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Suitability of Seafood Species as Raw Materials

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INTEREST in the recovery and utilization of minced fish flesh increased dramatically during the early 1970s (King and Carver, 1970; Miyuachi and Steinberg, 1970; Crawford et al., 1972). Five major conferences specifically devoted to the subject of mechanical separation and utilization potential of minced fish have been held since 1972 (Martin, 1972; Martin, 1974; Kreuzer, 1974; Connell, 1979; Martin, 1982). University, state, and federally supported researchers have demonstrated at these conferences that minced fish can be successfully used directly in various food systems and in a physically or chemically altered form to produce an array of nutritional and functional products (Spinelli and Dassow, 1982; Grantham, 1981; Suzuki, 1981).

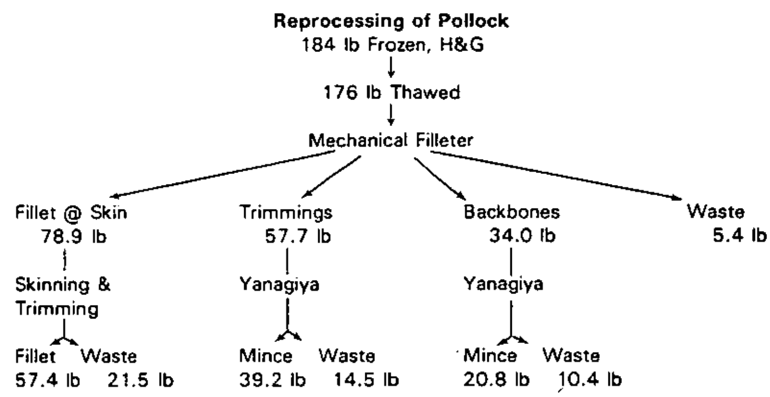

Fig. 1—**Recoveries** *obtained from the reprocessing of pollock (Babbitt et al., 1984)*

Uses of Minced Fish

The industry already has in the marketplace many tons of minced fish blocks which are being cut into fish sticks and portions (Martin, 1976). It is generally recognized that a minced fish block is more susceptible to the effects of storage conditions than a fillet block. Laminated blocks of fillets and evenly mixed minced fish in which the minced fish originates from fillet trimmings (such as V-cuts) have gained acceptance by U.S. producers of sticks and portions (King, 1977). Lamination represents a greater use of fish as food. Babbitt et al. (1984) reported that nearly 33% of the weight of headed and gutted pollock could be recovered as fillets using a mechanical filleting machine (Fig. 1). An additional 34% could be recovered as mince from the fillet trimmings and backbone by mechanical mincing (fillet trimmings 22%; backbone 12%). However, if laminated blocks contain too much minced fish, the changes in texture or in flavor are especially noticeable (Table 1).

The results shown in Table 1 indicate that the quality and changes occurring during frozen storage in blocks prepared from chopped fillets were similar to that of conventional fillet blocks. However, there were changes in texture, flavor, and color of minced fish blocks. What is important is that chopping the fillets and randomly packing them into fish blocks to facilitate handling did not affect the stability of the fish tissue during frozen storage or the desirability of the portion compared to a portion prepared from the traditionally layer-packed fillet block. Also, an acceptable product can be made by the addition of 20% mince to fillet blocks. Laminated cod blocks, containing up to 10% (United Kingdom) or 12–14% (Norway) evenly distributed minced fish have been accepted in the marketplace (King, 1977).

A recently completed study (Agnello, 1983) to incorporate minced fish directly into food systems examined the economic potential for utilizing minced fish in the production of hot dogs and other cooked sausage products. Since the U.S. Department of Agriculture (USDA) establishes identity standards for hot dogs, the potential utilization of minced fish in products labeled hot dogs would require USDA approval. The U.S. fishing industry would benefit with the opportunity for wider use of underutilized species through expanded markets, while the food industry would benefit from more flexibility with respect to cost and nutritional and functional formulations for cooked sausage products.

Properties of Minced Fish

Undoubtedly, the inherent value of minced fish is its unique texture-forming properties that make it such an excellent base for manufac-

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Table 1—**Desirability, Color, Flavor, and Texture** *of fried breaded pollock portions over a period of time*[a] *(Babbitt et al., 1984)*

Factor	Months of storage at −18°C	Fillets	Chopped fillets with percent mince added: 0%	20%	50%	Mince
Desirability[b]						
	1	7.3 ± 0.8[X]	7.4 ± 0.8[X]	6.9 ± 1.0[X]	5.1 ± 1.7[Y]	4.0 ± 1.4[Y]
	4	6.8 ± 1.1[X]	6.5 ± 1.3[X]	5.4 ± 1.0[X]	3.4 ± 1.2[Y]	2.2 ± 1.1[Y]
	8	6.9 ± 1.5[X]	5.9 ± 1.6[X]	5.3 ± 1.4[XY]	3.3 ± 1.9[YZ]	1.9 ± 1.7[Z]
Color[c]						
	1	7.6 ± 1.0[X]	7.6 ± 0.7[X]	6.9 ± 1.6[X]	4.7 ± 1.7[Y]	3.4 ± 1.2[Y]
	4	7.0 ± 1.4[X]	7.3 ± 1.4[X]	5.7 ± 1.1[X]	3.3 ± 1.2[Y]	1.3 ± 0.5[Z]
	8	6.9 ± 1.6[X]	6.4 ± 1.0[X]	4.8 ± 1.3[X]	2.9 ± 1.4[Y]	2.0 ± 1.5[Y]
Flavor[c]						
	1	7.4 ± 0.7[X]	7.1 ± 1.1[X]	6.8 ± 1.1[X]	5.8 ± 1.3[XY]	4.6 ± 1.8[Y]
	4	6.8 ± 1.1[X]	6.6 ± 1.3[X]	5.9 ± 1.1[XY]	4.2 ± 1.6[YZ]	3.7 ± 1.8[Z]
	8	6.9 ± 1.4[X]	5.9 ± 1.7[X]	5.5 ± 1.4[XY]	4.0 ± 1.4[YZ]	2.7 ± 2.0[Z]
Texture[c]						
	1	7.1 ± 1.3[X]	7.3 ± 1.2[X]	6.6 ± 1.7[X]	5.6 ± 2.0[X]	4.9 ± 2.1[X]
	4	7.1 ± 1.4[X]	6.5 ± 1.6[X]	5.6 ± 1.0[XY]	3.8 ± 1.2[YZ]	3.2 ± 1.5[Z]
	8	7.0 ± 1.6[X]	6.3 ± 1.4[X]	5.3 ± 1.4[X]	2.9 ± 2.0[Y]	1.9 ± 1.6[Y]

[a]Mean scores ± standard deviation with the same letter in a row *did not vary significantly* ($P < 0.05$) from each other ($n = 10$).
[b]*Hedonic scale:* 9, "liked extremely", to 1, "disliked extremely".
[c]Scale: 9, "excellent", to 1, "unacceptable".

turing a variety of seafood products (Lanier, 1981). Texture of new seafood products should not be regarded as of minor importance to the overall consumer acceptance. A study published by researchers at the University of Wisconsin (Wesson et al., 1979) investigating the sensory factors (taste, flavor, texture, etc.) which affect consumer acceptance of seafood products reported that while "flavor characteristics were major determinants of preference when distinctly oxidized flavors were present, texture was an extremely influential determinant of preference when samples exhibited moderate to low intensities of fishy and/or oxidized flavors." These findings were the result of utilizing the native binding properties of fish proteins in fabricating a minced fish-shrimp portion (Babbitt et al., 1974). Wesson et al. (1979), concluded that "the favorable consumer reaction to a new high-quality fish-shrimp portion should provide encouragement for the development of other products utilizing shrimp flavor and texture of lower-grade shrimp pieces, and other traditionally less sought-after fish species." Indeed, Early an Denton of the Torry Research Sta tion (1984), have reported usin this technique for the fabricatio and extrusion of a crab product.

Table 2—**Acceptance** *of intact and minced fish flesh held at −20°C (Babbitt, 1974)*

Species/weeks of storage	Acceptability (Scale 1-9)[a,b]: Intact fillet	Minced fillet	Minced fillet-skin	Minced frame	Minced headed and gutted
Pacific Whiting					
0 wk	6.98[c]	5.62[d]	4.32[e]	4.34[e]	4.68[e]
12 wk	5.78[c]	5.20[c]	4.16[d]	3.62[e]	4.42[d]
Ling cod					
0 wk	5.92[c]	4.60[d]	4.46[d]	3.38[e]	5.54[c]
12 wk	6.42[c]	4.92[d]	4.82[d]	3.78[e]	5.36[d]
Rockfish					
0 wk	6.80[c]	5.66[d]	5.82[d]	4.08[e]	4.78[e]
12 wk	6.06[c]	4.56[d]	4.88[d]	3.58[e]	4.46[d]
English sole					
0 wk	5.66[c]	4.72[d]	4.32[d]	2.66[f]	3.44[e]
12 wk	6.12[c]	4.90[d]	4.52[d]	2.74[f]	3.80[e]

[a]Mean score in a horizontal row with same exponent letter did not vary significantly ($P < .05$) from each other.
[b]*n = 25 taste panelists.*

Differences in Minced Fish Preparation

Up until recently, the seafoo industry has tended to look minced fish primarily as a source low-cost protein and as a potenti use for "scrap fish" and fish b products. Results of product deve opment and marketing aspects minced fish have been publish (Regenstein, 1980). The quality minced fish is affected by speci season of harvest, and handling the fish, as well as the method processing. Babbitt (1974) dete mined the composition and chem cal changes occurring during froz storage in minced fish made from fillets, fillets with the skin cleaned headed and gutted fish, a cleaned frames remaining after leting from several species of b tomfish. Acceptance of the min portions was evaluated on a scale 9 "excellent" to 0 "bad" (Table A score of 4 would be accepta and 6 would be very good; belo indicated unacceptability. mince from fillets and fillets w the skin on were found to be v acceptable. Panelists preferred portions from intact fillets prim ly because of the "flaky" textur the fillet. The minces prepared from headed and gutted fish began to show species differences. The mince from lingcod was found to be "very good", while the mince was borderline to unacceptable from English sole. In the case of minced fish from cleaned frames remaining after filleting, it was unacceptable from English sole and lingcod. Even though the minced flesh from the frames was found to be acceptable from Pacific whiting and rockfish when it was prepared, storage at −20°C resulted in much lower acceptance. Mechanical mincing had a pronounced effect on the formation of dimethylamine (DMA) in the minced fish (Table 3). The changes in DMA concentrations during frozen storage of Pacific whiting is typical of all gadidae species. Although mechanical mincing increased the initial level of DMA in the minced flesh from rockfish, English sole, and lingcod, the relative levels of DMA remained constant during frozen storage. Thus the differences detected in the various minces may be the reason why washing is so important in the production of surimi (a semi-processed wet fish protein). Washing can greatly improve the color of minced flesh, and the chemical systems that produce undesirable changes, like the formation of DMA, are removed.

Table 3—**Dimethylamine (DMA) Content** *of intact and minced fish muscle held at −20°C (Babbitt, 1974)*

Species/weeks of storage	DMA content (μg DMA/g sample) Intact fillet	Minced fillet	Minced fillet-skin	Minced frame	Minced headed and gutted
Pacific whiting					
0 wk	7.3	16.7	31.7	73.9	40.8
12 wk	63.0	80.7	86.2	322.8	260.2
Ling cod					
0 wk	1.4	3.1	6.2	5.5	2.4
12 wk	3.5	5.4	12.2	12.5	4.8
Rockfish					
0 wk	1.5	3.1	1.9	2.6	1.4
12 wk	2.8	4.9	4.5	4.7	3.6
English sole					
0 wk	1.9	2.5	4.3	3.1	2.3
12 wk	2.1	3.4	3.9	5.7	3.4

Properties of Surimi

The successful introduction of crab, shrimp, and scallop analogs made from surimi has rekindled the interests of U.S. processors in minced fish technology. The salt-soluble fish muscle proteins when heat-gelled take on a springy resilient texture. The texture-forming ability of these raw fish proteins decreases during frozen storage. Washing not only removes fat and undesirable materials, such as blood, pigments, and other water-soluble constituents, but more importantly, increases the concentration of myofibrillar proteins (actomyosin), thereby improving gel strength and elasticity, essential properties for surimi-based products (Kudo et al., 1973; Lee, 1984). In Japan, an entire "Kamaboko" industry has been built around the unique texture-forming properties of muscle proteins (Okada et al., 1973). Extensive literature is available on the use of various sugars, salts of organic acids, and other compounds to prevent the loss of the gelling properties in the frozen product (Grantham, 1981; Suzuki, 1981). Presently, the use of 4% sucrose, 4% sorbitol, and 0.3% phosphates for this purpose is satisfactory. With proper use of such additives and low storage temperatures, surimi may be held frozen with little loss of gelling properties for six months or longer. It is this keeping quality of surimi that has allowed the growth of the production of "kneaded" products, the most important form of fish processing in Japan, accounting for 25% of all raw fish by volume (Okada et al., 1973). Subsequently, frozen surimi production increased from 32 metric tons in 1965 to 380 metric tons in 1975, together with a production of 1.1 million tons of kneaded products (Lee, 1984).

Factors Affected by Washing Minced Fish

It is important to remember that surimi is an intermediate processed form of minced, washed, dewatered, and strained fish flesh, and different qualities of surimi are suited for different types and qualities of final kneaded products. Although the resulting surimi is a bland, light-colored, highly functional food item, there are changes in the compositional and nutritional properties as a result of washing or fresh-water leaching.

Adu et al. (1983) determined the yield and nutritional characteristics of unwashed and washed minced rockfish flesh and fillets. The yield of fillets from whole fish was 26%

Table 4—**Proximate Composition** *of unwashed and washed flesh from rockfish, croaker, and Alaska pollock*

	Rockfish[a] Unwashed	Rockfish[a] Washed	Croaker[b] Unwashed	Croaker[b] Washed	Pollock[c] Unwashed	Pollock[c] Washed
Moisture	77.31	90.30	73.7	77.0	81.76	88.01
Protein (N × 6.25)	18.17	9.50 (88.37)[d]	19.6	17.0 (76.23)[d]	16.89	10.75 (95.98)[d]
Fat	4.69	1.11 (10.33)	4.6	4.4 (19.73)	0.45	0.19 (1.70)
Ash	1.06	0.14 (1.30)	0.5	0.9 (4.04)	1.00	0.26 (2.32)

[a]Adu et al., 1983
[b]Rasekh et al., 1980
[c]Babbitt, 1985
[d]Dry weight values in ( )

compared to 43% for minced flesh. Washing minced flesh resulted in a 37% loss of solids. The greatest reductions were found in the ash (80%) and lipid (65%) levels in the washed flesh. Most of the sarcoplasmic proteins were lost during washing, while 77% of the total protein (N × 6.25) was recovered. Washing minced flesh did not affect the amino acid composition, and PER values for all three fish treatments were higher than the casein reference.

Recently completed studies with Alaska walleye pollock (Babbitt, 1985) support the findings of Adu et al. (1983); however, Rasekh et al. (1980), reported little difference in proximate composition between washed and unwashed minced fresh croaker (Table 4). Washing minced pollock flesh resulted in a 28% loss of solids. Reductions in ash (70%) and lipid (46%) levels were found, while 75% of the total protein (N × 6.25) was recovered. Croaker, rockfish and pollock are noted for their high gel-forming properties (Kudo et al., 1973; Suzuki, T., 1981), which is reflected by the similarity of amino acid patterns of the washed minced flesh (Table 5).

Thus, washing not only removes fat and other water soluble substances, but more importantly, increases the concentration of gel-forming proteins essential for producing surimi-based products. Washed minced Alaska pollock *(Theragra chalcogramma)* is comprised mainly of these proteins, and because of this, more than 95% of the world's surimi is made from pollock. The much higher fat content of washed rockfish and particularly washed croaker flesh must not affect the frozen storage stability, for croaker has been reported as being an excellent raw material for surimi production (Suzuki, 1981).

Table 5—**Amino Acid Composition** *of washed minced flesh from rockfish, croaker and Alaska pollock*

Amino acid	g/100 g protein		
	Rockfish[a]	Croaker[b]	Pollock[c]
Lysine	10.2	9.8	7.7
Histidine	2.2	2.2	2.6
Arginine	7.1	6.2	6.8
Aspartic acid	10.6	10.6	9.1
Threonine	4.8	4.8	5.0
Serine	4.2	4.2	4.8
Glutamic acid	17.6	16.7	13.6
Proline	3.8	3.9	3.6
Glycine	3.8	4.4	3.5
Alanine	5.6	6.1	6.1
Half cystine	0.3	—[d]	—[d]
Valine	5.1	5.1	5.2
Methionine	3.5	3.4	3.4
Isoleucine	4.7	4.6	4.9
Leucine	8.0	8.5	7.5
Tyrosine	4.2	3.8	4.2
Phenylalanine	4.1	4.0	3.8
Tryptophan	0.6	—[d]	—[d]

[a]Adu et al., 1983.
[b]Rasekh et al., 1980.
[c]Babbitt, 1985.
[d]Amino acid not determined.

Potential Supplies and Markets

Undoubtedly, Alaska pollock will be the leader in surimi production because of its chemical properties and tremendous resource. Recent results indicate that other domestic stocks, such as silver hake *(Merluccius bilinearis)* and red hake *(Urophycis chuss)*, also have excellent potential for surimi production (Lanier, 1984). Preliminary results suggest that, although menhaden may still have a slight flavor, odor, and color, because of its gelling ability, it may be easily blended out by the addition of other seafood products (Lebovitz, 1985).

To produce minced fish and surimi that meets the quality standards necessary for the continuing growth of these industries, close quality control is required. Basic understanding of the properties of minced fish and surimi must continue to be developed to ensure the growth of engineered seafood-based products.

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