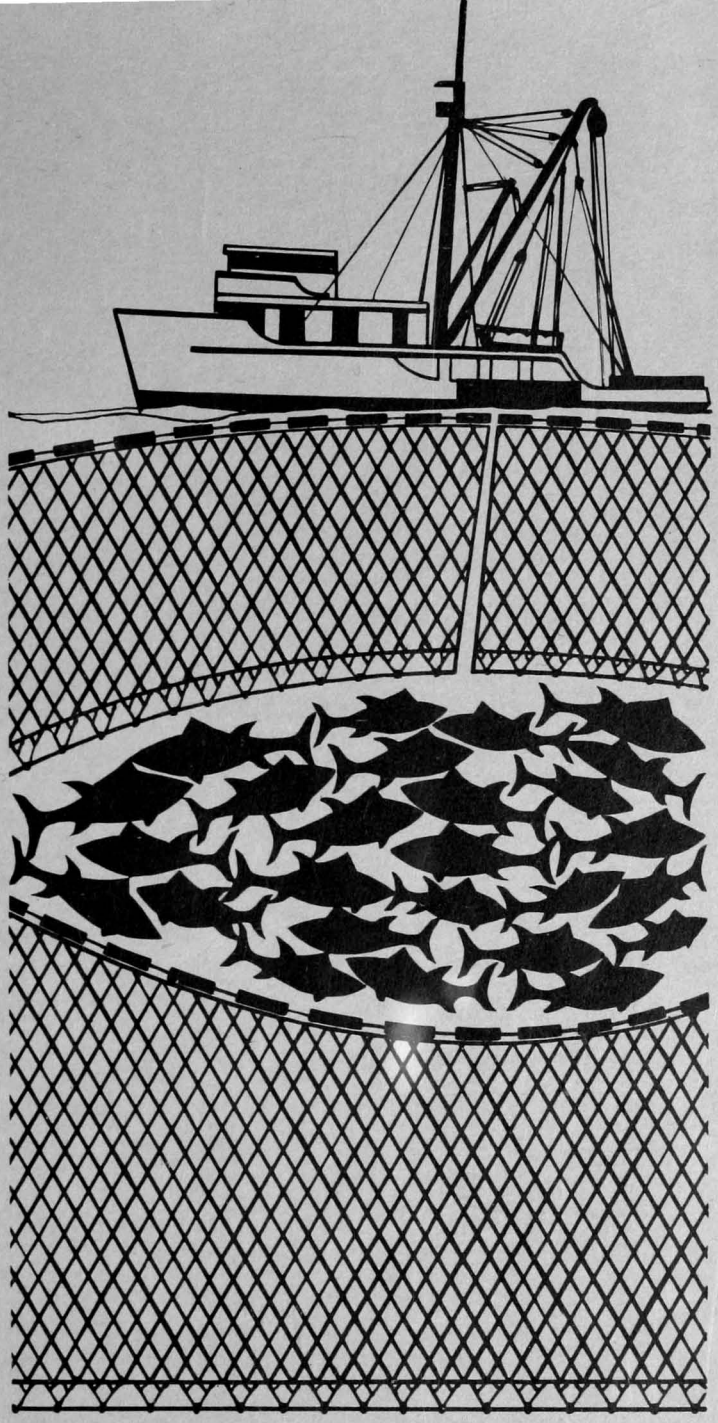

FISHERY INDUSTRIAL RESEARCH

VOLUME 2 NO. 1

United States
Department of the Interior
Fish and Wildlife Service
Bureau of Commercial Fisheries

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FISHERY INDUSTRIAL RESEARCH
Volume 2 - Number 1

Washington, D. C.

September 1962

QUALITY CHANGES IN WHITING STORED IN ICE AS INDICATED BY ORGANOLEPTIC AND OBJECTIVE TESTS

by

Joseph M. Mendelsohn and John A. Peters

ABSTRACT

Organoleptic tests were conducted on raw and cooked whiting to determine the keeping time of these fish stored in ice. Concurrently, objective tests were run on the raw fish to assess the value of the refractive index of the eye fluid test and the value of the thiobarbituric acid test, the volatile base content, and the trimethylamine nitrogen content on these ground fish as possible objective determinations of quality.

Whiting were found to have an iced storage life of 7 days. The refractive index of the eye fluid appeared to be the most promising of the objective tests studied.

INTRODUCTION

Need for the Research

Landings of whiting *(Merluccius bilinearis)* in New England have grown tremendously. The catch increased from 41 million pounds in 1940 (Fiedler, 1943) to 107 million pounds in 1958 (Power, 1959), when this species ranked third in landings of edible fish in New England and was exceeded only by ocean perch and haddock.

Whiting are caught principally by otter trawl. Aboard the vessel, they customarily are stored whole in ice; however, on many small boats which make 1- to 2-day trips, little or no ice is used. At the shore plant, they are headed and eviscerated, packaged, and frozen.

Whiting are tasty and inexpensive, so the potential market is great. If, however, this market is to be realized fully, the fish must be of high quality when they reach the consumer.

Unfortunately, even when whiting are stored in ice, they tend to lose quality rapidly. Exactly how rapid is not known, yet this information on storage life is sorely needed to enable vessel owners and operators to schedule their trips so that the landings of whiting of uniformly high quality can be made.

Selecting suitable methods for measuring the changes in quality in whiting stored in ice presents a major problem. The change can be measured organoleptically--that is, by smelling and visually examining the raw fish and by tasting the cooked fish--but the organoleptic method is slow and expensive. For routine determinations, which are needed to enable marketing of only the best quality whiting, a rapid, inexpensive objective test would be desirable. Previous studies indicate that tests involving the refractive index of eye fluid, the thiobarbituric acid value, the volatile base content, and the trimethylamine nitrogen content of the raw fish may serve this purpose. These

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tests require further evaluation, however, in comparison with the organoleptic tests.

Objectives of the Research

The objectives of the present study therefore were:

1. To determine the keeping quality of iced whiting by organoleptic tests on the raw and the cooked fish.

2. To evaluate, in the light of the findings of the organoleptic study, the suitability of the refractive index of eye fluid, the thiobarbituric acid value, the volatile base content, and the trimethylamine nitrogen content of the raw fish as possible objective tests of quality.

KEEPING QUALITY OF ICED WHITING

Procedure

About 250 pounds of round whiting were obtained for use in the experiments. These fish had been iced immediately after capture and were 1 day out of the water when unloaded from the vessel. Immediately after being unloaded, the fish were carefully iced in a large wooden box and transported to this laboratory for study. They were kept well iced during the entire test.

Twelve iced whiting, selected at random from different sections of the wooden box, were used for each examination, six for the organoleptic tests and six for the objective tests to be described later. Changes in quality were determined for the fish in both the raw and the cooked states. The first examination was made the day after the fish arrived at the laboratory, when they were 2 days out of water. Subsequent samples were taken at 2- or 3-day intervals during iced storage.

At each organoleptic examination, the six raw whole fish were washed with water, dressed, and examined by two members of the laboratory staff for the following factors:

1. Appearance of eyes, gills, skin, and flesh.

2. Odor of gills, gut cavity, and flesh.

3. Texture of flesh.

After the raw fish had been examined, they were cut into portions and steamed for 15 minutes. The portions were then served to a taste panel of eight laboratory staff members accustomed to grading cooked fish. This panel rated the sample for appearance, odor, flavor, and texture.

Results

The results of the organoleptic examinations of the raw and the cooked whiting (table 1) were as follows:

The raw whiting were judged to be of acceptable quality during the first 7 days after they were captured. By the 9th day, however, the whiting were rated as poor quality. Off-odors had developed in the gut cavity and in the flesh, and the texture of the flesh was quite soft, lacking the resiliency of the flesh of fresh fish. After 12 days on ice, the whiting were of very poor quality, the off-odors were quite pronounced, and the flesh was very soft.

The taste panel scores on the cooked whiting agreed closely with the ratings for the raw whiting. The panel judged the cooked fish to be of fair quality after 7 days of iced storage, of poor quality after 9 days, and of very poor quality after 12 days.

The results of the organoleptic examinations of both the round and the cooked whiting show that whiting is a delicate fish with a relatively short iced storage life of 7 to 9 days. In the industry, however, owing to the possibility of quality loss during unavoidable delays in unloading and processing, the iced storage period for this fish should not exceed 5 days.

OBJECTIVE TESTS

Studies were made on the refractive index of eye fluid, the thiobarbituric acid value, the volatile base content, and trimethylamine nitrogen content of the raw, ground flesh of whiting. These tests were evaluated in the

TABLE 1.--Results of organoleptic tests on whiting stored in ice[1]

Storage time on ice	Quality factors - raw fish								Taste panel scores[2] on cooked fish
	Appearance				Odor			Texture	
	Eyes	Gills	Skin	Flesh	Gills	Gut Cavity	Flesh	Flesh	
Days out of water									
2	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Good
5	Good	Good	Good	Excellent	Good	Good	Excellent	Good	Good
7	Good	Good	Good	Good	Fair	Good	Good	Fair	Fair
9	Fair	Fair	Good	Good	Fair	Poor	Poor	Poor	Poor
12	Fair	Poor	Fair	Fair	Very Poor	Poor	Poor	Very Poor	Very Poor
14	Poor	Very Poor	Poor	Poor	Very Poor	Poor	Very Poor	Very Poor	([3])
16	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor	-

[1] These results represent an average of ratings based on a grading scale of excellent, good, fair, poor, and very poor.

[2] These results represent an average of ratings based on the appearance, odor, flavor, and texture of the steamed samples.

[3] The scoring was concluded here because of the agreement of the panel that the fish were unfit for human consumption beyond the 11th storage day. The raw fish examination was continued for four days until all quality factors were scored as very poor. This was done to complete the comparison of results from the two methods of organoleptic grading.

light of the findings of the organoleptic test. The details of these studies were as follows:

Refractive Index of Eye Fluid

PROCEDURE.--Just prior to the preparation of the fish for the chemical tests, the eye fluid was removed from the vitreal cavity of one eye of each fish with a hypodermic syringe and was centrifuged until the fluid appeared clear. The refractive index (Proctor, Nickerson, Fazzina, Ronsivalli, Smith, and Stern, 1959) was determined with an Abbé-type refractometer kept at a constant temperature of 23° C.

RESULTS.--The increase in refractive index of the eye fluid with storage time of the whiting in ice approximates a straight line (fig. 2). This uniform increase in refractive index shows that the method has promise in determining the previous storage time of whiting in ice and therefore in providing an indication of its quality.

Thiobarbituric Acid Value

PROCEDURE.--For the thiobarbituric acid test and for each of the other chemical tests, six whole fish were placed in a food chopper and were ground until the mass was apparently uniform. The ground fish was then further homogenized in a food blender. This sample was frozen immediately and then was kept at -20° F. until used. All tests were run in duplicate. The development of rancidity was measured using the thiobarbituric acid method of Turner, Paynter, Montie, Bessert, Struck, and Olson (1954), except that 1-g. samples were used, and the color was read as optical density using a 19 x 105 mm. round cuvette in a spectrophotometer.

RESULTS.--Thiobarbituric acid values increased rapidly from the 4th until the 9th day of iced storage and then decreased through the 12th day after which time they appeared to level off (fig. 3). More data are needed to confirm the actual trend in the thiobarbituric acid value and to determine whether or not this method can be used in evaluating the freshness of whiting stored in ice.

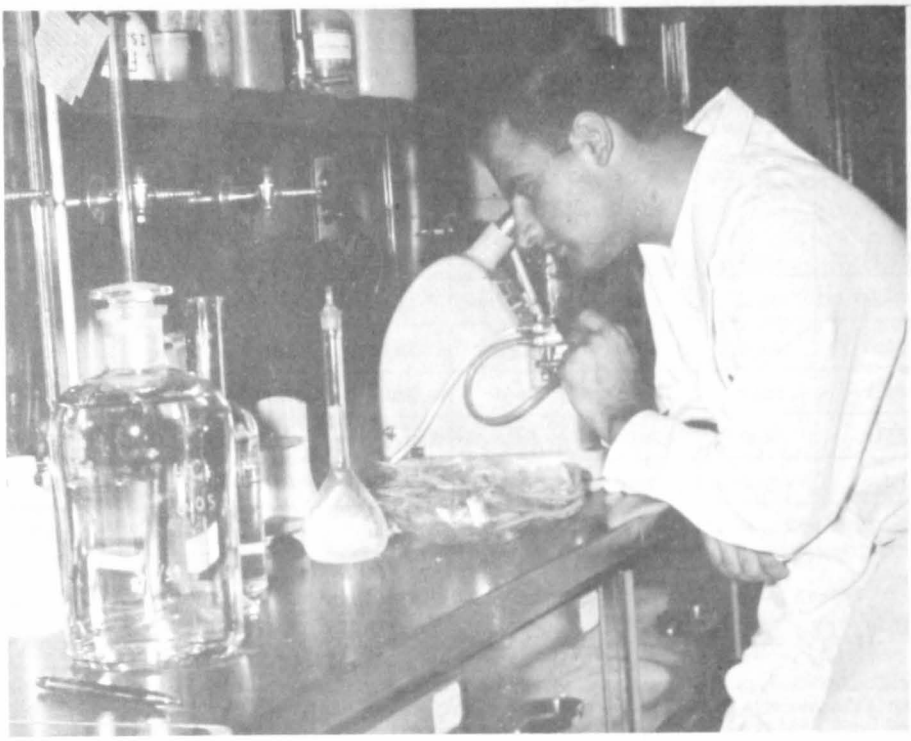

Figure 1.--Determining the refractive index of the eye fluid of whiting.

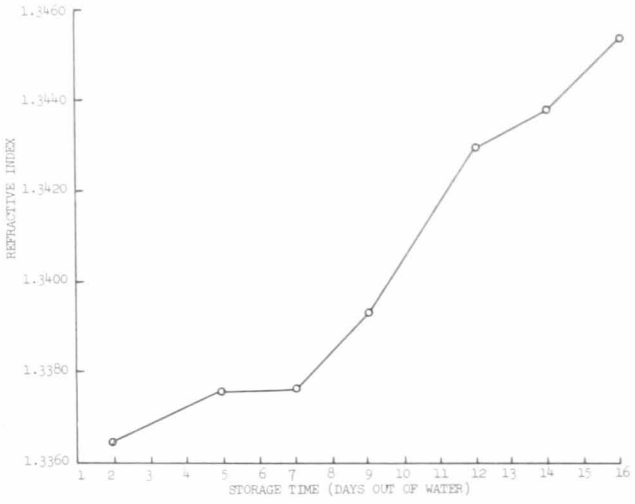

Figure 2.--Refractive indices of eye fluid of whiting stored in ice.

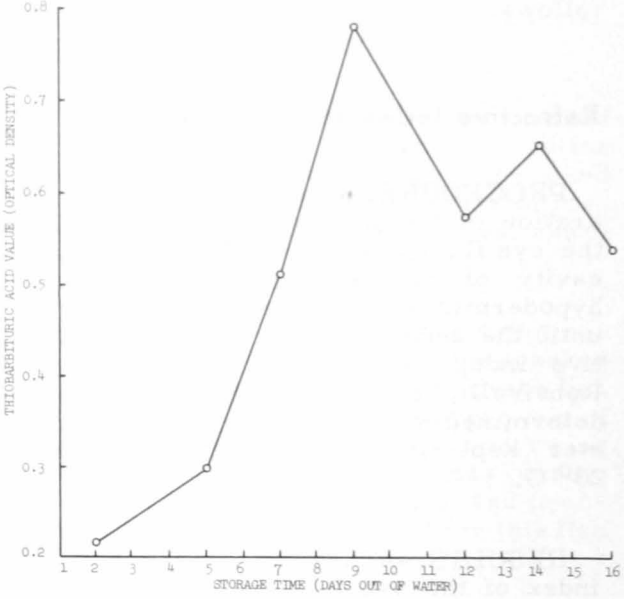

Figure 3.--Thiobarbituric acid value of whiting stored in ice.

Volatile Bases

PROCEDURE.--The method of Stansby, Harrison, Dassow, and Sater (1944) was employed in determining volatile bases. A silicone-type antifoam agent was used during the distillation, and a methyl red-methyl blue indicator was substituted for the methyl red used in the original procedure.

RESULTS.--The amount of volatile bases in the fish increased slightly during the first 9 days of iced storage followed by a sharp increase during the next 5 days

(fig. 4). After the 14th day of iced storage, however, the development of volatile bases appeared to level off. The beginning of the sharp increase in the amount of volatile bases occurred at about the same point during iced storage that the whiting became inedible as determined organoleptically. This test might be useful in establishing the point at which the fish become inedible but apparently not in determining quality losses prior to that time.

Trimethylamine Nitrogen

PROCEDURE.--The method of Dyer (1945) was used in the trimethylamine nitrogen determination.

RESULTS.--The amount of trimethylamine nitrogen increased only slightly during the first 7 days of iced storage followed by a very large increase between the 7th and 14th days, during which time the quality of the fish was changing from fair to inedible as determined organoleptically (fig. 5). Further work is needed to find whether this test will be useful in determining the quality of iced whiting.

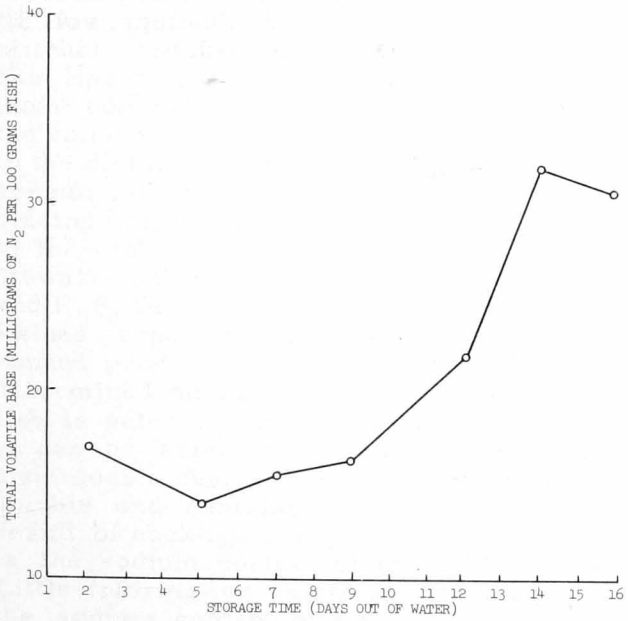

Figure 4.--Total volatile base in whiting stored in ice.

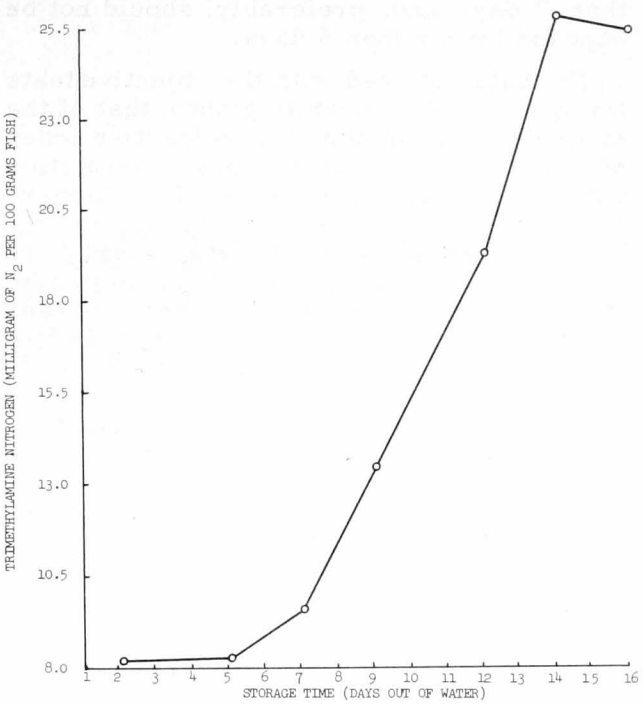

Figure 5.--Trimethylamine nitrogen in whiting stored in ice.

SUMMARY

Organoleptic and objective tests were made to determine the keeping quality of iced whiting and to evaluate the suitability of several objective tests--refractive index of eye fluid, thiobarbituric acid value, volatile base content, and trimethylamine nitrogen content of the raw, ground fish--as possible tools for determining the quality of whiting. Both raw and cooked whiting were examined by experienced graders, and the results of the objective tests were compared with the scores obtained in the organoleptic studies.

Examination of both the raw and the cooked whiting showed them to be of fair quality at the 7th day of iced storage, of poor quality at the 9th day, and of very poor quality after the 12th day. The taste panel scores on the cooked whiting were found to agree closely with the ratings for the raw fish. These results show that whiting should not be kept in ice for longer

than 7 days and, preferably, should not be kept for longer than 5 days.

The data obtained with the objective tests for quality of iced whiting show that of the methods investigated, the refractive index of the eye fluid has the best correlation with the organoleptic tests. The thiobarbituric acid test does not appear, in this work, to be a useful index of quality, as the data appeared to rise to a maximum and then fall rather than to increase steadily. More data are needed, however, before final conclusions are drawn as to the suitability of this test. The largest increases in trimethylamine nitrogen and total volatile bases occurred after the fish had undergone considerable loss of quality. Although these two tests may not be useful in showing initial loss of quality, they may be useful in establishing the point at which the whiting become inedible.

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MS #1173

EFFECT OF COOKING METHODS ON THE SODIUM CONTENT OF HALIBUT, HADDOCK, AND FLOUNDER

by

Bernard I. Sohn and Maynard A. Steinberg

ABSTRACT

Fresh and frozen halibut steaks, fresh flounder fillets, and fresh haddock fillets were baked, broiled, boiled, and steamed to determine the effect of these cooking methods on the sodium content of the cooked fish. Boiling was the most effective method used, resulting in a sodium loss of 70 percent regardless of species. Steaming was the next most effective cooking method followed by broiling and baking in that order.

INTRODUCTION

The increased emphasis being placed on the control of sodium intake in a number of vascular diseases (Cooper, Barber, Mitchell, and Rynbergen, 1957; and American Heart Association, 1958) requires a more complete and accurate knowledge of the sodium content of foods commonly found in the dietary. Several sources that list the sodium values for many common foods, including various species of fish, are available to the dietitian (Wooster and Blanck, 1949; Stewart and Clark, 1947; Sherman, 1952; and U. S. Department of Agriculture, 1950). Values reported for all fish except the canned product are the result of analyses determined on raw fish flesh. Since most fish is eaten in the cooked state and since it can be safely assumed that the flesh undergoes a change in the content of water-soluble and heat-labile components as a result of cooking, a more meaningful value is the sodium content of the cooked fish. Little information exists on the changes in the sodium content of fish as a result of cooking, and this matter requires study.

The effect of cooking on the sodium content of foods such as vegetables and macaroni has been reported (U. S. National Research Council, 1954). It was concluded that, in general, vegetables lose weight or shrink during cooking in unsalted water; and a loss of sodium occurs that is roughly proportional to the loss in weight.

McCance and Shipp (1933) investigated cooking losses in meats. Their conclusions may be summarized broadly: (1) No matter what method of cooking is employed, meats always shrink and express a portion of their juices and fats; as ordinarily prepared, meats may lose a third to a fourth of their raw weight. The readily soluble ions (including sodium) are lost in an amount proportional to the expressed juice. (2) When cooking is by steam, the loss of weight or shrinkage is very close to the percentage loss of water. (3) In boiling water, a leaching effect causes an additional loss of soluble salts. (4) In roasting or frying, fat is expressed and water is evaporated rapidly; but salt losses are low.

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The aim of this study was to determine the effect of various cooking methods on the sodium content of some common species of fish.

EXPERIMENTAL PROCEDURE

Selection of the species and specific cooking methods were made after discussions with dietitians at local hospitals to determine their cooking methods and the species of fish most commonly served to hospitalized cardiac patients.

Samples

Samples of fresh Atlantic halibut *(Hippoglossus hippoglossus)*, frozen Pacific halibut *(Hippoglossus stenolepis)*, fresh haddock *(Melanogrammus aeglefinus)*, and fresh flounder *(Limanda ferruginea)* were obtained from a local distributor. With the exception of the frozen halibut, which was cut into steaks on the dealer's bandsaw, all the fish were steaked or filleted at the laboratory. Frozen halibut steaks were thawed at room temperature before being cooked.

Previous work at this laboratory has shown that a variation exists in the sodium content of the flesh from different parts of the same fish. An effort was made to minimize the effect of this variation by using half of each steak or fillet examined as the raw control for the other half. Each cooking method was tested on two samples of each species of fish.

Cooking Methods

Samples of serving portion size were prepared and cooked[1] by the following methods:

1. *Baking* - The steaks or fillets were placed in pans and baked in a preheated oven at 375° F. for 30 minutes. The effect of baking with unsalted butter was also investigated. When fish were so prepared, the pans were first coated with approximately one-quarter ounce of melted butter. The samples were coated on both sides with the butter already applied to the pan and were then placed in the pan for baking.

2. *Broiling* - The steaks or fillets were placed on a wire rack approximately 2 inches below a gas flame and were broiled on each side for 5 minutes. When samples were broiled with butter, the upper sides were coated with melted butter. Approximately one-eighth ounce of butter was used for each side.

3. *Boiling* - Individual samples were placed in boiling water (approximately 2 quarts) and boiled for 30 minutes, after which they were removed from the water and allowed to drain on racks until there was no longer any evidence of dripping liquid.

4. *Steaming* - The samples were placed on wire racks in covered containers and steamed over boiling water for 30 minutes. Then they were removed and allowed to drain until there was no longer any evidence of dripping liquid.

Sodium Determinations

Samples were homogenized in a Lourdes Multimixer. Duplicate 2-g. samples of the homogenized fish were placed in tared porcelain filter crucibles and were heated in a muffle furnace at 550° F. until a white ash was obtained (Association of Official Agricultural Chemists, 1950). The ashed samples were digested with 10 ml. of a 9:1 nitric acid-water solution and were then filtered into a 100-ml. volumetric flask and diluted to volume with double-distilled water.

All sodium analyses were made at a wave length of 589.5 millimicrons using a flame attachment to the Beckman DK spectrophotometer.

RESULTS AND DISCUSSIONS

The various sources of information relating to the mineral composition of foods commonly report these data on the foods as purchased by the consumer. This method of reporting is satisfactory when it is applied to those foods (bread, fruits, milk, etc.) that are customarily eaten in the "as purchased" state. It may have shortcomings, however, when applied to foods that are cooked before being eaten. It can be argued that reporting the mineral values of cooked material is subject to the weakness that the process of cooking does not lend itself

[1] Although these are the cooking methods that are used in some hospitals, it is suggested that the fish would be more palatable if cooked as recommended by Kerr (1958); namely, baking 20 minutes at 350° F. or boiling or steaming 10 minutes.

to standardization when practiced by the consumer and, consequently, that the sodium values determined on foods cooked in the laboratory are not closely related to the sodium content of the foods as cooked by the consumer. This is a valid criticism; however, these values for sodium are closer to the values of the foods in the "as eaten" state than are the values that are determined on the same foods when in the "as purchased" state. Similar reasoning also probably applies to other water-soluble components.

A word of caution is necessary with respect to the interpretation of the sodium analyses made on the cooked fish. A comparison of these results with those made on the same fish in the raw state will more often than not indicate that the ratio of sodium to flesh has increased as a result of the cooking process. This increase is obviously due to a loss of moisture during the cooking process and emphasizes the need for reporting sodium values on a moisture-free basis to permit an evaluation of the effect of cooking on the sodium content. For the dietitian, this increase has an additional significance in that it emphasizes the need to determine the size of the serving portion on the raw food rather than on the cooked food.

In tables 1 through 4, each sodium value represents the mean of four determinations. Values for the raw controls are reported immediately below the values for the cooked samples to which they correspond. Sodium is reported in terms of mg. per 100 g. of wet tissue and mg. per g. of dry tissue, thus making possible direct comparisons between raw samples treated by different cooking methods. Because of the variation that exists in the sodium content of fish flesh and the limited number of samples used, the data are taken as indicating only the order of magnitude of change occurring in a given species of fish cooked by a given method. The data show that boiling consistently resulted in a sodium loss of approximately 70 percent and that from the standpoint of lowering sodium content, it was the most effective cooking method used. Steaming was found to be the next most effective cooking method, for it reduced the sodium 30 to 59 percent. The differences in effectiveness of broiling and baking either with or without butter are generally

TABLE 1.--Effect of various cooking methods on the sodium content of fresh halibut steaks

Method of preparation	Sodium content		Moisture content	Amount of sodium lost as a result of cooking (calculated on a moisture-free basis)
	Mg. per g. of dry tissue	*Mg. per 100 g. of wet tissue*	*Percent*	*Percent*
Baked with butter[1]	1.6	53.0	67.0	6
Raw control	1.7	44.0	76.4	
Baked without butter	1.9	55.0	71.2	5
Raw control	2.0	46.0	76.8	
Broiled with butter[1]	1.6	53.0	66.0	16
Raw control	1.9	42.5	77.9	
Broiled without butter	1.5	46.0	70.1	17
Raw control	1.8	39.0	78.8	
Boiled	0.7	19.0	71.3	70
Raw control	2.3	53.0	76.5	
Steamed	1.5	45.0	70.5	40
Raw control	2.5	56.5	77.0	

[1] Unsalted butter

TABLE 2.--Effect of various cooking methods on the sodium content of frozen halibut steaks

Method of preparation	Sodium content		Moisture content	Amount of sodium lost as a result of cooking (calculated on a moisture-free basis)
	Mg. per g. of dry tissue	*Mg. Per 100 g. of wet tissue*	*Percent*	*Percent*
Baked with butter[1]	2.6	80.0	68.9	7
Raw control	2.8	57.5	79.4	
Baked without butter	2.7	76.5	71.8	4
Raw control	2.8	57.5	78.6	
Broiled with butter[1]	2.7	94.0	65.2	4
Raw control	2.8	56.5	78.7	
Broiled without butter	2.6	95.5	63.4	4
Raw control	2.7	58.5	78.3	
Boiled	1.1	24.0	78.1	70
Raw control	3.7	79.0	78.7	
Steamed	2.5	64.0	74.6	31
Raw control	3.6	77.5	78.6	

[1] Unsalted butter

TABLE 3.--Effect of various cooking methods on the sodium content of fresh flounder fillets

Method of preparation	Sodium content		Moisture content	Percent sodium lost as a result of cooking (calculated on a moisture-free basis)
	Mg. per g. of dry tissue	*Mg. per 100 g. of wet tissue*	*Percent*	*Percent*
Baked with butter[1]	1.3	37.5	71.6	32
Raw control	1.9	38.0	79.6	
Baked without butter	1.4	36.0	73.6	36
Raw control	2.2	40.0	81.4	
Broiled with butter[1]	1.5	58.0	61.4	12
Raw control	1.7	32.5	80.4	
Broiled without butter	1.3	44.0	67.2	35
Raw control	2.0	35.0	82.4	
Boiled	0.5	12.5	76.5	67
Raw control	1.5	39.0	80.5	
Steamed	1.2	31.0	73.9	37
Raw control	1.9	38.0	80.0	

[1] Unsalted butter

TABLE 4.--Effect of various cooking methods on the sodium content of fresh haddock fillets

Method of preparation	Sodium content		Moisture content	Amount of sodium lost as a result of cooking (calculated on a moisture-free basis)
	Mg. per g. of dry tissue	*Mg. per 100 g. of wet tissue*	*Percent*	*Percent*
Baked with butter[1]	2.8	80.0	71.3	10
Raw control	3.1	57.5	81.5	
Baked without butter	1.7	55.0	68.0	37
Raw control	2.7	49.0	81.6	
Broiled with butter[1]	2.5	85.0	67.2	11
Raw control	2.8	53.0	81.5	
Broiled without butter	2.2	110.0	49.4	37
Raw control	3.5	66.5	80.9	
Boiled	0.7	16.0	76.5	74
Raw control	2.7	51.5	81.5	
Steamed	1.1	31.0	72.0	59
Raw control	2.7	50.0	81.0	

[1] Unsalted butter

not great when the cooking methods themselves are considered. Figure 1, which permits a convenient comparison of the response of each species studied to the cooking method employed, indicates, however, that flounder and haddock fillets lose more sodium than do halibut steaks, regardless of the cooking method. Although this may be due to a species difference, it is also quite possible that it is related to the relative liquid and salt retention characteristics of fillets and steaks.

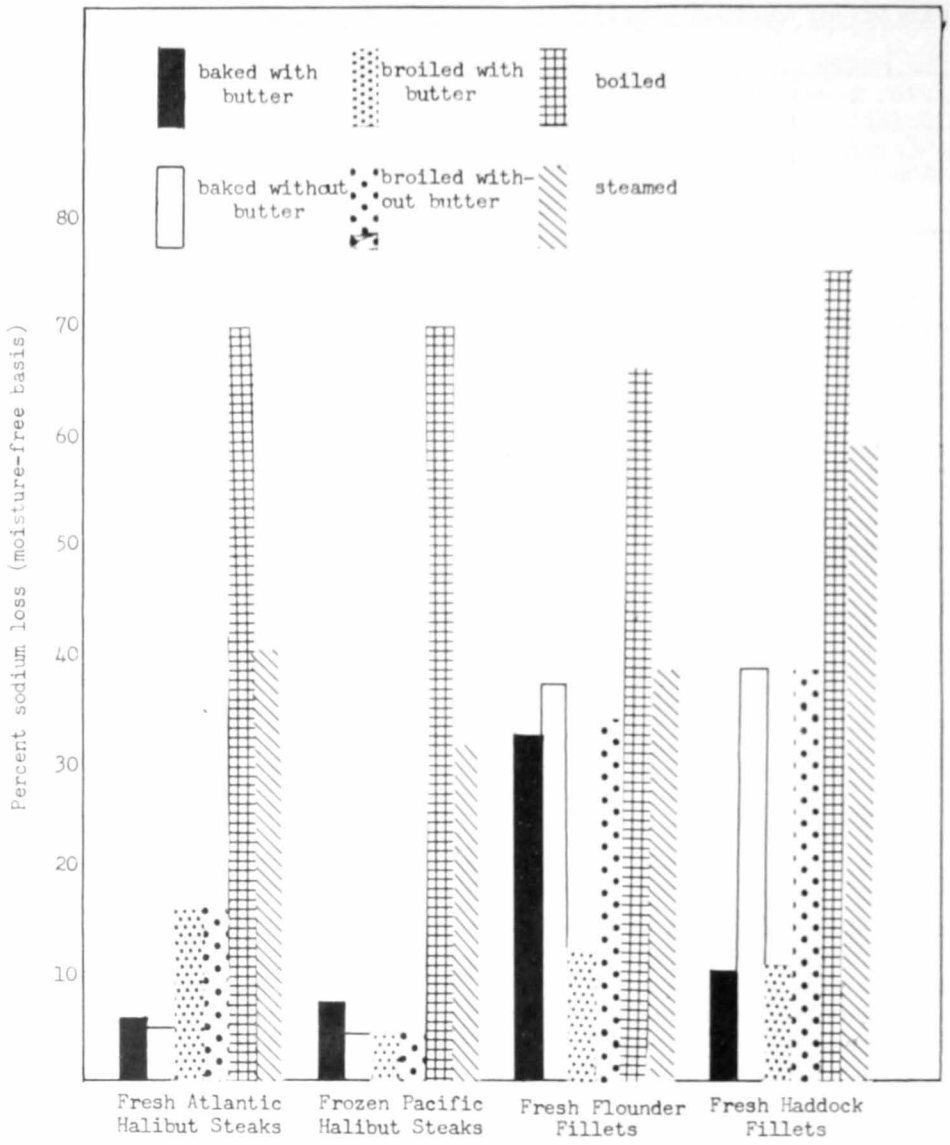

Figure 1.--Effect of cooking methods on sodium content.

CONCLUSIONS

1. Cooked fish have a lower sodium content, calculated on a dry-weight basis, than do the corresponding species of raw fish.

2. Boiling and steaming are more effective methods of lowering the sodium content of fish fillets and steaks than are broiling or baking.

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PROXIMATE COMPOSITION CHANGES IN SOCKEYE SALMON (Oncorhynchus nerka) DURING SPAWNING MIGRATION

by

Claude E. Thurston and H. William Newman

ABSTRACT

When sockeye salmon enter the spawning stream, they contain about 10 percent oil and 22 percent protein. The highest oil content is found in the belly flaps and in the dark meat (dark lateral muscle). The fish travel for 3 to 4 months over a distance of several hundred miles to reach the spawning grounds. Drastic changes take place in the composition of their flesh and organs during the migration: oil reserves are nearly depleted, except in the dark meat; protein is markedly decreased; and moisture and sodium are markedly increased.

INTRODUCTION

The sockeye salmon does not eat during its spawning migration which covers perhaps 300 to 800 miles and requires up to 3 or 4 months to complete. The fish expends a tremendous amount of energy in making the trip upstream (fig. 1) and in developing mature gonads. It dies shortly after spawning.

C. W. Greene (1913) reported on the changes that take place in the fat of king salmon during migration up the Columbia River. C. H. Greene (1919) and C. W. Greene (1919) reported that oil and protein contents of king salmon decreased markedly during spawning migration in the Columbia. Davidson and Shostrom (1936) studied physical and chemical changes that occur in pink salmon during migration and found an inverse relation between the sexual development and the amounts of oil, protein, and ash contents. Dunstan (1956) determined the variations in depot fat in the flesh of sockeye salmon caught at several localities in the Columbia River. The broadest, most complete study of the biochemical changes during migration of salmon yet attempted is being done at the Technological Station, Fisheries Research Board of Canada, Vancouver, B. C. (1958-60).

The present report concerns changes in proximate composition and sodium and potassium contents of sockeye salmon during their Columbia River migration in 1960. The specimens studied were from several hundred sockeye salmon collected during the migration to provide data for an investigation on energy expenditure.[1]

EXPERIMENTAL

Collection of Specimens

Three groups of fish were obtained from stations on the Columbia River (fig. 2): Group 1 near the mouth; Group 2 at an

[1] G. B. Collins and H. W. Newman. Manuscript in preparation, "Energy Expenditure of Salmon at Dams." Joint study by Corps of Engineers and Bureau of Commercial Fisheries.

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Figure 1.--Sockeye salmon leap at falls during spawning migration.

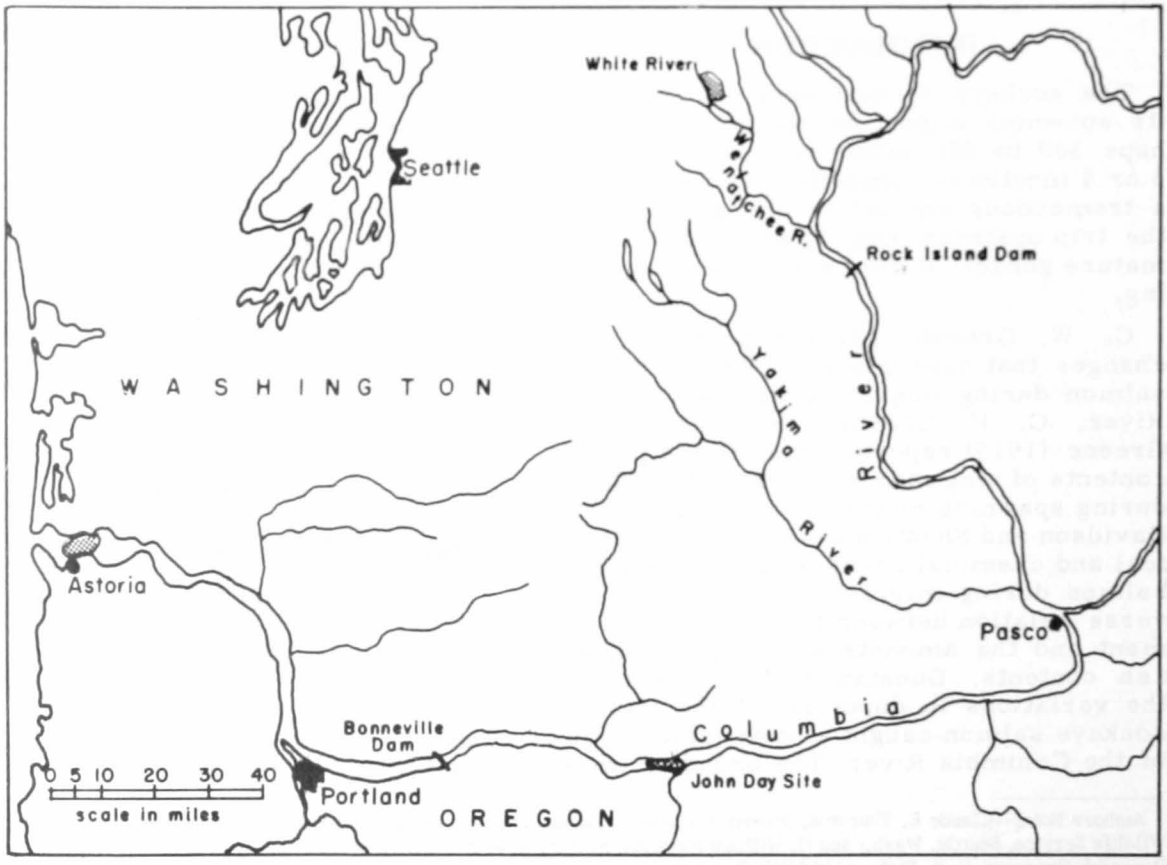

Figure 2.--Map of Columbia River showing collection areas.

intermediate point; and Group 3 at the spawning grounds. The first group consisted of 10 males and 10 females, selected to include a wide variety of sizes from a large group that were purchased from a commercial fisherman at Astoria, Oregon. They had been captured during 4- to 6-hour fishing periods from the 16th to the 19th of June. The second group consisted of 10 males caught at the John Day damsite (fig. 3), 225 miles upriver, during overnight fishing periods from July 13 to 15. The third group consisted of 10 males taken at the White River fish racks, 525 miles upriver. Artificially spawned fish carcasses obtained from hatchery crew members between September 2 and 9 made up this third group. These latter fish had been detained at the rack since their arrival beginning approximately August 19. Only males were available at the second and third locations.

The fish were processed in the field as follows: (1) weight was taken to the nearest gram, (2) length was measured in millimeters (±5 mm.) from hypural plate (base of tail) to snout by a spiral-drum measuring device, (3) sex was determined after making an incision in the belly, (4) each fish was placed in a numbered polyethylene bag and securely tied, and (5) except during transit, the bagged fish were held in a mechanical freezer. Transit times ranged from 4 to 6 hours.

Preparation of Samples

The frozen fish were removed from the bag and cut by bandsaw into cross sections approximately 2 inches thick. All of the edible flesh was removed from the nape, center, and tail sections. The dark lateral muscle (dark meat), and belly flaps were separated from the two remaining sections (fig. 4). The resulting five samples from each fish were individually ground and vacuum sealed in 1/4-pound fish cans for later analysis. No more than a partial thawing occurred during preparation and before the sealed samples were returned to the freezer.

Methods of Analysis

Each sample was analyzed in duplicate for moisture, protein, oil, ash, sodium, and potassium by standard methods previously described (Thurston, 1958a).

DISCUSSION AND RESULTS

The discussion can be conveniently grouped under the following topics: (1) comparison of physical data for the four series

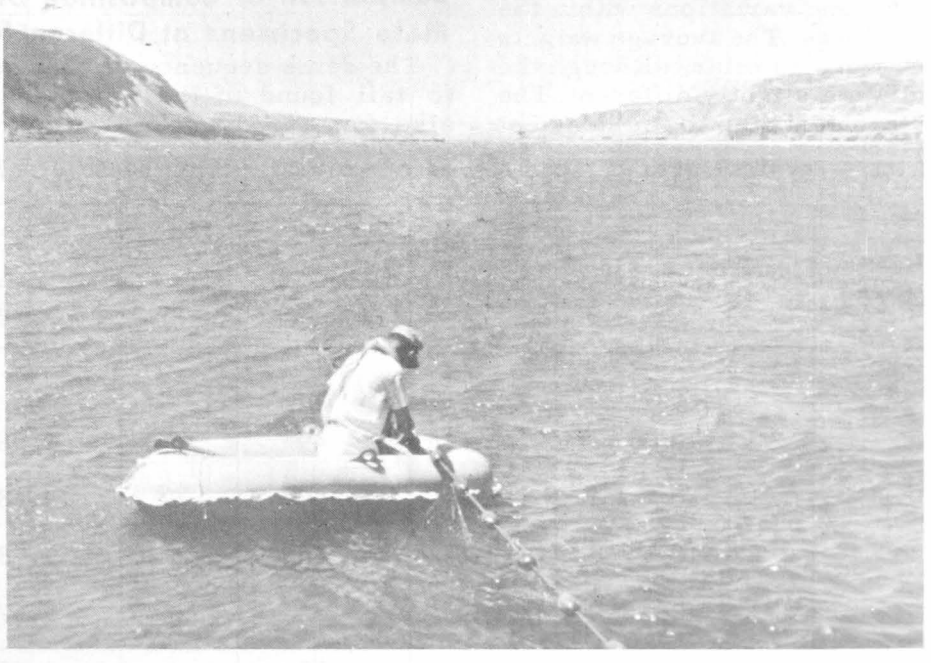

Figure 3.--Biologist fishing for sockeye salmon at John Day Dam site.

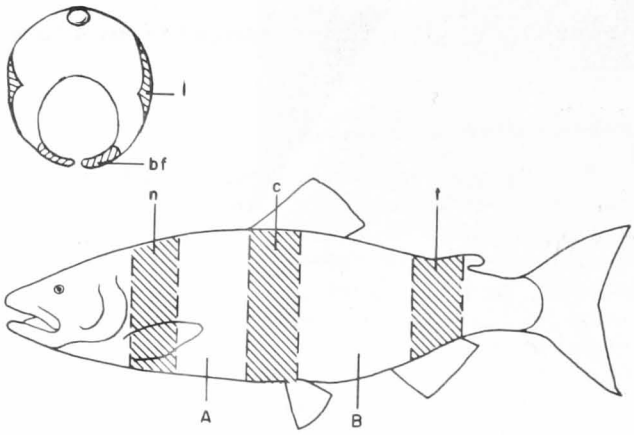

Figure 4.--Diagram of salmon showing sections from which samples were removed.

n - Nape
c - Center
t - Tail
l - Lateral dark meat
bf - Belly flap
A - Section from which l and bf were taken
B - Same as A

of samples of fish--one of females and three of males, (2) comparison of composition data for male and female specimens, (3) comparison of composition data for male specimens at the three stations--Astoria, John Day, and White River, and (4) comparison of results with findings of other investigators.

Comparison of Physical Data

The four samples were of quite uniform size (table 1). Average lengths were in close agreement, and variations within the samples were not large. The average weights of the samples were similar, although the ranges covered were slightly different. The range from the lightest fish to the heaviest was from 1.2 to 2.2 kg. There was also little variation in the physical appearance of the specimens in a given sample. Deterioration of specimens from the spawning grounds was very marked.

Comparison of Composition Data for Male and Female Specimens

The close agreement in composition between the sexes taken at Astoria is shown in table 2. Averages for nape, center, and tail steak sections were nearly identical for all constituents. The variations within the series were small except for sodium and potassium, but even in these constituents, the deviations from the average seldom exceeded 15 percent. The average values for nape, center, and tail sections, representing the average composition of the edible flesh, were nearly identical for all constituents. The definite increase in protein content and large decrease in oil content from nape to tail sections is characteristic for other species analyzed in this laboratory (Thurston, 1958b), as are the comparatively lower sodium and higher potassium contents of the center section. The belly flaps and the dark meat (dark lateral muscle) of the two sexes were also very nearly the same in composition. The belly flaps were higher in protein, moisture, sodium, and potassium than were the dark meat parts.

Comparison of Composition Data for Male Specimens at Different Stations

The same sequence of changes from head to tail found in the Astoria samples was also found in the John Day and White River

TABLE 1.--Physical data on four series of Columbia River sockeye salmon

Place of capture	Number of fish in samples	Sex	Length		Weight	
			Average	±	Average	±
			Cm.	*Cm.*	*Kg.*	*Kg.*
Astoria	10	Female	49	3	1.58	.3
Astoria	10	Male	50	2	1.68	.3
John Day	10	Male	48	5	1.78	.4
White River	10	Male	52	6	1.57	.4
Average			50		1.65	

TABLE 2.--Proximate composition of four series of Columbia River sockeye salmon

Location	Sex	Part	Moisture		Protein		Oil		Ash		Sodium		Potassium	
			Average	±	Average	±	Average	±	Average	±	Average	±	Average	±
			Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Mg Percent*	*Mg Percent*	*Mg Percent*	*Mg Percent*
Astoria	Female	Nape	65.6	2	20.9	1	13.2	2	1.13	0.03	42	4	365	20
		Center	67.5	1	22.1	1	10.3	2	1.16	0.05	36	5	379	13
		Tail	71.4	2	22.7	0.5	5.7	1	1.19	0.05	41	3	383	20
		Average	68.2		21.9		9.7		1.16		40		376	
		Belly flaps	58.3	3	18.5	2	22.2	2	0.95	0.1	52	8	292	20
		Dark meat	55.0	1	16.0	1	27.4	2	0.91	0.1	35	8	271	20
Astoria	Male	Nape	66.0	2	21.2	1	12.7	3	1.19	0.1	44	3	361	
		Center	67.3	2	22.4	1	10.5	2	1.24	0.1	36	2	375	
		Tail	71.4	2	23.1	1.5	5.7	2	1.28	0.1	40	6	377	
		Average	68.2		22.2		9.6		1.24		40		371	
		Belly flaps	58.5	2	19.1	1	21.9	4	0.97	0.1	56	5	292	30
		Dark meat	56.8	2	15.8	2	26.7	4	0.84	0.2	33	6	262	50
John Day	Male	Nape	71.7	4	20.7	2	7.7	4	1.14	0.1	55	10	354	40
		Center	72.4	3	21.9	1	5.9	2	1.13	0.1	41	12	370	30
		Tail	74.5	2	21.9	1	3.6	1	1.12	0.1	44	12	369	20
		Average	72.9		21.5		5.7		1.13		47		364	
		Belly flaps	67.7	6	20.0	2	12.3	7	1.04	0.1	53	10	333	40
		Dark meat	62.8	5	16.7	2	19.6	5	0.94	0.1	37	9	290	40
White River	Male	Nape	80.1	2	17.9	1	2.0	1	1.14	0.1	60	10	378	15
		Center	80.3	2	18.0	1	1.8	1	1.11	0.1	57	7	375	20
		Tail	79.8	2	18.4	1	1.6	1	1.10	0.1	58	8	366	15
		Average	80.1		18.1		1.8		1.12		58		373	
		Belly flaps	81.0	2	16.9	1	2.1	1	1.07	0.05	84	20	331	30
		Dark meat	77.3	4	15.5	1	6.8	4	0.88	0.05	65	10	264	20

samples (table 2), but the change in each constituent was uniformly large in most instances from Astoria to the White River. The large increases in moisture and sodium with corresponding decreases in protein and oil are similar to the results found for pink salmon (Thurston, 1958b). The high oil content of the dark meat in spawning specimens has also been noted in pink salmon (Thurston, 1958b). The small variation in potassium values is rather surprising in view of the large increase found for sodium. Usually, there is a fairly uniform inverse proportion between the sodium and potassium contents of fish flesh. This relation was not observed in the present spawning migration study.

Differences found in the oil content indicate that a more complete study of changes in lipids would be of interest. The lipid deposit found in the dark lateral muscle was not depleted as completely as were the deposits found in the belly flap and in the flesh sections. Iodine values were determined on the oil extracted from all the samples. Although the method used to extract the oil would be expected to cause a loss of unsaturation, all samples received the same treatment, and the results can be considered relative. The iodine value of the oil from steak sections from fish taken at the first two stations did not change and averaged 148. The average at the spawning grounds was 165. The iodine value in the dark meat did not change, and that of the belly flap increased from 137 to 147. In future investigations, the quantitative fatty acid composition of spawning salmon might well be determined and compared with that of fish from the beginning of the run.

As is shown in table 3, the comparable data obtained in this study are in good agreement with those reported by Canadian scientists in their extensive investigation of composition changes in sockeye salmon during their migration up the Fraser River (Idler and Bitners, 1958). The changes in moisture and oil were greater and the change in protein was smaller for the Columbia River specimens than they were for the Fraser River specimens, but the changes were of the same order.

TABLE 3.--Proximate composition of sockeye salmon from the Columbia and Fraser Rivers[1]

Location	Sex	Moisture		Protein		Oil	
		Columbia	Fraser	Columbia	Fraser	Columbia	Fraser
		Average percent	*Average percent*	*Average percent*	*Average percent*	*Average percent*	*Average percent*
Mouth of river	Female	68.2	67.0	21.9	22.0	9.7	10.6
Mouth of river	Male	68.2	67.2	22.2	21.9	9.6	9.3
Halfway point	Male	72.9	70.7	21.5	20.5	5.7	5.1
Spawning grounds	Male	80.1	78.2	18.1	16.8	1.8	3.2
Total change		+11.9	+11.0	-4.1	-5.1	-7.8	-6.1

[1] Fillets only, for three constituents (the only ones reported in the Fraser River study).

SUMMARY

1. The specimens in the different series of Columbia River sockeye salmon used in this investigation had the same range distribution for size.

2. Little difference was noted in composition of male and female specimens taken at the mouth of the river. The 22 percent protein and 10 percent oil contents, combined with a low sodium (40 mg. percent) content, indicate that sockeye salmon is a nutritious food.

3. At the spawning grounds, the protein content of the fish dropped markedly and the oil reserves were practically depleted.

This occurred even though the oil content of the dark meat remained high. The moisture and sodium contents greatly increased, but the potassium content remained about the same.

4. The iodine value of the oil, except for oil in the dark meat, tended to increase by the time the fish arrived at the spawning grounds.

5. Where data are available for comparison, as in amounts of moisture, protein, and oil, the changes in composition reported here are practically the same as the changes reported for sockeye salmon migrating up the Fraser River.

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MECHANICALLY DEICING AND WEIGHING GROUNDFISH AT THE DOCK IN NEW ENGLAND

by

John A. Peters, Joseph W. Slavin,
and Arvey H. Linda

ABSTRACT

Better methods of handling groundfish, both on the vessel and at the dock, are needed to increase the efficiency of operations and to improve the quality of product. This paper reports on the design of five mobile fish deicing and weighing units to improve the handling of groundfish at the dock as the fish are unloaded from the trawler. Information is included on the fabrication of two of these units and the subsequent testing of them under conditions of commercial operation.

INTRODUCTION

The Bureau of Commercial Fisheries Technological Laboratory at Gloucester, Massachusetts, has been engaged in a research program to develop new techniques for handling groundfish both on the vessel and ashore.

The first phase of this program dealt with an investigation of techniques that could be readily applied by the fishing industry to improve the handling of fish at the dock. The classical unloading method in New England is an operation that results in mishandled fish through pewing procedures and also requires much hand labor. This paper reports on results obtained in designing and testing machines for deicing and weighing cod and haddock at the dock as the fish are being unloaded from New England trawlers.

The paper is divided into two main parts. The first part describes the present methods used. The second part describes the various mechanical units designed.

PRESENT METHODS OF HANDLING AND WEIGHING COD AND HADDOCK AT THE DOCK

A survey of handling methods in use at Massachusetts fishing ports was conducted to obtain the information necessary for designing and fabricating the mechanical equipment.

The procedure at the Boston Fish Pier is to pew fish from the hold of the vessel into 100- to 150-pound-capacity canvas unloading baskets. Usually, two holds are emptied simultaneously. The full baskets of fish, containing some ice, are hoisted out through the hatch of each fish hold and swung onto the dock. At dockside, the fish are emptied from the baskets into four separate weigh boxes, each located on a 1,000-pound-capacity platform scale. The fish are weighed out in 500-pound lots and then are pewed from the weigh boxes into carts or boxes for transport to the processing plant.

Usually, a team of eight men handle and weigh fish at the dock as the fish are being

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unloaded through two hatches of a trawler. Six men, or three per hatch, empty the unloading baskets into weigh boxes, record the weight of fish, and pew the fish from the weigh boxes to carts or boxes. Two additional men serve as inspectors. The maximum unloading rate with this system is about 20,000 pounds of fish per hour per hatch, or 40,000 pounds per hour total.

MECHANICAL DEICING AND WEIGHING UNITS

Mechanical deicing and weighing of fish at the dock, although not being a panacea, will nevertheless do much to improve quality of the product and efficiency of fish handling operations. Important considerations in designing equipment for this purpose are adequate capacity, ease of mobility, ease of operation, and low construction and maintenance costs. Designs of five types of fish deicing and weighing units were prepared to afford industry a choice of machines possessing different attributes. After consultation with members of the New England fishing industry, two machines were built and tested in actual operations.

Fish-Handling Unit Number I

The first design (fig. 1) features a loading platform, receiving hopper, rotary deicer, culling belt conveyor, and weighing hopper supported from an enclosed lever system (Slavin, 1957). The scale is provided with a preset cutoff switch to immobilize the deicer and conveyor the moment the desired weight is attained. Weight settings can easily be made at any desired point up to 2,000 pounds. Contents of the hopper are emptied into a cart below by means of a manually operated gate.

Operation of the unit is as follows: The fish in the hold of the vessel are put into unloading baskets, each with a capacity of 100 to 150 pounds. A basket, which normally contains some ice along with the fish, is swung from the vessel to a man standing on the loading platform. He empties it into the receiving hopper. The fish and ice "tumble" through the deicer and washer, where the ice falls out through the wide mesh, and the fish are thoroughly washed. The fish then drop onto the belt conveyor and are carried up into the weighing hopper. When the weight of fish in the hopper reaches the point at which the scale cutoff has been set, the conveyor and deicer stop automatically. The operator then records the weight and opens the gate of the hopper, allowing the fish to drop into the cart or box for transport to the processing plant. The cycle of operation is then repeated.

This design is planned for an operating rate of 40,000 pounds of fish per hour, using two men on the dock--one to dump the basket of fish and the other to operate

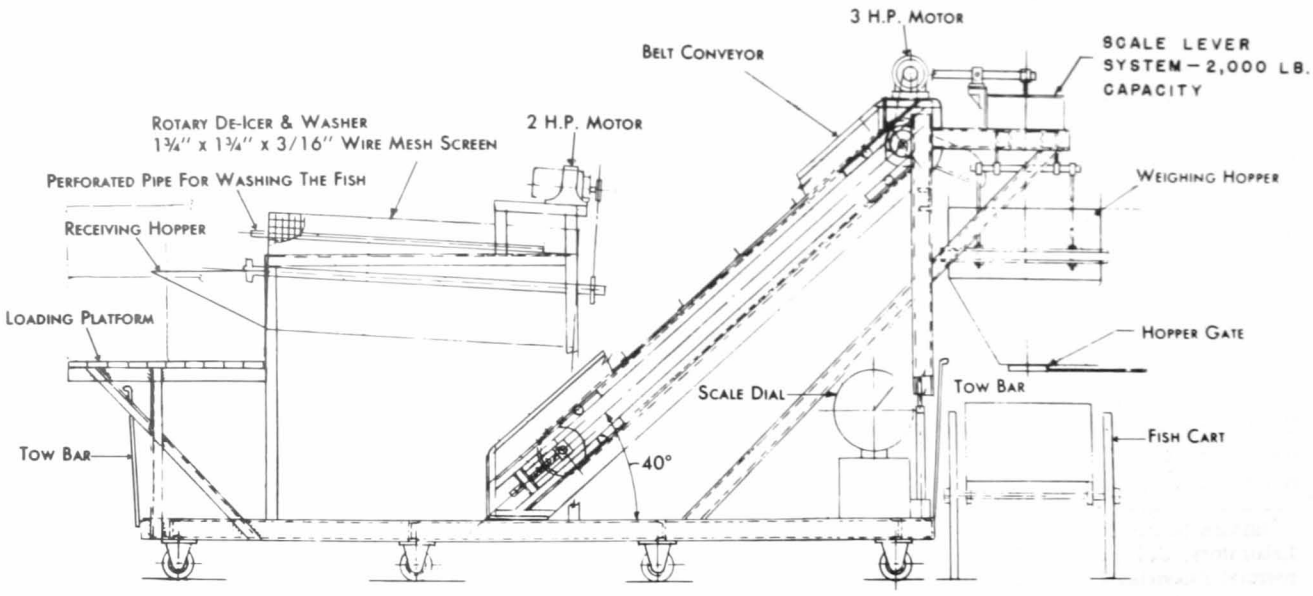

Figure 1.--Fish-Handling Unit Number I.

the hopper gate. An inspector is also required to check the quality of the catch.

This unit possesses the advantages of low labor requirements, washing and precise weighing of the fish, and ease of operation. Its high initial cost of $7,000, which may seem to be a deterrent to many firms, would be offset in a very short time by the savings attained in labor requirements. Because, however, of the automatic weighing equipment, maintenance would be higher than in subsequent fish-handling units.

Fish-Handling Unit Number II

The design illustrated in figure 2 incorporates some of the features of the previous unit. Here, fish are dumped directly into a culling chute made of longitudinal pipes spaced at 1-inch intervals. This chute allows large pieces of ice to be removed by hand and enables the small pieces to drop out. The weighing hopper is mounted on a 1,000-pound platform scale and has a capacity of 500 pounds.

In operation, the 100- to 150-pound-capacity baskets of fish, containing some ice, are emptied onto the culling chute. The fish are pushed along the chute as may be necessary, and the large pieces of ice are removed by hand. The small pieces fall through the openings between the pipes. The fish then enter the weigh box; and when a weight of 500 pounds is attained, they are emptied into a cart or box located below.

This unit has a capacity of about 20,000 pounds of fish per hour, so two units are required for unloading. Three men are needed to operate each unit: one to empty the fish basket, one to operate the dump lever, and one to cull out any spoiled fish and to remove large pieces of ice. The third man would also serve as an inspector to check the quality of the fish.

This unit, through of simple design, still has obvious advantages over existing handling methods. Its low initial cost, however, of $500 is achieved at a mechanical loss in operating efficiency, and the height of the culling chute above the dock may pose problems in transferring fish from the vessel at low tide. This problem may exist particularly in ports where there is a large change in tide.

Fish-Handling Unit Number III

Another design, illustrated in figure 3, is based on two belt conveyors, one operating horizontally and the other operating at an ascending angle and carrying fish to the weighing hopper. The arrangement of weigh box and scale is similar to that of the previous design. The flow of fish is also similar, except that the fish are conveyed and not pushed along a chute. Three

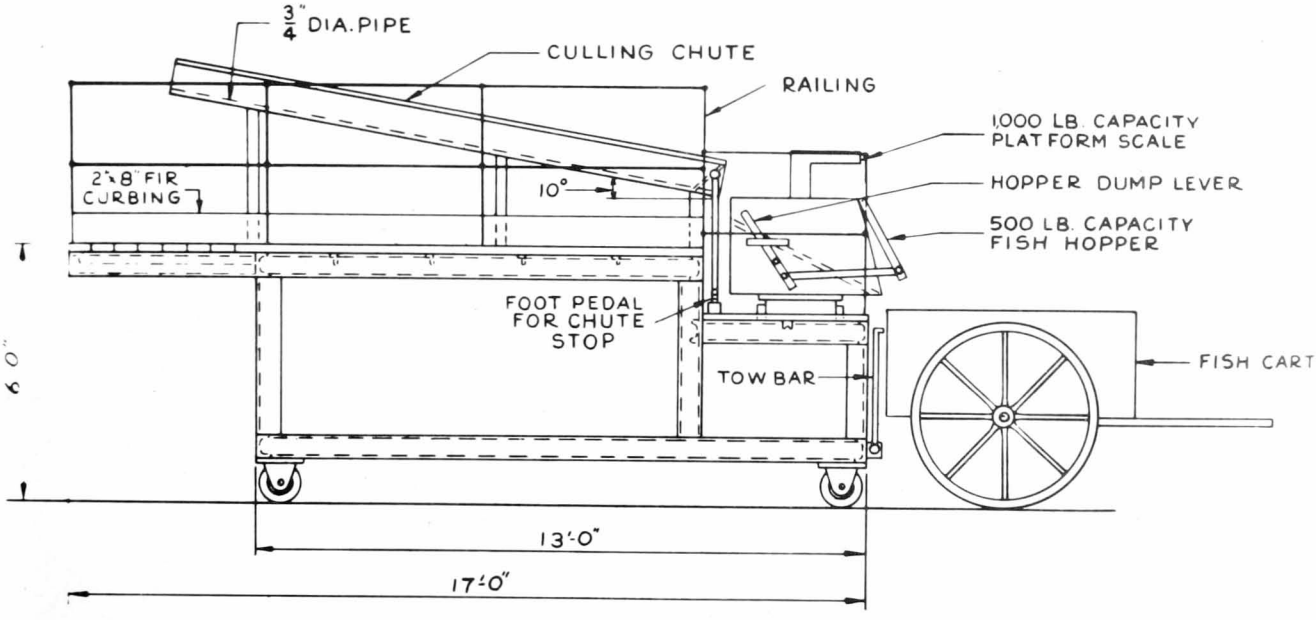

Figure 2.--Fish-Handling Unit Number II.

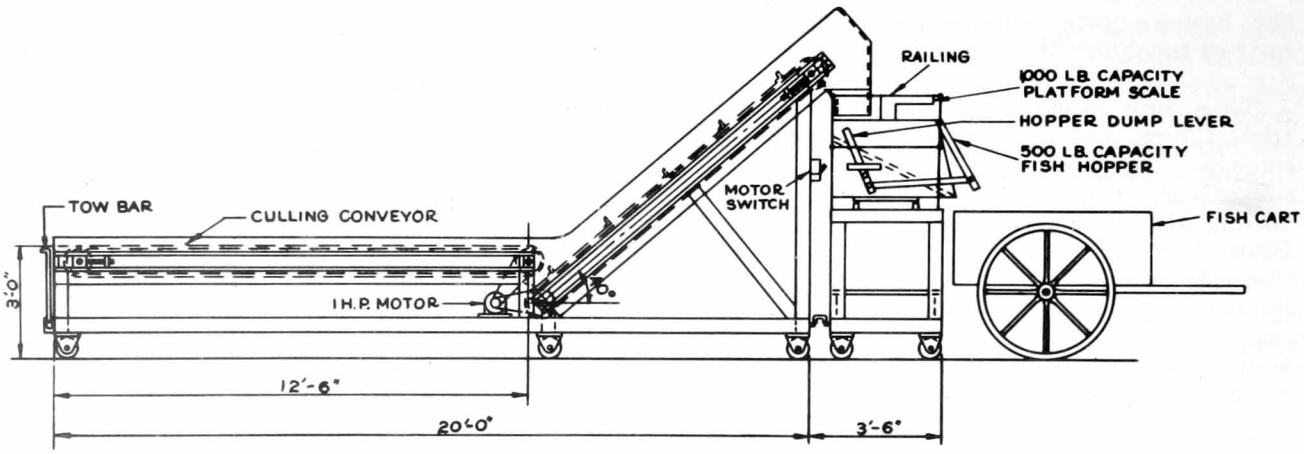

Figure 3.--Fish-Handling Unit Number III.

men are needed to empty the unloading basket, remove the ice, and empty the weigh box. An additional man is required to check the quality of the fish. The rated capacity of this unit is about 40,000 pounds of fish per hour. Its estimated cost is $2,500.

This unit possesses the advantage of high capacity at a relatively low cost. It, however, does not provide for mechanical removal of ice and, therefore, is most suitable for use in areas where little or no ice is unloaded along with the fish, or where there is an adequate supply of labor.

Fish-Handling Unit Number IV

The mobile fish-weighing unit, shown in figure 4, employs a horizontal culling and deicing conveyor leading to the conventional weigh box and scale. The conveyor is made

Figure 4.--Fish-Handling Unit Number IV being used for unloading fish from the *Delaware*.

up of multiple V-belts for removal of small ice and for transport. The weigh box, platform scale, and labor requirements are similar to those of Fish-Handling Unit Number II. The estimated cost of this unit is $1,300.

Unit Number IV was fabricated and tested in unloading fish from the Bureau's motor vessel *Delaware* and from a commercial trawler at the Boston Fish Pier. The unit handled 20,000 pounds of fish per hour, and its operation was satisfactory.

Two problems remained, however, that led to further investigation into the deicing and weighing problem. Because of the limited height of the boom topping gear on many of the fishing vessels, it was difficult, at low tide, to swing the fish basket to the high dump platform of the mobile fish weighing unit. In addition, the unit was only partially effective in removing ice, unloaded along with the fish.

Fish-Handling Unit Number V

The final design, shown in figure 5, features a wide-mesh dump hopper, an inclined wire-mesh conveyor belt with a vibrating action, and a weigh box and scale similar to Fish-Handling Unit Numbers II, III, and IV. The baskets of fish are emptied into the dump hopper, where most of the ice falls out through the mesh openings and the fish and remaining ice are fed onto the inclined conveyor. The vibrating motion of the conveyor jars the remaining small pieces of ice, causing them to fall out through the open mesh. Meanwhile, the large pieces of ice remaining are culled out by hand, and the fish are conveyed to the weigh box. When the weight of fish reaches 500 pounds, the operator stops the conveyor and opens the weigh box, emptying the fish into a cart or box located below. Three men are needed to empty the unloading basket, remove any large pieces of ice, and operate the mechanism of the weigh box. An additional man is needed to

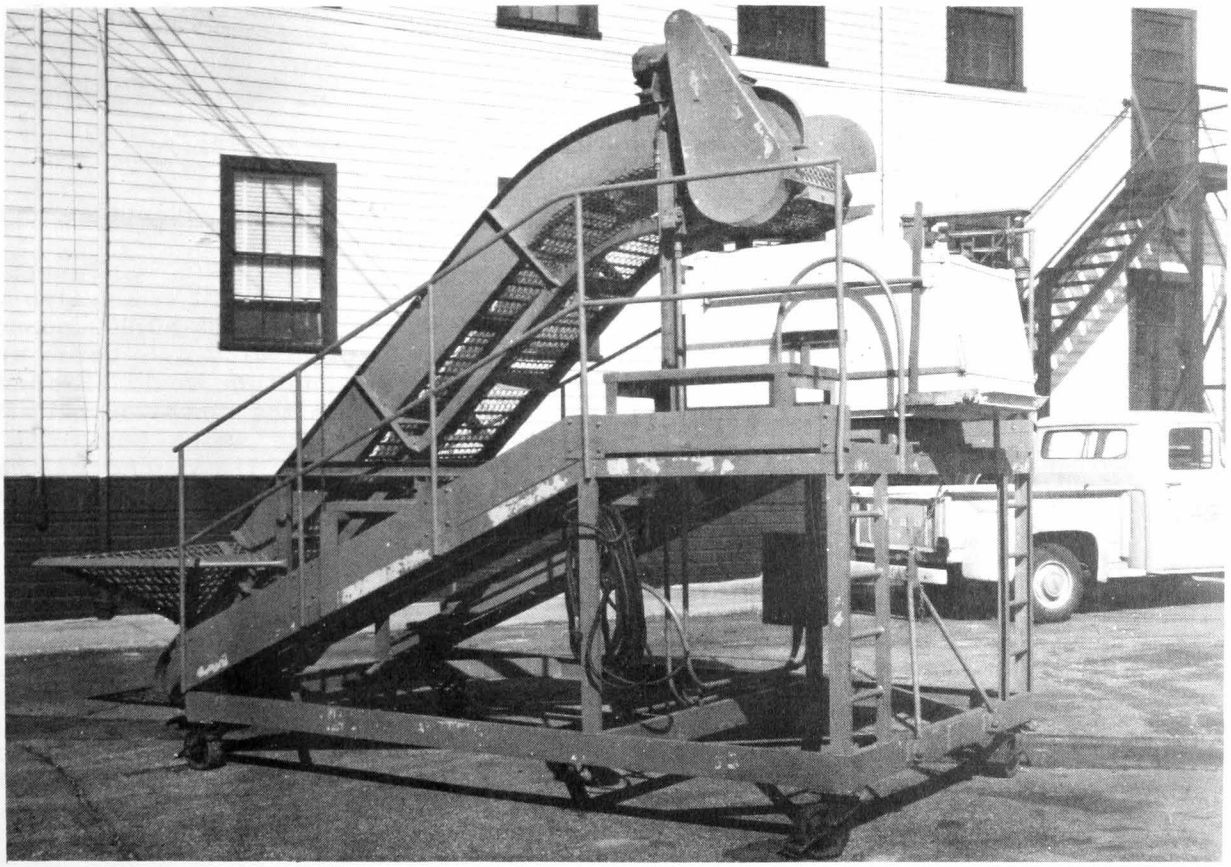

Figure 5.--Fish-Handling Unit Number V.

Figure 6.--Receiving hopper of Fish-Handling Unit Number V during tests at the State Fish Pier in Gloucester, Mass.

inspect the fish as they are being unloaded from the vessel. The estimated cost of the unit is $2,500.

A deicer of this design was fabricated, and the unit was tested in unloading groundfish from commercial fishing vessels at the State Pier in Gloucester, Mass. (fig. 6). It worked well and demonstrated a capacity of 33,000 pounds of fish per hour. If required, this rate could easily be increased to 40,000 pounds per hour by using deeper conveyor flights as well as by changing the gear ratio on the motor driving the conveyor belt.

Fish-Handling Unit Number V offers the advantages of high capacity and strikes a balance between initial cost and labor requirements. The unit is easy to operate and maintain and removes ice quite well. It offers many obvious advantages over present handling methods.

The capacity of this unit could also be increased further to about 50,000 pounds per hour by using two weigh boxes and two scales. This addition would eliminate the downtime while the conveyor halts to allow dumping of the weigh box. With a simple, movable gate, the deiced fish can automatically be diverted to the empty weigh box while the full one is being dumped.

SUMMARY AND COMPARISON

A summary of the significant variables in the designs of the five machines for unloading fish at the dock and comparison with the present method of unloading is shown in table 1.

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TABLE 1.--Comparison of methods of unloading fish at the dock

Type of unloading operation or device used	Labor requirements		Fish-handling capacity	Cost of unit	Overall analysis of operations in regard to:[1]			Ease of maintenance
	Inspectors	Handlers			Quality of product	Deicing of fish	Efficiency of operation	
			Pounds per hr.	*Dollars*				
Present methods	2	6	40,000	-	Poor	Fair	Poor	-
Unit Number I	1	2	40,000	7,000	Good	Excellent	Excellent	Fair
Unit Number II	1	2	20,000	500	Good	Fair	Fair	Excellent
Unit Number III	1	3	40,000	2,500	Good	Poor	Good	Good
Unit Number IV	1	2	20,000	1,300	Good	Fair	Fair	Good
Unit Number V	1	3	[2] 33,000	2,500	Good	Excellent	Good	Good

[1] The analysis of operations for Fish-Handling Unit Numbers I, II, and III are the authors' opinions of results that would accrue upon application of the designs, since these designs were not fabricated.

[2] Simple changes in design will permit an increase in capacity to 40,000 pounds per hour; further changes, to 50,000 pounds per hour.

METHODS OF SEPARATION OF FATTY ACIDS FROM FISH OILS WITH EMPHASIS ON INDUSTRIAL APPLICATIONS[1]

by

Edward H. Gruger, Jr.

ABSTRACT

Information from various research results and industrial processes is reviewed with the aim of understanding the methods of separation of fish oil fatty acids. Major emphasis is given to those methods that have industrial possibilities. These include distillations, solvent extractions, crystallizations, and related modifications.

INTRODUCTION

The future success of the fish oil industry of the United States, like that of other industries, may depend on the development of new or improved products. Fish oil products are most likely to be developed from particular fatty acids. The development of successful products will depend on the utilization of unique chemical features of certain fish oil fatty acids; namely, those with high degrees of unsaturation and long carbon chain lengths. Complete utilization of the fish oils will depend on the production and competitive costs of certain fish oil fatty acids that are also available from other sources. Purer fish oil fatty acids than are now industrially available are needed by researchers and industry for the production of new useful products.

Industry may best utilize those fatty acids from fish oils that have been fractionated and that possess particular physical and chemical properties. For example, short chain, long chain, saturated, and unsaturated fatty acids each are useful for specific purposes. These uses are often different for each type of fatty acid; consequently, we need to understand the methods of separation or fractionation of fish oil fatty acids to produce and evaluate the types of acids useful in the manufacture of industrial products. We must be thoroughly acquainted with the advantages, disadvantages, and limitations of each method so as to determine which method or combination of methods of separation meets the requirements of research and industry.

This paper is a review of some of the basic characteristics of various methods of separation that apply to fatty acids and includes some important results reported by various investigators. Based on this information, some ideas are given that will lead to a better understanding of practical industrial separations of fish oil fatty acids.

The methods of separation have been grouped into two categories. The first group includes methods that may not have immediate industrial application, because either

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[1]Presented at Eleventh Annual Conference, Pacific Fisheries Technologists, Gearhart, Oreg., March 27-30, 1960.

the processes are too new and have not been fully developed or certain basic features make them impractical. These methods include liquid thermal diffusion, chromatography, and electrophoresis. The second group includes methods that do have industrial application; namely, fractional distillation, fractional crystallization, liquid-liquid extraction, and fractionation of inclusion compounds such as urea-complexes. The first group of separation methods is discussed only to point out some of their basic features. The more important second group is discussed in greater detail.

METHODS LACKING IMMEDIATE INDUSTRIAL UTILITY

Liquid Thermal Diffusion

The recently developed method of liquid thermal diffusion has indicated promise as a means of separating fatty acids (Jones and Foreman, 1952; Seelbach and Quackenbush, 1958). Muckerheide (1954) describes the apparatus used for liquid thermal diffusion as follows:

> The apparatus consists essentially of two concentric tubes of suitable length having a one millimeter annular space. This space is filled with fatty acids, the outer tube is heated either by a steam or electrical jacket, and the inner tube is cooled with water. These conditions result in a temperature gradient across the liquid ranging from 40° C. to 80° C. This temperature gradient induces the diffusion of certain molecules from the hot wall to the cold wall of the tubes. Convective flow due to density differences produced by the temperature differential causes the diffused molecules to flow upward or downward and thus effect a separation.

Factors that influence the degree of separation in this process are (1) uniformity of size of the annular space, (2) temperature differential, and (3) time required for diffusion. The method should adapt readily to a continuous system.

Results of Seelbach and Quackenbush (1958) show that fatty acids can be separated by thermal diffusion according to length of the carbon chain. Fatty acids with longer chain lengths tend to concentrate in the bottom fraction. When two commercial samples of oleic acid and a commercial mixture of oleic, linoleic, and linolenic acids were diffused for 48 hours, the results showed only a small change in the iodine values between top and bottom fractions. It is concluded, therefore, that unsaturation in the aliphatic chain does not provide much of a basis for the separation of fatty acids by thermal diffusion.

Certain effects, such as molecular associations and countercurrent convections, take place in the presently designed apparatus that may be minimized by future improvements to permit practical large-scale separations. One such improvement might be the use of a multistage diffusion system (Seelbach and Quackenbush, 1958).

Chromatography

Chromatography is generally considered a laboratory analytical tool for performing separations. The method usually involves a column packed with an adsorbent or partitioning agent such as an ion exchange resin which causes the separation of various compounds in the adsorbate. The degree of chromatographic separation is a function of such characteristics as particle size of adsorbent, flow rate of adsorbate through the column (contact time), and physical and chemical behavior of both adsorbent and adsorbate. The separations are also influenced by temperature and relative amounts of adsorbent and adsorbate.

An industrial separation of fatty acids by chromatography would involve huge quantities of packing material. Adsorbents become inactivated by surface coatings of tars, polymers, and other products of oxidation, thus requiring the removal of the packing materials from the chromatographic column or tower. This packing would require periodic regeneration and probably costly replenishments, thus prohibiting adaptation to truly continuous operation. An industrial process of this type has the disadvantage that organic solvents are necessary to elute fatty acids. Hence, an expensive solvent recovery system would necessarily have to be included.

Ion-exchange chromatography has some advantages over "neutral" adsorbents; for example, greater specificity toward fatty acids that may be mixed with neutral lipids. Resins are available that will work in organic solvents. Tars, oxidation products, etc., are usually best removed by backwashing the resin.

Electrophoresis

Electrophoresis involves the migration of ionic species in solution in an electrical field. Size, shape, tendency to dissociate, and amphoteric behavior are characteristics that govern the ability of an ion to migrate

in solution. Similarly, such environmental factors as ionic strength, dielectric properties, pH, temperature, etc. influence the process (Block, Durrum, and Zweig, 1955). Likewise, the current intensity and its distribution will influence the process. Also, there are insufficient differences among fatty acids, due to various chain lengths and degrees of unsaturation (thereby altering the shape of ions), to permit successful separation of the soaps of fatty acids by electrophoresis. No reports were found that this process had been applied to long-chain aliphatic acids from natural sources. Probably a concentrate of shorter carbon chain acids (for example, C_{16}-C_{18}) could be separated from a concentrate of the longer chain length acids (C_{20}-C_{22}). This process, however, would be considerably less efficient for fish oil fatty acids than would other methods of separation. Finally, electrophoresis would have limited application. For instance, it would be ineffective if applied to esters of fatty acids.

METHODS HAVING IMMEDIATE INDUSTRIAL UTILITY

Fractional Distillation

The ability to separate fatty acids by fractional distillation is limited by the differences in vapor pressures of the fatty acids. The addition of two carbon atoms results in a substantial increase in the boiling points of fatty acids, making it possible to separate them by fractional distillation (Potts, 1956). Fractional distillation, however, is most effective when used to separate fatty acids of 4- to 6-carbon-atom difference in chain length (Muckerheide, 1954). Separation of saturated from unsaturated fatty acids of equal carbon chain length is not possible by this method.

The efficiency of separation is controlled by the number of plates in a distillation column and the reflux ratio. Theoretically, fatty acids having different boiling points can be completely separated. Efficiency of separation, however, must be compromised because economic factors, practical height of column, number of plates, and a reasonable reflux ratio must be taken into consideration in an industrial installation (Muckerheide, 1954).

Distillations of fatty acids are complicated by the requirement for high temperatures. Fatty acids decompose, for example, when subjected to temperatures above 225° C. for long periods of time. Unsaturated fatty acids, such as linoleic and linolenic acids, condense at high temperatures to form dimers, followed by additional complex polymerization reactions. This condensation results in high yields of "pitch." Because of this thermal instability, it is necessary to design the distillation equipment for maximum operating temperatures of about 250° C. (Potts, 1956).

Distillation techniques are varied. Recent improvements in the operation now permit most stills to function at reduced pressures between 5 and 50 mm. Hg, whereby lower temperatures can be used for distillation. This lowering of temperature is desirable for thermally unstable fatty acids from fish oils. In a typical industrial fractional distillation, fatty acids of a given carbon chain length are normally produced with a purity of 85 to 90 percent. Plant capacities may range from 3,000 to 4,000 pounds of feed stocks per hour. These figures are based on feed stocks of materials such as fatty acids from cottonseed oil, palm oil, and coconut oil (Muckerheide, 1954). Undoubtedly, fish oil fatty acids could be similarly processed; however, difficulty might be expected in the distillation of the longest carbon chain length acids.

Research at the Bureau of Commercial Fisheries Technological Laboratory in Seattle has shown that fish oil fatty acids up to C_{20} chain lengths can be fractionally distilled at 0.1 mm. Hg pressure without difficulty. However, deleterious effects from decomposition, isomerization, and polymerization have been experienced during distillations of polyunsaturated fatty acids above C_{20} chain lengths. To overcome the thermal hazards of distillation of fish oil fatty acids, we investigated the technique of multiple or "cyclic" molecular distillation. The improved design of stills for this technique enables fatty acids to distill at low pressures (for example, 1-10 microns Hg) with a minimum contact time with heated distillation surfaces. Considerably less time and effort is expended, at least in the laboratory, for the performance of this type of separation than for other separation methods.

The application of "cyclic" molecular distillation has been investigated in the past with menhaden triglycerides and used commercially to obtain vitamin concentrates from fish liver oils (Embree, 1941). Gray and Cawley (1940) studied molecular distillation separations of a mixture of lauric, myristic, palmitic, and stearic acids, and a mixture of stearic, oleic, linoleic, 9,11-linoleic, and α-eleostearic acids. It was noted that poor separations could be expected by a single molecular distillation of mixtures of these acids. Since fish oil fatty acids have a range of C_{14} to C_{22} in chain lengths, it would be expected that some degree of fractionation could be obtained.

Figure 1 shows the distillation apparatus now used for the purification of fish oil fatty acids at the Bureau of Commercial Fisheries Technological Laboratory in Seattle. The data in table 1 for menhaden oil fatty acids are representative of separations made by multiple molecular distillation. Fractionation results from repeated recycling of undistilled fractions accompanied by corresponding cuts of distillate. Iodine value analyses show that fractionation can be achieved on the basis of degree of unsaturation. This separation is reasonable

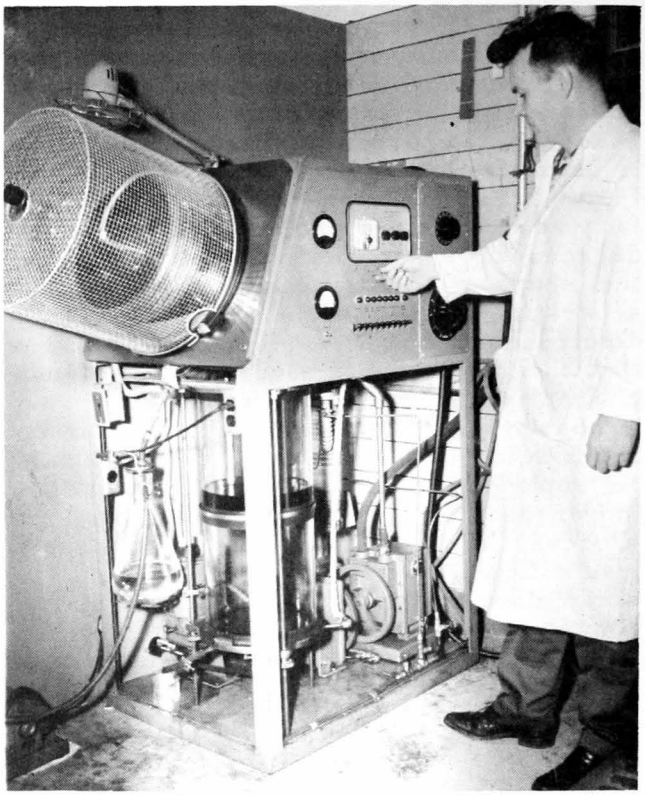

Figure 1.--The equipment shown here is used for molecular distillations of 5-gallon batches of fish oil fatty acids. The dark-colored raw material can be freed of most odor and color components to produce nearly "water-white" fatty acids.

TABLE 1.--Menhaden oil fatty acids fractionated by multiple molecular distillation[1]

Fraction	Weight-percent yield	Hanus I. V.	Ethylenic bonds per mole
	Percent	*Value*	*Number*
Mixture	100	[2] 194	2.1
1	24.9	83	0.8
2	19.8	127	1.4
3	30.1	216	2.5
4	21.6	347	4.4
Residue	3.6	---	---

[1] Distillation pressure range, 3-4 microns Hg; temperature range, 90°-122° C.

[2] Theoretical iodine value based on 185 for the menhaden triglycerides.

considering the large amounts of polyunsaturates that compose the C_{20}- and C_{22}-chain-length groups (Farquhar, Insul, Rosen, Stoffel, and Ahrens, 1959). Ultraviolet absorption spectrophotometry indicates only 0.5 percent conjugated dienes and only a trace of conjugated trienes in whole molecularly distilled fatty acids from menhaden oil.

Fractional Crystallization

If components of a mixture have volatility ratios that are too small or form azeotropes and if the boiling point at reasonable pressures is so high that thermal decomposition occurs, then fractional distillation is sometimes impractical. When this situation occurs, generally crystallization or extraction is used for separation.

Solvent methods in which selective action is involved and in which fatty acids remain in a liquid state have rather poor separation efficiency because of the mutual solubility characteristics of the fatty acids. Fractional crystallization, in which one component acid of a fatty-acid mixture is crystallized, to a large extent overcomes the difficulties of mutual solubility. Saturated fatty acids are separated because of differences in solubility that are due to differences in carbon chain length. Also, unsaturated fatty acids of the same carbon chain length can be separated because of differences in solubility that are caused by various degrees of unsaturation. Probably the greatest efficiency of fractional crystallization of fatty acids is found in the separation of saturated from unsaturated fatty acids (Muckerheide, 1954). We know from solubility properties that fatty acids can be separated into fractions with different degrees of unsaturation by varying (1) the concentration of fatty acids, (2) the temperature of crystallization, and (3) the type of organic solvent. The results reported by Kolb and Brown (1955) and Privett, Breault, Covell, Norcia, and Lundberg (1958) are typical of fundamental solubility data that are necessary for the selection of organic solvents.

The "Emersol process," in which fatty acids are fractionally crystallized from an organic solvent (90-percent methanol) at low temperatures, is typical of a continuous industrial process. Results of the Emersol process on fatty acids from sardine oil (iodine value 160.0) show a separation into two fractions of fatty acids having iodine values of 30.0 and 201.5, respectively (Kistler, Muckerheide, and Myers, 1946).

At the Technological Laboratory in Seattle, methyl esters of fatty acids from tuna oil have been fractionated by low temperature crystallization from a methanolic solution. By controlling the temperature of crystallization and the amount of methanol, we obtained fractions of fatty acids with the following iodine values: 40, 124, 199, and 278. In this case, the original mixture of fatty acids had an iodine value of 168.

The Edeleanu process, which utilizes liquid sulfur dioxide as a solvent, has been used industrially for the refinement of petroleum. Schlenk and Ener (1959) report the use of liquid sulfur dioxide for the effective fractional crystallization of both saturated and unsaturated fatty acids. Fatty acids are considerably less soluble in sulfur dioxide than in common organic solvents, although their solubilities in nitromethane, nitrobenzene, furfural, and similar highly polar solvents may be less than in sulfur dioxide.

Muckerheide (1954) reports that in a normal crystallization operation, commercial stearic acid of 5.0 to 6.0 iodine value and oleic acid of 2° to 5° C. titre are obtained using 90-percent methanol as the solvent. Process temperatures range from 85° to about 14° F. Industrial plant capacities range from 2,000 to 5,000 pounds per hour.

Liquid-Liquid Extraction

Presumably any mixture can be separated by extraction if its components differ from one another in molecular weight or molecular type. For this purpose, it is necessary to find a solvent in which the mixture is partially miscible and in which one component of the mixture (or one chemical type) is more soluble than the other (Pratt, 1953). One choice of solvent system suitable for fish oil fatty acids is isooctane, which is a relatively nonpolar hydrocarbon solvent, and furfural, which is an active polar solvent immiscible in the hydrocarbon solvent (Freeman, 1942). Other systems may include methanol, ethanol, or an aqueous alcohol as the polar solvent and a hydrocarbon, such as petroleum ether, as the nonpolar solvent.

As stated earlier, separations of fatty acids that involve selective action of solvents have rather poor separation efficiency, owing to mutual solubility characteristics. In spite of this poor efficiency, improvements in industrial designs have made liquid-liquid extractions quite effective for the separation of fatty acid mixtures. A recent major improvement in design is the introduction of countercurrent flow systems for solvents. The countercurrent extractors overcome some of the disadvantages of conventional extractors; for example, a shorter extraction tower can be used to achieve the equivalent of a given number of theoretical fractionation stages.

Another major improvement in design is the centrifugal contactor. Gravitational forces, generated by centrifugal action of a rotating drum, cause rapid and effective separation of liquid phases within the apparatus. Solvents are directed in a countercurrent manner. The design provides a large number of extraction stages and high capacity in a very small apparatus. Pratt (1956) reports that laboratory tests conducted on stocks from several refineries showed that the centrifugal contactor was a more efficient extractor than most of the towers in operation and equivalent to the best towers.

Various types of liquid-liquid extraction equipment are discussed by Von Berg and Wiegandt (1952). Besides the centrifugal contactor, such equipment is described as (1) the packed columns, (2) the baffle columns, (3) the York-Scheibel column, (4) the pulsating column, and (5) the Luwesta extractor. The latest types of extractor designs are also reported by Treybal (1958). Latest improvements in the well-known types of extraction equipment are discussed, and numerous references are given. Extraction of cod liver oil and related fatty acids is included in a list of described systems.

Fractionation of Inclusion Compounds

During the past decade, numerous reports have appeared concerning urea-inclusion compounds of fatty acids. Virtually all naturally occurring fatty acids will form adducts with urea (Schlenk, 1954). Extractive crystallization with urea causes simple and efficient separation of fatty acids on the basis of their degree of unsaturation. The efficiency of separation compares favorably with processes that use fractional crystallization or selective solvent extraction, and perhaps excells them in certain separations, for example, oleic acid separated from other fatty polyenoic acids (Newey, Shokal, Mueller, Bradley, and Fetterly, 1950).

The work of Abu-Nasr, Potts, and Holman (1954) typifies the isolation of concentrates of highly unsaturated fatty acids from fish oils with urea. Fatty acids from oils of cod liver, shark liver, pollack liver, menhaden, herring, and salmon were produced and separated. Separations were carried out at room temperature and at 5° C. The concentrates of fatty acids had iodine values as high as 356.

The use of urea-inclusion compounds for the fractionation of fatty acids from fish oils was also reported by Domart, Miyauchi, and Sumerwell (1955). A systematic study was made of the fractionation of fatty acids from herring, menhaden, tuna, seal, salmon egg, and salmon-head-and-viscera oils with urea at temperatures ranging from +25° C. to -30° C. Menhaden oil fatty acids were separated into fractions having iodine values ranging from 12.8 to 341.6. The degree of separation of saturated from unsaturated fatty acids and their yields were dependent on the temperature of the solvent system and on the ratio of urea to fatty acids. Generally, adduct-forming fractions contain more saturated fatty acids (lower degrees of unsaturation) than nonadduct-forming fractions from the same system. The data in table 2, compiled by Domart, Miyauchi, and Sumerwell (1955), show the separation effects of various ratios of urea to fatty acids under isothermal conditions. A 14-to-1 ratio, for example, promotes the separation of about 40 percent of mixed fatty acids having an iodine value greater than 300. High ratios of urea to fatty acids produce the greater degrees of unsaturation in the nonadduct-forming fractions. In figure 2 is shown a laboratory operation for the separation of fatty acids by urea-inclusion compound fractionation.

The process of fractionation of urea adducts is readily adaptable to industrial operations. A recent advance in this direction concerns the use of expanded urea--a modified crystalline form--that enhances its fractionating efficiency (Rosenstein and Gorin, 1957). From 1,000 pounds of a

TABLE 2.--The fractionation of menhaden oil fatty acids[1] with different mole ratios of urea in methanol at 1° C.[2]

Mole ratio of urea to fatty acids	Yield of fatty acids from complexes	Hanus I. V. of fatty acids from precipitate	Yield of fatty acids from filtrate	Hanus I. V. of fatty acids from filtrate	Unrecovered fatty acids
	Percent	*Value*	*Percent*	*Value*	*Percent*
4.6:1	11.6	12.8	80.8	192.7	7.6
9.1:1	29.8	22.1	61.6	243.4	8.6
13.8:1	49.4	48.1	41.6	308.9	9.0
18.4:1	61.0	54.5	36.4	330.7	2.6
23.0:1	63.0	72.7	34.2	341.6	2.8

[1] The Hanus iodine value (I. V.) for the menhaden oil fatty acids from which these fatty acids were prepared was 159.5.

[2] All values represent averages obtained by treating triplicate 50.0 g. samples of fatty acids. Source: Domart, Miyauchi, and Sumerwell (1955).

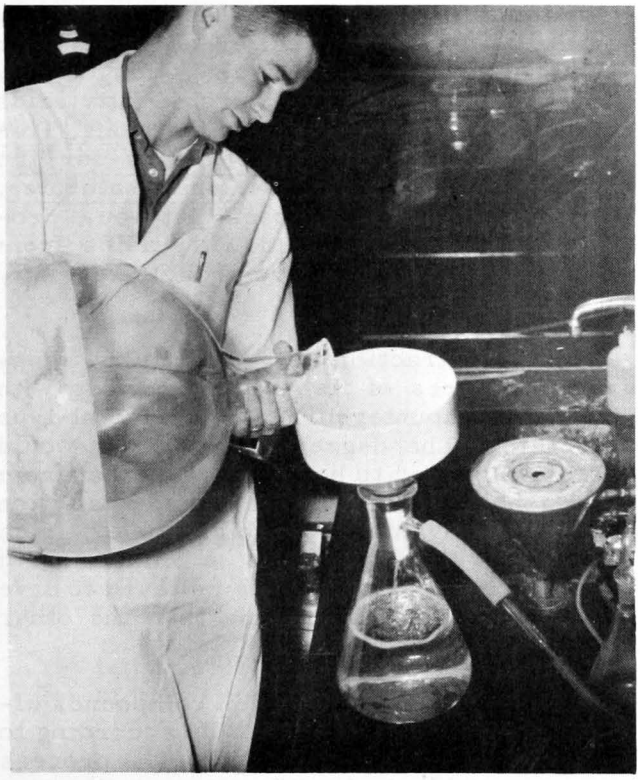

Figure 2.--Separation of urea-inclusion compounds is carried out in a large vessel. Here is shown the rapid suction filtration of solution to separate filtrate or non-urea adduct-forming fatty acids from fatty acids that have been complexed with urea.

particular mixture of cottonseed oil fatty acids, a residual fatty acid fraction was obtained that weighed 485 pounds. This fraction had an iodine value of 172, which indicated that it consisted of substantially linoleic acid with small amounts of oleic and linolenic acids. This process is unique in that the urea-adduct formation and fractionation step takes place at near-room temperatures. Temperatures of about 110° C. are needed, however, for the decomposition of the inclusion compounds and for the recovery of solvents, urea, and fatty acids.

Sumerwell (1957) reported the separation of fatty acids with the use of the combined methods of urea-inclusion compound fractionation and countercurrent liquid extraction. The method was successfully applied to a synthetic mixture of palmitic, stearic, and oleic acids, and to salmon egg oil fatty acids in batch processes.

Figure 3 shows the kind of fatty acid separation obtained in an 18-stage countercurrent distribution of salmon egg acids (Sumerwell, 1957). It might be expected that the peak fractions contain distinct features regarding chain length and unsaturation. The separations were carried out at -30° C. It would be interesting to observe

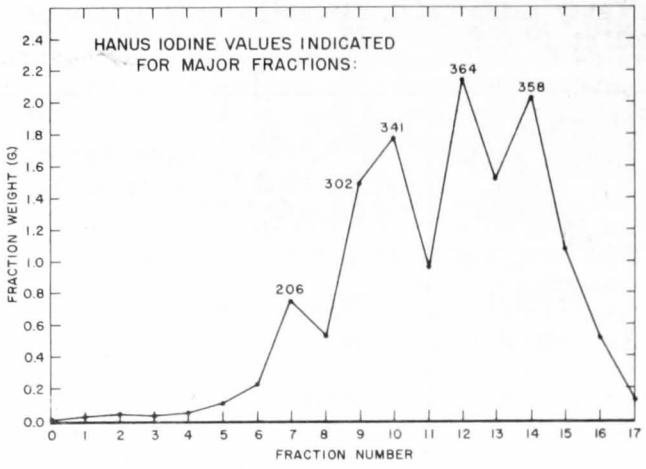

Figure 3.--Methanol-urea countercurrent distribution of fatty acids from salmon egg oil. Source: Sumerwell, 1957.

the kind of separation that one could get by performing this at room temperature and with higher ratios of urea to fatty acids than were reported. If this method is to be adapted to industrial production, a continuous rather than a batch process would be desirable.

SUMMARY AND CONCLUSIONS

Pertinent information necessary to understand possible methods to fractionate fatty acids was discussed. Numerous factors must be considered before the most suitable means to produce commercial quantities of fractionated fish oil fatty acids can be determined.

At this time, liquid thermal diffusion, chromatography, and electrophoresis are of little value for industrial fractionation and production of fatty acids from fish oils.

Fractional distillations have the advantage that they permit separations of fatty acids according to differences in chain lengths. Since the long-chain, high-molecular-weight fractions contain the highest degrees of unsaturation, both long-chain acids and highly unsaturated acids can be produced in the same fraction. The main disadvantage of distillations is the requirement for high temperatures, which can result in decomposition, isomerization, and polymerization of the highly unsaturated acids.

Research at the Technological Laboratory in Seattle has shown that fractionation under the conditions of multiple molecular distillation is a very effective method for the total distillation of fish oil fatty acids. Multiple molecular distillation, in contrast to ordinary fractional distillation, does not permit a clear-cut separation on the basis of chain length. Molecular distillation has the great advantage that separations are performed at the lowest possible temperatures for distillation, thus minimizing the thermal hazard. Analyses show almost no change due to thermal isomerization of unsaturated fatty acids that were purified by this method. With a minimum of time and effort, this method can produce high yields of unsaturated fatty acids with nearly as much unsaturation as produced by other methods of separation. The author favors this method over all others from the standpoint of simplicity, ease of handling, speed, and low cost in over all operation.

Fractional crystallization has the advantage that separations are performed at low temperatures. Thus there are no deleterious effects on thermally unstable polyunsaturated acids. This method separates fatty acids according to differences in their solubilities. The shorter chain-length fatty acids and the highly unsaturated fatty acids tend to collect in the same fractions. This method may be the best means for the separation of saturates from unsaturates. Conditions could be chosen that would produce highly unsaturated fatty acids from fish oils nearly free from saturated fatty acids.

Liquid extraction may effectively separate mixtures of fish oil fatty acids with the use of a countercurrent, centrifugal-type extractor. The degree of separation would not be expected to be as great as that from fractional crystallization. Liquid extraction has the advantage of high yields from equipment that requires a minimum of space. Liquid extraction is believed to have less operational problems than the other processes.

Fractionation of inclusion compounds effectively separates fatty acids according to their degrees of unsaturation. The process is comparable to fractional crystallization and could be adapted to continuous-flow operation. Inclusion-compound formation is not influenced by mutual solubility characteristics to the degree that is found in the

methods of fractional crystallization and liquid-liquid extraction. Fractionation of urea-inclusion compounds is more effective for the separation of saturated from unsaturated fatty acids than is ordinary fractional crystallization. The urea method, however, is less economical than the latter, at least on a laboratory scale.

Urea-inclusion compound fractionation is selected as the process that is most versatile. The reason for this is that the fractionation characteristics of the process can be altered simply by changing the amounts of either solvent or urea. In addition, the process can be performed at ordinary room temperatures. Similar alteration in the fractionation characteristics of ordinary fractional crystallization would require changes in the operating temperatures and possibly the choice of solvents. The problem of slow filtration velocities often associated with ordinary fractional crystallizations of fatty acids is not necessarily encountered with inclusion-compound fractionation.

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STORAGE OF FISH IN REFRIGERATED SEA WATER 1 - QUALITY CHANGES IN OCEAN PERCH AS DETERMINED BY ORGANOLEPTIC AND CHEMICAL ANALYSES

by

Edward H. Cohen and John A. Peters

ABSTRACT

Whole ocean perch stored in ice or refrigerated sea water were tested organoleptically and objectively.

After the tests had continued for several days, sensory evaluation of raw and cooked fish indicated a marked preference for fish stored in refrigerated sea water.

The correlation between subjective and objective tests for quality of ocean perch stored in refrigerated sea water was poor. The correlations for ocean perch stored in ice, however, were sufficiently high to warrant further studies of these tests.

The general conclusion from this investigation was that refrigerated sea water shows promise as a means for increasing the chilled storage life of ocean perch and therefore merits consideration by the industry.

INTRODUCTION

Need for the Research

Fishery technologists are continuously searching for newer and better ways of preserving the fresh qualities of fish. Extending the high-quality shelf life of fish, for even a few days, would be of immense economic benefit to the fishing industry.

Refrigerated sea water at 30° F. has found application on the West Coast in the storage of halibut and salmon on the vessel and ashore and on the Gulf Coast in the storage of menhaden and other industrial fish (Pacific Fishermen's News Section, 1957; Fishing Gazette, 1960). Little work has been done, however, toward applying refrigerated sea water to the storage of ground fish common to New England, such as ocean perch *(Sebastes marinus)*, or in comparing the keeping quality of fish stored in refrigerated sea water with fish kept in ice. This technique may result in considerable improvement in the quality of fish, both at sea and ashore, owing to the lower storage temperature used and the elimination of bruising of the fish by ice.

In a determination of the value of any new storage technique, the quality of the product must be assessed carefully. Since organoleptic analyses are subjective, reliable physical and chemical tests are needed to measure loss of quality objectively. Previous investigators in the field of objective tests for quality of fish have found the tests for volatile base nitrogen (Stansby, Harrison, Dassow, and Sater, 1944),

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trimethylamine (Dyer, 1959), and refractive index of the eye fluid (Proctor, Nickerson, Fazzina, Ronsivalli, Smith, and Stern, 1959) most applicable. Further study of these tests is required, however, to correlate corresponding results with organoleptic analysis.

Objectives of the Research

The objectives of the present study therefore were (1) to determine by organoleptic analysis whether storage of ocean perch in 30° F. refrigerated sea water results in an increase in the shelf life of ocean perch compared to its storage in ice and (2) to determine if tests for volatile base nitrogen, trimethylamine, or refractive index of the eye fluid can be used to measure changes in product quality objectively.

EXPERIMENTAL WORK

Conditions of Storage

Ocean perch, caught by a small Gloucester dragger and well iced, were from 36 to 48 hours out of the water when received at the laboratory. These fish were immediately stored in refrigerated sea water at 30° F.; and concurrently, fish from the same catch were stored in flake ice.

REFRIGERATED SEA WATER TANK.--The tank used in these tests (fig. 1) contained a stainless steel liner, of 18 gauge, measuring 30 inches long, 30 inches wide, and 30 inches deep, with cooling coils soldered to its outside walls. The walls and bottom of the tank were insulated with 4 inches of foamed hard rubber, which, in turn, was covered with 3/8-inch-thick marine plywood. Refrigeration was provided by a 1-1/2-horsepower Freon-12 compressor, and the temperature of the sea water was controlled to within ±0.5° F. by a thermoswitch that activated a solenoid valve to regulate the flow of refrigerant to the cooling coils. The detecting element of the thermoswitch was immersed in the sea water. A back-pressure regulator maintained the suction temperature at about 10° F. below the refrigerated sea-water temperature of 30° F.

Initially, circulation of the sea water in the tank of fish was attempted using a 50-gallon-per-minute centrifugal pump that took the water from a screened inlet in the center of the tank and pumped it through a spreader located along the sides at the bottom of the tank. During a preliminary trial of the unit, however, fish tended to freeze against the walls. After several modifications of the circulating system, the "jacketed" type of circulation shown in figure 2 was constructed and found to be satisfactory. In this system, the water was pumped through a space about 1-inch wide between the tank walls and the jacket to a gate in the back of the tank. The water then flowed around the fish to another gate at the front of the tank behind which was the intake of the pump. With this modification, none of

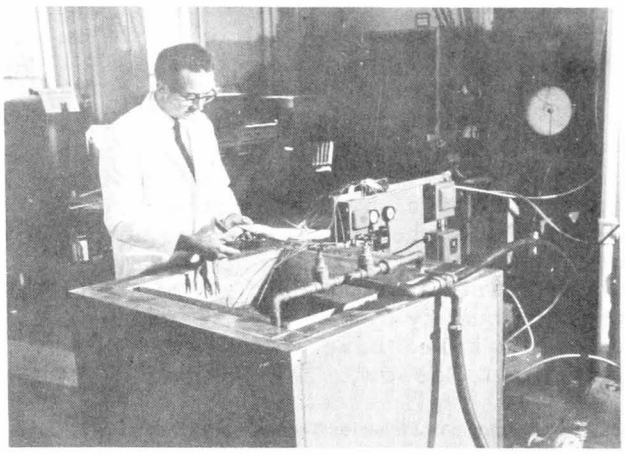

Figure 1.--Refrigerated-sea-water tank used in this experiment.

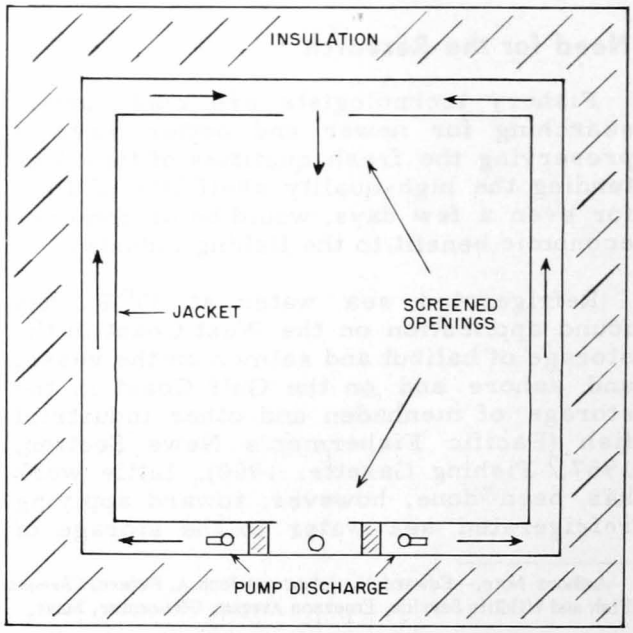

Figure 2.--Diagram of refrigerated sea-water tank.

the fish froze to the walls, and the temperature in the tank was uniform.

About 400 pounds of round ocean perch was placed in the tank, and sea water was added to give a density of 45 pounds of fish per cubic foot. This density was comparable to that of fish iced in the usual manner and yet provided for adequate circulation of the sea water. Approximately 200 pounds of water was added to the tank. Of this quantity, 150 pounds filled the voids between the fish. The remaining 50 pounds filled the jacketed section, the pump, and the piping. With this system, we had no difficulty in keeping the temperature of sea water at $30^{\circ} \pm 0.5^{\circ}$ F.

ICED STORAGE.--A large wooden box with removable penboards, to facilitate re-icing of the fish and removal of the samples, was used for the iced storage. About 200 pounds of round fish was carefully iced with 300 pounds of fresh-water flake ice and was re-iced as necessary.

Organoleptic Tests

During the test period, samples were examined organoleptically in both the raw and cooked states.

EXAMINATION OF THE RAW AND COOKED FISH.--The raw ocean perch were evaluated for quality in terms of appearance, odor, and texture. A minimum of six fish were removed at periodic intervals from storage in refrigerated sea water and in ice. The fish were graded by two or three people experienced in this type of examination.

After the fish had been examined, they were filleted, packaged in 1-pound cartons, overwrapped, plate-frozen, and stored at -20° F. until ready for organoleptic rating. In preparation for examination by the taste panel, the filleted fish were removed from storage, cut into pieces, and steamed in covered containers for 30 minutes. The fish were then served to a panel composed of eight members of the laboratory staff, who rated the fish for appearance, odor, flavor, and texture.

When the fish were first received at the laboratory, sufficient samples were prepared and held in frozen storage at -20° F. for use as controls in the taste tests. At each test, four portions of cooked fish were served to each panel member. Two of these portions were unidentified samples from fish stored in refrigerated sea water or in ice. The remaining two samples were controls, one identified as the "known control," and the other, not identified, was referred to as the "blind control." It was used to check the reliability of the panel.

RESULTS OF ORGANOLEPTIC TESTS.--The results of the organoleptic tests on raw and cooked ocean perch are shown in table 1. The scores for appearance were arrived at by examining six fish from each medium and rating the appearance of the eyes, gills, skin, and fillets cut from the fish. Fish rated below fair were considered unacceptable. The appearance of the iced fish was judged acceptable until the 5th day of storage, whereas appearance of the fish stored in refrigerated sea water was judged acceptable until the 14th day of storage.

The odor scores of the raw ocean perch, which represented a combined evaluation of the odor of the gills, abdominal cavity, and fillets, paralleled closely the scores found for appearance. When odor was used as a criterion, the iced fish were acceptable until the 5th day of storage, whereas the fish stored in refrigerated sea water were acceptable until the 12th day. Off odors appeared first in the gut cavity, then in the gills, and finally in the fillets.

The final score of the evaluation of the cooked ocean perch by the taste panel was the average of the ratings given for appearance, odor, flavor, and texture. Samples rated below the midpoint of fair to poor were considered unacceptable. The iced ocean perch were acceptable until the 10th day, whereas those stored in refrigerated sea water were acceptable until the 14th day.

Physical and Chemical Tests

The basic method of determining the quality of fish is by looking at them, smelling them, and tasting them. Although these methods are basic, they are time-consuming, expensive, and imprecise. For those reasons, objective physical and chemical tests are needed. To be of value, these objective tests, of course, must correlate with the subjective ones. The problem therefore is not only to devise the tests but to determine their degree of correlation. Such determinations are expensive.

TABLE 1.--Results of examination of ocean perch stored in refrigerated sea water and in ice

Storage time	Quality rating of raw fish[1]		Quality rating of cooked fish[2]	
	Refrigerated sea water	Ice	Refrigerated sea water	Ice
Days				
0	Very good	Very good	Very good	Good
3	Very good	Very good	Good	Very good
5	Good	Fair-poor	Good	Good
7	Fair	Poor[3]	Good	Fair
10	Fair	Poor	Fair	Poor[3]
12	Fair	Poor	Fair	Poor
14	Poor[3]	Poor	Fair	Very poor
17	Poor	Very poor	Poor[3]	(4)
19	Very poor	Very poor	Very poor	---

[1] Six fish from each storage medium were rated on a scale of very good, good, fair, poor, and very poor. These results represent an average rating based on appearance, odor, and texture.

[2] These results represent an average rating based on the appearance, odor, flavor, and texture of the cooked samples which were rated on a scale of excellent, very good, good, fair, borderline, slightly poor, poor, very poor, and inedible.

[3] Unacceptable for marketing.

[4] The scoring of the cooked fish stored in ice was discontinued because the fish were inedible.

Accordingly, whenever opportunity offers, we run objective tests concurrently with the subjective ones in order to reduce the cost of experimentation. Thus in the present study, our main objective was to determine the value of refrigerated sea water relative to icing, but since this study required a subjective test, we took advantage of the fact in order to continue our study of physical and chemical methods.

The physical and chemical tests used consisted of measurement of (1) weight changes, (2) salt content, (3) refractive index of eye fluid, (4) volatile base nitrogen, and (5) trimethylamine. The first two tests, though they do not indicate spoilage changes, do provide information necessary to assess the overall quality of the product.

WEIGHT CHANGES.--Weight losses and gains were determined on 10 tagged fish that were weighed at the beginning and the end of the storage tests both in refrigerated sea water and in ice.

The ocean perch samples held in refrigerated sea water showed an average increase in weight of 10.9 percent during the 19 days of storage, whereas the iced samples showed a gain of 0.1 percent in weight during the same storage period.

SALT CONTENT.--Determinations of the salt content of refrigerated-sea-water and ice-stored samples were made by the Volhard method (Association of Official Agricultural Chemists, 1960) using ferric ammonium citrate as the indicator.

The uptake of salt in samples stored in refrigerated sea water and the leaching of salt from the samples stored in ice are shown in figure 3. There was a sharp increase in salt in the samples stored in refrigerated sea water during the first 3 days, then a steady rise to a maximum around the 17th day. The iced samples showed a rapid loss of salt during the first 5 days and then a very slow loss for the remainder of the test.

REFRACTIVE INDEX.--The refractive index of the eye fluid was determined with a refractometer kept at a constant temperature of 25° F.

The refractive index showed no significant correlation with taste panel scores. These results are presented in table 2.

VOLATILE BASE NITROGEN.--Volatile base nitrogen determinations were made by Stansby's alcoholic extraction method (1944). The distillation was carried out with a 12-place electric macro-Kjeldahl unit (fig. 4). Methyl red-methylene blue indicator was substituted for the methyl red used in the original procedure.

Results of the volatile base nitrogen determinations on samples stored in refrigerated sea water exhibited no correlation (table 2) with taste panel scores; however, significant correlation was found between volatile base nitrogen content and taste panel scores in the ice-stored samples.

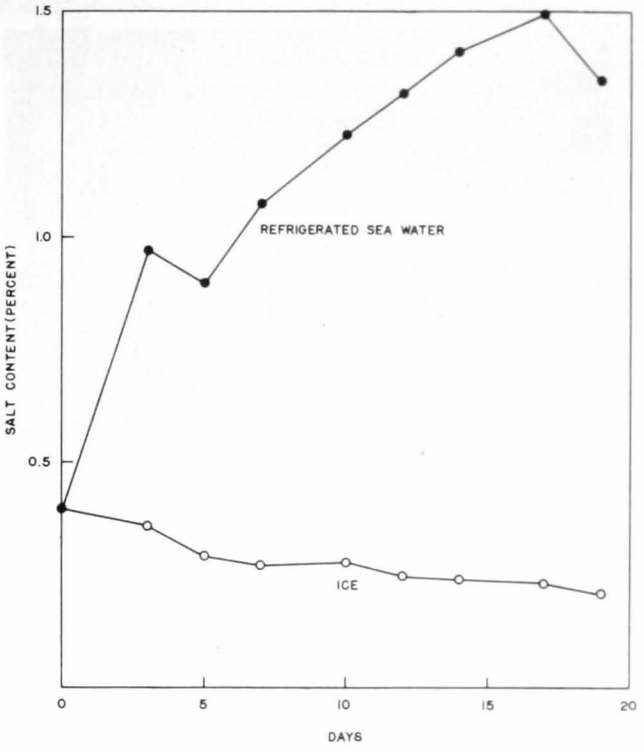

Figure 3.--Salt content of ocean perch (in percent) during storage in refrigerated sea water and in ice.

TRIMETHYLAMINE.--Trimethylamine determinations were carried out on fish samples according to Dyer's picric acid method (1959).

A significant correlation of trimethylamine content with taste panel scores was

TABLE 2.--Coefficient of correlation of physical and chemical tests on ocean perch with taste panel scores of the cooked fish

Storage medium	Coefficient of correlation			Value of coefficient of correlation at a level of significance of:[1]	
	Refractive index	Volatile base	Trimethyl-amine	5 percent	1 percent
Refrigerated sea water	.207	.216	.223	.468	.590
Ice	.417	.883	.892	.532	.661

[1] If the coefficient of correlation is as high or higher than the level of significance, the probability exists that there is a correlation between chemical indices and taste panel scores.

The coefficient of correlation was determined according to the simplified method described by Arkin and Colton (1959a).

The level of significance was taken from Arkin and Colton's (1959b) statistical tables.

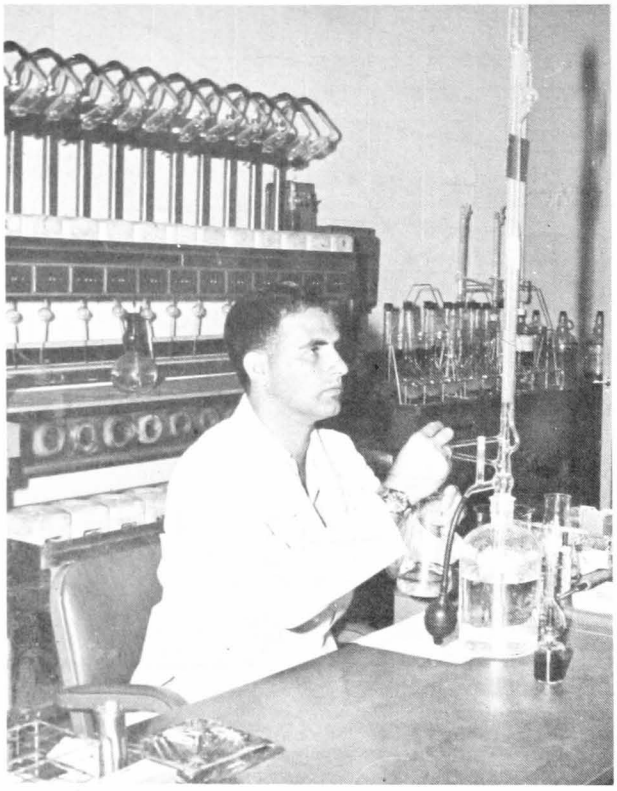

Figure 4.--Chemist conducting chemical analysis on fish samples.

found in the ice-stored samples (table 2), but no correlation was found in the samples stored in refrigerated sea water.

DISCUSSION

The fact that the coefficient of correlation between the subjective and objective tests was relatively good in the case of the fish held in ice and poor in the case of the fish held in refrigerated sea water raises a question as to why the difference. Exploring that question may give additional insight into the value of these tests for objectively determining the quality of fish.

Although it would have been desirable if the correlation had been good in all cases, the lack of complete correlation in no way invalidates the results of the organoleptic findings. They are basic, whereas the objective tests are still in the developmental state. In the present study, the organoleptic tests showed unequivocally that after several days of storage, the testers preferred the samples from the fish stored in refrigerated sea water over those from fish stored in ice.

CONCLUSIONS

1. Based on organoleptic scores of the raw and cooked fish, ocean perch stored in refrigerated sea water were of edible quality for about 7 days longer than were fish stored in ice. Also, the refrigerated sea water samples rated higher in quality at any one time during storage than the samples stored in ice.

2. Because complete correlation was not found between chemical tests and organoleptic results, it may be concluded that at present, these chemical tests are not satisfactory for measuring quality of ocean perch. There is, however, a need for further studies on objective tests to determine the quality of fish.

3. On the basis of these tests, we feel that the storage of ocean perch in refrigerated sea water at 30° F. resulted in definite improvement in quality over that found when these fish were stored in ice. Industry may therefore wish to consider the adoption of refrigerated sea water storage, since the improvement in maintaining the quality of the fish would result in a better product for the market and thus increase benefits for all concerned.

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NEW-TYPE MULTIPLE DEBREADER

by

Melvin E. Waters and D. J. Bond

ABSTRACT

A multiple debreader capable of debreading six samples of frozen raw breaded shrimp in less than 10 minutes (one operation) has been designed and built. This debreader, which cost about $445 to construct, consists of a stainless steel tank, a cylindrical wire basket with six compartments, and a 1/15-horsepower drive motor with reduction gears. For long wear, all parts in contact with water are made from corrosion-resistant materials. The debreader, as designed, permits reduction of the inspector's grading time.

INTRODUCTION

The U. S. Department of Interior's inspection service currently utilizes a debreader consisting of a cylindrical container approximately 9 quarts in capacity with a 1/20-horsepower motor and reduction gears turning the paddle vanes at 120 revolutions per minute (U. S. Department of the Interior, 1958). This debreader is used in conjunction with the grading of frozen raw breaded shrimp. The apparatus usually debreads a single sample in 10 minutes, although in some instances the remaining breading must be removed by hand. An experienced inspector requires 2 hours to complete the grading of six samples.

The development of a multiple debreader (fig. 1), capable of debreading six samples (one operation), would reduce grading time. With the objective in mind of developing such a debreader, we designed a device that would (1) reduce the time required to debread six samples of shrimp, (2) be as efficient as the one now used, and (3) be comparable in cost to the present one.

The purposes of this article are to report the construction of the debreader, describe its operation, and give data obtained in its use.

CONSTRUCTION

The apparatus occupies a space 15-1/2 inches by 15-1/2 inches by 31 inches. There are no special requirements other than that the debreader should be placed near a 110-volt outlet and a drain. The debreader is composed of three major parts: (1) tank, (2) drive, and (3) basket.

Tank

A 14- by 14- by 20-inch stainless steel tank (fig. 2) is constructed of 20-gauge steel and has a capacity of 58 quarts. The top edge is rolled inward 1 inch to prevent splashing when the basket rotates (fig. 2-A). A 1-1/4-inch drain is used at one end in the bottom of the tank to drain off the water and breading after the debreading operation (fig. 2-B). The tank is stabilized with four

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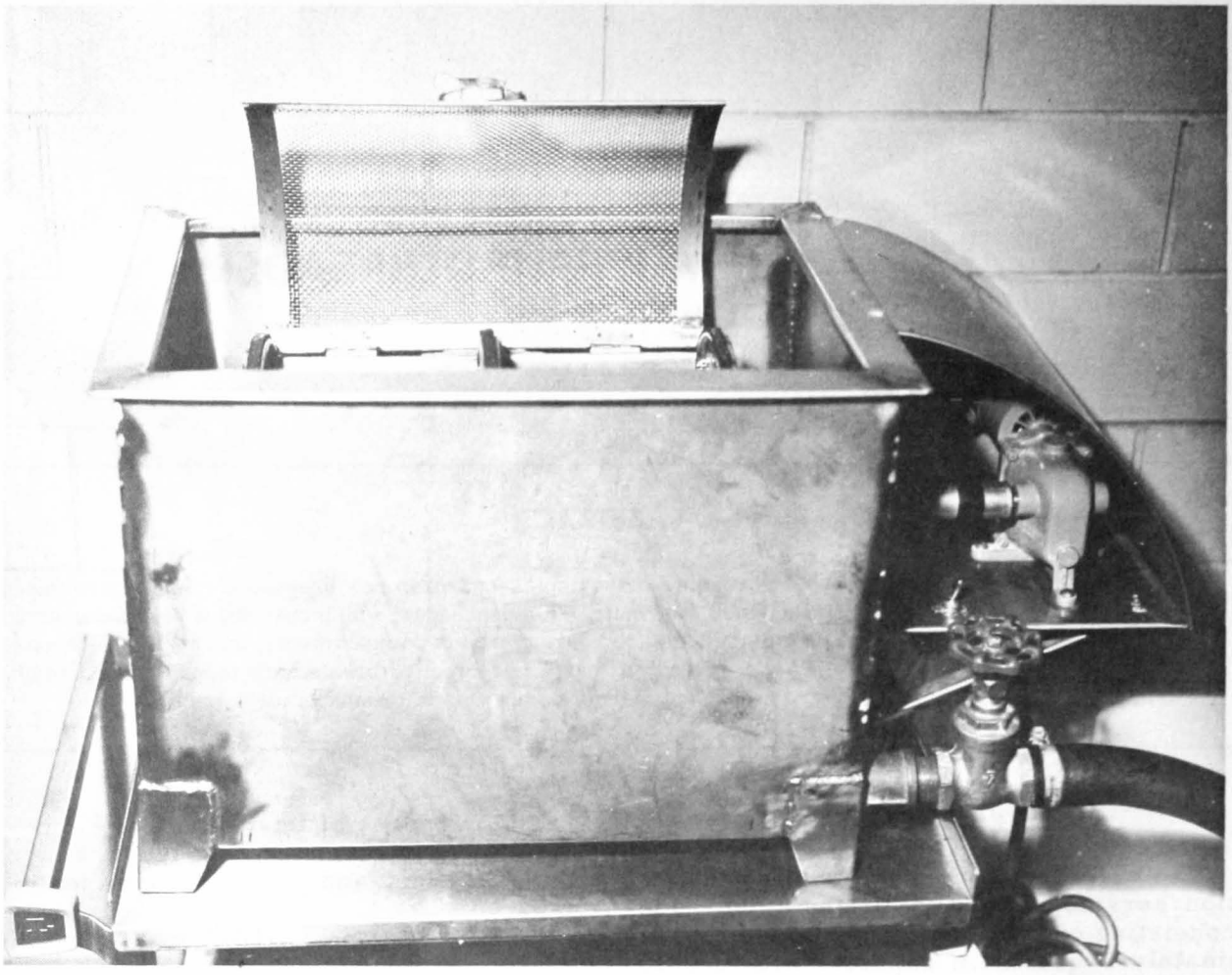

Figure 1.--Overall view of multiple debreader.

1-1/4-inch legs (fig. 2-C). A rack is mounted outside at one end of the tank to support the motor and reduction-gear box (fig. 2-D). Two supports (brass sleeves), one on each end, inside the tank, are used to support and facilitate rotation of the basket (fig. 2-E). A shield is placed over the drive to protect it against water splashing from the tank (fig. 2-F).

Drive

The drive assembly (fig. 2) consists of a 1/15-horsepower motor (110-volt, 60-cycle, alternating current) and a reduction-gear box. This assembly is mounted to the rack on the end of the tank (fig. 2-G). An aluminum-and-rubber coupling connects the shaft of the gear box to the jack shaft (fig. 2-H). A stuffing box containing the jack shaft permits turning, through the end of the tank, of the basket (fig. 2-I). The jack shaft is made from a 1/2-inch stainless steel rod with a male extrusion to fit the slot in the shaft of the basket. A toggle switch is mounted on the rack supporting the drive assembly (fig. 2-J).

Basket

The basket assembly (fig. 2) is a cylindrical wire basket, 14 inches in length and 10 inches in diameter, made from 20-gauge 1/8-inch mesh stainless steel screen (type 304). This assembly is divided into six compartments, each measuring approximately 7 inches in length and 5 inches in depth. The compartments are divided horizontally with the 1/8-inch mesh stainless steel screen. The central vertical partition and the ends are made from 20-gauge sheet stainless steel (fig. 2-K). Three doors open lengthwise of the basket, each door giving access to two compartments (fig. 2-L). The doors are hinged with two 1/2-inch butt hinges and are locked with

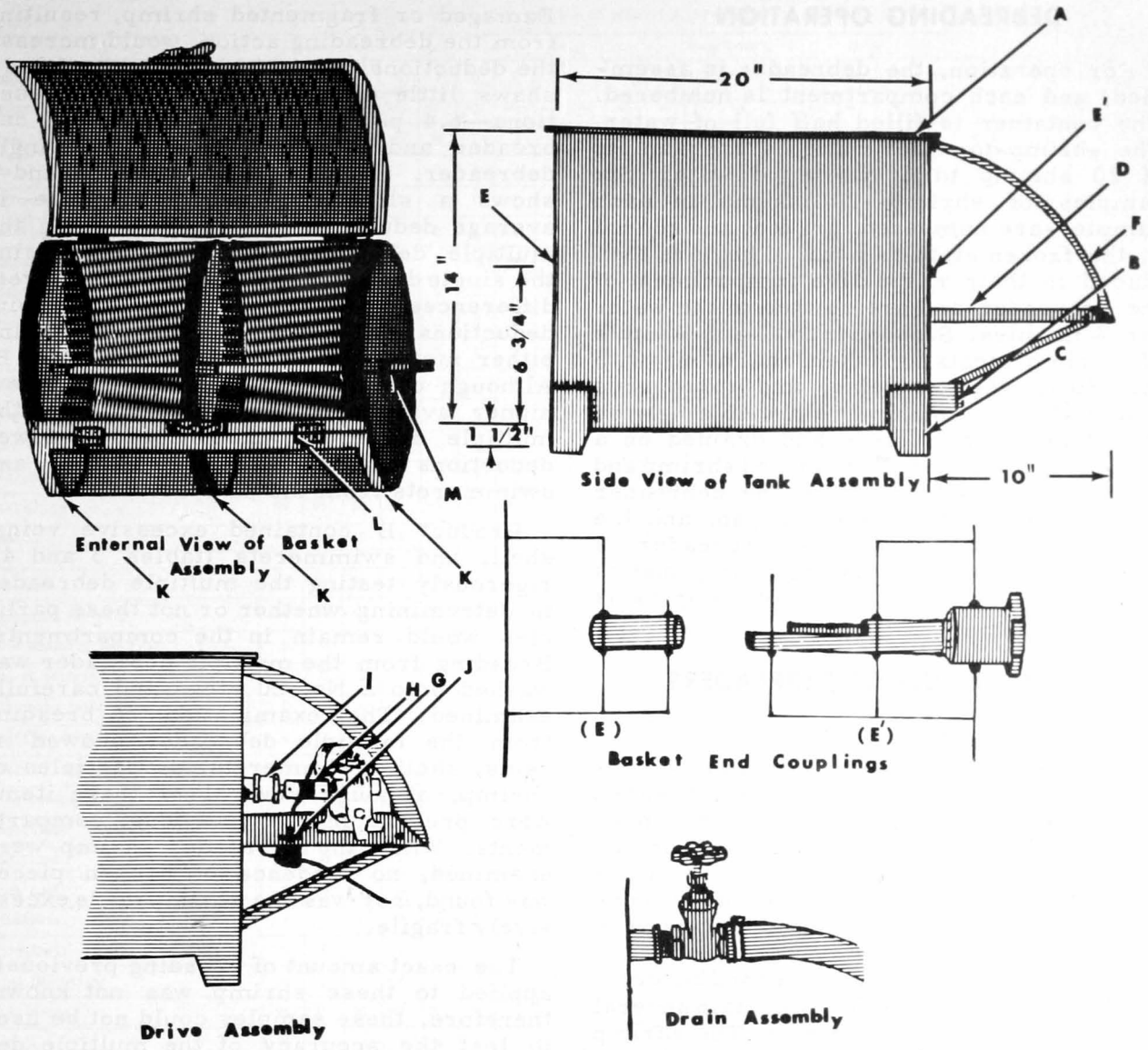

Figure 2.--Components of multiple debreader.

window-type latches. A 1/2-inch stainless steel shaft is welded lengthwise through the center of the basket to facilitate rotation on supports inside the tank as previously described (fig. 2-M).

This debreader is constructed of stainless steel (type 304) and other corrosion-resistant materials so that it will withstand many months of use. The debreader should be cleaned, however, after each day's operation to prevent possible corrosion and to comply with good sanitary practices. One-eighth-inch mesh stainless steel wire is used for the basket and compartments to permit free circulation of water around the shrimp and yet to retain, in the individual compartments, shells, veins, swimmerets, and extraneous material. The basket can be removed from the tank to allow thorough cleaning of the machine.

The rotation of the basket is set at 55 revolutions per minute to prevent possible damage to the shrimp and yet to permit the removal of the maximum amount of breading in the minimum amount of time. The three doors are spaced evenly around the basket to prevent eccentric motion caused by uneven balance of weight. This debreader operates smoothly with any number of samples up to six.

DEBREADING OPERATION

For operation, the debreader is assembled, and each compartment is numbered. The container is filled half full of water. The shrimp-to-water ratio is one sample of 20 shrimp to 5 quarts of water. Six samples of shrimp--20 shrimp in each sample--are numbered, graded, and scored in the frozen state as usual. They are then placed in their respective compartment of the debreader and are rotated in the water for 7 minutes. Subsequently, each sample of shrimp meats is taken out, along with tail fins, shells, veins, and extraneous material. The shrimp are placed singly on a 1/2-inch mesh sieve and drained on a slope for 2 minutes. The drained shrimp and other material taken from the debreader are placed on the weighing pan, and the grading is completed. The debreader is drained of water, breading, etc., and is washed before another lot of samples is started.

COMPARISON OF DEBREADERS

Efficiency

EXPERIMENT 1.--Two hundred 10-ounce packages of frozen raw breaded shrimp were used in this experiment to permit comparison of the efficiency of the multiple debreader method with the single debreader method. One hundred of the packages were designated as product A and were expected to have a low incidence of shell, veins, swimmerets, etc. The second hundred, product B, were expected to contain several of the above-mentioned items. The shrimp were of the butterfly style and *Penaeus duoarum* variety; processing methods, breading and batter material, were the same for both products. A comparison in recovery of extraneous material was made on both products by both debreaders to ascertain whether such material would be recovered equally by both machines. In addition, the somewhat more forceful agitation of samples in the multiple debreader make it necessary to determine if the shrimp meats themselves would be damaged during debreading.

Results are presented in tables 1 through 4. Ninety-three samples (15 to 18 shrimp each sample) of products A and B were graded with the single debreader. These samples were used to determine if a significant difference in deductions using the official scoring method would be caused by the use of another type of debreader. Damaged or fragmented shrimp, resulting from the debreading action, would increase the deductions. Comparison of tables 1 and 2 shows little difference in average deductions--6.4 points using the multiple debreader and 6.9 points using the single debreader. Comparison of tables 3 and 4 shows a slightly greater difference in average deductions--33.7 points using the multiple debreader and 40.1 points using the single debreader. Statistically, however, differences between the means of the point deductions are not significant when using either method for either product A or B. Although using the single debreader gave a higher average point deduction, using the multiple debreader did not lead to fewer deductions due to loss of veins, shell, and swimmerets from the compartments.

Product B contained excessive veins, shell, and swimmerets (tables 3 and 4), rigorously testing the multiple debreader in determining whether or not these particles would remain in the compartments. Breading from the multiple debreader was washed onto a No. 20 sieve and carefully examined. The examination of breading from the multiple debreader showed no veins, shell, swimmerets, or particles of shrimp, although several of these items were present in the individual compartments. When the debreaded shrimp were examined, no evidence of broken pieces was found, nor was the shrimp made excessively fragile.

The exact amount of breading previously applied to these shrimp was not known; therefore, these samples could not be used to test the accuracy of the multiple debreader as related to breading percentage. It became obvious, however, in the course of debreading, that the multiple debreader removed as much breading as the single debreader plus hand washing did. When the single debreader method is used, the remaining breading is washed off by hand as is the procedure in the official method; however, with the multiple debreader, such hand washing is not often necessary. Breading percentages presented in tables 1 through 4 should not be compared for efficiency of debreaders, since they do not represent the true removal of breading by the machine alone, but indicate total breading removal.

EXPERIMENT 2.--One hundred and fifty-four samples of shrimp (20 shrimp each sample) were breaded using two different batters and two different breading materials.

TABLE 1--Deductions and grade results of product A using multiple debreader

	Deductions																							
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Percent of Breading	46	46	47	46	48	43	46	42	46	47	49	50	46	48	48	47	50	46	48	49	48	48	43	44
Loose Breading and Frost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ease of Separation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uniformity Ratio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Condition of Coating	0	2	4	1	2	4	2	2	4	2	1	1	4	2	2	1	0	2	4	2	1	2	4	2
Damaged/Fragmented Shrimp	0	0	3	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
Deterioration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Dehydration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sand Veins	0	1	2	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1	0	0
Black Spot	3	0	3	0	3	3	3	0	0	3	3	0	3	3	0	0	0	3	3	9	6	0	3	0
Swimmerets	1	1	1	0	0	1	0	3	2	1	1	0	2	3	0	0	0	0	0	0	1	1	0	1
Extra Shell	1	1	3	1	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	2	0	1
Total Deductions	5	5	16	3	5	9	7	5	7	7	6	2	10	9	5	3	1	5	8	12	8	6	10	4
Total Score	95	95	84	97	95	91	93	95	93	93	94	98	90	91	95	97	99	95	92	88	92	94	90	96
Grade	A	A	B	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

Sample No.	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Percent of Breading	46	44	46	47	46	46	46	45	46	47	50	45	46	45	49	48	48	44	46	48	47			
Loose Breading and Frost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Ease of Separation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Uniformity Ratio	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Condition of Coating	4	2	2	2	4	2	2	2	2	4	1	1	2	2	1	2	0	4	4	2	2			
Damaged/Fragmented Shrimp	0	0	0	0	0	3	0	0	0	0	0	0	6	6	0	0	0	3	3	0	0			
Deterioration	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0			
Dehydration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Sand Veins	0	0	0	0	0	0	0	0	0	2	1	0	1	0	0	0	0	0	0	0	0			
Black Spot	0	0	3	3	3	3	0	0	0	0	0	0	0	3	3	3	3	3	3	0	3			
Swimmerets	1	0	0	1	0	0	1	0	0	1	3	0	0	0	1	0	0	0	0	0	0			
Extra Shell	0	0	0	0	2	0	0	0	1	2	3	0	0	1	0	1	2	1	1	0	0			
Total Deductions	5	2	5	8	9	8	3	2	6	9	8	1	9	12	5	6	5	11	11	2	5			
Total Score	95	98	95	92	91	92	97	98	94	91	92	99	91	88	95	94	95	89	89	98	95			
Grade	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A			

TABLE 2--Deductions and grade results of product A using single debreader

	Deductions																							
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Percent of Breading	49	49	49	48	48	48	46	49	49	49	48	48	46	49	48	49	48	48	49	49	48	48	48	49
Loose Breading and Frost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ease of Separation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uniformity Ratio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Condition of Coating	2	2	4	2	2	2	2	4	2	4	2	4	2	4	2	2	2	4	2	1	2	2	2	2
Damaged/Fragmented Shrimp	0	1	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0	1	2	0	0	1
Deterioration	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dehydration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sand Veins	2	0	0	2	5	2	1	1	4	2	2	1	0	1	1	0	0	3	3	5	4	2	4	1
Black Spot	0	3	3	3	0	3	0	3	3	3	0	0	3	0	3	0	0	0	0	0	3	0	3	0
Swimmerets	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	1	0	1	0
Extra Shell	1	0	0	0	1	0	0	0	0	0	0	0	2	0	1	1	7	4	0	0	0	0	0	0
Total Deductions	5	9	7	7	8	7	3	8	9	13	4	5	7	8	8	4	9	12	6	7	12	4	10	5
Total Score	95	91	93	93	92	93	97	92	91	87	96	95	93	92	92	96	91	88	94	93	88	96	90	95
Grade	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

Sample No.	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Percent of Breading	49	48	48	49	49	48	48	50	48	50	48	47	47	48	49	50	50	50	50	50	49	50	50	50
Loose Breading and Frost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ease of Separation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uniformity Ratio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Condition of Coating	1	2	2	1	2	2	1	2	1	1	1	4	2	4	2	0	2	2	2	1	3	1	2	2
Damaged/Fragmented Shrimp	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Deterioration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dehydration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sand Veins	3	2	1	1	2	5	1	6	2	4	5	4	1	2	3	0	1	2	0	1	1	1	3	3
Black Spot	3	0	0	0	0	0	3	0	3	0	3	3	0	3	3	0	3	3	3	3	3	0	3	3
Swimmerets	1	0	0	0	0	0	0	3	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0	1
Extra Shell	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Total Deductions	8	4	3	3	5	7	5	11	6	5	9	11	5	12	8	2	6	7	5	5	7	3	8	9
Total Score	92	96	97	97	95	93	95	89	94	95	91	89	95	88	92	98	94	93	95	95	93	97	92	91
Grade	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

TABLE 3--Deductions and grade results of product B using multiple debreader

	Deductions																								
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Percent of Breading	33	33	32	32	35	34	31	33	33	35	35	34	28	30	33	34	33	35	35	38	32	36	32	33
Loose Breading and Frost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ease of Separation	0	3	3	3	3	3	3	0	3	0	3	3	3	3	0	3	3	3	3	3	3	3	3	3
Uniformity Ratio	2	0	0	0	7	10	4	0	0	1	2	0	0	0	4	5	0	3	6	0	0	3	0	0
Condition of Coating	2	4	4	4	4	4	3	3	3	3	3	3	4	4	2	2	4	4	2	2	2	2	2	4
Damaged/Fragmented Shrimp	1	3	2	5	5	8	8	0	0	0	3	1	8	7	5	0	5	8	6	3	5	1	8	2
Deterioration	3	3	3	3	0	0	0	3	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Dehydration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sand Veins	11	29	17	18	18	17	26	15	21	13	15	19	18	22	19	12	19	10	13	19	29	21	14	17
Black Spot	3	3	3	0	3	3	3	3	3	3	3	3	3	3	3	3	3	6	3	3	3	3	3	3
Swimmerets	2	1	4	1	4	0	5	2	2	3	2	3	9	1	1	2	2	1	4	2	3	0	2	3
Extra Shell	1	1	2	1	0	0	2	3	0	2	3	2	6	1	1	3	3	0	0	1	1	1	0	1
Total Deductions	25	47	38	35	44	45	54	29	32	25	34	34	51	41	35	33	39	35	37	33	46	34	32	33
Total Score	75	53	62	65	56	55	46	71	68	75	66	66	49	59	65	67	61	65	63	67	54	66	68	67
Grade	B	SS*	SS*	SS*	SS*	SS*	SS*	B	SS*	B	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*

Sample No.	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Percent of Breading	36	34	33	34	30	33	34	36	30	33	33	33	38	38	33	33	33	37	34	37	33	35	28	33
Loose Breading and Frost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ease of Separation	3	3	3	3	3	0	0	3	0	3	0	3	3	3	3	3	3	3	3	3	3	3	3	3
Uniformity Ratio	0	6	0	0	0	0	0	0	0	2	0	0	0	0	0	5	0	4	6	0	0	0	0	0
Condition of Coating	2	2	2	4	2	2	2	2	2	2	4	2	1	4	2	2	2	4	4	4	2	4	4	4
Damaged/Fragmented Shrimp	0	7	0	9	1	0	1	0	1	2	4	2	1	2	8	1	0	5	1	1	1	3	1	4
Deterioration	3	3	0	0	0	0	0	3	0	0	0	0	3	3	3	0	6	3	3	3	3	3	3	0
Dehydration	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0
Sand Veins	13	14	21	22	13	16	22	19	19	15	9	18	3	21	11	19	2	5	12	7	9	12	15	12
Black Spot	3	3	3	3	0	3	3	6	3	3	3	3	3	3	3	3	6	3	3	3	3	3	6	3
Swimmerets	3	1	3	1	3	0	2	4	3	1	1	3	2	0	3	3	3	3	5	5	5	1	0	1
Extra Shell	1	0	0	0	1	0	2	1	1	0	1	0	3	0	0	1	0	0	3	0	2	1	1	0
Total Deductions	28	39	31	41	23	19	32	38	29	28	22	31	19	39	36	37	22	30	40	26	28	30	33	27
Total Score	72	61	69	59	77	81	68	62	71	72	78	69	81	61	64	63	78	70	60	74	72	70	67	73
Grade	B	SS*	SS*	SS*	B	B	SS*	SS*	B	B	B	SS*	B	SS*	SS*	SS*	B	B	SS*	B	B	B	SS*	B

*Sub-standard

TABLE 4--Deductions and grade results of product B using single debreader

	Deductions																							
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Percent of Breading	34	33	33	34	35	34	35	36	36	35	34	37	34	32	34	33	31	38	37	33	38	36	37	35
Loose Breading and Frost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ease of Separation	3	3	3	3	3	3	3	3	3	3	3	3	0	3	3	3	3	3	3	3	3	3	3	3
Uniformity Ratio	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	2	9	7	0	0	2	0	0
Condition of Coating	4	4	4	4	4	4	4	4	4	2	4	2	2	2	4	4	2	4	2	2	2	4	2	4
Damaged/Fragmented Shrimp	3	4	4	9	2	2	3	2	5	5	0	4	1	5	2	1	7	7	3	1	0	3	0	1
Deterioration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	0	3	3	0	0
Dehydration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sand Veins	15	17	23	21	24	19	30	21	14	26	20	24	25	17	20	24	27	21	25	14	27	25	24	22
Black Spot	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Swimmerets	2	2	2	4	6	5	1	7	9	1	0	3	1	3	6	1	2	3	0	6	1	1	4	6
Extra Shell	1	0	2	0	2	2	1	0	1	0	2	1	1	1	5	1	0	2	1	2	2	1	2	2
Total Deductions	31	33	41	49	44	38	45	40	39	40	32	40	33	34	43	40	46	55	44	31	41	45	38	41
Total Score	69	67	59	51	56	62	55	60	61	60	68	60	67	66	57	60	54	45	56	69	59	55	62	59
Grade	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*

Sample No.	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Percent of Breading	35	36	38	39	33	35	33	37	35	33	34	37												
Loose Breading and Frost	0	0	0	0	0	0	0	0	0	0	0	0												
Ease of Separation	3	3	3	3	3	3	3	3	3	0	3	3												
Uniformity Ratio	0	0	0	0	0	0	0	2	0	0	0	0												
Condition of Coating	2	2	2	4	2	2	2	2	2	4	2	4												
Damaged/Fragmented Shrimp	3	2	0	10	1	4	3	6	2	2	0	2												
Deterioration	3	0	3	3	3	0	0	0	3	0	3	3												
Dehydration	0	0	0	0	0	0	0	0	0	0	0	0												
Sand Veins	21	24	24	28	17	25	19	20	17	24	14	19												
Black Spot	3	3	3	3	3	3	3	3	3	3	3	3												
Swimmerets	5	2	5	7	6	4	1	3	3	1	3	10												
Extra Shell	3	1	2	2	2	2	2	2	1	0	1	3												
Total Deductions	43	37	42	60	37	43	33	41	34	34	29	47												
Total Score	57	63	58	40	63	57	67	59	66	66	71	53												
Grade	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	SS*	B	SS*												

*Sub-standard

Table 5.--Summary of results comparing debreaders using various breading materials

Experiment	Samples	Commercial breading and batter material	Debreader used	Mean value		Breading removed
				Weight of breading put on	Weight of breading taken off by debreader	
	Number			*Grams*	*Grams*	*Percent*
A	10	Breading A Batter B	Multiple debreader	153.4	115.4	75.2
	48	Breading A Batter B	Single debreader	163.4	69.4	42.5
B	48	Breading and batter C	Multiple debreader	158.6	132.1	83.3
	48	Breading and batter C	Single debreader	148.3	115.1	77.6

The shrimp were breaded with known amounts of breading and then frozen in a blast freezer at -40° F. These shrimp were of the *P. duoarum* variety and butterfly style and were breaded in the same manner. They were used to test the accuracy of the multiple debreader with different breading materials.

The single and multiple debreaders were used to remove the breading from the shrimp in two experiments using two different types of commercial batters and breading. Table 5 summarizes the results, which were subjected to statistical treatment in order to compare the efficiency of the multiple debreader with that of the single debreader using the Student t-test. The "t" values obtained showed that there was a significant difference (at the 95-percent level) between the debreaders in removing the same breading and between the debreaders in removing different breading. The multiple debreader removed significantly more of both breading materials than did the single debreader without hand washing. Although the official method using the single debreader with hand washing and the new method using the multiple debreader achieve the same end result (tables 1 through 4), unit effort is reduced considerably by the latter method. The new debreader removes in 7 minutes the breading from six samples that would require 60 minutes with the present debreader.

Cost

The cost of material for this debreader was $145. Labor and other costs were $300. The overall cost would have been considerably lower had the machine been made on a large-scale production. This conclusion is based on the manufacturer's estimate of about half the labor cost and of lower cost of materials when purchases are made in large quantities. Estimates on a production basis were $300 to $325, which are comparable with the price of the current debreader.

SUMMARY

Three hundred thirty-one samples of breaded shrimp were graded to compare the multiple debreader described here with the single debreader now commonly used. Statistical treatment of the results shows that the multiple debreader removed significantly more breading material than did the single debreader without hand washing.

The cost of the multiple debreader as constructed was $445--$145 for materials and $300 for labor. Manufacturers estimate that the debreader could be constructed for $300 to $325 on a production basis.

The multiple debreader debreads six samples of shrimp in 7 minutes. It also eliminates much hand washing, thereby reducing the grading time.

LITERATURE CITED

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