Suitability of Red Hake, *Urophycis chuss*, and Silver Hake, *Merluccius bilinearis*, for Processing Into Surimi

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Introduction

This report summarizes published and recently obtained information on the suitability of red hake, *Urophycis chuss*, and silver hake, *Merluccius bilinearis*, for the production of surimi. Surimi is a stabilized, frozen, intermediate product prepared by freshwater leaching of mechanically deboned fish muscle (Suzuki, 1981). This yields a bland, light-colored, and highly functional food product which is widely used to make analog seafood products resembling crab meat, scallops, shrimp, etc. (Lanier, 1981, 1983).

Gadoid species in general (and red hake in particular) possess an enzyme-substrate system, trimethylamine oxidase:trimethylamine (TMAOase: TMAO) which can generate formaldehyde during frozen storage (Dingle et al., 1977; Castell et al., 1972). This causes extensive denaturation of the muscle proteins and results in rubbery texture of fillets or minces during frozen storage (Castell et al., 1973; Gill et al., 1979). Holmquist (1982) demonstrated that the combination of water washing of comminuted red hake flesh, which apparently removes much of the enzyme, TMAOase, its cofactor, and/or its substrate TMAO, and the addition of sucrose and sorbitol, which retards freeze denaturation of proteins, yields a product with excellent gel-forming ability even after extended frozen storage. Fillets and mince deteriorated rapidly in frozen storage, exhibiting acceptable gel-forming ability for only 1.5 weeks. Both water-washing and the incorporation of sucrose and sorbitol are key steps in the commercial production of surimi (Suzuki, 1981).

An estimated 75,000 metric tons of silver hake and 40,000 metric tons of red hake remain unfished each year due to lack of markets (USDC, 1983). In light of the encouraging results of Holmquist (1982), which suggested that new markets might be found for this resource in the form of surimi, the New England Fisheries Development Foundation initiated a series of laboratory and commercial surimi processing tests of both species in cooperation with the North Carolina State University/North Carolina Sea Grant and the Gulf and South Atlantic Fisheries Development Foundation. Red and silver hake were each evaluated twice in laboratory trials and once in a commercial trial for their suitability in producing a surimi product having good gel-forming ability.

Materials and Methods

Laboratory Trials

Two laboratory trials for each species were conducted in the pilot plant facilities of the North Carolina State University Seafood Laboratory in Morehead City; one preceded the commercial processing trial and the other followed the commercial trial. In the first, conducted during March 1982, fish of both species were simultaneously air-shipped in ice, in the round, from Pt. Judith, R.I., to near Morehead City, N.C. The fish were about 2-3 days post-harvest upon arrival, and appeared in reasonably good condition except for some deterioration of the belly flaps. They were immediately headed and gutted and divided into two lots. The first lot was immediately deboned and processed into surimi, without prior removal of the belly flaps. Belly flaps were removed from the second lot in anticipation of their contribution to accelerated spoilage, and the fish were stored an additional 3 days in ice before processing.

In the second laboratory trial, the fish were much fresher, being obtained by air shipment within 1 day of harvest. The two species were tested separately, red hake in July and silver hake in October 1982. Half of the lot of each species had been headed and gutted and well cleaned inside prior to shipping, while the remainder were shipped whole. Fish from each were either immediately deboned and processed, or stored in ice for up to 8 days before processing. Storage of whole fish resulted in eventual deterioration of the belly area, especially in the red hake. Therefore, the napes were removed before processing from the red hake which had been stored whole, but were not removed from the silver hake. The headed and gutted fish showed no deterioration of the belly area, and the napes were left on the dressed fish of both species for processing.

The processing procedure for all

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laboratory trials consisted of the following steps. Headed and gutted fish were deboned using a Yanagiya[1] "mini" model drum-type deboner with drum screen orifices 3 mm in diameter. The mince was washed three times, each time in a quantity of ice water three times that of the initial meat weight. The slurry was dewatered following each wash by pouring through a nylon mesh bag and squeezing by hand. Salt (NaCl) was added to the final wash to a 0.15 percent concentration which facilitated dewatering. The final dewatering was accomplished by centrifugation of the mesh bag of mince in a Bock laundry-type centrifuge (Model 10XC, Bock Manufacturing Co., Toledo, Ohio) for about 15 minutes in a 2°C cold room. The final moisture content of this dewatered mince was about 80 percent. Lacking a strainer, the washed mince was directly chopped in a silent cutter (Hobart Model # 84142) with a combination of 4 percent sucrose and 4 percent sorbitol added to protect the proteins during frozen storage. The temperature of the mince was maintained below 10°C throughout processing. The surimi thus produced was vacuum packaged in bags of low oxygen permeability, frozen, and held at −20°C until determination of the gel-forming ability could be made (within 1 month).

Commercial Processing Plant Trial

About 900 kg each of red and silver hake were shipped in the round in ice by truck from Pt. Judith, R.I., to Bayou La Batre, Ala., during April 1982. Unfortunately, the fish were received in relatively poor condition due to a combination of factors: The fish had been harvested during heavy feeding on American sand lance, *Ammodytes americanus*, and were quite heavy with roe. Both conditions are commonly thought to contribute to rapid quality deterioration in the fish, particularly by promoting "belly burst" whereby stomach enzymes disintegrate the belly tissue and are released into the fish mass. This condition was observed in many of the fish of both species. Delay in shipping also occurred due to truck malfunctions causing the fish to be held in the round for 3 days prior to processing.

These fish were headed and gutted mechanically on Lapine equipment and the belly flaps were removed. The cleaned fish were washed briefly in a rotary washer and deboned with a Bibun type SDX18 deboner having 3 mm drum orifices. The mince was washed three times, each time with a quantity of cold (less than 5°C) water about three times that of the initial fish weight. Washing was conducted in large stainless steel vats (about 450 kg capacity) by gently stirring the water-mince mixture for 1 minute with a paddle, before allowing the meat to settle for 3 minutes and then dewatering. Dewatering was accomplished by gradually lowering a telescoping drain in the middle of the vat, resulting in removal of only about 75 percent of the added water between washes. Salt (NaCl) at 0.1 percent was added to the final wash to facilitate dewatering of the mince. The slurry from the last wash was passed through a rotating screen drum and finally pressed in a screw press to express excess water. The washed, dewatered mince was then strained in a Bibun type SUM 420 strainer having 1.2 mm orifices to remove remaining bones, scales, and other particulates. Sugar (sucrose) and sorbitol were each added at 4 percent in dry form and thoroughly mixed by comminution in a silent cutter for 1-2 minutes. The surimi was extruded into metal pans lined with plastic bags, each holding about 10 kg, and blast frozen at −20°C. The temperature of the mince and surimi was maintained below 12°C throughout processing and prior to freezing.

Evaluation of Gel-Forming Ability

Gel-forming ability was evaluated by first preparing heat-induced protein gels under standardized conditions, followed by objective (mechanical) measurement of the textural attributes of these gels (Lanier et al., 1982). The procedure used was similar in its approach to that used by the Japanese industry, but different in the methods employed to prepare the gels and measure the textural properties.

Gels were prepared by chopping tempered (about −5°C) surimi with 2 percent salt and ice to achieve a 5:1 moisture:protein ratio. This batter was chopped in a special laboratory vacuum cutter (Lanier et al., 1982) to an end-point temperature of 5°C and transferred to a plastic bag which was vacuum sealed to remove air pockets. The bag was slit at the corner and placed in a sausage stuffer where the cold batter was extruded, without air pockets, into stainless steel tubes (1.25 cm I.D. by 15 cm long) sealed at one end by a stopper and on the other by a threaded brass cap. The tubes were processed in a water bath by one of three schedules:

1) 40°C (104°F) for 30 minutes, followed by a 10-minute cook at 90°C (194°F). This process reveals the ability of the protein to "set" into an elastic gel at low temperatures (Lanier et al., 1982) and can reveal the presence of low-temperature protein-degrading enzymes.

2) 60°C (140°F) for 30 minutes. Marked textural degradation of gels at this temperature is indicative of the presence of so-called "alkaline protease" enzymes (Su et al., 1981; Lanier et al., 1981; Lin and Lanier, 1980).

3) 90°C (194°F) for 10 minutes. This rapidly cooks the batter without the influence of low-temperature setting or protease activity.

The tubes were immediately cooled in ice water after processing. The gels were removed with a Teflon plunger and stored in plastic bags under refrigeration (2°C) before evaluation of the gel texture (within 24 hours).

The texture of each gel was evaluated using a two-bite compression test (texture profile test, Bourne, 1968) between two parallel plates on an Instron Universal Testing Machine. Samples 2.54 cm in length were subjected to a cross-head speed of 100 mm/minute and twice compressed radially to 74 percent of their original thickness. "Hardness" of the samples is defined as the maximum force attained on the first bite divided by the sample weight, and is a measure of the toughness of the samples. "Cohe-

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

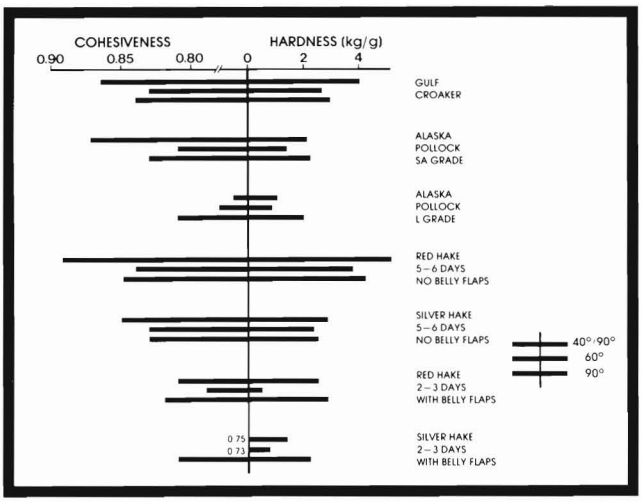

Figure 1.—Instron texture profile values (cohesiveness, hardness) of gels prepared from surimi processed in initial laboratory trial from red hake and silver hake stored 2-3 or 5-6 days in ice, processed with or without belly flaps, and from commercially obtained surimi samples. Process temperatures for gels: 40°/90°C = 40°C incubation for 30 minutes + 90°C incubation for 10 minutes; 60°C = 60°C incubation for 30 minutes; 90°C = 90°C incubation for 10 minutes.

siveness" is defined as the ratio of peak force of the second bite to the peak force of the first bite, and is an indication of the degree of structural integrity retained by the sample after being compressed one time. Hardness and cohesiveness values have been directly related to the "gel strength" and "folding test" values obtained by traditional Japanese methods in this laboratory (unpubl.) and by other workers (Toda et al., 1971).

For comparative purposes, Alaska L (land processed-lower grade) and SA (highest grade) pollock, *Theragra chalcogramma*, (Taiyo Fisheries) and top grade Atlantic croaker, *Micropogonias undulatus*, surimi (Nichibei Fisheries, Inc.) were evaluated for gel-forming ability under identical conditions.

Results and Discussion

The gel-forming abilities, as evidenced by the texture profile values obtained on heat-processed gels, of red and silver hake samples in comparison with pollock and croaker surimi are given in Figure 1. Fish of both species processed with belly flaps on yielded a much poorer gelling product than fish from which the napes were removed. Comparison of the gel-forming ability of the samples without belly flaps with that of commercial high-grade surimi showed that the red hake surimi had much better gelling properties than any of the commercial samples, while the silver hake surimi possessed about the same gelling properties as the high-grade commercial samples.

Surimi prepared from both hake species processed with belly flaps on had poor gelling properties similar to the L-grade Alaska pollock surimi. Textural degradation at 60°C was evident and likely attributable to the presence of heat-stable proteases which may have leached into the belly region from organ tissues (Su et al., 1981). The poor performance of these samples when processed by a 40°/90°C or 90°C schedule seems due to the inclusion of the belly tissue. This tissue likely had very poor gel-forming properties and may have actually inhibited gel formation of the more functional muscle proteins. Any protease contributed by inclusion of the belly flaps should have had no effect on the 90°C processed samples. Heat transfer was rapid in the sample tubes used such that protease would have quickly been inactivated.

Surimi prepared from both species of hake processed without belly flaps was held in frozen storage at −20°C for 3 months and the gel-forming ability evaluated as before. The results (Fig. 2) reveal that neither surimi significantly changed in gel-forming properties over this storage period. While 3 months is not an especially long storage period for surimi, changes in texture-forming properties of red hake minces have been known to occur rapidly over much shorter storage periods (Dingle et al., 1977; Holmquist, 1982). Our data thus confirm the Holmquist (1982) report that surimi produced from red hake is more stable in frozen storage than unrefined mince.

Commercial Processing Plant Trial

The encouraging results with respect to the high gel-forming ability obtained in the laboratory-processed surimi from both red and silver hake led to a processing trial in a commercial surimi plant.

However, problems were encountered during procurement of fish for this trial which resulted in poor quality fish for processing. The gel-forming ability of the surimi produced was therefore very poor (Fig. 3). The gel-forming ability was slightly less than that of surimi processed in the laboratory from fish with belly flaps on (Fig. 1). The low values for gel-forming ability, although disappointing, do accentuate the need to use high-quality fish of these species for processing into surimi, even for fish from which the napes are removed prior to deboning (as was done in this trial for both species).

The color of the surimi produced in this trial, although not precisely measured, was subjectively judged to be equal or greater in lightness to that of the high-grade commercial samples. The processing equipment used was therefore deemed adequate in its ability to remove the dark belly lining of the hake which might otherwise detract from the appearance of the surimi.

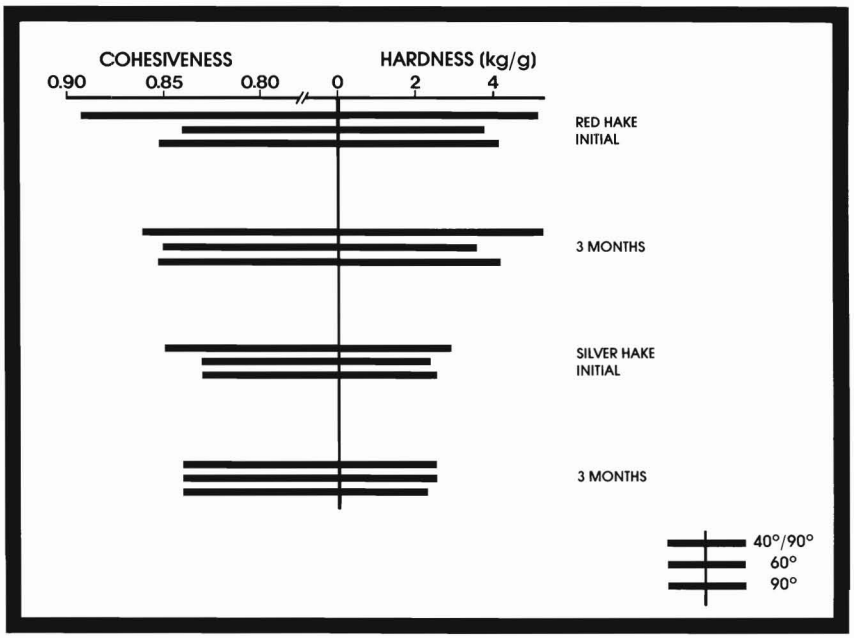

Figure 2.—Instron texture profile values (cohesiveness, hardness) of gels prepared from fresh (initial) and frozen (3 months) samples of red hake and silver hake surimi processed in the initial laboratory trials; gel process temperature codes are same as Figure 1.

Final Laboratory Trials

Final laboratory trials of red and silver hake were conducted to determine more accurately the effect of holding method (whole or eviscerated) and time in ice on the gelling quality of the processed surimi.

The results of this trial for red hake are shown in Figure 4. Surimi prepared from fish stored whole evidently possessed a high content of heat-stable protease, as evidenced by the poor texture of gels prepared at 60°C. However, the texture of gels prepared at 90°C or 40°/90°C was slightly better for surimi prepared from fish stored whole than for that processed from the fish stored dressed. This may be attributed to the absence of the napes in the processing of the fish stored whole. Hardness values decreased somewhat with time of holding while cohesiveness values remained nearly constant.

The results of the final laboratory processing trial for silver hake are shown in Figure 5. The fish stored whole for 8 days were judged unfit for processing; thus, no data is included for this treatment. Again, fish stored whole apparently possessed a higher content of

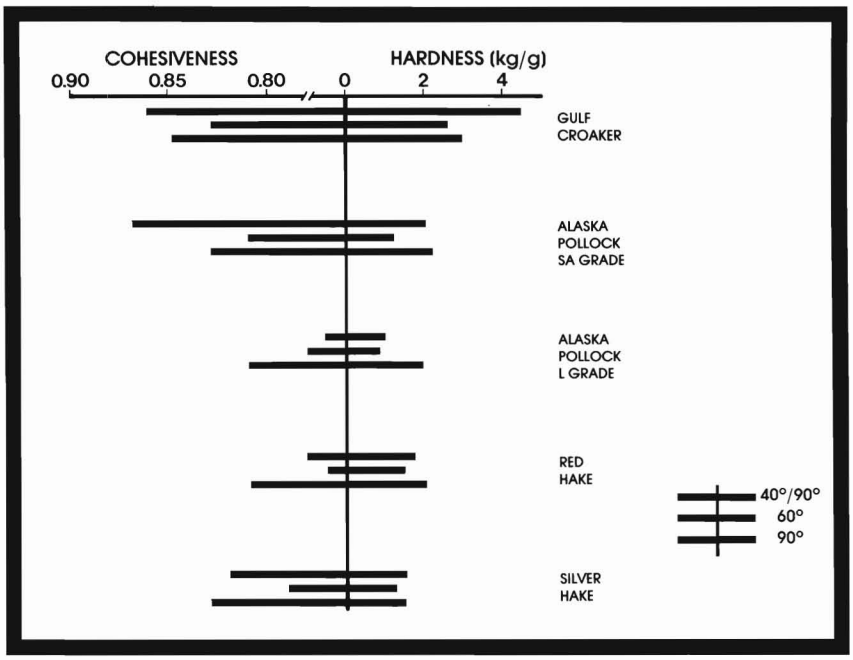

Figure 3.—Instron texture profile values (cohesiveness, hardness) of gels prepared from surimi processed in commercial trial of red and silver hake and from commercially obtained surimi samples; gel process temperature codes are same as Figure 1.

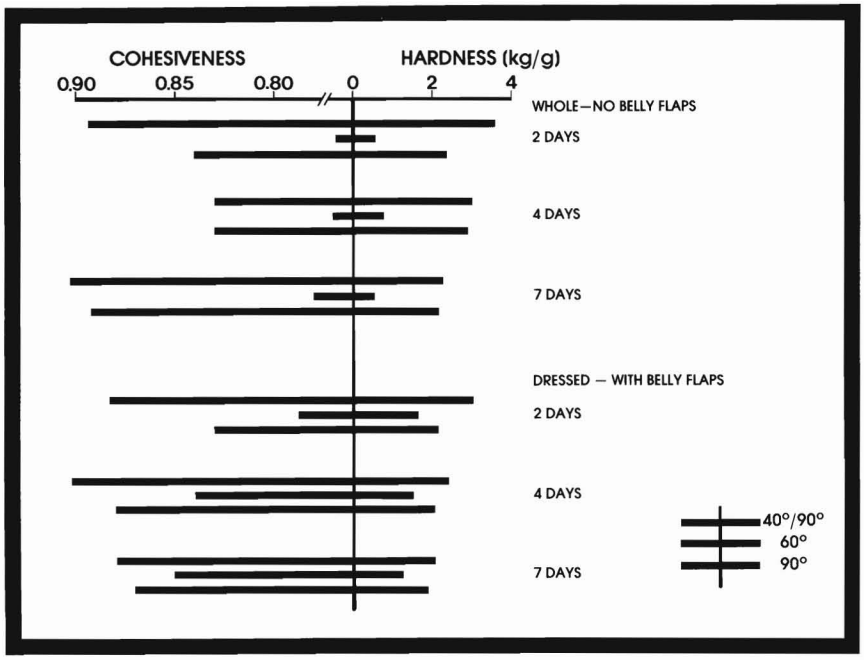

Figure 4.—Instron texture profile values (cohesiveness, hardness) of gels prepared from surimi processed from red hake stored whole (processed without belly flaps) or dressed (processed with belly flaps) in ice for 2, 4, or 7 days; gel process temperature codes are same as Figure 1.

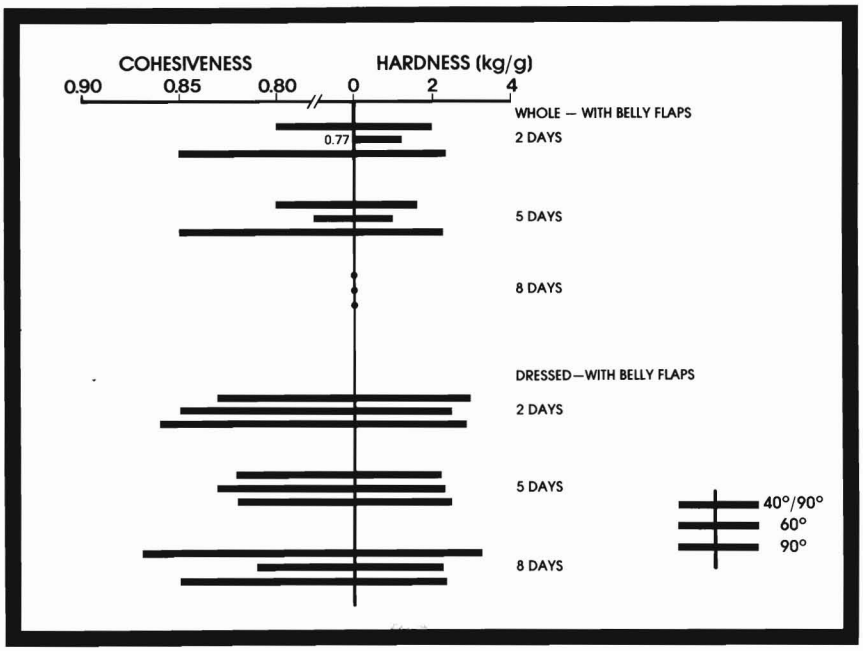

Figure 5.—Instron texture profile values (cohesiveness, hardness) of gels prepared from surimi processed from silver hake stored whole or dressed (both processed with belly flaps) in ice for 2, 5, or 8 days; gel process temperature codes are same as Figure 1.

heat-stable protease, as evidenced by the poorer texture of the gels prepared at 60°C. Contrary to the results for red hake (Fig. 4), the dressed fish produced surimi having higher gel-forming ability in most cases. The difference may be explained by the inclusion of the belly flaps in the processing of both treatments in the test of silver hake, whereas the belly flaps were removed from the whole-stored fish in the test of red hake. While the 90°C processing temperature resulted in similar texture values for gels prepared from fish stored both whole and dressed, the 40°/90°C process yielded much lower values for the whole-stored fish. This suggests that either the belly flap tissue contained protease that was active during the 40°C precook, or that deterioration of the belly flaps during storage resulted in a material which, when included in the processing of the surimi, interfered with the 40°C "setting" ability of the tissue.

From these data and those of the first laboratory trial, it must be concluded that removal of the napes prior to deboning and processing would be beneficial to the gel-forming ability of the resultant surimi, regardless of whether the fish had been dressed immediately upon harvest or later at the time of processing. The (presumed) elevated protease levels in surimi prepared from whole-stored fish are undesirable and could lead to serious textural problems in products prepared from such surimi if the thermal process temperature is not strictly controlled. Therefore, rapid gutting of fish is advisable, particularly when the fish have been feeding heavily as were the fish used for the commercial trial. While no objective measurements were made regarding the quality of fish at any day of processing, subjectively it was determined that gutting the fish enhanced overall fish quality during iced storage in agreement with other published studies (Townley and Lanier, 1981). This factor could influence organoleptic attributes of the surimi other than its gel-forming ability.

Conclusion

These results suggest that red and silver hake, and particularly red hake, have excellent potential as raw material

for surimi production when high-quality fish are used as the starting material. Besides producing a surimi of exceptional quality, the red hake are in good supply, have limited other food uses, and are therefore a low-cost material. As the consumption of restructured seafoods increases in this country, a rising demand for surimi will offer potential for development of underutilized fish species as a food resource. Such development of the hake resource would extend our domestic fishing industry and offset the need to import Japanese-processed products.

Acknowledgments

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Literature Cited

Bourne, M. C. 1968. Texture profiling of ripening pears. J. Food Sci. 33:223.

Castell, C. H., B. Neal, and W. J. Dyer. 1972. Production of dimethylamine in muscle of several species of gadoid fish during frozen storage, especially in relation to presence of dark muscle. J. Fish. Res. Board Can. 28:1-5.

_____, B. Smith, and W. J. Dyer. 1973. Effects of formaldehyde on salt-extractable proteins of gadoid muscle. J. Fish. Res. Board Can. 30:1205-1213.

Dingle, J. R., R. A. Keith, and B. Lall. 1977. Protein instability in frozen storage induced in minced muscle of flat fishes by mixture with muscle of red hake. Can. Inst. Food Sci. Technol. J. 10(3):143-146.

Gill, T. A., R. A. Keith, and B. Smith-Lall. 1979. Textural deterioration of red hake and haddock muscle in frozen storage as related to chemical parameters and changes in the myofibrillar proteins. J. Food Sci. 44:661-667.

Holmquist, J. 1982. Interrelations between salt-extractable protein, actomyosin, Ca^{+2}-ATPase activity and kamaboko quality prepared from frozen red hake fillets, mince and surimi. Masters Thesis, Univ. Mass., 91 p.

Lanier, T. C. 1981. Minced fish products: A short course. Ocean (Seafood) Leader, Winter, p. 18.

_____. 1983. Restructured products: Seafood alchemy for the eighties. Seafood Bus. Rep. 81(1):28.

_____, T. S. Lin, D. D. Hamann, and F. B. Thomas. 1981. Effects of alkaline protease in minced fish on texture of heat-processed gels. J. Food Sci. 46:1643-1645.

_____, T. S. Lin, Y. M. Liu, and D. D. Hamann. 1982. Heat gelation properties of actomyosin and surimi prepared from Atlantic croaker. J. Food Sci. 47(6):1921-1925.

Lin, T. S., and T. C. Lanier. 1980. Properties of an alkaline protease from the muscle of Atlantic croaker. J. Food Biochem. 4:17-28.

Su, H. S., T. S. Lin, and T. C. Lanier. 1981. Contribution of retained organ tissues to the alkaline protease content of mechanically separated Atlantic croaker (*Micropogon undulatus*). J. Food Sci. 46(6):1650-1653, 1658.

Suzuki, T. 1981. Fish and krill protein: Processing technology. Appl. Sci. Publ., Ltd., Lond., 260 p.

Toda, J., T. Wada, K. Yasumatsu, and K. Ishii. 1971. Application of principal component analysis to food texture measurements. J. Texture Stud. 2:207-219.

Townley, R. R., and T. C. Lanier. 1981. Effect of early evisceration on the keeping quality of Atlantic croaker (*Micropogon undulatus*) and grey trout (*Cynoscion regalis*) as determined by subjective and objective methodology. J. Food Sci. 46(3):863-867.

USDC. 1983. Status of the fishery resources off the northeastern United States for 1982. NOAA Tech. Memo. NMFS-F/NEC-22, 128 p.