Preservation and Processing Characteristics of Pacific Whiting, *Merluccius productus*

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Introduction

The Pacific whiting, *Merluccius productus*, has been the object of considerable interest and research for nearly 20 years. Population estimates made in the early 1960's showed that Pacific whiting was one of the most abundant species of commercially harvestable fish off Oregon and Washington (Alverson et al., 1964). Although less abundant than off the coast, Pacific whiting are also found in the inland waters of Washington and Canada where they are commercially fished for domestic markets.[1] The species has been evaluated for potential use in traditional product forms such as fillets (Dassow et al., 1970) and as animal feed (Berg, 1970; Stout et al., 1970) as well as for the production of fish protein concentrate (Havighorst, 1971). Despite these efforts, Pacific whiting has not gained wide acceptance and remains an underutilized species in the domestic fisheries.

The lack of domestic utilization of Pacific whiting (especially ocean caught) can be attributed to several factors that relate to the properties of the fish and to economics. The major impediment to further commercial development of Pacific whiting is soft texture in the flesh of many individual fish caused by a microscopic parasite Myxosporea. Details of the parasite infection have been previously reported by Dassow et al. (1970), Kabata and Whitaker (1981), and Tsuyuki et al. (1982) and are the subject of a separate paper in this issue of the *Marine Fisheries Review* (Kabata and Whitaker (1985)). The parasite infection results in a high enzyme activity in the tissue causing rapid softening dependent on degree of infection, pH, temperature, and time. Since these factors vary significantly between fish and fish catches, it is understandable that confusion about Pacific whiting quality and acceptability is common. Unfortunately, the infected fish are not easy to cull out during processing because the infected tissue is not always visually obvious. The chemical, physical, and biological properties that are important to the future use of the species are discussed below.

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Proximate Chemical Composition

The proximate chemical composition of Pacific whiting was analyzed at the Utilization Research Division, Northwest and Alaska Fisheries Center (NWAFC), Seattle, Wash., from 1964 to 1966 (Patashnik et al., 1970). The results of these analyses will be summarized here.

Pacific whiting is typical of white-fleshed fish. The protein content of the flesh ranges from 14 to 16 percent and the oil content ranges from 0.5 to 3.8 percent. Ocean whiting and Puget Sound whiting are apparently separate stocks and differ slightly in composition. Seasonal differences are also common. Tables 1-4 illustrate these variations.

Ocean Whiting

Tables 1 and 2 present average proximate composition values for ocean-caught whole whiting, edible fillets, and waste, and the range of variation for their average values. Whiting caught during the spring and early summer of 1964 and 1965 (March-July) had low fat contents of about 1.5-3.5 percent (Table 1). Subsequent composition data obtained from early season catches during 1966 were similar in content to composition data obtained from whiting caught in the early summers of 1964 and 1965. In contrast, whiting sampled during the falls of 1964-66 (September-November) had high fat contents of about 4-6 percent. The protein content, on the other hand, showed less seasonal variability. In 1964-66, the protein content was 13.4-15.0 percent during March-July periods, 14.4-15.6 percent during September-November periods. The ash content for the same periods was relatively constant at about 3.0 percent. The high moisture content during the spring and early summer was offset by the low total fat and protein contents.

The average values for moisture, protein, fat, and ash in Table 2 may be considered to reflect the average composition of whiting harvested during the months of May to November. The ranges in composition value may be considered the likely limits of variation in composition of the whiting during this same period. In Table 2, we note that the waste portion in comparison with the edible portion has a lower moisture and protein content and a substantially higher fat content.

Puget Sound Whiting

Tables 3 and 4 show the average chemical composition of Puget Sound whiting and the variation in average values for a year. The seasonal trends previously noted for whole ocean whiting were similarly apparent for Puget Sound whiting but were slightly out of phase. The fat content of whole whiting was highest from October 1965 through January 1966 and ranged from 6.4 to 7.4 percent; moderate from February through April 1966, 4.5-7.0 percent; and lowest from May to July, 2.5-5.0 percent. The average fat content of Puget Sound whiting was higher than that of ocean whiting, being 76 percent higher in the whole fish (5.7 percent vs. 3.3 percent), 56 percent higher in the fillets (2.5 percent vs. 1.6 percent), and 69 percent higher in the waste portion (6.4 percent vs. 3.8 percent).

The variation in protein content appeared to be related to the spawning cycle. The protein content was 13.6-14.7 percent from January through March. By April, the protein content dropped to 12.3-13.4 percent due to spawning. During May, protein increased from 13.2 to 14.9 percent, and by July, the protein had increased to 16.1 percent. By November and December, as the fat reached its maximum. protein dropped again to the 13.8-14.9 percent range noted early in the year.

Because the liver is known to be high in fat at certain times of the year, we analyzed male and female livers. For the period January through May and during October, the average fat content of female livers was 44 percent (33-49 percent) and that of male livers was 58 percent (34-68 percent). Male livers averaged 31 percent higher in fat than female livers. The liver generally is about 5-7 percent of the body weight so it represents a major contribution to the fat content of the whole fish.

The flesh quality of the Puget Sound whiting is superior to that of the offshore ocean whiting mainly because the abnormal (mushy) texture

Table 1.—Seasonal variation in proximate composition of whole Pacific whiting from coastal waters of Washington and Oregon, 1964-65[1].

Year and season	Proximate composition (%) Moisture	Protein	Fat	Ash
1964				
Spring	81.4 ± 1.41[2]	14.3 ± 1.03	1.6 ± 0.21	3.2 ± 0.45
Summer-Fall	78.2 ± 1.78	15.2 ± 0.34	5.0 ± 0.73	2.9 ± 0.11
1965				
Spring	80.7 ± 0.80	14.0 ± 0.61	2.3 ± 0.42	3.2 ± 0.15

[1]These diets are season averages based on 14 samples of about 12 fish per sample (Dyer et. al., 1966).
[2]Mean ± standard deviation.

Table 2.—Proximate composition and potassium and sodium contents of edible fillets and waste portion of Pacific whiting from coastal waters of Washington, Oregon, and California, 1964-66[1].

Item	Moisture (%) Fillets	Moisture (%) Waste	Protein (%) Fillets	Protein (%) Waste	Fat (%) Fillets	Fat (%) Waste
Average	81.5 ± 1.29[2]	79.1 ± 2.05	16.5 ± 0.87	14.4 ± 0.64	1.6 ± 0.74	3.5 ± 1.76
Range	79.4-84.0	75.3-83.4	14.0-17.8	12.7-15.5	0.5-3.1	14.0-7.5

Item	Ash (%) Fillets	Ash (%) Waste	Potassium (%) Fillets	Potassium (%) Waste	Sodium (%) Fillets	Sodium (%) Waste
Average	1.1 ± 0.18	3.8 ± 0.13	385 ± 44.4	269 ± 23.9	77 ± 18.6	173 ± 35.0
Range	0.5-1.5	2.3-4.7	335-470	237-304	51-103	135-228

[1]Composition data represent the average of 30 samples of about 12 fish per sample taken from January 1964 through October 1966. The potassium and sodium data represent 7 samples taken during 1964.
[2]Mean ± standard deviation.

Table 3.—Proximate composition of whole Pacific whiting from Puget Sound, 1965-66[1].

Item	Proximate composition (%) Moisture	Protein	Fat	Ash	Fish length (in.)	Fish weight (oz.)
Average	77.9 ± 1.60[2]	14.0 ± 0.86	5.7 ± 1.34	3.0 ± 0.61	14.2	13.7
Range	75.1 ± 80.8	12.3-16.1	2.6-7.4	2.4-5.2	9.8-25.6	3.5-64.6

[1]Composition data are based on 19 samples of about 25 fish per sample taken during July 1965 to October 1966. Samples were largely from Port Susan and Saratoga Passage but also from Carr Inlet and Hood Canal and off Everett and LaConnor.
[2]Mean ± standard deviation.

Table 4.—Proximate composition of the edible fillets and waste parts of Pacific whiting from Puget Sound, 1965-66[1].

Item	Moisture (%) Fillets	Moisture (%) Waste	Protein (%) Fillets	Protein (%) Waste	Fat (%) Fillets	Fat (%) Waste	Ash (%) Fillets	Ash (%) Waste
Average	81.3 ± 0.78[2]	78.5 ± 3.06	16.1 ± 0.95	13.7 ± 0.89	2.5 ± 0.85	6.4 ± 2.11	1.1 ± 0.19	3.8 ± 0.83
Range	80.2-83.1	72.6-82.7	14.0-18.7	11.7-15.3	1.2-3.8	1.6-9.8	0.9-1.7	3.1-7.0

[1]Composition data are based on 19 samples of about 25 fish per sample taken during July 1965 to October 1966. Samples were largely from Port Susan and Saratoga Passage but also from Carr Inlet and Hood Canal and off Everett and LaConnor.
[2]Mean ± standard deviation.

frequently found in ocean whiting is a relatively minor problem with the Puget Sound whiting so it can be more readily used in food-type products.

The average protein composition of the ocean whiting fillets was about 16.5 percent and that of the Puget Sound whiting fillets about 16.1 percent, making them both excellent food fish from a nutritional standpoint. Once the abnormal textural condition is completely resolved, whiting will have great demand as a high-quality food fish. The abnormal texture does not affect the availability of its high protein.

Sensory Properties

The sensory properties of any food product are extremely important in determining the acceptability and value of the product to the consumer. One of the major considerations in attempting to utilize Pacific whiting has been color, odor, flavor, and texture of the flesh. Texture is especially important in evaluating Pacific whiting as it is a major factor in determining the marketability.

Color

Athough color of the raw flesh varies from an off-white to pink, it is within the normal range of color found in the various Pacific coast species that are now filleted and marketed.

Odor

The raw flesh has a neutral odor typical of white-fleshed fish. As is common with most fish, Pacific whiting must be refrigerated immediately on landing aboard the vessel to avoid the development of strong odors on the skin.

Flavor

Very fresh whiting that is properly cooked has a bland flavor that consumers consider desirable. For many types of frozen prepared foods, such as precooked breaded fillets, this mild flavor permits modification with small amounts of additives.

Texture

In our preliminary evaluation of the potential use of whiting, fishermen and processors commented unfavorably on the soft, sometimes mushy texture of whiting. Our first concern was to determine the normal texture of fresh whiting, and then evaluate the problem of the abnormal mushy texture.

Normal Texture

The normal texture of whiting flesh is moist and tender but not mushy. Most testers find it quite similar to that of Dover sole, *Microstomus pacificus,* and English sole, *Parophrys vetulus.*

Abnormal Texture

In our investigation, we noted a high incidence of abnormal texture in cooked samples of whiting caught off the coasts of Washington and Oregon. This texture adversely affected the acceptability of the whiting as food. We observed that the mushy condition of cooked whiting was associated with a microscopic myxosporean parasite, *Kudoa* sp., in the muscle, similar to that reported in whiting and other fish species by Willis (1949), Fletcher et al. (1951). Patashnik and Groninger (1964), and more recently by Kabata and Whitaker (1981).

Impact of the Kudoa Parasite on Texture

Research reported by Kabata and Whitaker (1981) showed that two species of *Kudoa* infect Pacific whiting and that one of the two, *Kudoa paniformis,* is significantly more prevalent in the ocean whiting. Further, this species has more of an impact on the tissue. This explains why the Pacific whiting from the ocean fishery has softer texture than Pacific whiting from Puget Sound or Georgia Strait. The Pacific whiting from these inside waters is infected with *Kudoa thyrsitis,* which has less effect on texture.

The muscle portions seriously infected with the myxosporean parasite exhibit proteolysis of the tissue with accompanying liquefaction and mushiness. Similar observations were made by Tsuyuki et al. (1982) in research describing the relationship between acid and neutral protease activity in Pacific whiting muscle infected with *Kudoa* sp. parasites and the occurrence of soft or mushy texture. In some samples of fresh whiting, we found levels of proteolytic activity up to 14 times greater than those in normal-textured, uninfected controls. Research reported by Miller and Spinelli (1982) indicated that in addition to temperature control, the proteolytic enzyme in Pacific whiting could also be inactivated with chemical inhibitors permitted in human food systems. The texture of heavily parasitized whiting was almost always abnormal and mushy, but that of slightly parasitized whiting was frequently normal. Usually, the moderately parasitized condition did not significantly affect the proximate composition of whiting. However, in those extreme cases in which we could see the flesh had deteriorated, the proximate composition appeared to be significantly altered. For example, the muscle from a single excessively parasitized whiting taken from Puget Sound was 11.1 percent protein in contrast to an average of 16.1 percent and low value of 14.0 percent protein for all samples of Puget Sound whiting.

Parasite Significance

Although *Kudoa* sp. parasites are found in Pacific whiting, they are also common in certain species of marketed fish in other parts of the world (Willis, 1949). In studies by the National Marine Fisheries Service (NMFS) and others, the incidence of the parasite was found to vary on average from 20 to 40 percent in a sample, but 100 percent of the whiting have been infected in some samples; the degree of infection depended on the area of the catch and the size of the fish. From a commercial standpoint, a high incidence of infestation in a catch would preclude its use for fresh or frozen fillets, owing to the probable mushy texture. At levels of low incidence, fillets of good quality can be produced with appropriate handling and inspection to eliminate any abnormal fillets.

There is no evidence that the Myxosporea can cause illness or infection in man. No health problems related to these organisms have been reported from areas, such as Japan, where raw marine fish are consumed; cooking readily destroys the organism if it is present in the fish muscle. Our main concern is the relationship of the organism to the textural quality and aesthetic acceptability of the fresh and frozen whiting products.

Table 5.—Comparison of sensory texture[1] of Pacific whiting frozen in dry ice, sectioned[2], and after 1-2 days of additional storage at 34°F refrozen and slow-[3] or fast-cooked.[4]

		Average ratings in each texture category											
		Frozen control				Thawed: 1 day @ 34°F and refrozen				Thawed: 2 days @ 34°F and refrozen			
		Slow cooked		Fast cooked		Slow cooked		Fast cooked		Slow cooked		Fast cooked	
Vessel treatment	Texture scale	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Whiting frozen in dry ice	5 Normal+	22	49	44	98	24	53	36	80	21	47	35	78
	4 Normal-	21	47	1	2	10	22	7	16	13	29	5	11
	3 Soft	0	0	0	0	6	13	2	4	6	13	4	9
	2 Overly soft	1	2	0	0	3	7	0	0	3	7	1	2
	1 Mushy	1	2	0	0	2	4	0	0	2	4	0	0

[1]Average texture is indicated for each fish. Where over 25 percent of the fish sample had a 1 or 2 texture, the entire fish was rated 1 or 2. The texture of the fast-cooked, battered-and-breaded, deep-fried product was graded on the basis of the fish alone after removing the breading.
[2]Each whiting was cut into 3/8-inch slices from nape to tail and sequentially placed into six treatment groups as indicated on the table. The slow- and fast-cooked comparisons of texture represent adjacent slices from three to five sections from nape to tail for each fish.
[3]Slow-cooked by baking in an oven at 400°F.
[4]Fast-cooked by frying in vegetable oil at 385°F (deep-fat).

Effect of Cooking Method on Texture

Because the soft texture of the cooked flesh of Pacific whiting is caused by the proteolysis of the muscle infected with the myxosporea parasite, the method of cooking will greatly influence texture. Since the proteolytic enzyme is eventually destroyed by heat, the rate of heating has a direct relationship on the texture of the cooked fillets that are infected with the *Kudoa* organism. The relatively slow methods of cooking, such as baking, broiling, or steaming, raise the temperature of the flesh to the optimum temperature range of the proteolytic enzymes associated with the parasite for a sufficient length of time to permit the enzyme to soften or liquefy the fish flesh before the cooking temperature rises to the point of enzyme inactivation. Rapid cooking methods, such as frying in deep fat at temperatures between 375°F and 400°F, shorten the interval between the temperature of maximum enzyme activity and inactivation of the enzyme and result in fillets with considerably better texture than do the slower methods of cooking. In one sampling of 76 whiting landed at Charleston, Oreg., fillet portions from 37 fish (48.7 percent) were mushy when baked, but only 4 portions of the 76 fish (5.3 percent) were mushy when deep fried. In another sampling of 378 whiting caught off the mouth of the Columbia River, portions of 25 fish (6.6 percent) were mushy when baked; but portions from all 378 fish were acceptable in texture when deep fried. Thus, it is essential to use rapid methods of cooking to minimize the incidence of mushy/pasty texture in the cooked flesh.

Effect of Preservation Method on Texture

A major concern of fishermen and processors contemplating participation in a whiting fishery has been the storage requirements to avoid texture degradation. Research conducted by the Utilization Research Division (NWAFC) has shown that rapid chilling following landing plus maintenance of temperature between 29°F and 32°F is important for minimizing texture problems. However, the degree to which soft texture occurs is largely a reflection of the degree of infestation of *Kudoa* rather than of temperature and time of holding. The results of several studies relating to method and time of holding are presented here to illustrate these observations.

Dry Ice

To evalutate the texture when cooked, whiting were frozen in dry ice and cooked immediately (control) or thawed and held for 1 and 2 days at 34°F, then slow or fast cooked (experimental group). Texture distribution, as determined by taste panel evaluations, is summarized in Table 5. Each fish was cut into six treatment groups according to the sampling sequence of Figure 1. When slow cooked (baked at 400°F) from the frozen state, 4 percent of the control samples were overly soft or mushy. When fast cooked (deep fried at 385°F with breading), 100 percent of

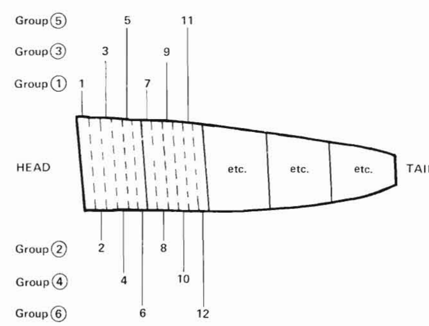
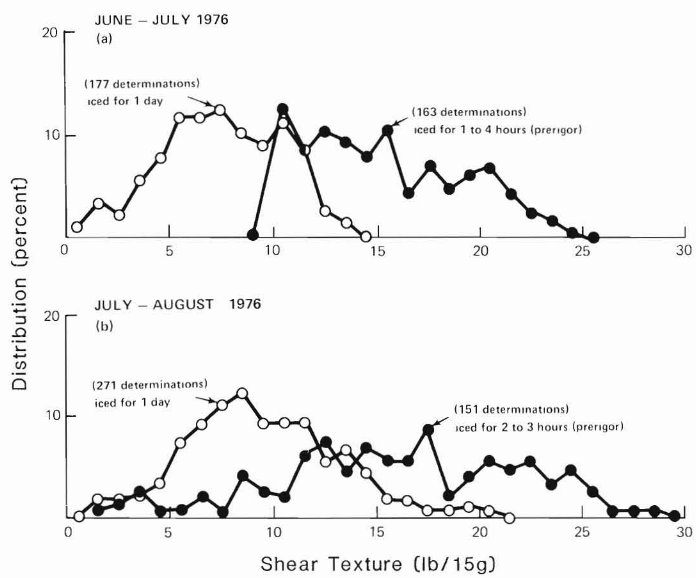


Figure 1.—Sampling sequence for dry-ice frozen and superchilled plate frozen whole Pacific whiting (18 to 30 3/8-inch slices), sequentially placed into 6 treatment groups of 3-5 slices per whiting per treatment.



Shear Texture Values	Sensory Texture Values
20 and over	Very firm
15-19	Firm
10-14	Soft
5-9	Very soft
0-4	Mushy

Figure 2. – Comparison of shear texture of steam-cooked fillets from Pacific whiting held iced prior to filleting and freezing for (a) 1-4 hours (prerigor) vs. 1 day and (b) 2-3 hours (prerigor) vs. 1 day (M/V *Willapa Bay*, 25 miles off Willapa Bay, Wash.). Shear texture values correspond to sensory texture ratings as shown in box (above right).

the control samples had a normal texture. When thawed and held for 1 day at 34°F, refrozen, and slow cooked, the texture of 11 percent of the whiting samples was unacceptably soft or mushy. But, when fast cooked, all these samples were acceptable. When samples were thawed and held for 2 days at 34°F., refrozen, and baked, 11 percent were observed to be soft textured. However, when fast cooked, only 2 percent were overly soft on the basis of the fish with the breading removed; evaluated with the crisp breading left on, the soft texture was not apparent and the product was considered acceptable. Thus, in spite of the predisposition of 11 percent of the frozen, thawed, and refrozen fish to have overly soft/mushy textures, the problem is largely overcome by fast cooking.

Storage in Ice

Experiments were conducted to determine how texture is affected by holding Pacific whiting on ice for various time periods prior to processing and freezing. Texture was measured using a shear-texture instrument developed at the laboratory (Dassow et al., 1962). The instrument consists of a hydraulically driven set of 5 movable and 6 fixed precision-ground blades that form a shear jaw. When actuated, the movable shear blades cut the sample and indicate the hydraulic force required. Samples of Pacific whiting obtained from several West Coast locations were held on ice for time periods of 1-8 hours and compared with fish held 1-3 days prior to freezing. The results show that longer holding on ice will cause more fish to have soft texture. However, there will be considerable overlap in texture values and some lots held short time periods will have a high incidence of soft texture. In Figures 2 and 3, comparative data have been objectively quantified using shear texture as a criterion. In replicate experiments (Fig. 2), whiting was held in ice for 1-4 hours, 2-3 hours (prerigor), and 1 day (24 hours), filleted, frozen, and steam cooked. The shear texture of the three groups was then compared, with a value of 0-9 being considered overly soft. In both tests, the steam-cooked fillets from whiting held for 1 day showed a significantly greater tendency to have mushy to overly soft-textured flesh than either the 1-to 4-hour test group (virtually none) or the 2- to 3-hour group (very little). In the third comparison (Fig. 3), in which whiting caught from two widely separated areas were held in ice for 5-8 hours vs. 2-3 days, we unexpectedly observed a high incidence of samples in the soft-to-mushy range when steamed or slow cooked.

These results suggest that high proteolytic activity in musculature of Pacific whiting may manifest itself shortly after capture and is very much apparent even in well-handled, 1-day-

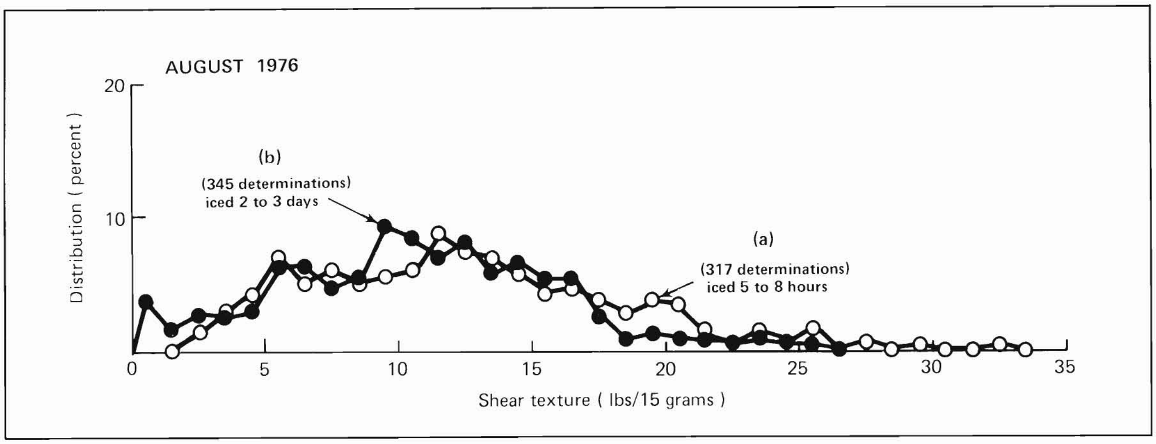


Figure 3.—Comparison of shear texture of steam-cooked fillets from Pacific whiting from two widely separated geographical areas held iced prior to filleting and freezing for (a) 5-8 hours (commercial vessel off Eureka, Calif.) vs. (b) 2-3 days (M/V *Willapa*, 25 miles off Vancouver Island, B.C.). Shear texture values correspond to sensory texture ratings as shown in Figure 2.

iced fish, when slow or steam cooked at 212°F. However, because of a wide range of textures in the slow-cooked product, some of the whiting have a rockfish-like texture with shear readings reaching 25-33 pounds/15 g.

Slush Ice and Ambient Temperature

During the summer of 1977, two tests were run aboard a commercial trawler to compare, by taste panel evaluation, the effect on texture of holding whole whiting for 6 hours on deck at ambient temperature and holding for 4 hours in slush ice. In the first test, using 25 fish in each treatment, a taste panel found that all of the fillets from the fish held in slush ice had an acceptable texture when baked, but 8 percent of the fish that were held at ambient temperature became mushy. In the second test, about 200 fish were treated in each manner. Surprisingly, the taste panel found that 13 percent of the fillets from the fish that were placed in slush ice immediately after landing had a mushy texture when oven baked, while 15.4 percent of those held at ambient temperature for 4 hours were mushy. However, the rapidly chilled fish had firmer textures and thus were easier to handle during machine filleting and skinning—a definite advantage.

But why the apparent large difference in percentage of mushy textured fish between the small-scale experiment and this larger experiment? The most probable reason for the difference in the results of the two tests lies in the levels of protozoan infection. In the first test, the whiting had a 28 percent level of infection with *Kudoa* cysts. In the second test, 59.3 percent of the fillets were infected with white *Kudoa* cysts. Variation in infection intensity within the individual fillets and from one fish sample to another appears to be the major factor that is responsible for variable texture. These natural variations in the protozoan level determine the postmortem proteolytic level and are most likely responsible for the inconsistent results in replicate experiments.

Collaborative tests on whiting preservation and quality were conducted aboard the Polish research vessel *Profesor Siedlicki* in the summer of 1977. With whiting taken from a trawl catch off northern California, the tests showed the level of proteolytic activity in whiting muscle to be independent of the time of storage both in slush ice through a 60-hour test period and at ambient temperatures (55°-64°F) through a 36-hour test period. The proteolytic activity and the texture changes were again determined more by the degree of *Kudoa* infection of the whiting muscle than by the temperature and length of time of storage of the fish after catch.

Superchilled Seawater

Whiting held in superchilled seawater (SCSW) for 1-2 days were examined for texture. Whole fish frozen after 1-2 days in 28.5°F seawater served as a reference point for texture of whiting as landed ashore and before plant processing. Sensory ratings for whiting samples (Table 6), were evaluated according to the sampling sequence of Figure 1. Differences in texture for whiting held in SCSW for 1 and 2 days are shown both for frozen controls and for whiting after freezing, thawing, and holding for 1 and 2 days at 34°F prior to refreezing for cooking.

The control samples representing fish held for 1 day in the SCSW were found to have normal textures when slow or fast cooked from the frozen state. When they were thawed and held for 1 day at 34°F, 12 percent had mushy textures when baked; but when fast cooked, all samples had normal textures. When thawed and held for 2 days and slow cooked, 26 percent had unacceptable textures. Again, all samples had acceptable textures when fast cooked. These results suggest that the proteolytic activity of the cysts in the 1-day superchilled fish was fairly localized despite 2-day chilled storage treatment after being thawed.

When baked from the frozen state, 6 percent of the control samples prepared from whiting held 2 days in SCSW had a mushy texture. All these samples were found to have normal textures when deep fried. When thawed and held refrigerated for 1 day, refrozen, and then slow cooked, 12 percent of the samples examined had a soft to mushy texture. Only 2 percent had unacceptable textures when fast cooked. No texture defects were observed when the crisp breading was left on. A similar trend in texture analyses was observed in the whiting that were refrigerated for 2 days after thawing.

It is interesting to note that the texture of the whiting frozen in dry ice at sea (Table 5) and held for 1 and 2 days in superchilled seawater and frozen (Table 6) was normal—without any significant evidence of softness when fast cooked from the frozen state. Thus, it appears that the freshly landed whiting, after being rapidly chilled and held up to 2 days in the superchilled condition, does not undergo serious deterioration of texture. The fact that the fish that were held for 2 days in SCSW had normal textures may be highly significant. This suggests the possibility that rapid chilling followed by maintenance of temperature by superchilling may keep the proteolytic enzyme localized within the cyst during the holding period. If this supposition is correct, it might permit extended vessel trips of up to 4 days with little difficulty. Thus, it would give the catcher vessel and/or the processing plant extra time needed for the successful exploitation of this species.

Table 6.—Comparison of slow- and fast-cooked sensory texture[1] of fillets from Pacific whiting held in superchilled seawater for 1 to 2 days, frozen whole, sectioned[2], and stored at 34°F for 1-2 days and frozen.

Vessel treatment	Texture scale	Average ratings in each texture category											
		Frozen control				Thawed: 1 day @ 34°F and refrozen				Thawed: 2 days @ 34°F and refrozen			
		Slow cooked		Fast cooked		Slow cooked		Fast cooked		Slow cooked		Fast cooked	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1-day superchilled (28-29°F)	5 Normal'	41	82	49	98	29	58	38	76	23	46	37	74
	4 Normal	7	14	1	2	11	22	11	22	7	14	12	24
	3 Soft	2	4	0	0	4	8	1	2	7	14	1	2
	2 Overly soft	0	0	0	0	3	6	0	0	6	12	0	0
	1 Mushy	0	0	0	0	3	6	0	0	7	14	0	0
2-day superchilled (28-29°F)	5 Normal'	36	74	49	100	34	69	37	76	28	57	36	74
	4 Normal	8	16	0	0	7	14	9	18	7	14	8	16
	3 Soft	2	4	0	0	2	4	2	4	5	10	3	6
	2 Overly soft	0	0	0	0	4	8	1	2	3	6	2	4
	1 Mushy	3	6	0	0	2	4	0	0	6	12	0	0

[1]Average texture is indicated for each fish. Where over 25 percent of the fish sample had a 1 or 2 texture, the entire fish was rated 1 or 2. The texture of the fast-cooked, battered-and-breaded, deep-fried product was graded on the basis of the fish alone after removing the breading.
[2]Each whiting was cut into 3/8-inch slices from nape to tail and sequentially placed into six treatment groups as indicated on the table. The slow- and fast-cooked comparisons of texture represent adjacent slices from three to five sections from nape to tail for each fish.

Comparison of Cooked Textures of IQF Fillets and Fillet Blocks

To determine whether the marketing form influences the incidence of mushy or pasty texture in cooked whiting samples, a taste panel comparison was made of the texture of deep-fried IQF fillets and portions cut from whiting fillet blocks. Fish that were caught and machine filleted aboard the trawler *Willapa Bay* in June 1978 and iced for 1½ days before freezing into IQF fillets or fillet blocks were used in this experiment. Of 324 deep-fried IQF fillet portions tested, 13 portions (4 percent) had borderline texture and 7 portions (2.2 percent) had unacceptable mushy or pasty texture. The amount of the fillet portion that had this unacceptable mushy or pasty texture varied from relatively small areas to almost the entire portion.

In evaluating the texture of portions cut from five 14-pound frozen fillet blocks (20″ × 11½″ × 1¾″), each block was cut lengthwise into three slabs about 20″ long, 3⅞″ wide, and 1¾″ thick. Each slab was then cut into portions ⅜″ thick, 1¾″ wide, and 3⅞″ long. About 135 portions were cut from each 14-pound fillet block.

Every fifth protion was "slow cooked" by baking for 25 minutes in an oven at 350°F to determine the distribution within the fillet block of any mushy or pasty fillets. When a portion was judged by the panel as unacceptable (mushy or pasty) in texture when slow cooked, the four portions that were adjacent to the portion judged mushy were battered-and-breaded, deep fried, and judged for texture.

Of the five fillet blocks examined, one block has all portions with acceptable texture; three blocks had several portions that were mushy or pasty when baked but were of acceptable texture when deep fried; and one block had two portions cut from two out of three slabs that had small areas of mushy/pasty texture.

The results of this experiment demonstrate that the relatively small number of fillets that become mushy when cooked rapidly would have less of a negative impact on consumer acceptance if they were used as part of a fillet block rather than as an IQF fillet because of the dilution effect in the portions cut from fillet blocks.

Texture Improvement

Whiting fillets of otherwise good quality tend to show a significant amount of drip when held under refrigerated storage, frozen and thawed, or cooked. For whiting to be used as fresh fillets or frozen blocks, it would be desirable to reduce the drip and firm the muscle texture. Treatments with polyphosphates and salt are used in other meat products for such purposes. Based on the experiments in our laboratory with treatment of other fish, we implemented studies to determine the effectiveness of a combined 7.5 percent sodium tripolyphosphate plus 2 percent sodium chloride dip treatment on chilled whiting fillets.

Separate groups of whiting fillets were selected at random from a single lot, treated as above, and stored with untreated controls for 11 days at 33° and 36°F. The treated fillets had no free drip, whereas the control group had 2.3 percent drip. On being cooked, the treated samples continued to show lower drip (3 percent vs. 5 percent). Evaluation of texture by means of the hydraulic shear instrument (Dassow et al., 1962) showed that the treated samples had a firmer texture with 1.7 times greater shear resistance than the untreated fillets.

Frozen Storage Characteristics

Pacific whiting is very susceptible to the development of oxidative rancidity during frozen storage. The dark, fatty layer next to the skin and adjacent to the lateral line is particularly vulnerable to rapid oxidation. Of course, the degree of protection provided by packaging materials as well as the temperature of storage has a major impact on the degree of oxidative change. In addition, antioxidants can be used to provide significant protection against oxidation.

The dark, fatty layer along the lateral line can be partially removed by using a processing technique called "saberizing" or "deep-skinning." During machine skinning, the blade of the skinning machine is adjusted to an opening that removes a thin layer of flesh along with the skin. This removes all but the thickest portion of dark flesh. The major disadvantages to this practice are the need to closely control the skinning operation and the loss of usable flesh compared with normal skinning. However, the procedure can and does influence the quality of the frozen fillet, fillet blocks, and portions held in frozen storage.

Table 7.—Development of rancidity in Pacific whiting portions stored at 0° and 20°F with and without glaze.

Storage conditions		Sensory score (rancidity[1] of whiting portions after storage for (weeks):											
		0	2	3	4	5	6	10	13	18	24	30	36
0°F	Unglazed	8.3	4.3	5.3	4.0	4.6	4.0	3.5	2.7	3.3	2.0		
	Glazed	8.3	7.3	5.6	8.0	7.0	6.0	6.7	4.7	4.3	5.7	3.0	
−20°F	Unglazed	8.3	6.0	7.7	7.7	6.6	8.7	7.7	6.0	5.7	4.7	5.0	3.5
	Glazed	8.3	8.3	8.0	6.0	6.3	6.6	8.0	6.7	5.7	6.3	4.3	4.0

[1]A score of 10 indicates no detectable rancidity; scores from 9 to 6 indicate increasing rancidity with an overall acceptable rating; italicized scores of 5 or less indicate rancidity with an overall unacceptable rating.

Frozen Fillet Blocks

During storage tests conducted at 0°F on frozen blocks made from whiting fillets, taste panel evaluations of the texture and flavor of the lean flesh showed little adverse change, but that early oxidative rancidity was apparent in the fatty surface flesh (Table 7). Unglazed whiting portions cut from the blocks and stored at 0°F became rancid within 2 weeks. However, ice-glazed portions stored at the same temperature were acceptable for at least 10 weeks. If glazed and stored at −20°F, the portions were acceptable for up to 24 weeks. With suitable antioxidants and packaging to provide protection from oxidation, the storage is extended significantly.

The strong oxidative rancidity that developed in unglazed whiting portions stored for only 2 weeks at 0°F demonstrated that the lipids in the surface fatty layer of whiting are highly labile. Nevertheless, the limited tests made show that blocks of frozen whiting can be packaged and stored successfully at lower temperatures. Inasmuch as glazing is normally not feasible in blocks (most blocks are cut into portions and breaded), the use of approved antioxidants and packaging films with low oxygen-transmission characteristics should be encouraged.

Recent studies by the NWAFC Utilization Research Division have demonstrated that whiting blocks can be successfully held in frozen storage if the fillets are treated with a combination of erythorbate and phosphate at the time the blocks are prepared. The solution used to treat the fish contained 2 percent sodium chloride, 2 percent sodium erythorbate, 2 percent sodium hexametaphosphate, and 4 percent sodium tripolyphosphate. The treatment is effective in retarding rancidity for at least a 6-month period when the blocks are held at 0°F and longer at −20°F.

Results of comparative analysis for chemical changes occurring in the whiting fillets blocks during 6 months of storage at 0°F (Table 8) show that the untreated (control) blocks had 2-3 times as much malonaldehyde (as measured by the thiobarbituric (TBA) test for oxidative rancidity) as the block samples treated with sodium erythorbate. A TBA value of 0.36-0.40 micromoles of malonaldehyde/100 g is considered indicative of a moderate to strong degree of organoleptic rancidity in frozen whiting. Saberizing fish in this study did not appear to significantly protect the fillets from the oxidation process. Sensory evaluations made on the

Table 8.—Thiobarbituric acid, free thaw drip, express drip, cook drip, and shear texture measurements of Pacific whiting fillet blocks treated with chemical dips or saberized[1] after 6 months of 0°F storage.

Description of lots	TBA: Average of 2 (M/100 g)	Free thaw drip: Average of 3 (%)	Express drip: Average of 2 (ml/20 g)	Cook drip: Average of 3 (%)
Control: Whole fillets	0.24	4.4	9.5	18.0
Control: Chopped fillets	0.35	4.6	8.4	21.8
Saberized fillets	0.22	4.4	8.8	24.4
Erythorbate-phosphate dipped	0.12	3.1	7.6	12.9

[1]Saberized: Deep-skinned to remove most of the dark flesh from the fillet.

Table 9.—Results of sensory evaluations of steamed and deep-fried Pacific whiting fillet blocks treated with chemical dips or saberized[1] after 6 months in 0°F storage.

Sample treatment	Appearance	Odor[2]	Flavor[2]	Texture[2]	Desirability[2]	Rancidity[3]
Steamed						
Control: Whole fillets	6.6	5.8	5.5	5.9	5.2	1.9
Control: Chopped fillets	6.6	6.3	5.7	6.1	5.3	2.0
Saberized fillets	6.8	6.3	5.2	5.6	4.9	1.8
Erythorbate-phosphate dipped	6.3	6.4	6.3	6.6	6.1	1.2
Deep Fried						
Control: Whole fillets	7.3	7.1	6.4	6.2	5.7	2.1
Control: Chopped fillets	7.0	6.9	6.1	6.1	5.8	2.2
Saberized fillets	7.4	7.4	7.2	6.5	6.8	1.0
Erythorbate-phosphate dipped	6.7	7.1	7.3	6.8	6.8	1.0

[1]Saberized: Deep-skinned to remove most of the dark flesh from the fillet.
[2]Rated on the 9-point hedonic scale: 9, Like extremely; 8, like very much; 7, like moderately; 6, like slightly; 5, neither like nor dislike; 4, dislike slightly; 3, dislike moderately; 2, dislike very much; and 1, dislike extremely.
[3]Rated on a scale of 1 to 5: 1 = none, 2 = trace, 3 = slightly, 4 = moderate, and 5 = strong.

whiting block samples generally support the results of the chemical analysis for rancidity.

Taste panel scores given in Table 9 show that, irrespective of the method of cooking (steamed or deep fried), the erythorbate-treated whiting fillet blocks were found to be essentially free of rancid flavors. The apparent differences in sensory attributes evaluated between the steamed and deep-fried samples are attributed to the masking effect of breading on flavor and texture characteristics. Treatment with phosphates resulted in lower free, express, and cooked drip loss in the erythorbate-treated samples than in the control samples. Minimizing the formation of drip in whiting helps to stabilize the adhesive properties of the breading material during cooking.

Frozen H&G Whiting

Frozen headed and gutted (H&G) whiting is also subject to oxidative rancidity during storage. Since the headed and gutted fish is normally frozen with the skin on, there is some protection from the skin layer plus the thin layer of ice formed on the skin during freezing. Once the ice layer is lost and oxygen is available to penetrate the skin, rancidity will develop. The rate of development depends upon time, temperature, the degree that temperature fluctuates during storage, and the form of packaging.

On-shore Processing Study

Research conducted aboard fishing vessels during the period 1976-80 showed that Pacific whiting could be successfully held at sea for periods of at least 2 days. These results prompted a pilot scale shore-side processing study completed in 1980. The purpose of this study was to determine the feasibility of commercially processing Pacific whiting into fillet blocks. The test included the use of automated processing when possible. Two major questions were to be answered by the study. These were: 1) Would the quality of the blocks be acceptable? 2) Would the labor and other processing costs be reasonable?

Plant Layout

The process study was conducted at a fish plant located at Astoria, Oreg. Processing space was leased for the study, and workers were paid directly by the project. Equipment was leased when required and included an 8″ Temco pneumatic unloader[2], a Baader 160 heading and gutting machine, a Baader 188 filleting machine, and a Trio skinning machine. The schematic diagram in Figure 4 shows the flow of product through the processing line. Figure 5 shows the actual layout of the plant.

Fishing

The fish required for the study were caught by the chartered commercial fishing vessel *Kupreanof*. Six fishing trips were made from the port of Astoria during August and September. Because the fish were so widely dispersed, fishing was confined to standard roller gear. Each trip lasted from 1 to 2 days with an average catch of 21,522 pounds per trip. The fish were held aboard the vessel in superchilled seawater as discussed earlier.

Results

Unloading the Vessel

Fish from the first two trips were unloaded by hand because the pneumatic pump was not in place. The unloading was done by plant employees stationed in the vessel well and on the dock. Shrimp forks with rounded tines were used to scoop fish into a metal bucket which was then dumped into plastic totes containing slush ice (a mixture of water and flake ice).

Beginning with the third trip, the

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

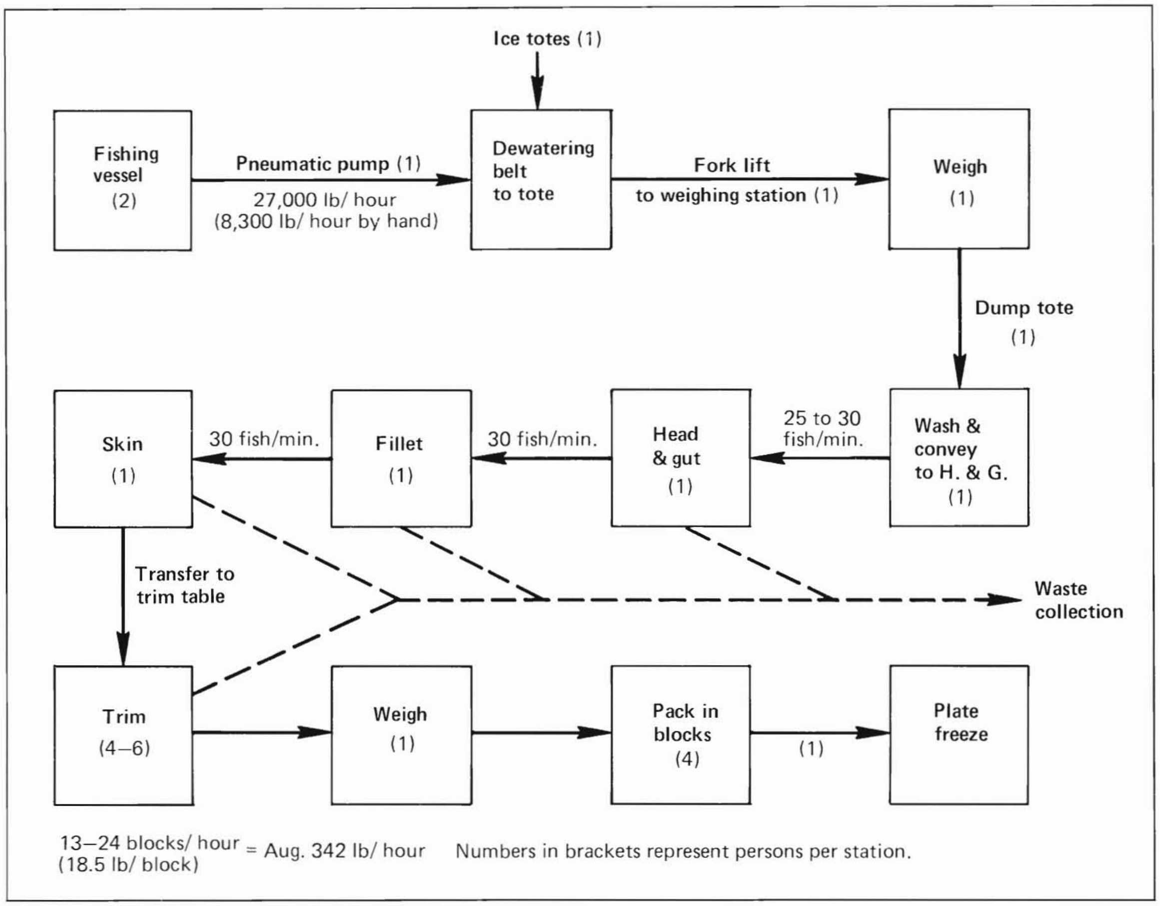


Figure 4.—Fillet block product flow diagram.

fish were unloaded by pump. the pump greatly facilitated unloading and increased the rate from the 8,300 pounds per hour achieved by hand to 27,000 pounds per hour. Damage to the fish was minimal (estimated at less than 1 percent). The fish discharged from the pump were passed over a dewatering belt, then into tared totes containing slush ice. Each tote was weighed and top iced.

Processing

Actual processing was begun by emptying totes of preweighed whiting into a wash tank that was designed with a chain-link conveyor and spray washer that transferred the fish into the processing room. Water used in the spray washing operation was prechilled to about 33°F to help maintain the fish at a low temperature during processing. Once in the processing room, the fish were hand loaded into the Baader 160 heading and gutting machine. Fish from the header and gutter were conveyed by gravity to the operator of the filleting machine. The heading and gutting operation easily maintained sufficient speed to keep up with the filleting machine. The header and gutter was a source of loss in yeild, the amount of which depended on the size and condition of the fish and the ability of the operator. Small fish frequently fell from the station to the waste chute. Inattention by the operator also resulted in unnecessary loss of fish. Although the machine is capacity-rated at 45 fish per minute, it was never operated at that level because the operator could not maintain the pace for any length of time. Actual sustained feed rates ranged between 25 and 30 fish per minute.

Filleting

The Baader 188 was used to fillet all of the product used in block production in the study. Normally the Baader 188 does not remove the pinbones from the fish. A slight modification of the cutting blade angle was made which resulted in pinbone removal. Of course, the yield was adversely affected. Boned-out, trimmed fillet yields ranged from 17.3 to 20.5 percent. The filleting machine was operated at about 30 fish per minute.

The average size of the fish during most of the study was 2.0 pounds and ranged between 1.9 and 2.1 pounds. At the rate of 30 fish per minute, the fillet machine would theoretically pro-

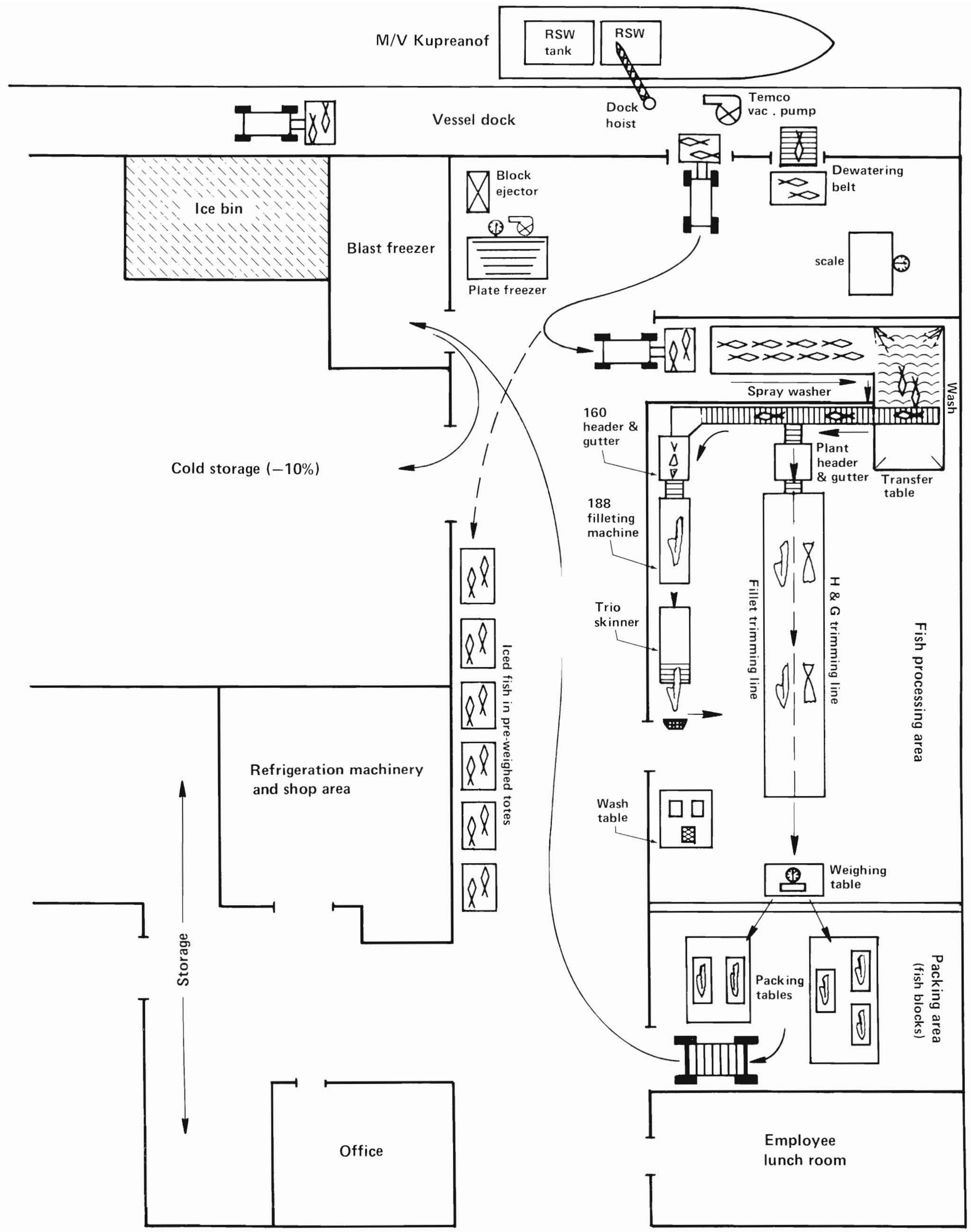


Figure 5.—Pacific whiting processing line layout.

duce 720 pounds of fillets per hour, assuming an average of 0.4 pounds per fish. In actual practice, downtime and employee breaks would reduce the theoretical yield by 25 to 50 percent. Thus, a sustained fillet production estimate of 360-540 pounds per hour is more realistic.

Skinning

The skinning operation using the Trio skinning machine easily kept pace with fillets delivered by the filleting machine. One operator was required to properly feed the skinning machine. The cutting blade was adjusted to remove as much dark flesh as possible in one pass without significant removal of light flesh. Although resulting in lower yields, deep skinning avoided the rancidity problem observed in earlier research with frozen whiting where the fatty layer was not removed.

Trimming and Weighing

Despite the care and precautions used in filleting and skinning, it was essential to inspect each fillet for remaining skin and bone and trim when necessary. Fillets with visually apparent infection of *Kudoa* parasite were removed.

Block Makeup

The block preparation step was the bottleneck of the operation. Some of the problem can be attributed to lack of experience as the workers were not familiar with the manufacture of fillet blocks which required special handling procedures. Some employees required up to 15 minutes to complete an 18.5-pound block because they were required to carefully place individual fillets into cartons. Since each block averaged 90 fillets, it is understandable that labor input was intensive.

Near the very end of the study, it was decided to speed up the block-making operation by producing a modified block product. This block was made by diagonally slicing fillets into small pieces (about 2 in wide) and then randomly filling the block cartons with the correct weight of the chopped product. This approach to the production of blocks required significantly less time to make a block of the same general quality as the fillet block made by the old method. An 18.5-pound block could be made in about 1 minute.

Freezing and Storage

The completed fillet blocks in their frames were frozen in a pressure plate (average of 260 psi) freezer at −35°F. The frozen blocks were removed from the frames by a pneumatic block ejector and stored in plastic totes in the plant cold storage at −10°F until they could be packed in master cartons.

Quality Evaluation

Owing to uncertain marketing conditions for whiting blocks at the time this study was made, the block products made during this study were not evaluated commercially. The blocks were tested, however, by the NWAFC Utilization Research Division. Using U.S. Department of Commerce standards for frozen fish blocks, whiting blocks, stored for 3 months at −15°F, were rated as "U.S. Grade A" in all categories except for cooked texture. Deductions for such factors as color, blemishes (skin, blood spot, fin, etc.) and dehydration were determined to be minor. However, the persistent problem of enzymic breakdown was seen as pockets of soft or mushy flesh in the thawed blocks and in the slow-cooked (baked at 350°F) samples, and the blocks were hence rated as "U.S. Grade B" or substandard depending on the degree and extent of the texture problem. This particular problem was also observed in a Pacific whiting demonstration project aboard the offshore factory trawler M/V *Blue Ocean* (1980). All of the blocks tested had normal textures when fast-cooked.

Headed and Gutted

In addition to the leased processing equipment, a heading and gutting machine owned by the plant was used occasionally. The machine, manufactured by Bel-Elm Industries of South Bend, Wash., used a circular saw blade for removing the heads from fish and a vacuum apparatus to aspirate viscera from the carcass. The machine processed about 120 fish per minute or as fast as the operator could hand feed it. This system was employed when a glut of whiting occurred that could not efficiently be handled by the filleting operation or when mechanical problems were encountered on the filleting line. At these times, fish would be diverted through the plant's heading and gutting machinery to compensate for the backup of fish.

Headed and gutted fish were washed and trimmed and packed into 20-pound cartons. The cartons of fish were then sent to the sharp freezer where they were frozen.

The quality of the H&G product was not evaluated. However, experience from previous H&G research would indicate that some of the H&G product would undoubtedly have an unacceptably soft texture, but otherwise by of good quality. The results of processing studies conducted aboard the M/V *Blue Ocean* (1980) did not indicate a problem with the texture of H&G ocean-caught whiting introduced into the consumer market.

Production Analysis

The study was planned to be completed during the summer season when whiting was readily available along the Oregon-Washington coast. However, funding was delayed and the project was not begun until late August. Unfortunately, the whiting were not available in large concentrations during the period of operation in September. This resulted in a rather short operation in which processing was done only 1 or 2 days per week. With any new program of this nature, there is a learning curve. Thus, considering poor fishing conditions which limited processing time, persons managing the project had insufficient time to adequately train plant personnel in the operation of equipment or with processing techniques necessary to produce quality fillet blocks. It was not until nearly the end of the project that a reasonably smooth operation was obtained.

In the beginning of this section, it was stated that it was not the intent of this project to do a complete economic and marketing analysis but rather to assess the basic costs of producing a quality, machine-processed whiting block. The data presented below therefore reflect only those direct costs dealing with labor (time) and production but not packaging material, miscellaneous supplies, energy, maintenance, or repairs. Indirect costs such as insurance, depreciation, administration, etc. were also not considered in this study.

The data in Table 10 show the breakdown in man-hours of labor to produce the H&G and fillet-block products in this study. Labor man-hours shown under "Fillet Blocks" for foremen and maintenance include the time required to modify and test the Baader 188 filleting machine to remove pinbones. Although the filleting machine produced a fillet with good appearance, it required considerable maintenance by an experienced operator/plant engineer to keep it operating normally during the project. The man hours under "Fillet Blocks" for machine operators include processing time on the Trio fish skinner. As expected, those operations requiring the most labor in this project involved the filleting/packaging phase of block production.

The relatively low block production rate, i.e., 9.3 pounds/man-hour (Table 10) is attributed in part to the inexperience of the machine operators, the capacity and design of the Baader heading and gutting machines, and to the labor intensive trimming and packaging operations. By comparison, block production rates in the Blue Ocean project (1980) were almost double the production in this study. This was achieved by using Baader's latest and fastest filleting machine (Model 190) which, when properly adjusted, produced a fillet faster and required less trimming and handling than what was experienced in this project.

Costs in time of production are shown in Table 11. As explained, these figures only reflect those costs attributable to labor. The general market price for whiting fillet blocks at the time of this project was about $0.80/pound, well under the costs observed here. Based on these actual labor costs, the figures given in Table 12 were prepared to show projected costs for the production of fillet and H&G fish blocks at various hourly pay rates. Table 13 shows the comparative costs of the fish for various fillet yields as they were obtained from actual production and from a controlled test.

Markets

Prior to 1979, Pacific whiting was marketed in the United States as Pacific hake. The rationale followed by the U.S. Food and Drug Administration for changing the name in 1979 was to avoid whatever negative reputation that is associated with "hake" and to use a name nearer to one that is shared by other fishes of the genus *Merluccius* (Anonymous, 1979).

Pacific whiting has been marketed with limited success as fresh and frozen fillets, fillet blocks, and in the headed and gutted form. The most notable success has been the H&G product utilizing the Puget Sound stock of fish. The average size of the Puget Sound whiting and the Canadian whiting taken from the Strait of Georgia is small enough to make them ideal for the H&G market. These areas provide an excellent winter and spring fishery for a limited number of vessels. The fish are available in good concentrations and can be taken readily in water protected from all but the most severe storms. Since 1979, in excess of 20,000 metric tons (t) of Puget Sound whiting have been landed. However, it was not until the 1980-81 fishing season that these whiting were designated for food fish when 21 percent of the landings were used for human consumption. Until then, the whiting were mainly harvested for industrial use. Since the 1980-81 season, essentially all of the landings have been processed as food fish. In 1982-83, 90 percent of the landings, (6,551 t) were processed as food fish. The waste is converted by local rendering companies as a by-product of this activity. It is estimated that

Table 10.—Pacific whiting production labor in man hours.

Item	H&G product	Fillet blocks	Total
Unload	55	75	130
Foremen and maintenance	100	310	410
Machine operators	101	304	405
Butcher/fillet	69	332	401
Pack/weigh/cleanup	151	454	605
Freeze/warehouse	57	79	136
	533	1,554	2,087
Production (lb.)	23,940	14,465[1]	
Production (lb./man-hour)	44.9	9.3	

[1]Total includes 1,960 pounds of fillets frozen individually.

Table 11.—Actual labor costs per pound production.

Item	Headed and gutted	Blocks
Production (lb.)	23,940	14,465
Payroll/man-hour = $9.08		
Man hours	533	1,554
Average production/ man-hour	44.9	9.3
Cost per pound	$\frac{9.08}{44.9}$ = $0.202	$\frac{9.08}{9.3}$ = $0.976

Table 12.—Projected production costs at various labor costs.[1]

	Production costs at		
Item	$6.00/hour	$8.00/hour	$10.00/hour
H&G/pound	$0.134	$0.178	$0.222
Blocks/pound	$0.645	$0.860	$1.08

[1]Based on average production rates achieved during this study.

Table 13.—Fish cost based on various yields.

	Fish cost			
Yield	$0.06/lb.	$0.07/lb.	$0.08/lb.	$0.10/lb.
17% yield[1]	$0.353	$0.412	$0.471	$0.588
20% yield	$0.300	$0.350	$0.400	$0.500
23% yield[2]	$0.261	$0.304	$0.348	$0.435

[1]Actual yield obtained during this study.
[2]Yield obtained during controlled test using 100 fish.

Puget Sound can produce about 10 million pounds of whiting per year for commercial use[3].

Although the "inside" whiting is infected with the *Kudoa* parasite, the tissue is not as adversely affected as that of the "outside" or ocean whiting. Tsuyuki et al. (1982) reported significant differences in the texture between the inside and outside whiting that can be attributed to the difference in enzyme activity associated with the species of *Kudoa* that infects the two groups.

Landings of Pacific whiting were almost nil until the middle 1960's when several events occurred that stirred interest in the species. Exploratory fishing along the coasts of California, Oregon, and Washington demonstrated that a substantial stock of the species was available and that huge catches could be made by the use of midwater trawls. In 1965, a fish reduction plant was built at Aberdeen, Wash., especially to process Pacific whiting. Unfortunately, the price of fish meal on the world market dropped during the time the plant was in operation. Thus, the price of fish for reduction was affected and fishermen were reluctant to deliver whiting to the fishmeal plant at the price offered. During the same period the Bureau of Commercial Fisheries (now the NMFS) was developing technology to produce fish protein concentrate (FPC) from lean, white-fleshed fish. Aberdeen, Wash., was selected as the site for a demonstration pilot-scale plant to produce FPC. The FPC plant operated during 1971 and 1972, but was closed when funds to operate were no longer available. Private attempts to produce FPC from whiting also failed when markets did not develop as predicted. Even countries with shortages of protein foods did not accept FPC as a nutritional supplement.

[3]Mark G. Pedersen, Chief, Groundfish Management, Washington Department of Fisheries, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115, and Dale Ward, Research Analyst, Washington Department of Fisheries, 115 General Administration Building, Olympia, WA 98504. Unpubl. data.

Attempts to market Pacific whiting in the fillet block form have also not been completely successful due to a combination of factors. First, potential users have rejected the product on the basis of the texture problem. Second, the cost of production of domestically produced blocks has made it difficult to compete with imported whiting blocks. Third, there has not been a major effort to sell whiting blocks produced on the Pacific Coast. The first two factors are good explanations for the third.

Marketing Pacific whiting will continue to be a problem as long as the limitations dictated by the presence of the *Kudoa* parasite are ignored. The texture problem can be overcome by using a specific technique of cooking such as deep frying portions. Slow cooking methods simply are not acceptable unless the fish is free of the parasite.

Present Situation

The brightest spot in the current market situation for Pacific whiting is the frozen H&G product from the Puget Sound area. Several companies are engaged in H&G operations. The current price of $0.32/pound is competitive with foreign imports. The operations are providing two important benefits. One, fishermen and processors are working; and two, good quality fish is going onto the market at reasonable prices.

Small quantities of Pacific whiting are being reduced to fish meal in the Puget Sound area. Of course, the quantity of fish available for reduction is adversely affected by the demand for fish to be processed into the H&G form.

Northern California plants continue to produce H&G products and fillets. In addition, at least one company has the capability of producing fillet blocks.

Joint ventures in which American fishing vessels catch whiting and transfer the net codends directly to foreign factory ships are continuing. This has provided a source of income to a number of vessels that might not have markets otherwise.

Interest in processing ocean whiting remains high. The major impediments to successful development, however, remain the soft texture, production costs, and market demand. Potential for developing new products from whiting will be discussed in the following section.

Future Markets

As mentioned, the predisposition of ocean-caught Pacific whiting to have soft-textured flesh places limitations on the method of cooking the fish. Because of these limitations, the product form and the markets that can accommodate this fish should be considered. From our experience, fillet blocks would appear to offer the most viable product form for marketing. If Pacific whiting blocks are properly cut into protions, battered and breaded, then cooked by frying in deep fat, the product can be excellent. Fillets can also be portioned and cut to reduce thickness to about ⅜ inch and handled in the same way with good results. The requirement to use only deep frying as the cooking method is a major problem and may make marketing very difficult.

Other possibilities for marketing Pacific whiting are dependent on overcoming the texture problem. One potential is to market fillets that are cooked in the processing plant. This would enable the processor to cull out the fillets that become overly soft during cooking. The cooked product could be prepared in TV-type dinners or as frozen entrees combined with sauces. The institutional market should also be explored as a potential for these types of products.

Another approach to marketing is in the fabricated food area. Minced whiting flesh should be evaluated for use as the raw material to prepare a wide variety of products such as imitation shrimp, crab legs, scallops, and other products that use cooked, minced flesh as the basic ingredient. The possibility is currently being researched by the National Marine Fisheries Service and the West Coast Fisheries Development Foundation.

Expansion of the ocean fishery in

any form of traditional products would be dependent on either developing a way of avoiding the highly parasitized fish or a way of detecting and removing during processing those individuals with a high level of parasites. Chemical treatment to inactivate the enzyme responsible for altering the texture is another possibility. Recent research, previously discussed, has shown that several chemicals control enzyme activity when minced whiting flesh is treated.

Production of industrial products such as fish meal, fish silage, and protein hydrolyzates from Pacific whiting, although technically feasible, does not appear economically attractive at this time. However, this outlook could change if other markets develop so that waste from filleting or mincing operations could be used to prepare industrial products.

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