8847

"Bone Softening," a Practical Way to Utilize Small Fish

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Introduction

Many of the fishery resources available on the U.S. west coast are being harvested at maximal levels. To increase fisheries production, there is a need to turn to presently underutilized species. Reasons for not using certain fishes are varied, but small size is frequently cited as one of the chief impediments. This is principally because most Americans, and indeed people throughout much of the world, are accustomed to eating boneless fillets of fish, and small fish are usually uneconomical to debone or fillet.

Even in Japan, where per-capita fish consumption is about 5 times that of the United States, small fishes present problems in utilization. Thus, the enormous catch of sardines there (more than 4 million tons in 1986) is used primarily for fish meal rather than for direct human consumption. Looking for ways to increase direct consumption of sardines and other small fishes, Japanese researchers considered various alternatives. One of the more successful products developed was "bone-softened" fish, which utilized small fish that were "dressed," i.e., head, tail, and viscera removed, but with skeletal bones, spines, and some scales left intact. The obvious advantages of using dressed fish rather than fillets are higher yield and lower processing costs. A further advantage may be in increased nutritional value, as bone is a good source of many essential minerals, particularly calcium.

In the fall of 1986, JAC Creative Foods, Inc.[1], Los Angeles, Calif., and the West Coast Fisheries Development Foundation, Portland, Oreg., obtained a Saltonstall-Kennedy fisheries development grant from the National Marine Fisheries Service to study ways to increase utilization of certain California fishes. One aspect of this project was to study bone softening techniques using small species of fish that are abundant off the California coast. The principal objectives were to learn if hard parts (bones, scales, and spines) of these species could be softened so that they would be undetectable when eaten, and to attempt to manufacture products made with bone-softened fish that are palatable to American tastes. This paper presents findings of that study to provide the fishing industry as well as consumers with information about the production and consumption of bone-softened fish.

Materials and Methods

Most of the fish used in this study were caught with bottom trawls and were provided by fishermen from Monterey and Morro Bay, Calif. Species included shortbelly rockfish, *Sebastes jordani*; Pacific sanddab, *Citharichthys sordidus*; white croaker, *Genyonemus lineatus*; plainfin midshipman, *Porichthys notatus*; rex sole, *Glyptocephalus zachirus*; English sole, *Parophrys vetulus*; Dover sole, *Microstomus pacificus*; and ratfish, *Hydrolagus colliei*. Additionally, samples of so-called "small pelagic species" (i.e., jack mackerel, *Trachurus symmetricus*; Pacific mackerel, *Scomber japonicus*; and Pacific sardine, *Sardinops sagax*) caught off southern California with roundhaul nets, were obtained from wholesale fish dealers in Los Angeles. Specimens of yellowfin tuna, *Thunnus albacares*; and goosefish, *Lophius americanus* (often called "monkfish"), which were used in two comparative experiments were also purchased at a wholesale fish market. All fish except the last two and the ratfish were smaller than 28 cm (11 inches) in total length.

Processing operations and most evaluation procedures were carried out at two fish processing plants in Los Angeles, JAC Creative Foods and Yamasa Enterprises. For each experiment, frozen fish were thawed at room temperature, then measured and weighed. They were then dressed, and the visceral cavity scrubbed clean. After being weighed a second time to determine the amount of waste, several fish were lined in a single layer, wrapped in aluminum foil[2], and cooked in a laboratory-sized autoclave. The cooker was a Barnstead Benchtop Autoclave, with a chamber 39×25 cm (15½×10 inches), and a capacity of around 1.15 kg (2.5 pounds) of material. Pressure within the chamber was dictated by the experimental temperature, i.e., the pressure was constant for each chosen cooking temperature: At 116°C, the pressure was 0.7 kg/cm^2 or k.s.c. (240°F, 10 pounds/inch^2 or p.s.i.); at

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[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[2]This was necessary only because the small autoclave used in this study could not accommodate juices that emanated during processing. Commercial operations would utilize open racks.

121°C, 1.05 k.s.c. (250°F, 15 p.s.i.); at 127°C, 1.40 k.s.c. (260°F, 20 p.s.i.); at 132°C, 1.75 k.s.c. (270°F, 25 p.s.i.). Fish prepared for outside evaluation were cooked in an autoclave that was similar, but with slightly greater capacity.

Experiments were also conducted to attempt to improve the texture and moistness of bone-softened fish. These trials entailed pretreatment of the fish by soaking dressed fish overnight in cold salt (sodium chloride) brine solution of various concentrations. The samples and solutions were kept refrigerated at about 5°C (41°F). Other treatments tried were addition of varied amounts of citric acid or sodium tripolyphosphate (TPP) to vary the pH level of the soaking solution.

To remove the "fishy" odor of some species, we used extracts of powdered Japanese green tea in salt brine solution. Various amounts of tea were steeped in 800 ml (1.06 quarts) of tap water at 95°C (203°F) for 30 minutes. The tea solution was then filtered through cheese cloth and enough water was added to make up a volume of 1 liter. Test fish were soaked in the tea solution overnight. About 1.2 kg (2.6 pounds) of fish were treated in 1 liter of solution. Different species were kept in separate containers.

The cooked samples were drained, and allowed to cool. For most tests the extent to which the bones were softened was determined by having a number of persons (usually five, including the first two authors and three plant personnel) eat the samples of processed fish and report whether the hard parts were: 1) Detectable when eaten, 2) slightly noticable when eaten, or 3) undetectable when eaten. A fourth, nonorganoleptic measure was also used: 4) Bones crumble easily after slight finger pressure. Both items 3 and 4 were considered desirable endpoints of our experiments. Evaluation of other attributes such as texture and moistness was made by the first two authors.

Chemical analyses of bone-softened shortbelly rockfish and jack mackerel were carried out by a private firm, Michelson Laboratories, Inc., 6280 Chalet Drive, Commerce, CA 90040. Samples of both species were dressed, then soaked overnight in brine solution (1.5 percent salt for shortbelly rockfish and 2 percent for jack mackerel) which also contained 0.25 percent tea solution. In addition, the soaking solution for jack mackerel included 0.25 percent TPP. One liter of solution was used for each 1.2 kg of fish. After soaking, the fish were cooked in an autoclave at 121°C and 15 p.s.i. for 40 minutes. For each analysis, two fish of each species were ground and blended together.

Formal organoleptic evaluation of bone-softened shortbelly rockfish and jack mackerel was conducted by a taste panel composed of members of the staff of the Utilization Research Division, NMFS Northwest and Alaska Fisheries Center, Seattle, Wash. The panel members were trained to conduct such tests.

Results

Bone Softening

Effects of Cooking Temperature and Pressure

Ten species of fish were cooked for a constant time (40 minutes) at varied temperatures and pressures to learn the effects of these treatments on softening bones, scales, and spines. Of the four temperatures and pressures used, the lowest (116°C; 10 p.s.i.) was sufficient to soften the bones of most fish satisfactorily (Table 1). At 121°C, only the midshipman failed to attain a good score (3 or 4). Increasing temperature (and pressure) clearly resulted in greater softening of hard parts.

Vertebral bones of shortbelly rockfish and white croaker were somewhat more difficult to soften than the other fishes. Bones of the small pelagic species (mackerels and sardines) were easily softened, as were those of small flatfish (rex, Dover, and English soles) and Pacific whiting.

Effects of Cooking Temperature, Pressure, and Time

Samples of jack mackerel whose average weight was around 104 g (0.23 pound) were cooked at 110°, 116°, and 121°C for 25-50 minutes. Prolonged cooking time did not result in increased softening of bone (Table 2). On the other hand, increasing the cooking temperature from 110° to 116° and 121°C markedly softened the bones, as was found in the first experiment. At 116°C a cooking time of 25 minutes was sufficient to soften bones of jack mackerel.

Effects of Fish Size

Samples of Pacific mackerel and shortbelly rockfish were separated into three size groups and cooked at three temperatures for a constant time. The results (Table 3) indicated that within the

Table 1.—Extent of softening of bone with varied temperatures and pressures. Cooking time was 40 minutes. Numerals are average scores of five tasters, and correspond to: 1 = bone detectable when eaten, 2 = barely detectable when eaten, 3 = not detectable when eaten, and 4 = bone crumbles easily when rubbed between the fingers.

Species	Cooking temperature (°C) and pressure (p.s.i.)			
	116° (10)	121° (15)	127° (20)	132° (25)
Plainfin midshipman	1	2	3	4
White croaker	2	3	4	4
Shortbelly rockfish	2	3	4	4
Pacific whiting	3	4	4	4
Pacific mackerel	3	4	4	
Pacific sardine	3	4	4	
Jack mackerel	3	4	4	
Dover sole	3	4	4	
English sole	3	4	4	
Rex sole	3	4	4	

Table 2.—Effects of cooking time, temperature and pressure on softening bones of jack mackerel. The scoring system is the same as that given in Table 1.

Cooking time (minutes)	Cooking temperature (°C) and pressure (p.s.i.)		
	110°C (5)	116°C (10)	121°C (15)
25	2	3	4
30	2	3	4
45	2	3	4
50	2	3	4

Table 3.—Effects of fish size and cooking temperature on extent of bone softening. Cooking time was 45 minutes. The scoring system is the same as that used in Table 1.

Species	Fish size (total weight)	Cooking temp. (°C)		
		110°	116°	121°
Pacific mackerel	Lg. (580 g; 1.28 lb)	2	3	4
	Med. (265 g; 0.58 lb)	2	3	4
	Sm. (167 g; 0.37 lb)	2	3	4
Shortbelly rockfish	Lg. (295 g; 0.65 lb)		1	3
	Med. (205 g; 0.45 lb)		1	3
	Sm. (100 g; 0.22 lb)		1	3

range of sizes tested, fish size was not related to cooking temperature (110°, 116°, and 121°C) with respect to degree of softening of bone. The minimum temperature required was the same for large as well as small individuals. Apparently the specific composition of the bone was more important than fish size in determining whether the bones became soft.

Minimum Cooking Temperatures

Cleaned vertebrae of nine species were cooked at various temperatures for 30 minutes to learn the minimum temperature necessary to soften vertebrae. As before, the test samples were eaten (in this test only by the first two authors) and given a numerical score correlated with the tasters' ability to sense the texture of bone. The vertebrae were also rubbed between the fingers to determine softness. Tuna vertebrae were the most difficult to soften and goosefish vertebrae were the easiest (Table 4). A cooking temperature of 121°C was sufficient to soften bones of nearly all species tested. Shortbelly rockfish bones required a slightly higher temperature to attain a satisfactory degree of softness.

To further study the relationship between bone composition and cooking time needed to soften the bone, the vertebrae of several species of fish were boiled and thoroughly cleaned and dried, and sent to Michelson Laboratories for analyses of chemical composition. Results of the analyses of calcium and nitrogen content of the bone are given in Table 5, along with the minimum temperature needed to soften the vertebae (from Table 4). No correlation between calcium or nitrogen content and the amount of heat necessary for softening bone was evident. English sole vertebrae had the highest calcium content, yet a relatively low temperature was sufficient to soften it. Also, shortbelly rockfish and goosefish bones were similar in calcium content, but the latter's vertebrae were much more easily softened.

Table 4.—Minimum temperatures needed to soften vertebrae of fishes. After most flesh was removed, segments of vertebrae were cooked for 30 minutes in an autoclave.

Species	Min. temp. (°C)	Score	Comments
Yellowfin tuna	>127°	1	Bone only slightly softened
Shortbelly rockfish	>121°	2	At 121°C slightly gritty
Pacific sardine	121°	3	
Dover sole	121°	3	
Pacific mackerel	>116°	2	At 116°C slightly gritty
English sole	>116°	2	At 116°C slightly gritty
Jack mackerel	116°	3	
Ratfish	110°	3	
Goosefish	<110°	4	At 110°C bone crumbles easily

Table 5.—Calcium and nitrogen content (percent of total vertebral weight) of vertebrae of some fishes, and the minimum temperature necessary to soften bone. Time of cooking in the autoclave was 30 minutes.

Species	Calcium (Ca)	Total nitrogen (N)	Ca/N	Min temp. (°C)
Yellowfin tuna	21.5%	4.42%	4.86	>127°
Shortbelly rockfish	18.5	2.67	6.93	>121°
Dover sole	14.8	2.46	6.02	121°
Pacific mackerel	13.7	2.29	5.98	>116°
English sole	26.1	2.96	8.82	>116°
Ratfish	7.5	9.71	0.77	110°
Goosefish	17.5	5.75	3.04	<110°

Table 6.—Effect of tea concentration on deodorization of Pacific sardine and jack mackerel. Fish were tested organoleptically after being soaked in the tea solution overnight, then cooked for 40 minutes at 121°C.

Grams of tea in 1 liter of water	Pacific sardine	Jack mackerel
0[1]	Very fishy	Fishy
2	Slightly fishy	Slightly fishy
2.5	No fishy odor	No fishy odor
3	No fishy odor	No fishy odor
5	No fishy odor	No fishy odor
10	No fishy odor, but slight tea odor	No fishy odor, but but slight tea odor

[1]Control

Table 7.—Effect of citric acid in reducing ammonia odor of bone-softened fish. Dressed fish were soaked in chilled 2.5 percent brine solutions overnight, then cooked for 30 minutes at 121°C.

	Citric acid concentration (%)		
Species	0.0	0.1	0.3
Shortbelly rockfish	Slight ammonia odor	No ammonia odor	No ammonia odor
Pacific whiting	Ammonia odor	Slight ammonia odor	No ammonia odor

Deodorization

Preliminary tests showed that solutions of Chinese black tea and oolong tea and Japanese green tea were all effective in deodorizing the flesh of small pelagic species. However, we found that Chinese teas imparted a noticably dark stain on the fish flesh, so their use was discontinued. After the fish were soaked overnight in green tea solution, they were cooked at 121°C for 40 minutes. The effects of soaking fish in various concentrations of green tea solutions on the flesh of Pacific sardine and jack mackerel are given in Table 6. An amount of 2.5 g of green tea in 1 liter of water (2.5‰) was sufficient to deodorize at least 1 kg of small pelagic species. When a tea solution of 10‰ was used, an odor and taste of tea was imparted to the flesh.

When cooked in an autoclave, bottomfish were inherently less "fishy-smelling" than small pelagic species. Both shortbelly rockfish and Pacific whiting emitted a slight ammonia odor, however, and the odor was even stronger in midshipman. White croaker and flatfish had a slight but unobjectionable odor. To reduce the ammonia odor in shortbelly rockfish and Pacific whiting we tried a treatment of citric acid solution. Dressed fish were soaked overnight in chilled 2.5 percent brine solutions containing citric acid, then cooked in the autoclave for 30 minutes at 121°C. Organoleptic evaluation of the cooked fish revealed that a 0.1 percent solution was sufficient to remove the ammonia odor in shortbelly rockfish, while a 0.3 percent solution was required for Pacific whiting (Table 7).

Texture and Moistness

Treatments tested for improving texture and moistness of bone-softened fish included variations in cooking temperature, pH level of the cooked flesh, and salt concentrations of brine solutions. The flesh of jack mackerel soaked overnight in a 2 percent salt solution before cooking was juicy and firm compared to the control (no salt) which was watery and soft (Table 8). A 1.5 percent solution was not effective, while a 3.0 percent salt solution resulted in drier flesh

Table 8.—Effects of different concentrations of salt solutions on texture and moistness of bone-softened fish. The dressed fish were soaked in the solutions overnight, then cooked at 121°C for 40 minutes.

Amt. of salt (%)	Jack mackerel	Pacific sardine	Flatfish
0[1]	Watery Soft	Watery Soft	Watery Soft
1.5	Watery Soft	Watery Somewhat firm	Watery Somewhat soft
2.0	Moist Firm	Somewhat watery Firm	Somewhat mushy
2.5	Moist Firm	Moist Firm	Somewhat mushy
3.0	Dry Firm	Somewhat dry Firm	Mushy

[1]Control.

Table 9.—Texture and moistness of bone-softened fish at varied cooking temperatures. Fish were soaked in 2.5 percent salt solution overnight, then cooked for 40 minutes in an autoclave.

	Characteristics of cooked flesh at specified cooking temperatures		
Species	116°C	121°C	127°C
Pacific sardine	Moist Somewhat soft	Watery Firm	Watery Firm
Jack mackerel	Moist Firm	Dry Firm	Dry Firm
Shortbelly rockfish	Moist Firm	Moist Somewhat soft	Dry Soft
Flatfish	Moist Somewhat firm	Watery Mushy	Watery Mushy

Table 10.—Effect of pH adjustment on texture and moistness of bone-softened fish. Fish were soaked overnight in 2.5 percent salt brine solution, and citric acid (CA) or sodium tripolyphosphate (TPP) was used to adjust pH. Fish were then cooked at 121°C for 40 minutes in an autoclave.

	Characteristics of cooked flesh			
Treatment	Jack mackerel	Pacific sardine	Dover sole	Pacific whiting
Control (2.5% salt)	pH 6.31 somewhat dry; firm	pH 6.15 somewhat dry and watery	pH 6.75 mushy and watery	pH 7.11 soft; somewhat watery
+0.3% TPP	pH 6.51 moist; firm	pH 6.34 moist; somewhat soft	pH 6.95 very mushy	
+0.1% CA			pH 6.66 somewhat soft; moist	pH 7.02 somewhat soft and watery
+0.2% CA			pH 6.60 somewhat firm; moist	pH 6.85 firm; somewhat dry
+0.3% CA	pH 5.80 very dry; firm	pH 5.67 dry; firm		

Table 11.—Proximate composition of bone-softened shortbelly rockfish and jack mackerel. The fish were dressed, and cooked in an autoclave at 121°C and 15 p.s.i. for 40 minutes. Results are expressed in percent of dressed weight, or as otherwise indicated.

Item	Shortbelly rockfish	Jack mackerel
Moisture (%)	71.09	70.46
Total protein (%)	22.45	25.71
Fat (ether extract, %)	4.54	2.35
Ash (%)	1.67	1.66
Calories/100 g	132.00	124.00
Calcium (mg/100 g)	291.00	94.20
Sodium (mg/100 g)	136.00	239.00

and was judged to be not as good as that prepared with a 2.0 percent salt solution. Pacific sardine required a 2.5 percent salt brine to produce moist and firm flesh. The flesh of several species of flatfish did not improve with the addition of salt, however, and in fact the texture was markedly worsened as more salt was used.

To test the effects of cooking temperature, dressed fish were soaked overnight in a 2.5 percent salt solution, then cooked separately at three levels of heat and pressure for 40 minutes. The lowest temperature used (116°C) generally resulted in the best texture and moistness in the flesh of the fish tested (Table 9). The flesh qualities of all species of flatfish were significantly better when cooked at 116°C. Unfortunately, somewhat higher temperatures are needed to soften the bones of some species (Table 1).

To learn the effects of pH on texture and moistness of bone-softened fish, we soaked several dressed fish overnight in solutions that contained 2.5 percent salt, and either citric acid or sodium tripolyphosphate (TPP), then cooked the fish at 121°C for 40 minutes. The pH of the cooked fish was then measured and the fish tested organoleptically. The results (Table 10) indicated that addition of 0.3 percent TPP effectively increased moistness in jack mackerel and Pacific sardine, but caused Dover sole flesh to become very mushy. When the pH was lowered by addition of citric acid, the flesh of jack mackerel and Pacific sardine became too dry. Conversely, the same treatment caused an improvement in texture of Dover sole and Pacific whiting and there was also a noticable improvement in reduction of objectionable odor.

Proximate Analysis

The compositions of dressed and cooked shortbelly rockfish and jack mackerel caught in October are given in Table 11. Prior to cooking, shortbelly rockfish was soaked overnight in 1.5 percent and jack mackerel in 2.0 percent brine solutions. The percentages of total protein, 22.45 percent and 25.71 percent for shortbelly and jack mackerel respectively, were relatively high due to a reduction in moisture content from brine soaking and cooking. The calcium level was high as expected because of the presence of bone, and sodium was elevated by the brine treatment.

Product Yield

The yields of bone-softened shortbelly rockfish and jack mackerel are given in Table 12. Shortbelly rockfish yield, 37.5 percent of the initial weight, was low compared to that for jack mackerel, 45.7 percent. Some of the weight loss for shortbelly rockfish is attributible to our processing and handling methods as considerable amounts of the soft cooked flesh fell apart and was lost during removal from the aluminum foil pouch. The moisture contents of both species are similar, averaging 76 and 75

Table 12.—Product yield for bone-softened shortbelly rockfish and jack mackerel. The fish were soaked overnight in brine solutions and cooked at 121°C and 15 p.s.i. for 40 minutes (shortbelly rockfish) or 30 minutes (jack mackerel).

Item	Shortbelly rockfish	Jack mackerel
Avg. total length	208 mm (8.2 in.)	250 mm (9.8 in.)
Avg. total wt.	88 g (3.1 oz.)	164 g (5.8 oz.)
Avg. dressed length	111 mm (4.4 in.)	
Avg. dressed wt.	48 g (1.7 oz.)	99 g (3.5 oz.)
Avg. wt. after cooking	33 g (1.2 oz.)	75 g (2.6 oz.)
Yield: Weight of cooked fish as percent of total wt.	37.5%	45.7%

Table 13.—Sensory evaluation of bone-softened shortbelly rockfish and jack mackerel. This table was provided by Harold Barnett, Utilization Research Division, Northwest and Alaska Fisheries Center, NMFS, Seattle, Wash.

Sample	Odor[1]	Flavor	Texture	Acceptability	Rancidity[2]
Rockfish (control)	4.8 ± 1.7[3] (4)	4.5 ± 1.8 (6)	4.8 ± 1.6 (4)	4.5 ± 1.5 (4)	3.0 ± 2.1 (5)
Rockfish (soaked)	5.6 ± 1.4 (4)	4.9 ± 1.4 (4)	4.8 ± 1.6 (4)	4.9 ± 1.4 (4)	2.8 ± 2.3 (7)
Mackerel (soaked)	3.5 ± 2.1 (6)	4.1 ± 2.3 (6)	4.7 ± 2.2 (6)	3.4 ± 2.0 (6)	5.1 ± 2.6 (7)

[1]Sensory scale (except for rancidity) 9 to 1, with 9 indicating excellent and 1 poor quality. A score of 3 indicates a product of unacceptable quality.
[2]Rancidity scale 1 to 9, with 1 indicating no rancidity, 5 slight and 9 strong rancidity.
[3]Each number represents the mean of seven or eight evaluations ± the standard deviation. Numbers in parentheses represent differences between the highest and lowest scores.

percent for shortbelly rockfish and jack mackerel, respectively[3].

Outside Evaluation

The following procedure was followed to provide samples of bone-softened fish for outside evaluation.

Shortbelly Rockfish Samples

Fish were obtained directly from a fisherman and kept on ice for 2 days prior to processing. Fish averaging 88 g total weight were headed and gutted and washed. Half of the fish were then soaked in a 1.5 percent salt solution overnight at 5°C. One liter of this solution was used for 1.2 kg of dressed fish. The cured fish were aligned and wrapped in aluminum foil, and cooked in an autoclave at 121°C and 15 p.s.i. for 40 minutes. The uncured fish were also cooked in the same manner. All samples were then drained, and frozen individually at −25°C (−13°F).

Jack Mackerel Samples

Fish were obtained from a wholesale fish company, so no details of catch or handling were available. They were processed shortly after purchase. Fish averaging 164 g total weight were headed and gutted and washed, then soaked in chilled 2 percent salt solution, with the addition of 0.25 percent sodium polyphosphate. Tea extract at a concentration of 0.25 percent was included in the soaking solution. The extract was prepared by steeping 2.5 g of crushed green tea leaves per liter of water at 100°C for 40 minutes. One liter of soaking solution was used for each 900 g of fish. The cured fish were aligned and wrapped in aluminum foil and cooked at 121°C and 15 p.s.i. for 30 minutes. The fish were then drained and frozen individually at −25°C.

Samples of bone-softened shortbelly rockfish and jack mackerel were shipped to the Utilization Research Division of the NMFS Northwest Alaska Fisheries Center, in Seattle. Before evaluation by a taste panel the samples were further treated by twice being dipped in batter and breaded. They were then deep-fried in vegetable oil from the frozen state at 190°C (375°F). Time required for cooking ranged from about 4 minutes for shortbelly rockfish to 7 minutes for jack mackerel. The cooked fish were served warm to an 8-member taste panel. The evaluation by the panel is summarized in Table 13.

Generally, individual panelists' reactions to both species were highly varied, but the average scores of both indicated a low to medium acceptance level. Shortbelly rockfish was judged to be better than jack mackerel in all respects, but this may have been due to high variability in the quality of the mackerel samples, some pieces of which were so rancid that one panelist declined to eat the product[4]. Shortbelly rockfish soaked in brine was preferred in all respects over those that were not soaked. Two panelists gave scores of 7 (= "good") in all of the sensory evaluation categories to soaked shortbelly rockfish. No hard bones were detected in either species by the panelists.

Discussion

Evidently many species of fish are amenable to a bone softening process. Among the groundfish and small pelagic species we tested, only the plainfin midshipman proved to have bones so hard as to be unsuited for the process. A secondary problem, emanation of objectionable odors, results from treatment at high temperatures. The odor, which is most pronounced in mackerels and sardines, probably needs to be reduced to increase acceptance of these species as bone-softened products.

The pelagic species have relatively large proportions of dark muscle, which contains higher levels of trimethylamine oxide (TMAO) as well as iron, than light muscle (Tokunaga, 1970). TMAO is broken down through cooking or bacterial action to trimethylamine (TMA), which is the source of most "fishy" odor (Tokunaga, 1975). Iron is a catalyst of thermal decomposition of TMAO to TMA. In Japan, green tea extract is commonly used to reduce this odor. The effective agents are the catechins, substances found in tea, which react with trimethylamine (Hata et al., 1980). Formation of disagreeable odors can also be decreased by using minimum times and temperatures when cooking fish in the autoclave. Thus, it is possible to manufacture satisfactory bone-softened products even with pelagic species which characteristically contain higher levels of TMAO.

In bone, insoluble calcium salts are supported by proteins and mucoids (nitrogen compounds), and the greater the calcium content, the harder the bone (Otani and Fujikawa, 1937). Bone softening by cooking is supposedly related to thermal decomposition of collagen, the main proteinacious component of

[3]Guide to underutilized species of California. Admin. Rep. T-83-01 (unpubl.) avail. at Tiburon Laboratory, Southwest Fisheries Center, 3150 Paradise Drive, Tiburon, CA 94920.

[4]Harold Barnett, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. East, Seattle, WA 98112. Personal commun.

bone, thus loosening the supporting texture. We expected that the minimum temperature necessary for softening bones of various species of fish might be correlated with the amount of calcium and collagen (or other nitrogen compounds) in the bone, but found no such relationship (Table 5). In fact of 11 species we studied, only the bones of the plainfin midshipman, and a rather large yellowfin tuna could not be easily softened, so this technique could be applied with many fishes.

In California, jack mackerel and Pacific mackerel are used mainly in canned form, for human consumption as well as cat food. A fair amount is also frozen for bait, and a small amount is sold as fresh fish. The average annual catch of these two species is high, compared with other California marine resources, amounting to over 50,000 tons annually. Thus these fish are good candidates for bone softening. Jack mackerel may be better suited for this process because it has firmer flesh with less red meat, however.

We find it particularly heartening that shortbelly rockfish makes an acceptable product, since this species is one of the most plentiful unused marine resources found off California. Although recent assessments of populations of shortbelly rockfish are not available, earlier works indicate that this species is abundant and easily caught in large numbers (Lenarz, 1980; Kato, 1981). Direct consumption of this fish is difficult because of the abundance of small bones and spines, and filleting is impractical because of the cost. Also, each fillet from mature individuals weighs only around 30 g (1 ounce), which is too small for most traditional methods of preparing rockfish.

Small, bony fish are not only inconvenient to eat, but their sharp bones and spines are also hazardous, especially to young children. Removing such bones before marketing is usually too costly, so most small fishes are not consumed directly. The introduction of bone-softening techniques around 1980 in Japan immediately made it possible to use a variety of small fishes and greatly increased the potential market for them. Because of its abundance, the Japanese sardine is the fish most used to make bone-softened products. A ready-to-fry breaded product is the most popular item. The bone-softening method used in Japan is essentially the same as that described here, but fish with coatings of various flavors are marketed, including curry, cream and parsley, and tomato. In addition, uncoated bone-softened fish are also sold. These are used directly in salads or other dishes applicable to canned tuna, or coated by the cook and fried. The composition of a breaded sardine product, with sesame seeds added for flavoring, is given in Table 14. Breaded fish are graded and packed in uniform size groups, around 25, 30, or 40 g per fish. At present, bone-softened fish is sold directly to institutional users only, and not in retail stores. The wholesale price in Japan for this product is about 25 yen per 25 g fish, or 1,000 yen/kg ($3.50/pound, at an exchange rate of 130 yen=$1.00). The price seems rather high when converted to U.S. dollars, but this is due to recent weakening of the dollar.

Table 14.—Proximate composition of Japanese commercial bone-softened breaded product made with sardine, *Sardinops melanostictus*, and percent composition of ingredients used to make the product. The data were provided by the manufacturer, Suzuhiro Co., Ltd., 245 Kazamatsuri, Odawara City, Kanagawa Prefecture, Japan.

Proximate composition of breaded product		Percent composition of ingredients	
Item	Comp	Item	Comp.
Protein	17.6%	Bone-softened sardine	63%
Fat	8.2%	Breading	20%
Carbohydrate	9.0%	Wheat flour	5%
Ash	0.6%	Salt	1%
Calcium	338 mg/100 g	Sesame seeds	5%
Salt	700 mg/100 g		
Calories	183 KCal/100 g		

To learn how U.S. consumers might react to bone-softened fish products, we obtained from Japan samples of bone-softened and breaded sardine, *Sardinops melanostictus*, and filefish, *Thamnaconus modestus*. The samples were deep-fried in vegetable oil and presented to several staff members of the Tiburon Laboratory of NMFS. Nearly everyone who tasted the samples thought that the filefish, a mild, white-fleshed fish, was good in taste and texture when deep-fried. The other sardine, however, was thought to be too "fishy." The bones of both species were undetectable to all tasters.

Samples of filefish were next given to about 400 persons, most of whom were connected with the fishing industry. One sampling was conducted at a seafood and wine tasting event held at the Olde Port Inn, in Avila Beach, Calif., in February 1987. A second informal tasting was also done in February in Sacramento, Calif., in conjunction with the "Fishermen's Forum," which is conducted annually by state legislators. Most comments received from tasters were favorable, and the use of small fish, with bones intact, was thought to be an excellent idea both from the standpoint of fish utilization, as well as health aspects because of high calcium content. Most tasters also liked the flavor and texture of the product. Negative comments related mainly to the addition of calories by frying in oil. Practically no tasters were able to detect the presence of the softened bones and spines.

Recommendations

To knowledgably start commercial production of bone-softened products in the United States, several questions still need to be answered. The most important is to learn whether American consumers would purchase such products, and how much they would be willing to pay. We also need to learn which species are acceptable, and if costs associated with processing of those species allow commercial production. Research is also needed on ways to maintain quality of frozen bone-softened products and, especially, to lower or slow the onset of rancidity.

Should market studies be contemplated, we feel that satisfactory sample products can be made by using the procedures outlined in Figure 1. Types of coatings applied to bone-softened fish is a different area of research, but we feel that plain batter and breading is sufficient to allow representative test marketing of the product. Another way to obtain samples for test marketing may be to have a Japanese firm already manufacturing bone-softened products provide market samples made from

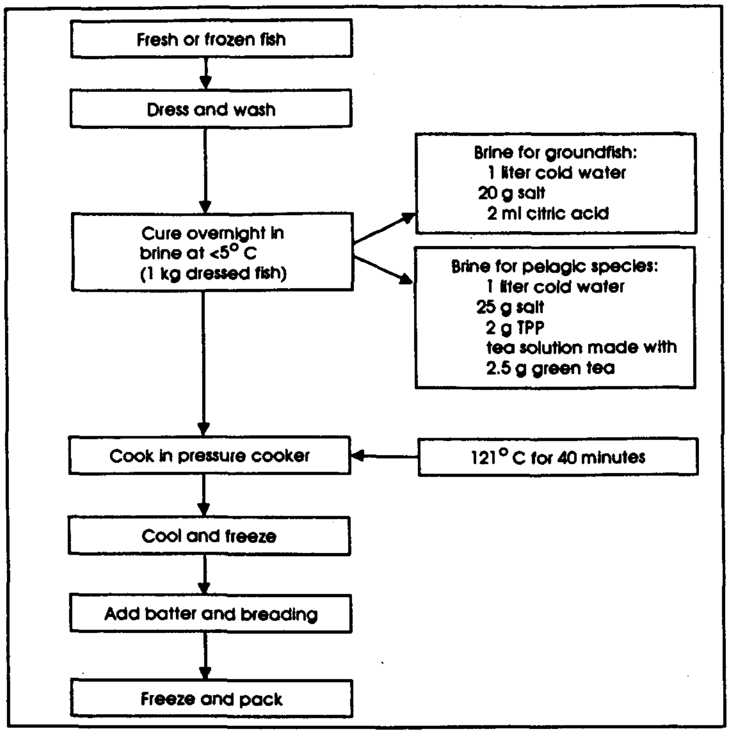

Figure 1.—Recommended procedures for making bone-softened groundfish and small pelagic species.

shortbelly rockfish and jack mackerel or other species with good potential (i.e., a large biomass). Processing costs may also be derived through such an arrangement.

Market research is needed to see if products other than deep-fried bone-softened fish are acceptable to the American consumer, who is becoming more and more conscious of calorie intake. Notwithstanding the questions remaining, we feel that bone softening is an effective means of utilizing species of fish that are too small for use in traditional forms, and we hope that this study will lead the way to eventual acceptance of this product form in the United States.

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