separation of light and dark muscle cannot be obtained in the deboner, however.

The deboned meat is then dumped into a stainless steel tank. From 3 to 5 parts fresh water are added for every one part meat (weight basis). The water should be low in mineral content and as cold as possible—preferably less than 10° C (about 50° F). (3° to 5° C is preferable.) To aid in the removal of water-soluble components when washing the meat of pelagic species such as herrings, the Japanese have recommended that sodium bicarbonate (baking soda) be added to the first wash at a level of 0.1-0.2 percent. We have not been able to verify any pronounced improvement in washing efficiency by incorporating this step, however.

In any case, the pH (acidity) of the water should be carefully controlled in the range of 6.8 - 7.0 (near neutral). Higher acidity (lower pH) may result in partial denaturation of the fish proteins and in loss of gelling properties. Low acidity (higher pH) can result in losses of desirable protein and cause difficulty in dewatering of the meat because of swelling of the

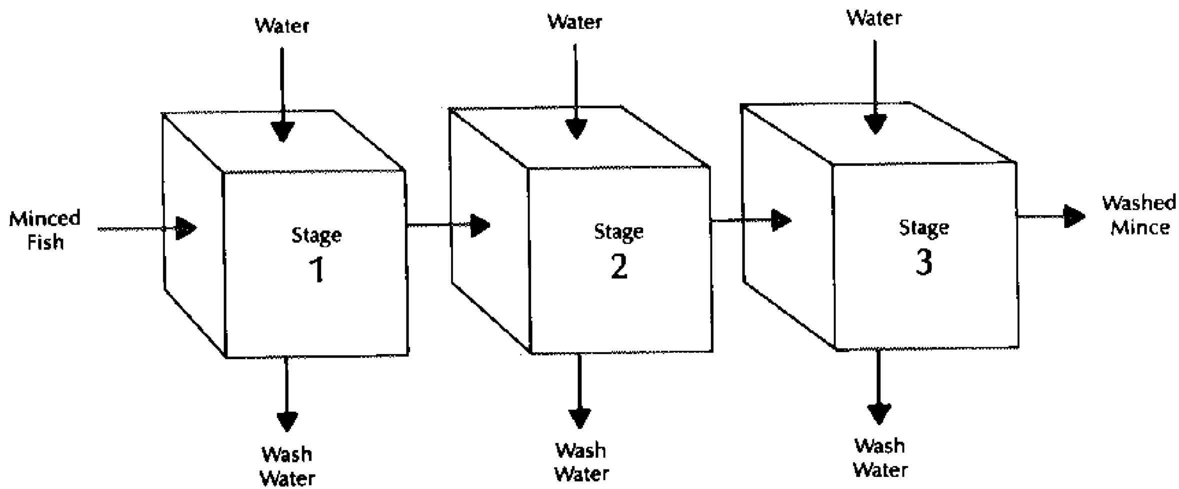


Figure 1. The conventional lateral-flow washing process used for Alaska pollock surimi production

meat particles in the water. The pH can be adjusted with sodium bicarbonate or a weak solution of either hydrochloric acid or sodium hydroxide (food grade).

The meat is usually washed three times, each time at the same meat : water ratio. If the fish meat is high in fat content, the first washing tank should be equipped to skim off the fat which floats to the top during washing. Agitation should be gentle, but enough to ensure constant mixing of all particles.

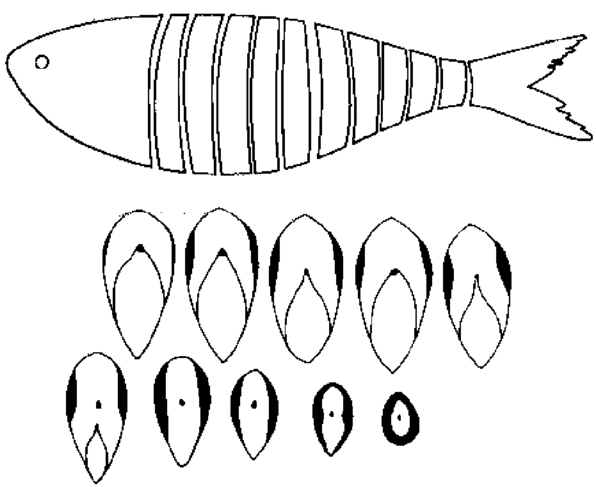


Figure 2. Cross section of menhaden shows dark muscle

Washing should be completed in 15 to 20 minutes if possible. Too long a washing time may result in excessive swelling of the meat and difficulty in subsequent dewatering. Between washes, the water may be separated from the meat by allowing the meat to settle followed by decanting. Alternately, the meat may be briefly screened (rotating screens work best) or even centrifuged between washes.

Following the final wash, the meat is screened or centrifuged for partial dewatering. Next the meat may be strained through a refiner before final dewatering, or it may be dewatered and then strained through a strainer. The former method results in less heat buildup because the refiner operates with a slurry. Traditionally the final dewatering is carried out with a refrigerated screwpress, which removes any heat added during refining. However, a high-speed centrifuge may also be used to dewater. Obviously there is some latitude at this step; experience will ultimately determine the best choice of equipment for straining and dewatering.

The refining/straining step in pollock surimi manufacture is a means of removing any stray bone, scale or skin which may have passed the deboning step earlier in the process. In the case of menhaden, this step plays a much more important role. It is in the strainer that final separation of the light and dark meat is accomplished; this will be discussed in more depth in a subsequent section.

The washed, dewatered meat normally possesses a water content about equal to that of the whole fish meat, unless the fish is fatty. In this case, the moisture content of the surimi will be higher than the whole fish, but the fat content will be much lower. In other words, the protein content of the surimi and whole fish muscle should be approximately equal (about 15 to 16 percent). We currently believe that a high-speed centrifuge instead of a screwpress may enable higher protein contents (lower water contents) to be attained, perhaps yielding a "concentrated" surimi (up to 24 percent protein).

The meat is then placed in a silent cutter/mixer, or a ribbon/paddle mixer, and cryoprotective substances are added. Traditionally this has been about 8 to 9 percent of a 50 : 50 blend of sucrose (sugar) and sorbitol (the sweetener used in sugarless chewing gum). Sorbitol alone may be used to lower the sweetness since it is about 60 percent as sweet as sugar; however, it has the same caloric content as sugar, and is more expensive. Our laboratory has recently applied for a patent for the use of Polydextrose,® a product of Pfizer, Inc., as a cryoprotectant for surimi. This material has no sweetness and only one-fourth the calories of sugar or sorbitol.

Incorporation of the cryoprotectant is faster with a silent cutter/mixer. A longer mixing time is necessary when using a ribbon/paddle mixer to ensure thorough incorporation of the cryoprotectants. The meat is then shaped into blocks by an extruder and rapidly frozen. Plate freezing is preferable since it is faster than blast freezing in most cases. Fast freezing is necessary to prevent formation of large ice crystals which can damage the tissue. It is preferable to freeze the blocks (about 10 kg each) to -30° C within four hours. Storage should be at -30° C with little fluctuation of the temperature.

Separating light and dark meat

In our early laboratory and commercial pilot plant processing trials, we found that a light-colored, excellent gel-forming surimi could be produced from menhaden by using very fresh fish and by relying on the straining step in the surimi process to separate the light and dark muscle tissues. This was effective because the dark muscle, when fresh, seemed to be tougher and more resistant to being broken down than the light meat. The light meat easily passed through the small (about 1 mm) holes of the strainer while the dark muscle particles (about 3-5 mm from the deboning drum) were retained in the waste.

In the first commercial pilot plant trial, a very light surimi was produced from Gulf menhaden, but the gel-forming ability of this product was not as good as expected due to a high fat and moisture content. (The Gulf species is very high in fat compared to the Atlantic species.)

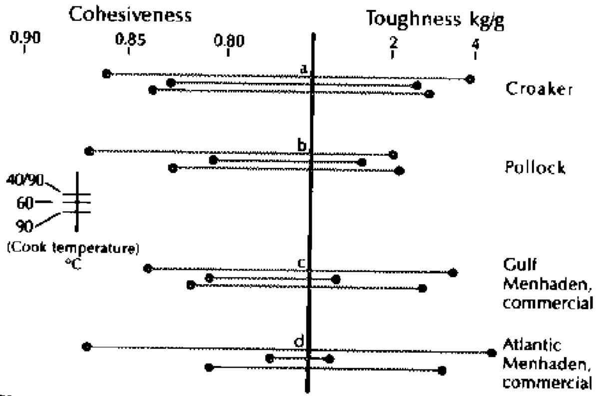


Figure 3. Comparison of textural values obtained on gels prepared from commercial (a) croaker and (b) pollock surimi with (c) Gulf menhaden surimi and (d) Atlantic menhaden surimi in commercial trials

Because of problems in the procurement and shipping of the fish to the Alabama plant from Virginia, the Atlantic fish was less fresh. This resulted in a darker product. The dark muscle had become softer and did not separate in the straining step. However, this product had excellent gel-forming ability because of its lower fat and moisture content. Gel-forming values for these samples versus Alaska pollock and Gulf croaker are shown in Figure 3 (above).

Separation of the light and dark meat is essential to the production of a high-quality surimi. Only the light meat can be processed into a light-colored surimi. The dark meat is not appreciably lightened by the washing process, as can be seen in Figure 4. Dark meat left in the surimi is finely distributed during high-speed comminution of the surimi later in the manufacturing process or in the making of surimi-based products. This removes the speckled appearance due to the presence of dark particles, but adds undesirable color to the product.

More important than the color contribution of the dark meat particles is their flavor contribution. Recent work has revealed that while light meat, hand-

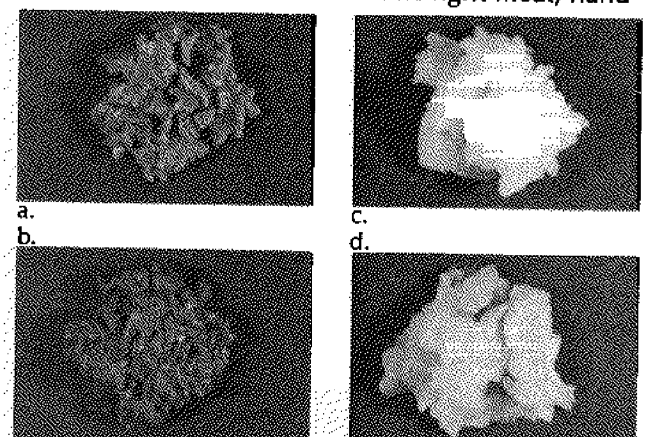


Figure 4. Menhaden muscle after conventional leaching process. (a) washed dark muscle, (b) unwashed dark muscle, (c) washed light muscle, and (d) unwashed light muscle

filleted from the fish, has a very low odor and flavor profile, the dark muscle tissue is quite odorous and strong-flavored. This is likely associated with the higher fat (lipid) content of the dark meat. Thus, separation of the dark muscle from the light during the processing of menhaden surimi is considered essential to obtaining a product which possesses a light color, bland flavor and odor, and a low fat content. Japanese efforts to produce an acceptable surimi from sardines have been unsuccessful largely because of their inability to develop an economical method of separating the light and dark muscle during the surimi manufacturing process.

Control of heat-stable protease

We also found that cooking of menhaden surimi pastes in the 50° to 75° C temperature range caused virtual disintegration of the gel texture. This was most likely due to the presence of heat-stable, protein-degrading enzymes—termed "protease"—in the tissue (see the texture values for menhaden gels prepared at 60° C, Figure 3.) Such proteases are found in many fish species now used for surimi production. However, the levels encountered in menhaden were far greater than those for other fish.

Previous work with croaker in this laboratory indicated that high levels of such proteases may be caused by contamination of the minced muscle tissue by gut juices or fragments, resulting from improper cleaning of the fish prior to deboning, or by leaching of gut materials into the muscle tissue during holding of whole fish prior to processing.

Thus, an experiment was conducted to determine whether the high protease content of menhaden might also be derived from gut contamination. Fish were obtained onboard a menhaden fishing boat and either immediately iced whole or dressed and iced. Dressing was accomplished with a single knife stroke to remove the belly cavity without its being opened, thus avoiding any chance of contamination of the muscle tissue.

The fish dressed at sea were processed in an identical manner to the fish iced and held overnight before dressing. The results of this experiment (Figure 5) clearly show that the surimi produced from the fish of either treatment possessed very poor gel-forming ability when processed at 60° C. This indicates that the high protease activity almost assuredly is not derived from gut contamination.

Surprisingly, the fish held overnight produced a surimi with a slightly higher gel-forming ability than those fish dressed and processed as soon as possible. A more extensive test of handling and storage will be conducted in the immediate future to verify this surprising result and to better understand the effect of freshness and handling on the quality of menhaden surimi.

Studies were subsequently conducted to assess

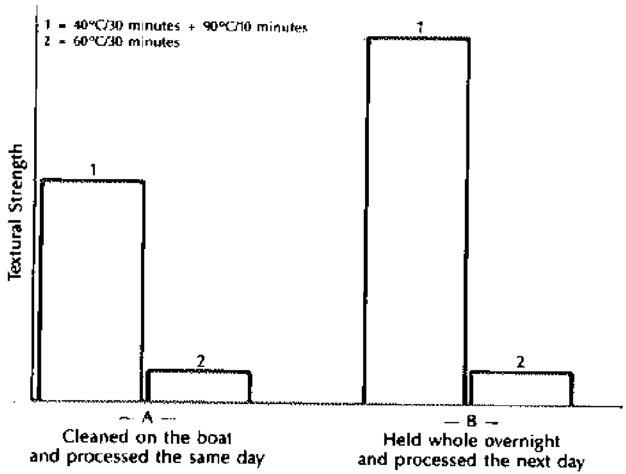


Figure 5. Effect of menhaden handling procedures on the gelling property of the surimi

the impact this elevated protease level might have on the use of menhaden surimi in the food industry and to explore possible means of inhibiting the enzyme in food applications.

Figure 6 shows the results of a study designed to more precisely define the processing temperature range over which this protease is active. The samples were pre-incubated at temperatures from 40° to 80° C for up to 20 minutes, then cooked at 90° C for 10 minutes prior to measurement of the gel strength (hardness value). From the results, it appears that the enzyme has some activity at 50° C, which greatly increases over the range of 55° to 70° C, becoming inactivated at 75° to 80° C. This behavior is almost identical to that of other heat-stable proteases of croaker previously studied by this laboratory.

A subsequent experiment was conducted to determine what deleterious effects might result if menhaden surimi were used in the manufacture of seafood analog products such as simulated crab legs, scallops, shrimp, etc. These products are generally small in diameter or thickness (0.5-1.0 inches) and are processed by a two-step schedule involving a pre-set temperature of 40° C followed by cooking at 80° to 100° C. In this experiment, all gels were pre-set at 40° C inside stainless steel tubes of up to 1 inch in diameter, then cooked at temperatures from 70° to 90° C for up to 30 minutes. The gel strength (hardness value) of each sample was then measured.

The results demonstrated that, even with poor temperature control of the final cooking step, the presence of the protease should present no problems in the manufacture of seafood analog products made from menhaden surimi. However, if manufacturers of traditional meat "sausage" products such as hot dogs, bologna, luncheon meats, etc., choose to add surimi to these products, surimi from menhaden should presently be avoided. Processed meat products are normally cooked over the temperature range at which the menhaden proteases are most active.

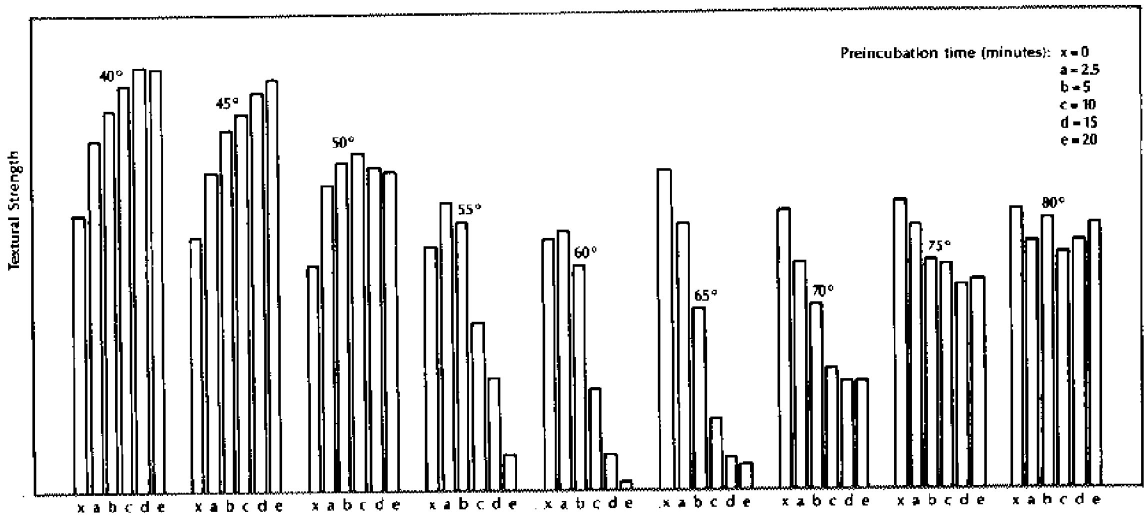


Figure 6. Effect of processing time and temperature on textural strength of menhaden surimi gels

The presence of elevated protease levels thus poses no real concern for the use of menhaden surimi in seafood analog products. A means of inhibiting the enzyme might prove advantageous in opening new markets in the future. Therefore, we have recently initiated experiments to determine whether a food-grade (considered edible by the FDA) inhibitor might be developed for this enzyme.

Previous investigations of croaker proteases suggested that an extract from white potatoes could effectively inhibit heat-stable protease activity in that species. Other known sources of food-grade protease inhibitors are egg white and raw soybeans. Such inhibitors were recently reported to be effective against the potent heat-activated protease found in Pacific whiting (hake). The protease activity of this species originates from a small parasite in the flesh.

A similar origin may exist for the protease in menhaden since we earlier showed that the gut was not the primary origin, as with some other fish species. However, recent examinations of many menhaden fish specimens revealed a very low level of parasite infestation of the type capable of generating such a proteolytic enzyme. The temperature response to the menhaden protease is also quite different from that reported for Pacific hake. Further investigations into the source and properties of the menhaden protease are still in progress.

Fat content and stability

Early commercial trials with Gulf and Atlantic menhaden yielded surimi with fat contents of 5 and 2 percent, respectively. More rigorous attention to skimming of the fat during washing has now resulted in producing surimi of less than 1 percent fat from Atlantic menhaden, and of less than 3 percent from Gulf menhaden. Some modifications to the process may be necessary to further reduce the fat content.

Because the fat level of these samples was still somewhat greater than that of commercial pollock surimi, it was felt that this might detract from the long-term storage stability of the surimi due to the onset of fat rancidity. Therefore, a storage study was conducted to determine the stability of the fat in menhaden surimi during frozen storage with and without the use of stabilizing treatments. The treatments tested were:

(a) a control sample, packaged in the conventional manner, a polyethylene (oxygen permeable) bag;
(b) a sample treated with a food-grade enzyme system designed to consume oxygen, and subsequently vacuum-packaged as in (b);
(c) a sample treated with a lemon juice/phosphate preparation designed to retard rancidity, and vacuum-packaged as in (b); and
(d) a sample treated with a combination of sodium ascorbate/sodium citrate, and vacuum-packaged as in (b).

All samples were placed in frozen storage and subsequently evaluated at 1, 3, 5 and 10 months for evidence of fat rancidity by a chemical test (TBA, 2-thiobarbituric acid) and a trained profile panel. The results are shown in Figure 7. Compared to the control sample, the sodium ascorbate treatment appeared to accelerate, rather than retard, rancidity development. The lemon juice/phosphate treatment (and possibly the enzyme treatment), in conjunction with vacuum-packaging in an oxygen barrier material, seemed to have afforded some protection against development of fat rancidity. Except for the samples treated with the ascorbate/citrate, none had panel rancidity scores that rated above a "slightly detectable" level of rancidity (score of 5). This indicates that the fat was fairly stable in the majority of samples over 10 months of frozen storage.

Water reduction in surimi processing

A final concern has been to modify the surimi manufacturing process to lessen the water requirement without affecting the product quality. Water consumption would be reduced, and the solubles and particulates removed from the fish mince during the washing process would be concentrated, thus making water treatment and/or by-product recovery more economical.

The conventional method for washing the minced fish involves several washing stages. Fresh water is added at each stage and the waste water subsequently removed by the screening or settling of the meat before the next washing stage (Figure 1). This approach makes efficient use of the water in the first stage where the bulk of solubles are removed, but the last wash is merely a rinse of the washed meat.

A more efficient use of the wash water might be obtained through counter-current washing (Figure 8). In this procedure, the same water is used in all washing stages. However, the water moves in a direction counter to the flow of meat through the process. Table 1 shows the results of an experiment comparing the washing of fish by the conventional process (9-to-1 total water-to-meat volume ratio) to

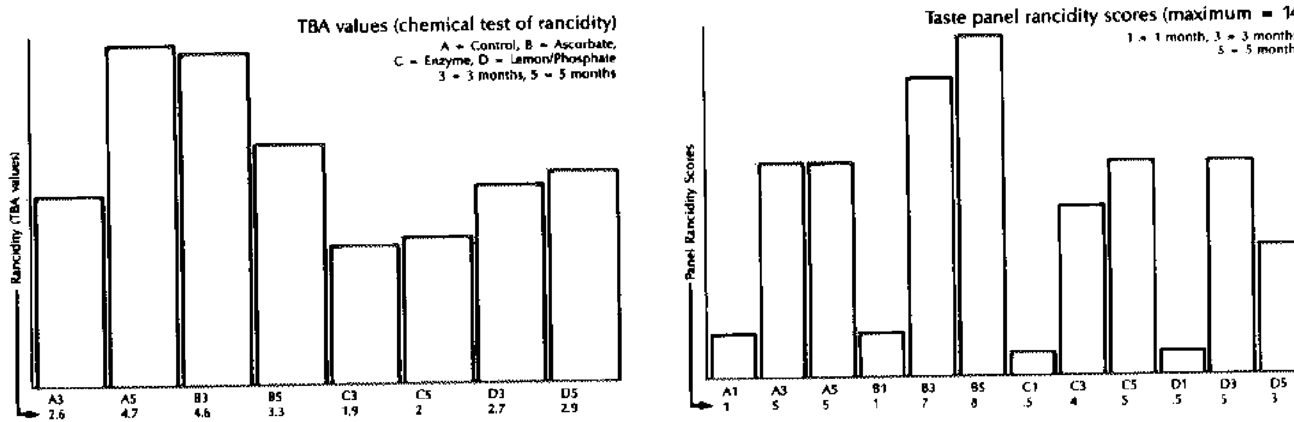


Figure 7. Effect of packaging and additive treatments on development of fat rancidity

the same process conducted in a counter-current manner (3-to-1 total water-to-meat volume ratio).

Surprisingly, counter-current washing removed an equal or greater amount of soluble protein as the conventional process, but requires only one-third the volume of water needed for the conventional process. The effluent is therefore three times as concentrated as with the conventional process. It may be possible for this effluent stream, with or without further concentration, to be directly processed by existing menhaden reduction plants and be totally recovered for feed or fertilizer. Counter-current washing is now being scaled up to ensure that the surimi quality does not suffer from such a

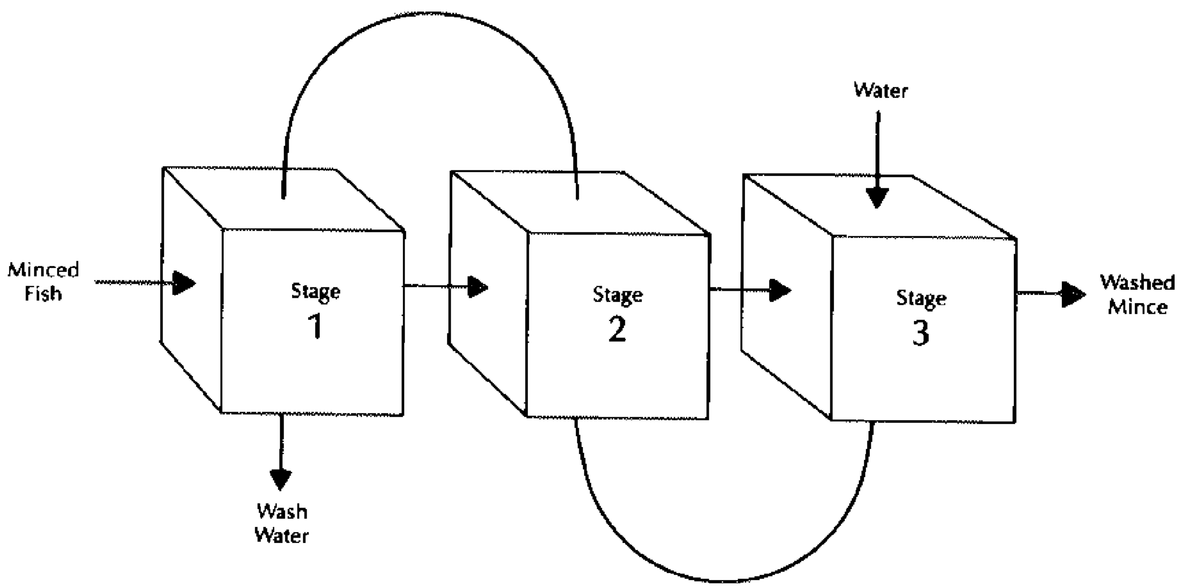


Figure 8. Counter-current (reverse flow) washing may reduce the amount of water required

washing process and to work out the equipment parameters needed to conduct such a process on a large scale.

Another approach to water reduction in surimi processing has recently been reported from Japan. The process entails use of a vacuum chamber for the leaching process. Washing under reduced pressure is said to greatly accelerate the removal of the undesirable components. One wash, using no more than a 4:1 water:meat ratio, reportedly produces a product which is more bland, lighter in color and lower in fat than several washes with a conventional process. Studies are now being planned to test this concept in the washing of menhaden. If the approach is valid technically, there still may be problems in applying such a technique at the commercial scale in terms of equipment design and cost.

Table 1. Washing efficiency of conventional versus counter-current process

Category	Meat[1]	Water[2]
Not Washed	33.73	
Conventional	10.78	2.33
Counter-current	9.42	2.35

[1]Values are extractable water-soluble nitrogen as a percent of the total nitrogen in the washed meat

[2]Values are total recovered water-soluble protein in the wash water as a percent of the total fish weight being washed

Waste utilization

The yield of surimi from whole fish is not very high. For large fish such as pollock, the yield may approach 25 percent, while for smaller fish such as menhaden, the yield may be only 15 percent. The presence of existing menhaden reduction plants and of a well-established market structure for menhaden meal and oil presents an excellent means of handling both solid and soluble wastes from a menhaden surimi plant.

The soluble protein portion, if concentrated enough, could enter the stickwater stream within the reduction plant where it would be converted to either concentrated solubles or dried into meal (stickwater is the liquid remaining after rendering and pressing the fish). The solid wastes from a menhaden surimi process will be relatively high in protein content and low in quantity compared to the tremendous volumes of fish normally processed by a reduction plant. Therefore, use of this stream by the reduction plant should result in little or no effect on meal composition or quality.

Close situation of the two types of processing plants, as well as joint ownership or cooperation of both, would offer several advantages. Firstly, this would facilitate total utilization of the fish caught. Secondly, it would permit a directing of raw fish flow through the two plants based on current market conditions for the different products, condition of the fish being caught, and other variables. Lastly, procurement of the fish would be facilitated by a joint effort of the two plants, with the pursed fish divided at sea between by-boats (equipped to handle food fish) and the larger boats currently used by the menhaden reduction industry.

Effects on the fishery

A worry has been expressed by some that development of food products from menhaden might increase the fishing pressure on this species, ultimately resulting in a decline in the fishery. It should be noted that fishing pressure on a given species will be dictated by market conditions for the products of that fishery. In the present case, the demand for domestic fish meal from menhaden has been falling because animal nutritionists have been able to formulate feeds using cheaper grain protein sources. This fact is reflected in the dramatic price decreases of menhaden meal in recent years. Just as fish meal served as a new market when the demand for fish-based fertilizer disappeared a century ago, it is anticipated that surimi may fill the market gap for menhaden processors as the demand for meal declines. Because no more than 20 percent of a fish can be converted into surimi, the remainder is still potentially available for meal manufacture. Thus it is highly unlikely that even the development of a strong market for menhaden surimi will result in increased fishing pressure on this species.

Conclusions

The results obtained to date indicate that a light, bland and excellent gel-forming surimi can be produced from menhaden. Such a product should be capable of partially or fully substituting for pollock or other commercially available surimi in the manufacture of seafood analog products and other foods.

However, further work must be conducted to assure that such a product can be economically produced in commercial quantities. Work must also be done to ensure that the fat content and color of menhaden surimi can be consistently controlled. The presence of heat-stable proteases may be a limiting factor in the use of menhaden surimi. Further research will be directed at eliminating or inhibiting the enzyme. Counter-current washing promises to make the surimi manufacturing process more efficient and economical, but the process must be scaled up to verify this assumption. Vacuum washing also may be useful, but has not yet been applied to surimi processing from menhaden.

If you're contemplating a business enterprise based on the manufacture of surimi from menhaden, carefully study the technical problems which remain to be solved. To assure success of such a venture, conduct a study of the potential markets for surimi made from menhaden or for products made from menhaden surimi. The market and product forms are currently in the infant stages, and therefore subject to rapid change. As the number of product applications for surimi increases in the domestic food industry, it is certainly feasible that market niches might develop in which menhaden surimi could best compete.

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