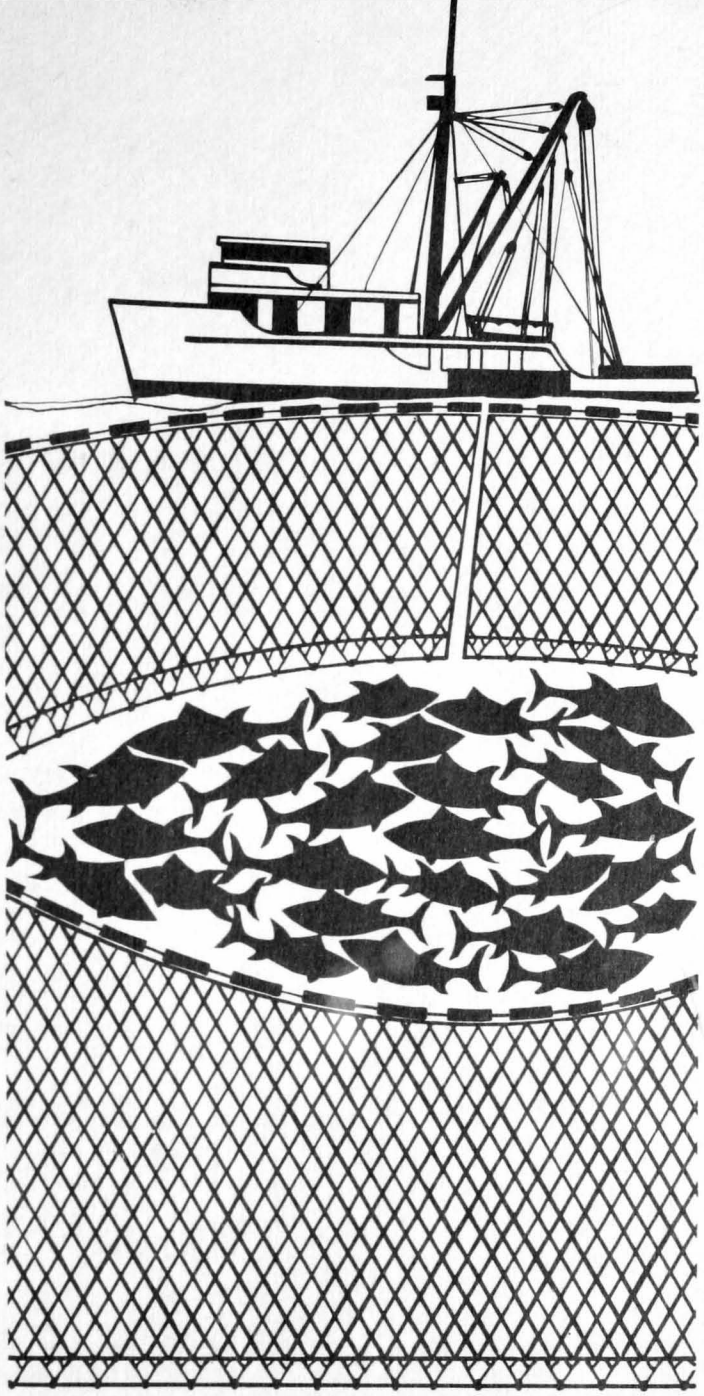

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EXTENDING THE SHELF LIFE OF FROZEN CISCO *(Coregonus artedii)* PRODUCTS THROUGH THE USE OF WATER-SOLUBLE ANTIOXIDANTS

by

R. A. Greig, J. A. Emerson, and G. W. Fliehman

ABSTRACT

The effectiveness of various water-soluble antioxidants for retarding the development of rancidity in frozen cisco (lake herring) products was studied. Ascorbic acid was found to be more effective than propyl gallate, monsodium glutamate, or sodium tripolyphosphate. At 0° F., ascorbic acid extended the shelf life of frozen cisco portions and fillets at least twofold.

INTRODUCTION

In a previous paper, Greig, Seagran, and Emerson (1964) discussed the problem of storing and marketing cisco products. They reported that cisco is highly regarded by consumers when it is strictly fresh but that it rapidly becomes less desirable during chilled and frozen storage. A primary cause of the loss of acceptability during frozen storage (the shelf life ranges from 3 to 6 months at 0° F.) is the rapid onset of off-flavors and off-odors caused by oxidative rancidity.

Several methods are available for retarding rancidity in frozen fishery products — for example, (1) vacuum packaging in gas-impermeable bags, (2) coating with an ice glaze made from plain water or from alginate solutions, or (3) applying chemical antioxidants. The use of antioxidants with marine fish has been studied (Tarr, 1947; Lilzemark, 1964), but their use with fresh-water fish has received little attention.

Most commercially available antioxidants are insoluble in water, so problems are encountered in the application of such materials to fishery products. Ordinarily, the complexities of application make these antioxidants unsuitable for use by the fresh-water fishing industry. For this reason, the work reported here was directed toward investigating the possibility of using water-soluble antioxidants; in particular, extending the shelf life of frozen cisco products was explored.

Studies in which water-soluble antioxidants were used on frozen cisco products are reported. Some of these were laboratory investigations; the others were field studies made under normal commercial conditions.

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I. LABORATORY STUDIES

Although our interest was in fish blocks and portions, we worked also with ground fish because the ground material (1) was homogeneous, (2) was readily amenable to the incorporation of antioxidants, and (3) was oxidized rapidly, thereby quickly revealing the effects of different antioxidant treatments.

A. GROUND FISH

1. Materials and Methods

a. Antioxidants.—The following water-soluble antioxidants[1] were purchased commercially and used without further purification: ascorbic acid, monosodium glutamate, sodium tripolyphosphate, and propyl gallate. These antioxidants have been reported to be generally effective when used on certain marine and fresh-water fish (Bauernfeind, Smith, and Siemers, 1951; Norton, Tressler, and Farkas, 1952; Ramsey and Watts, 1963; Greig, 1965).

b. Preparation of samples.—Cisco fillets (skin-on) were passed four times through a meat grinder having a plate with holes 1/4 inch in diameter. The ground material was divided into portions, and each portion was mixed thoroughly with one of the antioxidants listed above; three different concentrations of each antioxidant (only two with propyl gallate) were used with different lots of the ground fish (Table 1).

[1] Of the materials tested, propyl gallate is probably the only primary or true antioxidant. The others are generally classed as synergists and do not directly retard the onset of oxidative rancidity. For simplicity, however, all of these compounds will be referred to as antioxidants in this paper.

Table 1.—Concentration of antioxidants used in ground cisco flesh

Lot No.	Antioxidant	Concentration (based on total weight of flesh) of antioxidant in:		
		Sample 1	Sample 2	Sample 3
		Percent	*Percent*	*Percent*
1	Monosodium glutamate	0.05	0.20	0.5
2	Sodium tripolyphosphate	0.05	0.20	0.5
3	Ascorbic acid	0.20	0.50	0.7
4	Propyl gallate	0.01[1]	0.02[1]	---[2]

[1] Percentage based on the concentrations of oil (5 percent) in the flesh.

[2] Concentrations of propyl gallate higher than 0.02 percent of the oil in the flesh are not permitted by the United States Food and Drug Administration.

Each antioxidant was dissolved at the indicated concentration in 100 milliliters of water and then mixed well with a part of the ground fish. Each sample was frozen into blocks and cut into thin slices (1/4 by 2 by 4 inches), and the frozen slices were packaged in unsealed, air-permeable polyethylene bags for storage at 0° ± 4° F. Nontreated samples were prepared in a similar manner (lacking only the antioxidant) to serve as controls.

c. Analysis for rancidity.—2-thiobarbituric acid (TBA) data, which are objective and are relatively easy to obtain, have been found to correlate reasonably well with taste-panel evaluations of the development of rancidity in frozen fish and other products (Ramsey and Watts, 1963; Greig, 1965). Therefore, a TBA test was used to follow the onset of oxidative rancidity in the samples.

After periodic intervals of storage, samples were thawed and well kneaded in the bag, and duplicate 5-gram samples were taken for the TBA test. The procedure by Tarladgis, Watts, Younathan, and Dugan (1960) was used except that the TBA reagent was dissolved in triple-distilled water instead of in glacial acetic acid.

2. Results

Figure 1 shows the plot of the TBA data from the various samples against time in storage. The concentration did not significantly affect the shape of the various curves; therefore, only one curve for each antioxidant is shown. All the antioxidant-treated samples except those treated with ascorbic acid showed progressive increases in TBA values[2].

3. Conclusion

Ascorbic acid was the most effective antioxidant of those used for retarding the onset of rancidity in ground cisco flesh.

B. BLOCKS AND PORTIONS

1. Materials and Methods

The same antioxidants used with the ground fish were used in a study with blocks and portions.

The procedure followed is shown in Figure 2.

[2] TBA values usually are reported as milligrams of malonaldehyde per 1,000 grams of sample; for simplicity, we preferred, however, to use the absorbance at 536 millimicrons of the colored solution that results when the TBA reagent reacts with a sample distillate.

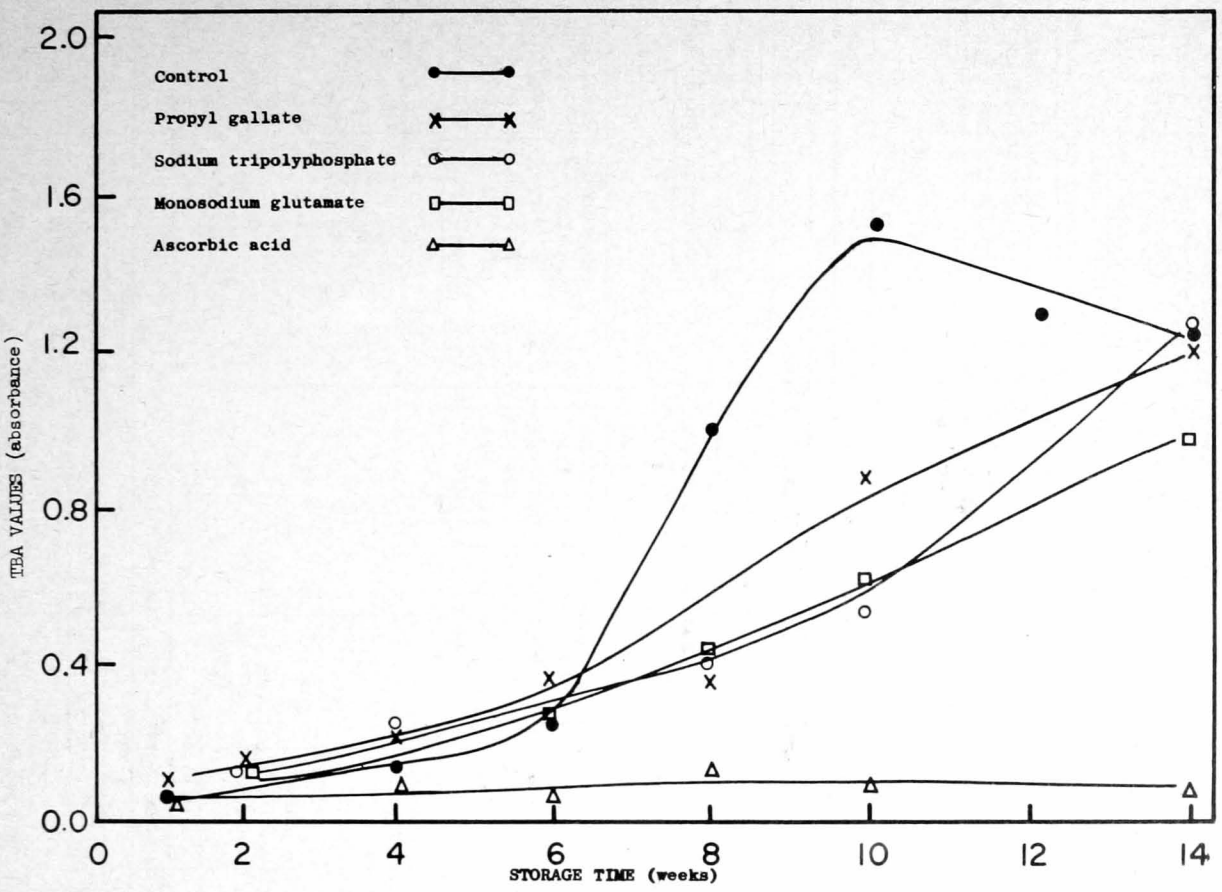

Figure 1.—Results of TBA test on ground cisco flesh stored at 0° F.

2. Results

a. Blocks stored 6 months.—Sensory evaluation (at the time the blocks were cut) (Table 3) showed that the outer portions were objectionably rancid in all samples except those treated with propyl gallate or with ascorbic acid (both when applied as a glaze on the portion or as a dip for the fillet). Propyl gallate-treated samples, however, had an objectionable, bitter, "chemical" taste. Ascorbic acid-treated portions had no strong rancid off-flavors, but they did have a slightly sour, lemonlike flavor that was objectionable to some panelists. TBA data (Table 3) generally supported the sensory data.

Sensory evaluation of the inner portions (Table 4) made at monthly intervals following the 6-month initial storage showed that the control sample was slightly rancid at the initial sampling time and that in the form of portions it became objectionably rancid after just 1 month of storage. Portions cut from the alginate-glazed block were rancid after only 2 months of storage. Portions cut from a vacuum-packaged block and glazed with a 1-percent ascorbic acid solution were found to be objectionably rancid after 7 months' storage. The overall quality of these portions was quite good up through 5 months' storage, but was borderline after 6 months.

Portions cut from a block made from ascorbic acid-treated fillets were also objectionably rancid after 7 months' storage. Overall quality was somewhat impaired through 4 months by slight-to-moderate sour, lemonlike flavors. After 5 months, these samples were slightly bitter instead of lemonlike in flavor and were borderline in acceptance. After 7 months, they became unacceptable. Objectionably rancid off-flavors were found in the monsodium glutamate-treated portions after 4 months of storage; however, the overall quality of the portions was found to be only borderline after just 3 months' storage. Sodium tripolyphosphate-treated portions became objectionably rancid after 4 months' storage, but were borderline in quality throughout the storage test. Propyl gallate-treated samples had an objectionable "chemical" taste throughout the storage study; therefore,

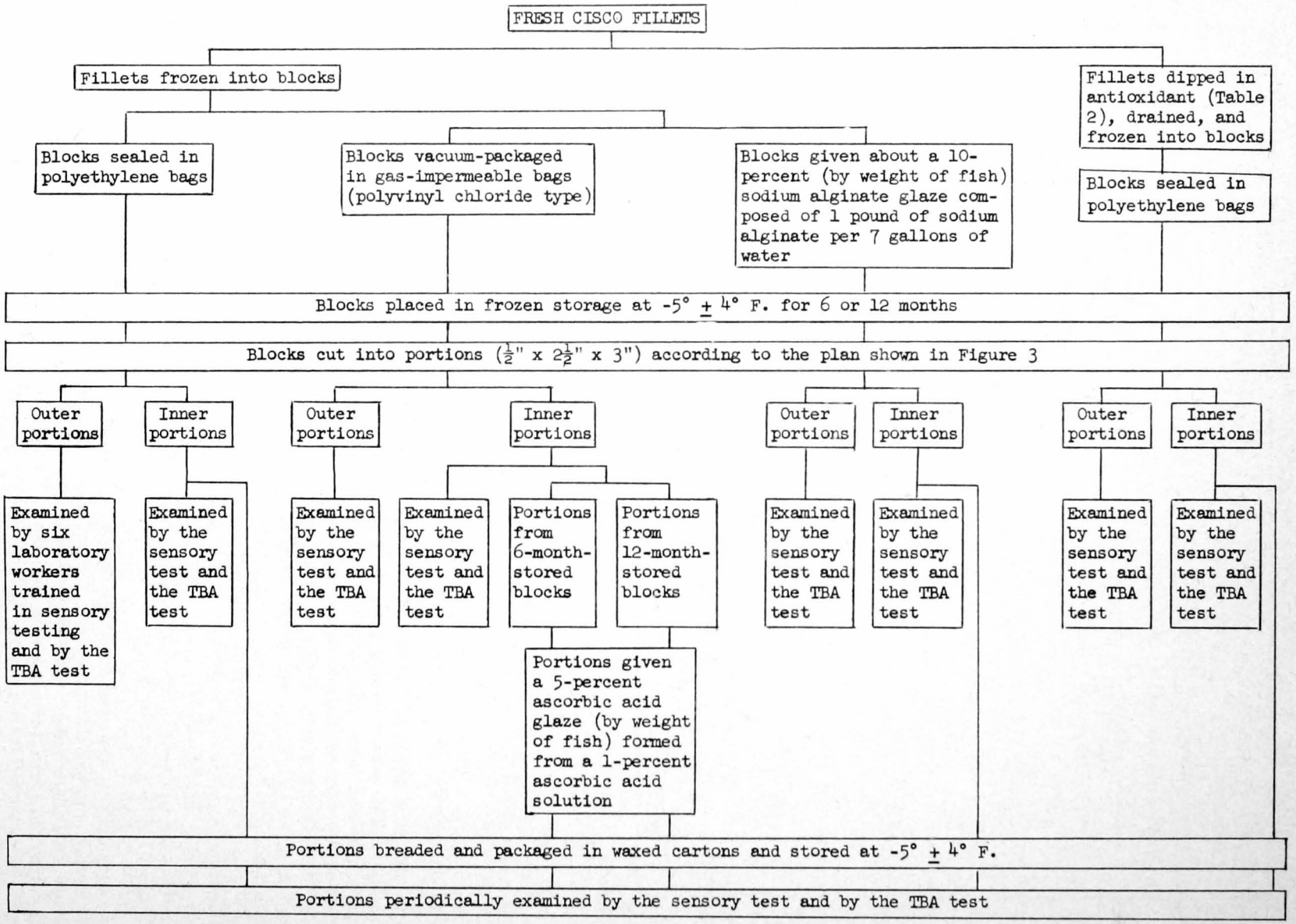

Figure 2.—Procedure followed in the experiment on blocks and portions.

Table 2.—Concentration of antioxidant solutions and immersion time for treating cisco fillets prior to their being frozen into blocks

Antioxidant	Concentration of antioxidant	Filet-immersion time
	Percent	*Seconds*
Sodium tripolyphosphate ..	3.0	45
Ascorbic acid	3.0	45
Monosodium glutamate ..	3.0	60
Propyl gallate	0.4	3,600 (1 hour)

Note: The long immersion time for the propyl gallate-treated fillets was necessitated by the low concentration of the propyl gallate; the low concentration was caused by the low solubility of propyl gallate in water.

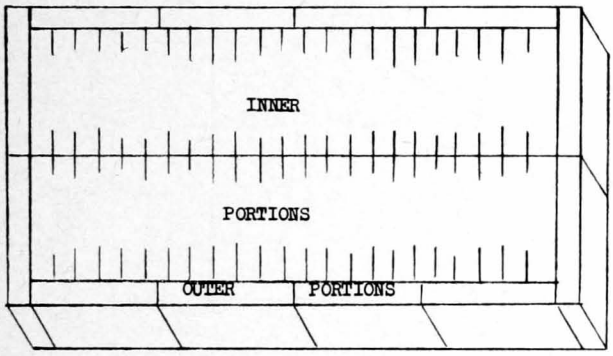

Figure 3.—Plan for cutting cisco blocks into portions.

Table 3.—Results of sensory and chemical tests on outer portions cut from cisco blocks stored 6 months

Treatment	Sensory scores	TBA values (absorbance)[1]
	Arbitrary scale[2]	
None (control)	2.5	0.70
Vacuum, packing (plus ascorbic acid glaze) ..	3.0	0.64
Alginate glaze	2.2	1.40
Sodium tripolyphosphate ..	2.0	0.70
Monosodium glutamate ..	2.5	---
Ascorbic acid	3.8	0.16
Propyl gallate	---	0.16

[1] Average of duplicate determinations.
[2] Panelists rated the samples for rancid off-flavors and off-odors according to a scale of: 5—not rancid; 3—slightly rancid; 1—strongly rancid. A rating of below 3 indicated that the sample was unacceptible.

no taste-panel results are given as to the development of rancidity.

TBA data (Figure 4) generally support the sensory evaluation of the onset of oxidative rancidity in the inner portions. The oxidation process that results in rancid off-flavors and off-odors was slowed considerably in both the ascorbic acid-glazed portions (from vacuum-packed blocks) and the portions obtained from blocks made from fillets treated with ascorbic acid prior to initial freezing. On the other hand, the onset of rancidity was fairly rapid in samples treated with sodium tripolyphosphate, monosodium glutamate, and alginate and in the control

Table 4.—Results of sensory tests on inner portions cut from cisco blocks stored 6 months at -5° F.

Storage time	Sensory tests on: Blocks treated with: No treatment (control)	Vacuum packing (portions given an ascorbic-acid glaze)	Alginate glaze	Blocks made from fillets treated with: Monosodium glutamate	Sodium tripolyphosphate	Ascorbic acid
Months[1]			*Arbitrary scale*[2]			
0	3.3	3.7	3.8	3.2	---	3.8
1	2.2	---	---	4.6	3.0	4.6
2	---	---	2.3	3.0	4.2	3.8
3	---	4.0	---	3.0	3.4	3.8
4	---	---	---	2.3	2.5	3.5
5	---	4.0	---	---	2.0	3.0
6	---	3.0	---	---	---	3.4
7	---	2.3	---	---	---	1.4

[1] Number of months to be added to the initial 6-month storage period given to the blocks.
[2] Panelists rated the samples on a 5-point scale (see Table 3).

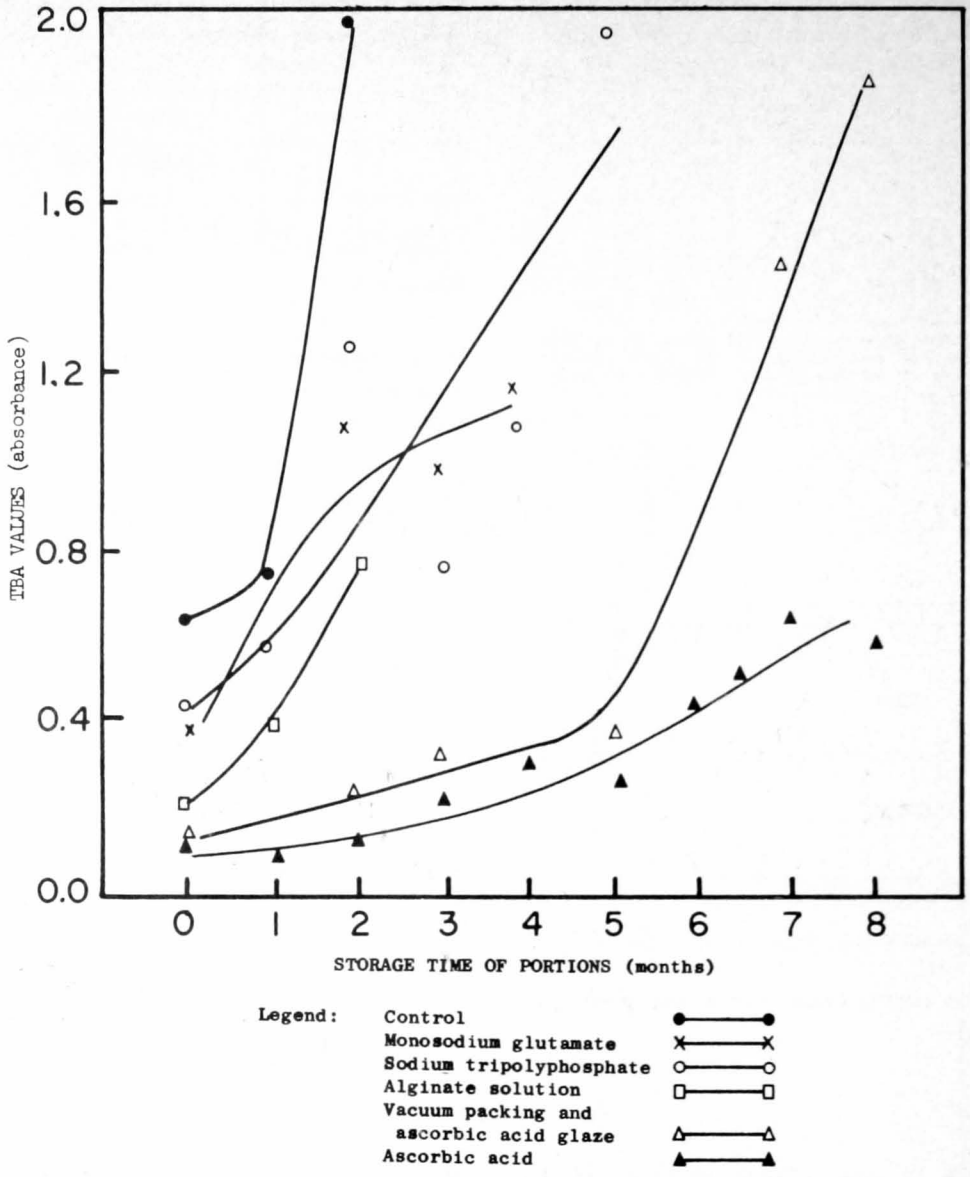

Figure 4.—Results from TBA test on inner portions cut from cisco blocks stored 6 months at -5° F.

samples. Ascorbic acid concentration (Table 5), determined for the same samples as for those in the TBA test, did not change appreciably during storage. Antioxidant concentrations were not determined for samples given the other treatments.

b. Blocks stored 1 year.—Sensory evaluations were made on the inner portions of the blocks stored 1 year. All the portions except those treated with ascorbic acid or cut from blocks made from ascorbic acid-treated fillets were objectionably rancid after just 1 month's additional storage (Table 6). Portions cut from a vacuum-packaged block and glazed with an ascorbic acid solution became objectionably rancid after 3 months' additional storage. (No evaluation was made at the 2-month point.) Portions cut from the ascorbic acid-treated blocks became objectionably rancid after 4 months' additional storage; however, throughout storage these portions had fairly strong off-flavors, which were described as sour or lemon-like in some samples and as somewhat bitter in others. Ascorbic acid concentration in portions similar to those used for sensory evaluation ranged from 0.21 to 0.27 percent (Table 5). The propyl gallate-treated samples (not reported in Table 6) had a bitter "chemical" taste throughout the storage study.

Table 5.—Ascorbic acid concentration in cisco portions (cut from blocks stored 6 months and 1 year) during storage at -5° F.

Storage time	Ascorbic acid concentration[1] in:	
	Portions cut from 6-month old blocks	Portions cut from 1-year old blocks
Months[2]	*Percent*	*Percent*
0	0.17	0.23
1	0.19	0.23
2	0.19	0.21
3	0.17	---
4	0.19	0.27
5	---	---
6	0.16	---
7	0.14	---

[1] Samples used for the TBA test (see Table 3 and Figure 4) were used in the analysis for ascorbic acid. Each concentration presents 1 determination only.
[2] Number of months to be added to the initial 6- or 12-month storage period.

TBA data (Table 7) supported taste-panel results for all but the portions from ascorbic acid-treated fillets. Comparatively high TBA values were obtained on all but the latter portions and those from fillets treated with propyl gallate, which indicates that oxidation had already progressed considerably. With ascorbic acid-treated portions, fairly low TBA values were obtained throughout the storage test, indicating little development of rancidity; these results were contrary to the taste-panel results, which showed that these samples had become rancid. TBA data from the portions obtained from propyl gallate-treated fillets indicate that the development of rancidity was retarded in these samples as well.

3. Discussion and Conclusions

Results of sensory and TBA tests on the portions supported the results of TBA tests on the ground fish as to the relative effectiveness of the antioxidants

Table 6.—Results of sensory tests on inner portions cut from cisco blocks stored 1 year at -5° F.

Storage time	Sensory tests						
	Control	Vacuum packing		Alginate glazed	Sodium tripoly-phosphate	Mono-sodium glutamate	Ascorbic acid
		Acsorbic acid glaze added	No glaze added				
Months[1]				*Arbitrary scale*[2]			
0	3.4	4.2	4.6	---	3.6	3.3	4.0
1	2.4	3.9	2.8	2.0	2.0	2.5	4.0
2	---	---	---	---	---	---	3.3
3	---	2.5	2.0	---	---	---	2.3
4	---	---	---	---	---	---	2.3

[1] Number of months to be added to the initial 12-month storage period.
[2] Panelists rated samples on a 5-point scale (see Table 3).

Table 7.—Results of the TBA test on inner portions cut from cisco blocks stored 1 year at -5° F.

Storage time	TBA values (absorbance)[1]							
	Control	Vacuum packing		Alginate	Sodium tripoly-phosphate	Mono-sodium glutamate	Ascorbic acid	Propyl gallate
		Ascorbic acid glaze added	No glaze					
Months[2]								
0	0.7	0.3	0.5	---	1.1	0.5	0.3	0.1
1	1.6	0.6	0.9	---	1.4	1.1	0.3	0.1
2	---	2.0	1.6	---	---	---	0.3	0.2
3	---	1.1	1.8	---	---	---	0.2	0.4
4	---	---	---	---	---	---	0.3	0.7

[1] Averages of duplicate determintaions.
[2] Number of months to be added to the initial 12-month storage period.

studied; therefore, TBA results from different lots of ground fish treated with antioxidants apparently are acceptable bases for selection of an effective antioxidant for a particular species of fish. Considerable time can be saved by using this basis of selection; a storage study on a product such as frozen fillets takes about 1 year to complete, whereas this study on ground fish was completed in about 3 months. The omission of sensory evaluation, however, can result in an unawareness of the side effects an antioxidant may have on a product—for example, ascorbic acids' producing an undesirable sour flavor.

A commercial processor would not cut the cisco blocks as shown in Figure 3 and throw away the outer portions. Therefore, all the cisco blocks tested (except the vacuum-packaged blocks and the blocks from the acid-treated fillets) would be unacceptable for commercial use, since the outer portions from the blocks were not acceptable at the time of the initial cutting.

II. FIELD STUDIES

The field studies were part of a technical assistance project designed to introduce industry members to new and improved methods of handling, processing, and storing cisco products. Storage studies were made to demonstrate the use of an ascorbic acid treatment (found to be quite effective in the laboratory studies) and various other treatments to prolong the storage life of frozen cisco products.

These studies were made in several different commercial processing plants and in the Bureau's Biological Laboratory, Marquette, Michigan.

A. COMMERCIAL-PROCESSING-PLANT STUDIES

1. Materials and Methods

Individually quick-frozen breaded cisco fillets (skin-on) were prepared and stored at several commercial processing plants. Samples placed in frozen storage were as follows: (1) fillets dipped in a 2-percent ascorbic acid solution for 45 seconds, drained, and individually frozen; (2) fillets treated as above except that the frozen fillets were glazed with water to give about a 5-percent glaze (by weight of fillet); (3) fillets treated the same as those in (2), except that a 1-percent monosodium glutamate solution was used instead of water to give about a 5-percent glaze; and (4) nontreated frozen fillets used as controls. (The main purpose of the glazes was to provide protection against dehydration.) All fillets were sealed in polyethylene bags. Samples were held in a freezer at about 0° F. and periodically examined by one of the authors, together with several industry members.

2. Results

Sensory examination of the cisco fillets by industry members showed that, after from 4 to 6 months of storage, the control fillets were unacceptable because of strong off-flavors and off-odors. In contrast, all of the treated fillets were of consistently good quality through 12 months of storage. Glazed samples generally were more moist than were the other samples. Dehydration, however, was not a serious problem with any of the samples—perhaps because of the breading. Some improvement in flavor was noted in the samples that had been glazed with the monosodium glutamate solution.

B. STUDIES AT THE MARQUETTE STATION

1. Methods and Materials

Samples were prepared in the same manner as were the processing plant samples and were held at about -5° F. at the Bureau of Commercial Fisheries Biological Station, Marquette, Michigan. Deep-fat-fried portions of the samples were periodically examined by a taste panel of 12 laboratory workers. A fresh cisco sample was prepared each time as a reference to guide the panel in rating the test samples.

2. Results

The results of the taste examination of frozen cisco fillets (Table 8) at the station in Marquette were similar to the results obtained by industry members. Fillets treated with ascorbic acid and then glazed with a 1-percent solution of monosodium glutamate were acceptable and of good quality through 12 months of storage (no tests were made beyond 12 months). The other treated samples (those treated with ascorbic acid only and those treated with ascorbic acid plus a water glaze) were acceptable and of good quality through 10 months of storage. No tests were made beyond 10 months. Because of rancid off-odors and off-flavors, nontreated fillets became unacceptable by 6 months. (No tests were made between 4 and 6 months.) None of the samples had the sour, lemonlike flavor described under the study on blocks and portions. The ascorbic acid content of these samples was not determined.

Table 8.—Results of sensory evaluation of frozen cisco fillets

Storage time	Scores of sensory tests on:			
	Control	Samples treated with ascorbic acid:		
		No glaze[1]	Plus water glaze[2]	Plus monosodium glutamate glaze[3]
Months	*Arbitrary scale*[4]			
0	8.0	8.5	8.2	8.0
2	8.3	---	---	---
4	7.0	---	---	---
6	3.0	9.3	8.1	8.6
8	---	8.9	8.0	7.6
10	---	8.9	7.5	8.2
12	---	---	---	7.4

[1] Fillets were dipped in 2-percent ascorbic acid for 45 seconds and then frozen.

[2] Fillets were dipped in the ascorbic acid, frozen, and then glazed with water to give about a 5-percent glaze.

[3] Fillets were dipped in the ascorbic acid, frozen, and then glazed with a 1-percent monosodium glutamate solution to give about a 5-percent glaze.

[4] A 10-point scale for flavor was used, where 10 is excellent; 5, average; and 1, poor. A rating of below 5 ranked the sample as unacceptable.

C. DISCUSSION

Ascorbic acid has been used on a number of marine fishes with varying success (Tarr, 1947; Bauernfeind, Smith, and Siemers, 1950; Anderson and Danielson, 1960; Lilzemark, 1964). Tarr and Bauernfield, Smith, and Siemers indicated that, for optimum results, a concentration of 0.05 percent ascorbic acid should be used in the product. Lilzemark, on the other hand, suggested 0.5 percent ascorbic acid as the optimum concentration in the product. This high value may have been a misprint, for Lilzemark apparently based his suggestions on the findings of Tarr and Bauernfiend, Smith, and Siemers.

Results presented in this report show that ascorbic acid concentrations of higher than about 0.17 percent in the flesh will produce undesirable acidic off-flavors in cisco portions. Unfortunately, we do not know the concentration of ascorbic acid in the cisco fillets used in the field studies. According to the results, however, the amount of ascorbic acid used in the field studies will not produce any undesirable off-flavors even after the products have been stored for 12 months.

Subsequent analysis of a small lot of fillets dipped in a 2-percent ascorbic acid solution for 45 seconds (the treatment used in the field studies) showed that concentration among the individual fillets ranged from 0.12 to 0.17 percent (on a weight-of-fillet basis). These data suggest a useful order of concentration that can be used to extend the shelf life of cisco blocks and portions without producing any undesirable acidic flavors. No acidic flavors were found in portions cut from vacuum-packaged blocks and glazed with a 1-percent ascorbic acid solution; therefore, a combination of vacuum packaging the blocks (if economically feasible) and glazing the portions with ascorbic acid might be commercially useful, since such a treatment increases storage life without the off-flavor produced when the fillets forming the blocks are dipped directly into ascorbic acid.

SUMMARY

The effect of various water-soluble antioxidants, alone or in conjunction with several packaging methods, on the storage life of various frozen cisco products was examined.

In a laboratory study, propyl gallate, ascorbic acid, sodium tripolyphosphate, and monosodium glutamate were mixed at several concentrations with ground cisco flesh, which was then held at 0° F. From 2-thiobarbituric acid (TBA) data alone, ascorbic acid was considered the most effective of the four antioxidants.

In another laboratory study, a single concentration of each of these antioxidants was used in frozen cisco blocks; and, in addition, control, vacuum-packaged, and alginate-glazed control blocks were prepared from nontreated fillets. Sensory and TBA data showed that only ascorbic acid, propyl gallate, and vacuum packaging significantly retarded the development of rancidity in the frozen cisco blocks. The propyl gallate-treated samples, however, had an objectionable "chemical" flavor. Portions cut from ascorbic acid-treated blocks that had been stored for 6 months became rancid after 7 months' additional storage. All portions cut from the other blocks became rancid after from 1 to 3 months' additional storage except those cut from a vacuum-packaged block glazed with a 1-percent ascorbic acid solution —these portions had a shelf life of about 6 additional months.

In field studies, breaded, frozen cisco fillets treated with ascorbic acid alone or with various ice glazes were examined by sensory means. Results showed that all ascorbic acid-treated fillets were acceptable through from 10 to 12 months of storage at 0° F.; control fillets became rancid after from 4 to 6 months of storage.

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MS #1604

TECHNOLOGICAL STUDIES OF DUNGENESS CRAB PROCESSING PART 3 -- LABORATORY EXPERIMENTS IN THE CONTROL OF DRAIN TIME

by

Harold J. Barnett, Richard W. Nelson, and John A. Dassow

ABSTRACT

This study indicates the possibility of improving consumer acceptability of Dungeness crab-meat products by controlling drain-time procedures closely. Specifically, it indicates that the drained weight of crab body and leg meat can be controlled within narrower limits than is customary and that the amount of unsightly nutrient-eluting thaw fluids can be markedly decreased. The result is a product of higher quality.

INTRODUCTION

Project

Need.—In response to a request from the National Fisheries Institute, the Bureau of Commercial Fisheries Technological Laboratory at Seattle has undertaken studies related to the quality of Dungeness crab *(Cancer magister)* products. As an initial step, Nelson [1] made a survey of the major Dungeness crab processing plants on the West Coast and found that methods of processing varied considerably from plant to plant. As a result of this survey, we felt that controlling drain time more closely might result in improved consumer acceptability of the products made from Dungeness crab.

Purpose.—The purpose of the work reported here therefore was to study the effect of drain time on the acceptability of these products.

[1] Richard W. Nelson. Unpublished data presented at the 19th National Fisheries Institute Convention on April 24, 1964. This information is available from the Bureau of Commercial Fisheries Technological Laboratory, Seattle, Washington 98102.

Experimental Approach

Background.—One of the problems arising from variations in drain time is the inclusion of excess process water in the final product—excess water contributes to variations in drained weight. Another problem is the effect of drain time on the quality of the frozen product—variations in drain time contribute to the formation of fluids-freed-upon-thawing. [Fluids-freed-upon-thawing is defined by Collins and Brown (1964) as exudates composed of unknown relative amounts of fluids freed from the original muscle, fluids exchanged during aqueous cooking, and fluids arising from processing water and glaze.] If these fluids are excessive, the product becomes unsightly to the consumer, loses many of its proteins and minerals, and has less pleasing flavor, texture, and color.

Main divisions.—Accordingly, the work reported here was concerned specifically with the effect that varying the drain time would have on (1) the drained weight of the product and (2) the quality of the product.

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I. EFFECT OF VARIATIONS IN DRAIN TIME ON DRAINED WEIGHT

Drained weight is governed in part by the amount of process water that drains away or evaporates and in part by the amount of natural water (drip) that drains away or evaporates.

Drip and other fluids-freed-upon-thawing have been the subject of considerable study. Miyauchi (1963) reviewed the causes of drip formation, Collins and Brown (1964) studied the effect of processing conditions on fluids-freed-upon-thawing from frozen king crab, and Nelson[2] studied variations in the drained weights of Dungeness crab meat. Miyauchi (1962) found that the cook-drip of cod fillets increased during the final 4 or 5 months of frozen storage, and Osterhaug and Nelson (1957) observed that thaw-drip values of frozen Pacific oysters also increased with storage.

These studies indicate that the amount of drip and other fluids exuding from a product depends in part upon its previous history, particularly on whether it has been frozen and held in frozen storage. Thus, in our study of the effect of variations in drain time on drained weight, we studied the product both before it had been frozen and after it had been frozen, stored, and thawed.

A. DRAINED WEIGHT BEFORE FREEZING

1. Samples and Methods

In March 1964, we obtained fresh, commercially cooked and picked (but otherwise unprocessed) Dungeness crab meat in Bay Center, Washington. We blended the body meat and divided it into four rough lots, as we did also the leg meat. Then, according to the following procedure, we:

a. Weighed out exactly 12 pounds of body meat and 12-1/2 pounds of leg meat from each lot.

b. Placed the meat in a tank of saturated brine for 45 seconds to float away shell and then rinsed it for 2.5 minutes in fresh water to remove excess salt.

c. Spread the meat in each portion to a depth of about 2 inches on a stainless-steel tray having 3/16-inch openings on 9/32-inch centers and allowed it to drain at room temperature at an angle of 15 degrees for 2, 5, 15, or 30 minutes.

d. Weighed the drained meat.

e. Adjusted the weight of the processed crab meat by mathematically subtracting 1/2 pound from the weight of each of the initial 12-pound portions of body meat to give a weight of 11-1/2 pounds and 1/2 pound from the weight of each of the initial 12-1/2-pound portions of leg meat to give a weight of 12 pounds. (Prior to laboratory processing, we experimentally determined that an average of 1/2 pound of meat, shell, and extraneous material per 12 to 12-1/2 pounds of sample was lost during brine flotation and fresh-water rinsing. Thus, this new corrected weight allowed us to compare systematically the effects of varying drain times on drained weights.)

2. Results and Discussions

a. **Body meat.**—The effect of variations in drain time on the drained weight of the body meat is shown in Table 1. After a short drain time (either 2 or 5 minutes), the weight of the rinsed meat showed a net gain over the original weight, whereas after a long drain time (30 minutes), the weight of the rinsed meat showed a net loss. This loss can be attributed to the loss of small particles of meat, of soluble nitrogen compounds, and of water that had evaporated. The minimum change in weight (+ 0.5 percent) occurred following a drain time of 15 minutes. Hence,

[2] See footnote 1.

Table 1.—Weight of body and leg meat of the Dungeness crabs after fresh-water rinse and varied times of draining

Drain time	Body-meat data						Leg-meat data					
	Corrected weight		Weight after rinsing and draining		Weight change		Corrected weight		Weight after rinsing and draining		Weight change	
Min.	*Lb.*	*Oz.*	*Lb.*	*Oz.*	*Oz.*	*%*	*Lb.*	*Oz.*	*Lb.*	*Oz.*	*Oz.*	*%*
2	11	8	12	8	+16	+8.7	12	0	12	7	+7	+3.8
5	11	8	12	1	+ 9	+4.9	12	0	12	0	0	0
15	11	8	11	9	+ 1	+0.5	12	0	11	12	- 4	- 2.1
30	11	8	10	15	- 9	- 4.9	12	0	11	8	- 8	- 4.2

Note: "Corrected weight" is the weight of the meat after shell and other materials were lost during brine flotation.

15 minutes is about the optimum drain time for body meat from the standpoint of uniformity of weight control.

b. Leg meat.—Table 1 also shows the effect of drain time on the processed leg meat. Although the changes in the drained weight of the leg meat differed from those of the body meat, the pattern of change was similar. That is, after a 2-minute drain time, the weight of rinsed leg meat showed a net gain over the original weight, whereas after a long drain time (either 15 or 30 minutes), it showed a net loss. The data indicate that, under the conditions of the experiment, a drain time of about 5 minutes is optimum for leg meat.

The optimum drain time is much shorter for leg meat than for body meat because the leg meat has greater integrity—that is, since the interstices are fewer, the capillary action has less effect, and water can drain away faster.

B. DRAINED WEIGHT AFTER FROZEN STORAGE AND THAWING

1. Samples and Methods

In our study of crab meat that had been frozen, stored, and thawed, we:

a. Divided each of the eight drain lots (consisting of four 12-pound portions for each type of meat) into approximately 1-pound samples, packed each sample into a No. 2 tin, and sealed the tins hermetically under vacuum.

b. Packed, about 1 pound to a tin, 12 No. 2 tins with body meat and 12 No. 2 tins with leg meat that had not been subjected to brine flotation, fresh-water rinse, or draining, and sealed the cans hermetically under vacuum for use as control samples.

c. Quick froze the samples at -20° F. for 12 hours and stored them at 0° F.

d. At intervals of 0, 1, 3, and 6 months, removed three cans from each of the eight lots and from the control samples.

e. Thawed the samples at 35° ± 1° F. overnight; spread them to a depth of about 1 inch over a 12- by 15-inch, 8-mesh, stainless-steel screen; and drained them individually for a standard 5-minute period.

f. Weighed the thawed and drained samples to determine their loss in weight due to the formation of fluids-freed-upon-thawing and combined these fluids for use in the experiment, described in the next section, on the effect of varying drain time on quality.

2. Results and Discussion

a. Results.—Table 2 shows the effect of frozen storage and drain time on the fluids-freed-upon-thawing. In general, the amount of these fluids tended to increase with storage time and to decrease with drain time. In the body meat, the amount of the fluids-freed-upon-thawing associated with a drain time of 15 minutes (optimum from the standpoint of drained weight) was not markedly greater than the

Table 2.—Formation of the fluid-freed-upon-thawing in body and leg meat of the Dungeness crabs after frozen storage

Storage time at 0° F.	Fluids-freed-upon-thawing from:									
	Body meat that was drained for:								Body-meat control	
	2 minutes		5 minutes		15 minutes		30 minutes			
	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Months	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0	12.6- 2.1	6.6	3.2-0.7	2.2	4.7-1.6	2.8	3.0-1.0	1.7	—	3.8
1	9.2- 6.5	7.7	4.2-3.1	3.4	4.0-2.2	3.3	2.7-1.2	2.0	—	2.1
3	11.7-11.2	11.3	8.1-4.8	6.0	3.1-1.2	2.2	3.3-2.8	3.0	5.5-3.9	4.7
6	12.6- 9.8	11.6	6.9-5.6	6.2	3.6-1.0	2.7	5.9-2.4	3.6	6.4-4.3	5.6
Storage time at 0° F.	Leg meat that was drained for:								Leg-meat control	
	2 minutes		5 minutes		15 minutes		30 minutes			
	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Months	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0	5.4-4.1	4.9	4.8-2.1	3.5	3.5-2.2	2.7	3.4-2.2	2.9	—	2.6
1	5.5-5.1	5.3	4.5-4.2	4.3	3.7-2.7	3.1	5.3-4.2	4.5	—	3.2
3	7.8-5.5	7.0	7.0-6.2	6.5	4.9-4.3	4.6	5.0-3.6	4.3	4.1-2.8	3.6
6	7.5-6.1	6.7	6.2-5.5	5.8	5.4-4.1	4.7	6.4-5.6	5.9	4.0-3.7	3.8

amount associated with a drain time of 30 minutes. In the leg meat, the amount of the fluids associated with a drain time of 5 minutes (optimum from the standpoint of drained weight) also was not markedly greater than the amount associated with a drain time of 30 minutes.

b. Discussion.—In comparing the relative amounts of fluids-freed-upon-thawing with drain time, we expected the starting amount of physically entrained water to be greatest for the shortest drain period. We found this relation to be particularly true of the body-meat samples drained for 2 and 5 minutes prior to being packaged. The increases can be explained by the nature of the packing conditions, as body flesh is drained in such a manner that water is both physically entrained and occluded in the flesh. Large amounts of processing water are subsequently carried over into the finished product. Although the leg meat that had been drained for 2 minutes retained excess process water (Table 1), the other leg meat did not; consequently, the variation in drain time had a greater effect on the amount of fluids-freed-upon-thawing from body meat than on the amount from leg meat. Except for the increased fluids from the body-meat samples drained for 2 and 5 minutes and from leg-meat samples drained for 2 minutes, increases in fluids-freed-upon-thawing were due more to the effects of frozen-storage time than to those of drain time.

II. EFFECT OF VARIATIONS IN DRAIN TIME ON QUALITY

A. OBJECTIVE MEASUREMENTS

1. Chemical Measurements

A number of workers have studied the composition of drip from processed fish and have used it as an indication of changes in quality. Good (1954), Miyauchi (1964), and Sanford (1952)[3] observed changes in drip from fish muscle, and Brown and Collins (1961) reported on the composition of drip from processed king crab. Procedures used by these workers were adapted to this study.

The samples used were prepared and the fluids-freed-upon-thawing were collected as previously described. The fluids were analyzed for total solids and for nitrogen components, so that we could gain an indication of what effect varied drain times had on loss of protein and other substances, such as minerals.

[3] F. Bruce Sanford. 1952. Unpublished data from progress reports of the Bureau of Commercial Fisheries Technological Laboratory, Seattle, Washington 98102.

a. Total solids.—Total solids were determined by weighing from 3 to 5 grams of fluids-freed-upon-thawing into 2-3/8- by 5/8-inch aluminum dishes and drying the fluids at 105° F. in a mechanical convection oven to constant weight.

Both body-meat and leg-meat total solids (Table 3) for all processed samples increased during the first month of storage regardless of the amount of time the samples were drained. However, after 3 months' storage, a marked decrease from the 1-month results was noted in most of the samples. A conspicuous exception was the body-meat sample drained for 30 minutes, which had a large unexplained increase. During the period from 3 to 6 months, the changes did not appear to follow a well-defined pattern.

b. Nitrogen components.—Total nitrogen and protein nitrogen were determined.

(1) Total nitrogen.—Total nitrogen was determined by the standard macro Kjeldahl method (Association of Official Agricultural Chemists, 1955).

Table 3.—Total solids in fluids-freed-upon-thawing from body and leg meat of the Dungeness crabs that had been drained for varying periods and held in frozen storage

Storage time at 0° F.	Total solids in fluids-freed-upon-thawing from:									
	Body meat drained for:				Body-meat control	Leg meat drained for:				Leg-meat control
	2 min.	5 min.	15 min.	30 min.		2 min.	5 min.	15 min.	30 min.	
Months	%	%	%	%	%	%	%	%	%	%
0	3.7	3.3	4.2	3.4	2.4	5.9	5.0	5.7	5.8	4.5
1	6.6	8.2	7.1	5.9	4.5	6.0	7.3	7.2	6.8	6.6
3	4.9	6.2	6.0	7.5	3.6	5.9	6.1	6.1	6.5	6.8
6	4.9	6.1	6.6	5.7	3.1	6.5	6.7	6.9	6.7	6.5

Table 4.—Total nitrogen in fluids-freed-upon-thawing from body and leg meat of the Dungeness crabs that had been drained for varying periods and held in frozen storage

Storage time at 0° F.	Total nitrogen in fluids-freed-upon-thawing from:									
	Body meat drained for:				Body-meat control	Leg meat drained for:				Leg-meat control
	2 min.	5 min.	15 min.	30 min.		2 min.	5 min.	15 min.	30 min.	
Months	%	%	%	%	%	%	%	%	%	%
0	0.26	0.30	0.29	0.34	0.50	0.41	0.60	0.56	0.71	0.71
1	0.26	0.28	0.30	---	0.52	0.56	0.49	0.49	0.72	0.79
3	0.23	0.28	0.26	0.13	0.46	0.50	0.56	0.56	0.64	0.75
6	0.26	0.31	0.20	0.15	0.40	0.77	0.78	0.78	0.76	0.85

Total nitrogen (Table 4) in fluids-freed-upon-thawing from the body meat did not change significantly in any of the treated lots.

Total nitrogen in fluids-freed-upon-thawing from the leg meat increased in all samples. The samples drained for 30 minutes showed the least change in nitrogen content after frozen storage for 6 months.

(2) Protein nitrogen.—Protein nitrogen was determined by biuret analysis (Snow, 1950).

Protein nitrogen in fluids-freed-upon-thawing from body meat (Table 5) for all drained lots and control samples increased twofold during frozen storage for 6 months. The increase in protein nitrogen was due primarily to the frozen storage rather than to the drain procedure.

Protein nitrogen in fluids-freed-upon-thawing from leg meat (Table 5), although higher than that in the fluids from body meat, showed little or no change as a result of variation of drain time.

The concentration of protein nitrogen in the fluids-freed-upon-thawing was low because the protein was denatured by heat during the commercial cook; hence, less protein was dissolved in the fluids.

2. Physical Measurements

Measurements of shear force were used to show changes in texture, and therefore quality, in the frozen crab meat. The hydraulic shear instrument described by Dassow, McKee, and Nelson (1962) was used in this experiment.

Data presented in Table 6 show the shear data for body meat only. (Leg segments are irregular in size and toughness; hence, they do not give reproducible measurements and so were not used.) No appreciable differences in texture were evident as a result of drain-time treatments; therefore, only average values are given for processed samples from each drain period.

Table 5.—Protein nitrogen in fluids-freed-upon-thawing from body and leg meat of Dungeness crabs that had been drained for varying periods and held in frozen storage

Storage time at 0° F.	Protein nitrogen in fluids-freed-upon-thawing									
	Body meat drained for:				Body-meat control	Leg meat drained for:				Leg-meat control
	2 min.	5 min.	15 min.	30 min.		2 min.	5 min.	15 min.	30 min.	
Months	%	%	%	%	%	%	%	%	%	%
0	0.07	0.07	0.06	0.06	0.03	0.13	0.17	0.19	0.20	0.11
1	0.10	0.10	0.13	0.12	0.09	0.09	0.18	0.19	0.17	0.14
3	0.10	0.13	0.15	0.15	0.07	0.13	0.13	0.14	0.15	0.15
6	0.11	0.14	0.06	0.14	0.06	0.18	0.18	0.18	0.18	0.15

Table 6.—Results of texture measurements and sensory evaluations of the crab meat of the Dungeness crabs

Storage time at 0° F.	Drain time	Texture readings		Sensory judgments (comments)
		Average of 10 readings	Control	
Months	*Minutes*	*Lb./15 g. sample*	*Lb./15 g. sample*	
0	2 5 15 30	20 21 21 21	20	Normal color, odor, and flavor; texture slightly firm—resilient
1	2 5 15 30	26 26 26 27	27	Normal color, odor, and flavor; texture firm
3	2 5 15 30	26 30 30 28	26	Moderate degree of change in color, odor, and flavor; texture slightly tough
6	2 5 15 30	31 32 32 29	29	Strong degree of change in color, odor, and flavor; texture tough

Texture values for all samples increased during storage. The greatest increment of change occurred during the first month of storage. Results indicate that frozen storage had a greater effect on the changes than did drain time.

B. SUBJECTIVE MEASUREMENTS

Subjective measurements were made so that we could determine what effect, if any, process drain time would have on color, odor, and flavor.

The changes in color, odor, and flavor (Table 6) were determined by a taste panel familiar with the organoleptic testing of Dungeness crab. Organoleptic changes after 1-month storage were slight; only after 3 months was the magnitude of the change sufficient to be detected with certainty. No particular correlation was found between process treatment and sensory changes.

SUMMARY AND CONCLUSIONS

The purpose of the research reported here was to study the effect of processing drain time on the acceptability of Dungeness crab products. The experimental work was concerned specifically with the effect of drain time on (I) the drained weight of the product and (II) its quality.

I. Variation in drain time affected loss of weight in body meat to a greater extent than it did the loss of weight in leg meat. A drain period of 15 minutes prior to packaging appears to be optimal for body meat, and a drain period of 5 minutes appears to be best, or at least adequate, for leg meat.

Varying the drain time affected the formation of fluids-freed-upon-thawing from the frozen product. Drip losses from body meat were greater than those from leg meat.

II. Drain procedures affected the amount of total solids lost in the fluids-freed-upon-thawing. The effect was greater in body meat than in leg meat.

Nitrogen components in the fluids-freed-upon thawing increased slightly during frozen storage. The content was higher in the fluids from the leg meat than in those from the body meat. However, the increases showed no trend in relation to drain time and can therefore be attributed more to storage conditions than to drain time.

Shear-force values used to gain an indication of the texture of body meat increased for all processed samples during frozen storage. The small differences occurring in texture as a result of differences in drain times suggest that storage time had a greater effect on quality change than did drain time.

Deterioration of color, odor, and flavor was noticeably affected more by frozen storage than by drain time.

The overall conclusion from this study is that controlling drain time closely will improve the consumer acceptability of Dungeness crab-meat products primarily as a result of closer control of drained weight and of decreased loss in total solids.

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MS #1615

TEMPERATURE, WEIGHT, AND DRIP CHANGES DURING PRECOOKING OF TUNA

by

Alexander M. Dollar, Andrew Goldner, and Harold S. Olcott

ABSTRACT

Changes in temperature, weight, and drip of tuna during precooking under commercial conditions were studied. The increase in internal temperature during precooking was delayed by incomplete thawing of the tuna prior to the cooking. Solids in the collected drip averaged from 3 to 4 percent of the drip. The pH of the drip remained virtually constant at 6.3 or 6.4 as the cooking progressed.

INTRODUCTION

Preparing tuna for canning includes cooking the fish before the trimming or cutting operations. This precooking alters the texture of the tissue in such a manner that the dark and light meat can be separated easily. It also removes odors as volatiles but causes some of the water, oil, and extractives to be lost as drip—that is, as exuded liquor.

During studies on the color of canned tuna (Brown, Tappel, and Olcott, 1958; Dollar, Brown, and Olcott, 1959; and Dollar, Brown, and Olcott, 1961), we became interested in the change that takes place in the internal temperature of the fish during the precooking operation. Also, because the loss of weight resulting from drip is of commercial importance, we became interested in the factors involved in weight loss as well as any changes that might take place in the drip itself. Through the courtesy of a firm in San Francisco, California, we were able to investigate these variables during typical commercial precooking runs.

The purpose of this paper, therefore, is to report our findings concerning (I) the changes that take place in the temperature of tuna flesh during commercial precooking and (II) the loss of weight through drip and evaporation and the changes in the composition of the drip as cooking progresses.

I. TEMPERATURE CHANGES

A. PROCEDURE

The procedure primarily involved (1) preparing the fish for precooking, (2) precooking, and (3) measuring the internal temperature of the fish during the precooking operation. Two runs were made, each taking about 5 hours' cooking time.

1. Preparation of Fish for Precooking

Frozen yellowfin tuna *(Thunnus albacares)* were unloaded and placed on the cement floor of the firm's butchering shed to thaw. In commercial practice, before the fish are completely thawed, the heads are removed, and those fish received in the round are gutted. Normally, fish larger than 20 pounds are sawed in half lengthwise; very large fish are sawed in quarters. In the present experiment, the fish were already gutted. They were similar in size, and none was exceedingly large. Accordingly, it was necessary only to remove the heads and to cut the fish in half. The pieces were placed, cut-side down, on butcher paper in wire baskets, and the baskets, in turn, were placed on racks. The racks

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were wheeled into the retort area and loaded into the retort. There was no direct control of the thawing operation, so the baskets contained incompletely thawed as well as completely thawed fish.

2. Precooking Procedure

When the retort was filled, the doors were closed and clamped. (The retort chamber is constructed of heavy sheet steel and is vented so that the air can be expelled.) A warming period of 45 minutes preceded the cooking time. Steam was admitted into the retort through a manifold at a pressure of from 14 to 15 pounds per square inch. Positive steam pressure was maintained in the retort chamber at 5 pounds per square inch throughout the cooking operation. Toward the end of the cook, as in regular commercial practice, the steam was turned off, the retort was opened, and one or two racks were wheeled out. The internal temperature of the fish pieces was spot-checked with a metal meat thermometer inserted into the thickest portion of the fish. When, by this method of checking, the internal temperature of the fish reached 155° F. or higher, the precooking was terminated, and the retort was unloaded.

3. Internal Temperature Measurements

Before the precooking operation began, three thermocouples (copper-constantan) were imbedded in various parts of the tuna halves—one thermocouple near the surface (about 1/4 inch deep), one midway between the surface and the center (about 1 inch deep), and one near the center of the meat (about 2 inches deep). The tuna halves being studied for temperature change were located in the top basket (Fish T), the middle basket (Fish M), and the bottom basket (Fish B) of a rack located next to the door of the retort. The thermocouple leads were passed through a stuffing gland to the exterior of the retort and connected to an internally compensated Leeds and Northrup potentiometer[1] calibrated to read temperature directly in degrees Farenheit.

B. RESULTS

Data from the first run show that the rate of increase in the temperature of the test pieces varied considerably, depending upon (1) the depth within the fish at which the temperature was measured, (2) the initial temperature of the flesh, and (3) the location of the fish in the cooking rack (Figure 1).

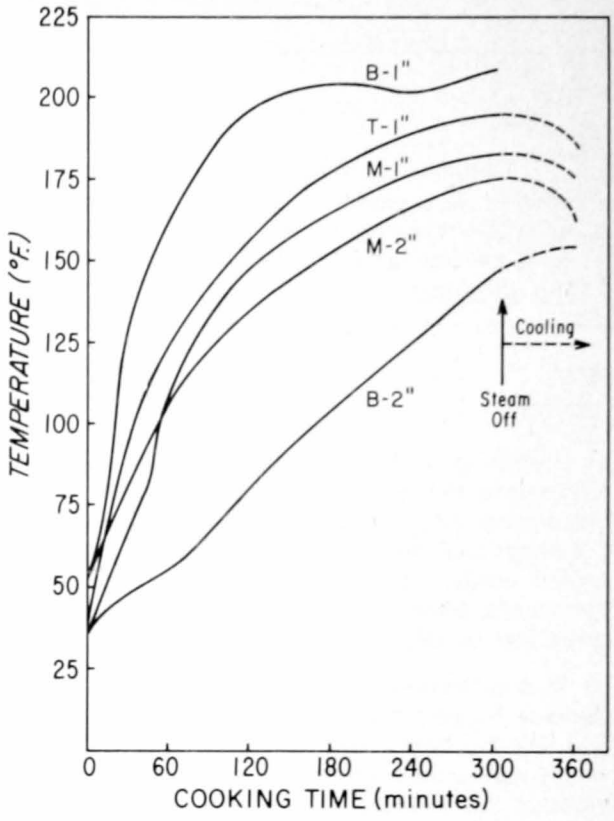

Figure 1.—Change of temperature in tuna during an industrial cooking operation — Run 1. (T = top basket; M = middle basket; B = bottom basket. 1" = thermocouple that is 1 inch deep; 2" = thermocouple that is 2 inches deep.)

The data for the second run (Figure 2) indicate that the rate of heating was influenced by the position of the fish in the retort.

[1] Trade names are mentioned merely to simplify the description of the experimental equipment; no endorsement is implied.

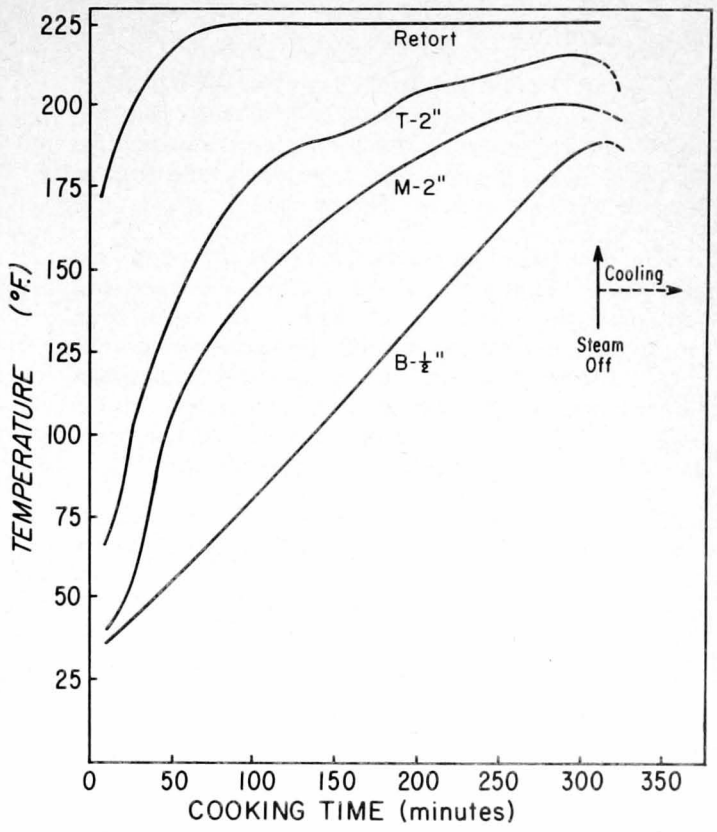

Figure 2.—Change of temperature in tuna during an industrial cooking operation — Run 2. (T = top basket; M = middle basket; B = bottom basket; ½" = thermocouple that is ½ inch deep; 2" = thermocouple that is 2 inches deep.)

II. WEIGHT AND DRIP CHANGES

A. WEIGHT CHANGES

1. Procedure

The loss in weight of the halves was determined by weighing them before and after they were precooked and comparing the weights. Changes in moisture concentration were determined by drying weighed portions of the fish to constant weight in a vacuum oven at 70° C. and then making the appropriate calculations.

Weight changes were measured at the same time that drip was collected. Because the drip-collecting device occupied the place that otherwise would have been filled by the bottom basket, Fish B was not included in the study of weight or drip changes.

2. Results

During the precooking operation, the fish lost more than one-fourth of their weight (Table 1). Although the decrease in the concentration of moisture accounted for most of this loss, moisture concentration decreased by only 3.6 percent (74.0-70.4). These seemingly anomalous data result because moisture is the major constituent in fish and, even after a large amount of moisture is lost, a large amount relative to the other constituents still remains.

Table 1.—Changes in weight and moisture in tuna halves during the precooking

Fish	Weight			Moisture	
	Raw fish	Cooked fish	Loss	Raw fish	Cooked fish
	Pounds	*Pounds*	*Percent*	*Percent*	*Percent*
T (Top basket)	38	28	26.3	74.1	70.6
M (Middle basket)	39	28	28.3	73.9	70.3
Total	77	56			
Average			27.3	74.0	70.4

B. DRIP CHANGES

1. Procedure

To collect drip, we installed a series of five tubes 1.1 inches in outside diameter and 3 feet long beneath the fish rack and interconnected them by glass tubing to allow the overflow from each tube to pass into the succeeding tube (Figure 3).

The first tube was connected to the drainage hole at a corner of the pan fitted under the basket rack containing the fish being studied. We hoped that, as each tube filled with drip, the drip would flow into the next tube and be collected continuously. Any progressive changes in the composition of the drip (as indicated by pH and percent solids) could thereby be determined as cooking continued.

Two runs were made. The second run differed from the first in that the coagulum was recovered.

The amount of dry solids in the drip was determined by drying weighed portions of the drip to constant weight in a vacuum oven at 70° C. pH was measured electrometrically.

2. Results

In Run 1, the tray installed to catch the drip was not inclined sufficiently, so the collected liquid failed to drain quickly and completely. Furthermore, not all the drip could drain because part of it coagulated at the high temperature of the retort. The solids in the collected drip varied from 3.4 to 5.0 percent (average, 4.1), and the pH remained quite constant at 6.3 or 6.4 (Table 2).

Table 2.—Data on drip, Run 1

Tube	Drip		
	Volume	Dry solids	pH
Number	*Ml.*	*Percent*	
1	485	5.0	6.3
2	560	3.7	6.4
3	525	3.4	6.4
4	60	4.3	6.4
Total	1,630		
Average		4.1	6.4

1,630 milliliters of drip having a specific gravity of about one was collected. This volume represents about 43 percent of the total loss in weight, since the actual loss in weight of the fish was 8.4 pounds. The remainder of the loss was due to evaporation and to the coagulum adhering to the drip pan.

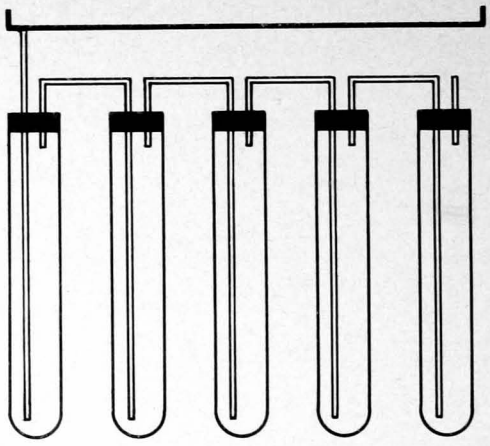

Figure 3.—Series of tubes for collecting drip (not to scale).

The collected drip contained about 4 percent of the solids (Table 2), which represents an estimated loss of solids of about 0.2 pounds per 100 pounds of the original fish. No progressive changes in pH took place in the collected samples of drip.

In Run 2, about the same pH was observed as in Run 1, but the concentration of solids in the drip was lower, averaging only 2.7 percent (Table 3). As in Run 1, the greater amount of solids was lost during the early stages of the precook.

Table 3.—Data on drip, Run 2

Tube	Drip		
	Volume	Dry solids	pH
Number	*Ml.*	*Percent*	
1	530	3.5	6.3
2	570	2.6	6.3
3	550	2.4	6.3
4	400	2.3	6.3
Total	2,050		
Average		2.7	6.3

The fish used in the second run had an original weight of 28.8 pounds, a postcooking weight of 19.7 pounds; thus, the net loss (9.1 pounds, or 4,126 grams) was 31.6 percent. 66 grams of coagulum was recovered, which, with the 2,050 grams of drip from the collection tubes, made a total of 2,116 grams recovered. Hence, drip and coagulum accounted for 51 percent of the total loss in weight of the fish during the cooking operation. The remaining 49 percent of the loss was evidently due to the evaporation of moisture and to the loss of other volatiles.

SUMMARY

Observations on the changes in temperature in tuna during the precook operation showed that the rates of heating differed markedly at various depths in the fish. These rates depended essentially on the temperature of the fish when it was put into the retort and on the position of the fish in the retort.

The results suggest that drip may account for about half of the 26 to 28 percent loss in weight during the cook. The solids content of the recovered drip averaged from about 3 to 4 percent. The greater amount of solids was lost during the early stages of the precook. During the entire time of the precook, the pH of the recovered drip remained at a constant 6.3 or 6.4.

ACKNOWLEDGMENT

T. Sanford and the staff of the F. E. Booth Company of San Francisco, California, cooperated in this study and made available the commercial equipment used.

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MS #1605

EFFICACY OF FISH OILS IN HEALING WOUNDS AND BURNS

by

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ABSTRACT

Traditionally, fish oils are purported to effect rapid or improved healing of skin lesions, such as wounds and burns. To test this belief, we carried out an experimental study on hairless mice, which were given reproducible cuts or burns and treated with various types of fish oil. Experimental treatments included the use of (1) menhaden oil containing glyceryl ethers, (2) cod-liver oil containing a considerable amount of vitamin A, (3) a highly unsaturated fish oil (menhaden) without additives, (4) a commercially prepared ointment containing cod-liver oil, and (5) a laboratory prepared ointment also containing cod-liver oil. Control treatments included the use of (1) mineral oil, (2) the use of an ointment containing no fish oil, and (3) no treatment whatever. Completely negative results were obtained except that, in some cases, the use of any oil, including mineral oil, shortened healing time.

INTRODUCTION

A widespread belief exists that fish oils or fish-liver oils possess properties that enable them to promote the healing of various skin lesions such as wounds and burns. Few published scientific reports can be found supporting this view, however, other than some that deal with fish-liver oils as a source of vitamin A used for such purposes (Drigalski, 1934; Grayzel, Heimer, and Grayzel, 1953; Proto, 1937) and a few that indicate the effectiveness of glyceryl ethers (Bodman and Maisin, 1958; Brohult, 1964).

Actually it has not been established that any chemical component will promote the healing of skin lesions, aside from providing vitamins (where they may be deficient), reducing bacterial growth, or preventing the access of air.

Nevertheless, fish oils are incorporated in several ointments that are used for healing various types of skin lesions; moreover, these ointments have widespread sale in American markets. Users insist that these preparations are highly effective in promoting rapid healing of various skin conditions. To determine whether fish oils actually possess some kind of healing property, the Mayo Clinic, under contract to the Bureau of Commercial Fisheries, carried out an experimental study of wound and burn healing.

I. EXPERIMENTAL CONDITIONS

Hairless mice under 3 months of age were used as the experimental animals. They were selected at random from a colony developed and kept at the Mayo Clinic for various experimental purposes. Once selected, the mice were held at 76° F. and were fed only a standard Purina laboratory chow diet[1].

By the use of techniques designed to make as uniformly reproducible a lesion as possible, each mouse was given either a wound or a burn. The wounds were made by grasping the dorsal lumbar fold of skin and cutting away, with sharp scissors, a 1- by 2-centimeter area. Although the cuts were made through both the dermis and epidermis, no significant hemorrhages occurred. The burns were made by placing, for 1 second on the dorsal region

[1] Use of trade names is to simplify descriptions; no endorsement is implied.

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of the mouse, the flat spatula end of a cautery device (Post Electric Company, Inc.) heated electrically to almost a red heat. This cauterizing produced a third-degree burn of uniform size in from 2 to 3 seconds.

Immediately following the cutting or burning operation, each wound or burn was brushed with one of the oils being evaluated. Thereafter, daily observations were made to determine the number of days required to effect healing. A wound or burn was considered to be healed when the crust dried and dropped off leaving a scar.

The following oils were used in the treatment of the wounds or burns:

1. A heavy grade of mineral oil (Number 5) and sufficient dimethyl aminoazobenzene dissolved in the oil to give it a color matching the average yellowish tint of the other oils. This oil served as a control.

2. A light, cold-pressed, menhaden oil obtained from Haynie Products, Inc., Baltimore, Maryland. This oil had an iodine value of 176 and a saponification number of 192. It was further refined by clay bleaching and molecular distillation (Gauglitz and Gruger, 1965).

3. A U.S.P. cod-liver oil manufactured by Marine Products Company, Boston, Massachusetts.

4. A menhaden oil similar to the oil in 2 but containing 1 pound of glyceryl ethers per gallon of oil (13 percent glyceryl ethers). The glyceryl ethers were obtained from Western Chemical Industries Company, Vancouver, British Columbia. They were made by saponification of dogfish *(Squalus acanthias)* liver oil and contained, as an impurity, about 5 percent of soaps. Although no analysis of the glyceryl ethers of this batch was available, they doubtlessly were typical of the usual mixed glyceryl ethers from dogfish-liver oil; such ethers are generally 80 percent or more selachyl alcohol, with most of the remainder being chimyl alcohol.

5. A commercial ointment containing cod-liver oil, zinc oxide, lanolin, petrolatum, and talcum.

6. A control ointment containing the same ingredients as the ointment in 5, except that the cod-liver oil was omitted.

The oils and ointments were applied daily. In some of the initial experiments, the oils were applied twice daily; but, because this treatment did not improve healing and even seemed to cause adverse effects, most of the trials were made with one daily application. Ten mice were always used for each experimental group, and the healing time for the 10 animals was averaged.

II. RESULTS

Completely negative results were obtained. In no experiment did any of the fish-oil preparations give better results than did the mineral-oil control. In most experiments, the mineral-oil control effected shorter healing times than did the fish oils, but the differences were slight and were not considered to be significant. The results were the same whether a wound or a burn was being healed. Controls in which no oil of any kind was used sometimes caused the healing to take significantly longer than when the mineral or fish oils were used. In other experiments, no difference was noted.

As an example of the negative results obtained, typical data for an experiment are shown in Table 1. In this experiment, as with most of the others, the animals treated with the fish product (in this case, cod-liver oil) took about a day longer, on the average, to heal than did those treated with either the control without oil or the control with mineral oil. This difference, however, is not statistically significant.

Table 1.—Healing time for burns on hairless mice

Identifying number for the mouse used in each experimental group	Healing time with:		
	No oil (Control)	Mineral oil (Control)	Cod-liver oil
	Days	*Days*	*Days*
1	21	16	18
2	19	20	22
3	24	21	20
4	22	21	23
5	25	23	23
6	20	28	20
7	21	23	28
8	22	20	23
9	(Died)	20	27
10	22	24	21
Average for the group	21.8	21.6	22.5

III. DISCUSSION

The three fish oils were selected on the basis of their containing at least one of the three components to which the alleged healing properties of fish oils have been ascribed. Menhaden oil is a source of highly polyunsaturated fatty acids, which some times have been believed to be valuable in the promotion of healing. The cod-liver oil, in addition to containing polyunsaturated fatty acids, also contained vitamin A, often also supposed to promote healing. The glyceryl ethers, present to a considerable extent in various fish oils, especially in those from shark, have additionally been suggested as agents in the healing of certain types of wounds.

With respect to glyceryl ethers, internal consumption rather than external application is the more, usual method of use, so the absence of beneficial results in our experiments is not particularly surprising. With respect to the vitamin A effect from the cod-liver oil, most literature references that endorse the use of vitamin A for healing are fairly old; modern theory probably offers no great support to the view that the external application of vitamin A preparations is helpful. Nevertheless, the continued use of commercial products containing vitamin A for skin lesions warranted our testing a vitamin A product. To our knowledge, the efficacy of externally applied unsaturated fatty acids as healing agents has never been well documented, though their use is often suggested in references to vaguely mentioned experiments.

An explanation of the general attitude toward fish oils as healing agents may be found in our own attitudes toward the lesions while the experiments were in progress. We observed that the oil-treated lesions were cleaner, so we gained the impression that they were healing faster. A clean lesion, as we found out, however, is not the ultimate test of quick recovery. It may be that this feature of an oil-treated lesion has been deceptive in indicating fast as well as neat healing to generations of observers.

CONCLUSIONS

Fish oil of three types — one an oil (menhaden) containing 13 percent glyceryl ethers, one an oil (cod liver) containing vitamin A, and one a refined highly unsaturated oil (menhaden) — applied externally to wounds and burns on hairless mice failed to promote healing to any greater extent than did mineral oil applied in the same manner. On occasion, however, mice treated with any one of the oils, including the mineral oil, would heal slightly faster than would mice treated with no oil at all.

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MS #1613

CHEMICAL COMPOSITION OF COMMERCIALLY IMPORTANT FISH OF THE UNITED STATES

by

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ABSTRACT

The chemical composition of fish varies widely from species to species and also from fish to fish within a given species. Data on the composition of important American food fish are tabulated with respect to proximate composition, content of water, minerals, proteins, amino acids, lipids, vitamins, and other constituents.

CONTENTS

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Revision of Fish and Wildlife Service Fishery Leaflet 116.

INTRODUCTION

When we attempted to revise Fish and Wildlife Service Fishery Leaflet 116 *(Composition of Fish* by M. E. Stansby) prepared in 1944, we found that more information had accumulated on the chemical composition of fish since the leaflet was issued than existed in all sources up to 1944. Accordingly, we have subsantially rewritten the leaflet. In doing so, we have considered the chemical composition of the commercially important fish of the United States from two points of view: (1) proximate composition and (2) chemical constituents.

Section 1. PROXIMATE COMPOSITION

During the latter part of the 19th century, W. O. Atwater, working at Wesleyan University, Middletown, Connecticut, established what became the first experimental station of the United States Department of Agriculture (Maynard, 1962). He worked extensively on composition of agricultural products and fertilizer. In 1879, the United States Commission of Fish and Fisheries (a predecessor of the United States Fish and Wildlife Service, Bureau of Commercial Fisheries) and the Smithsonian Institution sponsored work to extend his investigations to fishery products.

During the next 5 years, Atwater and his students analyzed for proximate composition many thousands of samples of food fish. The analytical methods they used were adequate even by present standards. When the work was completed, in 1884, a vast amount of data on proximate composition of fish, useful even today, became available. For more than 50 years, these data represented almost the only information on proximate composition of American food fish in existence. Many of the results of this work can be found in the report for 1888 to the Commissioner, Commission of Fish and Fisheries (Atwater, 1892).

To fill in gaps on composition of fish not important in Atwater's day, the Bureau of Commercial Fisheries Technological Laboratory at Seattle began to analyze the proximate composition of fish — in 1936, of fish from the Pacific Northwest and, in 1951, of those from the Great Lakes and the rivers of the Central United States. Since 1960, this effort to increase knowledge of proximate composition of food fish from all American sources has been centralized in the Bureau's Technological Laboratory at Pascagoula, Mississippi.

In this report, unless otherwise stipulated, references to the composition of fish (or of shellfish) relate to the composition of edible flesh, free of bone, skin, or shell.

Composition may vary greatly from fish to fish, so analyses made on only a few samples are not necessarily representative. In many instances, the variation between individual fish is so great that the average composition is of only theoretical interest.

The component showing the greatest variation is oil. Certain species of fish produce and store excess oil when feeding. Many such fish use these reserves during migrations or periods of adverse conditions. This pattern of oil production and usage is manifested by the seasonal variations that occur in the concentration of oil. For example, the concentration of oil in mackerel (Stansby and Lemon, 1941) may vary as much as elevenfold between fish caught in the spring, when the concentration is low, and those caught in the summer, when the concentration is high. Other factors that may cause a variation in the concentration of oil in fish include type of food consumed, locality where fish are caught, and size, age, and sexual condition of the fish. Within a given species, the concentration of oil tends to vary less in small fish than in large fish.

Other components also vary. The concentration of water, for example, usually varies inversely with oil concentration. In the edible portions of the flesh, the sum of the concentrations of water and oil is ordinarily close to a constant value, usually about 80 percent.

Most species of fish fall into one of five categories, based upon the content of oil and protein ordinarily occurring in the flesh (Table 1).

Table 2 lists fish by category, with certain species falling into more than one category. The oil in some species, especially those that have more than the minimum oil content, varies appreciably from batch to batch — for example, the fish may ordinarily fall into one oil-protein category, but at certain seasons of the year they may occasionally fall into another. This variation is particularly noticeable for species in Category B, some of which occasionally fall into Category A or Category C.

Table 1.—Categories according to oil and protein content

Type	Oil content	Protein content	Category	Prototype	Remarks
	Percent	*Percent*			
Low oil—high protein	Under 5	15 to 20	A	Cod	Most common category; oil content usually closer to 1 or 2 percent than 5 percent
Medium oil—high protein	5 to 15	15 to 20	B	Sockeye salmon	Second most common category
High oil—low protein	Over 15	Under 15	C	Siscowet lake trout	A less common category; when the oil is high, the protein content is usually low — under 15 percent
Low oil—very high protein	Under 5	Over 20	D	Skipjack tuna	Though not a common category, several species in it are highly important commercially — for example, tuna and halibut
Low oil—low protein	Under 5	Under 15	E	Clams	Category for shellfish such as clams and oysters

Source: Stansby (1962).

Table 2.—Oil and protein categories of commercially important fish and shellfish

[P = primary category; S = secondary category]

Fish and shellfish	Category					Remarks
	A Low oil	B Medium oil	C High oil	D Low oil—very high protein	E Low oil—low protein	
Alewife		P				
Anchovy		P	S			
Buffalofish	P					
Butterfish	P					
Carp	P	S				
Clam					P	Oil content very low
Cod	P					Oil content very low
Crab	P					Oil content very low
Croaker	P					
Flounder	P					
Haddock	P					Oil content very low
Hake	P					
Halibut				P		
Herring:						
Lake	P					
Sea		P	S			
Lobster	P					Oil content very low
Mackerel		P	S	S		
Menhaden		P	S			
Mullet	P	S				
Oyster					P	Oil content very low
Perch:						
Ocean	P					
Yellow	P					Oil content very low
Pollack	P					
Rockfish	P					
Sablefish		P	S			
Salmon:						
Atlantic	S	P				
Chum	S	P				
King		P	S			
Pink	S	P				
Silver		P				
Sockeye		P				
Sardine		P	S			
Scallop	P					Oil content very low
Sheepshead	S	P				
Shrimp	P			S		Oil content very low
Spot	P					
Trout, rainbow		P				
Tuna:						
Albacore		S		P		Canned product contains a considerable amount of added vegetable oil
Bluefin		S		P		Canned product contains a considerable amount of added vegetable oil
Skipjack				P		Canned product contains a considerable amount of added vegetable oil
Yellowfin				P		Canned product contains a considerable amount of added vegetable oil
Whiting	P					
Yellow pike	P					Oil content very low

The composition in different parts of the same fish vary also, as shown in Table 3 (Thurston and Groninger, 1959). The concentration of oil is generally lower near the tail than near the head — an important consideration for buyers of fish. Those desiring lean fish should buy cuts from near the tail; those desiring oily fish should buy cuts from near the head.

Table 3.—Proximate composition of male and female pink salmon (fresh fish flesh)

Sex and part	Content of moisture		Content of oil		Content of protein		Content of ash	
	Average	Range	Average	Range	Average	Range	Average	Range
Male:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Dorsal	65.1	58.6-69.2	24.4	18.5-32.4	11.0	9.7-14.6	0.8	0.6-0.9
Lateral	69.7	67.9-71.1	11.3	8.5-14.5	18.2	16.9-19.1	1.1	1.0-1.1
Belly flaps	72.9	71.2-74.4	8.8	6.1-11.6	18.1	16.6-18.8	1.0	1.0-1.1
Light meat	77.2	76.1-78.1	1.7	1.2-2.1	21.1	20.2-21.8	1.2	1.1-1.3
Nape	75.7	74.8-76.7	4.3	3.2-5.8	19.9	19.4-20.4	1.2	1.1-1.3
Center	76.2	75.1-77.3	2.8	2.0-3.8	21.0	20.4-21.5	1.2	1.2-1.3
Tail	76.6	75.6-77.4	2.7	2.0-3.5	20.8	20.5-21.2	1.2	1.1-1.3
Average[1]	76.2	74.8-77.3	3.3	2.0-5.8	20.6	19.4-21.5	1.2	1.1-1.3
Female:								
Dorsal	55.4[2]	41-72[2]	29.5	9.7-46.7	14.2	11.4-17.0	0.9	0.8-1.0
Lateral	67.3	63.7-72.3	13.7	8.4-18.5	18.5	17.4-19.7	1.1	1.0-1.3
Belly flaps	70.5	64.2-78.2	11.3	3.3-18.3	18.2	17.0-18.9	1.0	0.9-1.1
Light meat	76.7	75.6-78.4	2.3	1.9-2.9	21.1	20.1-21.6	1.3	1.2-1.4
Nape	74.6	72.6-78.2	5.5	2.5-7.9	19.7	19.1-20.6	1.3	1.2-1.3
Center	75.5	74.2-75.4	4.0	2.1-5.8	20.9	20.1-21.5	1.3	1.2-1.5
Tail	76.0	74.7-77.5	3.1	2.3-3.6	20.9	20.4-21.5	1.3	1.2-1.4
Average[1]	75.1	72.6-78.2	4.1	2.1-7.9	20.5	19.1-21.5	1.3	1.2-1.5

[1] Average of only nape, center, and tail.
[2] Not analyzed, values calculated by difference.
Source: Thurston and Groninger (1959).

Section 2. CHEMICAL COMPOSITION

I. INORGANIC CONSTITUENTS

The main inorganic constituents of fish are water and minerals.

A. WATER

Water is the principal constituent of fish, amounting to about 80 percent of the edible flesh.

The water in fish does not freeze at 32° F. Rather, it starts to freeze at 30.5° F.; but even at 22° F., only about 90 percent of the water is frozen. Substantially all of the water is frozen, however, at about -30° F.

Since the water in fish is, for the most part, held in chemical and colloidal union, little water can be removed from fresh unfrozen fish, even by tremendous pressure. When fish deteriorate or when they are processed, as by canning or freezing, the binding force is reduced, and much of the water is easily released. The approximate retentivity can be determined by measuring the amount of water released after a sample of the fish is centrifuged at a given centrifugal force for a given time.

B. MINERAL

Part of our knowledge of the minerals in fish is derived from a study of fish meals. Newell and McCollum (1931) made a semiquantitative spectrographic analysis of certain fish meals and found relatively large amounts of calcium, copper, iron, magnesium, phosphorus, potassium, sodium, and strontium. Smaller amounts of aluminum, fluorine, lithium, and manganese were present, and traces of barium, chromium, lead, silicon, titanium, vanadium, and zinc could be found in most samples. A few samples contained traces of boron, nickel, niobium, silver, and tin. Although some of these less abundant elements may possibly be contaminants picked up during manufacture of the fish meal, they probably were present initially in the fish from which the meal

was prepared. In addition to these elements, chlorine and sulfur were always found in relatively large quantities, and bromine and iodine were found in trace amounts.

Table 4 gives the results of analyses for certain mineral constituents of nutritional importance in a number of species. Of the elements listed, iodine, although occurring in the smallest quantities, is probably the most important nutritionally. This element, essential to the prevention of goiter, is more abundant in seafoods than in any other natural foodstuff. Oysters are an excellent source of iron and copper, being exeeded only by pork liver and beef liver. Canned sardine, owing to the presence of the softened, edible bone, is a good source of calcium; only cheese and certain nuts have more calcium. Other canned fish from which the bone has not been removed, such as salmon, are equally good sources of calcium, provided of course that the bone is not discarded.

Considerably higher contents of fluorine are found in fish than in most foodstuffs. According to Lee and Nilson (1939), the average content in fish is about 5 parts per million compared with 0.5 to 2.0 parts per million in most other common foods. Because fluorine in excess of 2 parts per million in drinking water will cause mottled teeth and because the United States Food and Drug Administration prohibits the addition to foods of fluorine in excess of

Table 4.—Mineral content of the edible portion of certain fish

Fish and shellfish	Samples	Dry matter[1]	Calcium	Magnesium	Phosphorus	Iron	Copper	Iodine
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Fish								
Cod *(Gadus morhua)*	4	17.7	0.0110	0.0280	0.1859	0.000518	0.000041	0.000103
Haddock *(Melanogrammus aeglefinus)*	4	18.7	0.0165	0.0236	0.1731	0.000516	0.000041	0.000513
Mackerel *(Scomber scombrus)*	2	19.9	0.0048	0.0281	0.2169	0.001224	0.000115	0.000053
Red snapper *(Lutjanus blackfordii)*	3	21.7	0.0162	0.0276	0.2279	0.001158	0.000038	0.000031
Mullet *(Mugil cephalus)*	3	23.9	0.0261	0.0318	0.2198	0.001779	0.000082	0.000485
Pilchard, California *(Sardinops caerulea)*[2]	2	20.5	0.0422	0.0237	0.2115	0.002483	0.000166	0.000013
Flounder *(Pleuronectidae* species)	2	21.3	0.0117	0.0305	0.2053	--	--	0.000029
Lake herring *(Coregonus artedii)*	1	17.9	0.0116	0.0172	0.1518	--	--	--
Salmon, canned:								
Red *(Oncorhynchus nerka)*	3	31.3	0.2082	0.0292	0.3364	0.001180	0.000081	0.000053
Chinook *(Oncorhynchus tschawytscha)*	3	33.2	0.1071	0.0267	0.2778	0.001270	0.000077	0.000067
Coho *(Oncorhynchus kisutch)*	2	30.1	0.2304	0.0298	0.3382	0.000890	0.000064	0.000023
Pink *(Oncorhynchus gorbuscha)*	2	29.6	0.1735	0.0299	0.3206	0.000760	0.000056	0.000021
Chum *(Oncorhynchus keta)*	2	27.3	0.2492	0.0299	0.3518	0.000740	0.000050	0.000022
Shellfish								
Oysters, Eastern *(Crassostrea virginica)*	4	15.0	0.0579	0.0320	0.1121	0.006100	0.003730	0.000049
Oysters, Pacific natives *(Ostrea lurida)*	2	17.9	0.0632	0.0242	0.1540	0.004940	0.001240	0.000030
Oysters, Pacific, Japanese *(Crassostrea gigas)*	2	21.4	0.0628	0.048	0.1922	0.007510	0.001230	0.000036
Shrimp *(Penacus brasiliensis:*								
Raw	4	20.0	0.0542	0.0421	0.2285	0.002188	0.000331	0.000023
Boiled	2	28.7	0.0614	0.0509	0.2432	0.003973	0.000302	0.000021
Blue crab *(Callinectes sapidus):*								
White meat	4	21.1	0.1028	0.0336	0.2052	0.002262	0.001582	0.000042
Claw meat	3	20.4	0.0706	0.0345	0.1796	0.000746	0.000368	0.000015

[1] Samples first dried on steam bath and finished in electric air oven at 80° C.
[2] Whole fresh fish.
Note: Four units to the right of the decimal point equals parts per million or milligrams per kilogram.
Source: Nilson and Coulson (1939).

1.4 parts per million, it might appear that the 5 parts per million of fluorine in seafoods would have a harmful effect. Lee and Nilson (1939) have shown that this is not so. Apparently, fluorine in fish is in a form that is less completely assimilated than are inorganic fluorides. Similarly, the relatively high copper content of oysters has no harmful effect, for copper does not accumulate rapidly in the body when large quantities of oysters are consumed (Coulson, Remington, and Lynch, 1934).

Arsenic also has been reported (Chapman, 1926) to occur in seafoods in quantities higher than in most other foods. The data reported by Chapman showed that arsenic, expressed as parts per million, is present in various species as follows: British oysters, 5; Portuguese oysters, 50; mussels, 82; lobsters, 37; shrimp, 24; crabs, 46; crawfish, 32; sole, 7. Coulson, Remington, and Lynch (1935) have shown that the arsenic in shrimp is organically combined in a form that keeps it from being readily absorbed during human metabolism.

Knowledge of the sodium and potassium contents of food is of utmost importance to the clinician and the dietician. A diet in which sodium content in rigidly controlled must be maintained for patients with such physical impairments as congestive heart disorder. Thurston and Osterhaug (Thurston, 1958, 1961; Thurston and Osterhaug, 1960) have reported the sodium and potassium contents in various fishes. Sodium content varies widely among different species (Table 5) and also among fish of a single species. Some of the factors that influence the content of sodium in fish flesh include sex, size, and season.

Even species with the highest sodium values are well suited for low-sodium diets, since no species contains as much as 100 milligrams of sodium per gram of fish. Some forms of processing, however, negate this advantage. Since salt is added to salted and canned fish and, to a lesser extent, to some frozen fish fillets (which may have been dipped in a salt solution before being frozen), the fish that reaches the consumer may contain an amount of sodium far exceeding that naturally present in the fish.

The ratio of sodium to potassium is quite similar in fresh and salt-water fish, being about 1 part by weight of sodium to 5 parts by weight of potassium (Thurston, 1958).

Table 5.—Sodium content in the edible flesh of fish

Fish	Sodium	Fish	Sodium
	Mg./100 g.		*Mg./100 g.*
Fresh-water fish:		Pacific flat and rockfish:	
Carp	48	Sand sole	56
Yellow pike	50	English sole	72
Whitefish	51	Flathead sole	72
Buffalofish	55	Petrale sole	72
Herring	56	Halibut	51
Mullet	59	Orange rockfish	46
Sheepshead (river)	59	Yellowtail rockfish	50
Yellow perch	69	Chilipepper-rockfish	55
Sheepshead (lake)	77	Ocean perch	59
		Red rockfish	66
Atlantic salt-water fish:		Black rockfish	66
Pollock	48	Greenstripe rockfish	68
Mackerel	48		
Flounder	56	Pacific salmon, tuna, and cod:	
Seatrout	59	Silver salmon	51
Haddock	61	Sockeye salmon	47
Porgy	63	Pink salmon	56
Whiting	65	Chum salmon	50
Seabass	70	Albacore tuna	34
Red snapper	70	Skipjack tuna	41
Mullet	81	Lingcod	62
		Gray cod	76

Source: Thurston and Osterhaug (1960).

II. ORGANIC CONSTITUENTS

It is convenient to think of organic constituents in terms of "major" and "minor". Some of the minor constituents, though quantitatively limited, greatly influence the economic value of the fish. They therefore are minor, not from the standpoint of importance, but from the standpoint of amount.

A. QUANTITATIVELY MAJOR ORGANIC CONSTITUENTS

The organic constituents found in greatest quantity in fish are (1) the proteins and amino acids and (2) the lipids.

1. Proteins and Amino Acids

The amino acid composition of fish protein is more directly related to nutritive value than is merely the "protein content", which is generally calculated from the nitrogen content without correction for the nonprotein nitrogen moities. In certain elasmobranch fishes, such as dogfish, part of the nitrogen occurs as urea, so the protein content, if calculated only from the amount of nitrogen present, is too high.

Table 6 gives results of analyses for amino acids in certain species of fish. The variation in the amino acid content among these species is minor compared

with the variation in oil content from species to species.

Table 6.—Range of amino acid content found in certain species of fish

Amino acid	Range of amino acid content
	Percent of protein
Arginine	4.3 - 7.6
Histidine	1.6 - 5.7
Isoleucine	4.4 - 7.7
Leucine	6.7 - 11.4
Lysine	7.8 - 14.4
Methionine	2.2 - 3.7
Phenylalanine	2.9 - 5.0
Threonine	3.7 - 6.2
Tryptophane	0.1 - 1.4
Valine	4.0 - 7.4
Tyrosine	2.2 - 4.6
Cystine	1.2 - 1.5
Alanine	5.2 - 8.5
Aspartic acid	6.2 - 11.2
Glutamic acid	14.3 - 16.6
Glycine	3.5 - 5.6
Proline	3.1 - 4.3
Serine	4.6 - 6.0

Source: Braekkan and Boge (1962); Beach, Munks, and Robinson (1943); Deas and Tarr (1949); Ingalls, Klocke, Rafferty, Greensmith, Chang, Tack, and Ohlson (1950); Konosu, Katori, Ota, Eguchi, and Mori (1956); Lahiry and Proctor (1956); Landgraf (1953); and Neilands, Sirny, Sohljell, Strong, and Elvehjem (1949).

Table 7 gives approximate contents of amino acid in myosin, actin, and collagen—the three common proteins occurring in fish. Ordinarily, the variation in amino acid content from protein to protein within a given species is considerably wider than is the variation in amino acid content from species to species.

Because the composition of amino acids in fish is similar to that in man, people can acquire the essential amino acids in abundance and in proper balance by eating fish.

2. Lipids

The chief lipids found in fish oils are fatty acids. Minor lipid components include sterols and the hydrocarbon squalene; the latter is sometimes a preponderant part of the liver oil of sharks.

a. Fatty acids.—Fatty acids are principally combined in triglycerides, but they also occur in phospholipids and, in certain fish, in alkoxydiglycerides and waxes. In this section, fatty acids in (1) oils and fats, (2) phospholipids, (3) alkoxydiglycerides, and (4) waxes will be considered.

(1) Fatty acids in oils and fats.—Fatty acids derived from fish oil differ markedly in degree of unsaturation and molecular chain length from those derived from vegetable sources or from other animals. These differences will be considered, and then the fatty acids from some of the principal species of fish processed in the United States will be examined.

(a) Animal- and vegetable-oil fatty acids.—As was just indicated, the fatty acid composition of fish oils differs markedly from that of land-animal fats or of vegetable oils. Very small quantities of the fatty acids in the fat of land animals have more than 2 double bonds per fatty acid molecule, and very small quantities of those in vegetable oils have more than 3 double bonds per fatty acid molecule; however, up to one-third of the fatty acids of fish oils have 5 or 6 double bonds per fatty acid molecule. Also, certain of the fatty acids of fish oils have many more carbon atoms per fatty acid molecule than do the fatty acids from other sources. Considerable amounts of 20- and 22-carbon-atom fatty acids occur in fish oils, but very small quantities of 20-carbon-atom-fatty acids and only minute amounts of 22-carbon-atom fatty acids occur in vegetable oils and land-animals fats. Despite the relatively large amount of highly unsaturated fatty acids present, however, fish oils also contain considerable amounts of saturated and monoene fatty acids.

Table 7.—Amino acid content of fish proteins

Amino acid[1]	Approximate concentration in:		
	Myosin[2]	Actin[2]	Collagen
	G./100 g.	*G./100 g.*	*G./100 g.*
Alanine	6.5	5.4	10.4
Arginine	6.7	7.4	9.1
Aspartic acid	11.5	9.7	7.5
Cystine	0.9	1.4	0
Glutamic acid	21.7	13.3	11.3
Glycine	3.4	5.0	28.2
Histidine	2.1	3.3	1.2
Hydroxylysine	0	0	1.0
Hydroxyproline	0	0	9.0
ISOLEUCINE	4.6	7.7	1.7
LEUCINE	9.4	6.6	3.2
LYSINE	10.6	6.5	3.7
METHIONINE	3.0	4.1	2.0
PHENYLALANINE	3.9	4.6	2.0
Proline	3.5	6.0	12.4
Serine	4.9	5.9	7.9
THREONINE	4.3	6.9	0.6
TRYPTOPHANE	0.8	1.6	0
Tyrosine	2.7	6.0	0.6
VALINE	5.3	5.9	2.3

[1] The capitalized amino acids are those now recognized as essential to human health. Arginine can be synthesized, but only slowly, so that its addition to the diet of young growing chickens accelerates growth. Cystine may replace part of the methionine requirement, and tyrosine may replace part of the phenylalanine requirement.

[2] Myosin and actin account for 50 percent and 20 percent, respectively, of the total protein of white muscle. They combine to form actomyosin during muscle contraction.

Source: Stansby and Olcott (1963, table 26.8).

Although fish oils contain highly polyunsaturated fatty acids, these acids are not the classical essential fatty acids of the linoleic acid family found in land-animal and vegetable fats and oils. Instead, they are largely of the linolenic acid family. Accordingly, the first double bond is in the 3,4 position rather than in the 6,7 position (counting from the terminal CH_3 end). This difference has raised questions about the nutritive value of fish oils. Though research has now shown that they cure skin ailments in rats to a small extent only, it has nevertheless proved that they are useful as a source of fatty acids for the important function of promoting growth.

(b) Fish-oil fatty acids.—Only within the past 10 years, since the technique of gas-liquid chromatography was developed, has it been feasible to make complete fatty acid analyses of the oils from many different species of fish; and even now, only a small start has been made toward filling the gaps in knowledge.

The most complete data of this type on American species of fish was reported by Gruger, Nelson, and Stansby (1964) on analyses of the fatty acid composition of the oil from 21 different species (Table 8). Because the data in Table 8 are based on very small samples, with only a relatively few fish per sample, and because the fatty acid content like the oil content varies widely from sample to sample, the values in the table may not accurately represent the species. Nevertheless, these data are the only ones available for the fatty acid composition of the oil of many important American species; for that reason, they are valuable.

Several important facts can be concluded from the data in Table 8. Highly polyunsaturated fatty acids with 4 or more double bonds, though not occurring in quantity except in fish, occur in abundance in all the species analyzed. In scallops, these 4, 5, and 6 double-bonded fatty acids make up about 52 percent of the total fatty acids; in sea herring, which have the lowest content of these fatty acids, the quantity is still high—about 19 percent. All species, in spite of their relatively large content of highly polyunsaturated fatty acids also contain considerable amounts of saturated ones as well, the amount varying from about 21 percent in rainbow trout to about 44 percent in cod.

The oils in fresh-water fish differed from those of marine fish in several ways. The linoleic acid content is higher in the fresh-water fish oils, which average 4.8 percent and range from 4.3 to 5.5 percent, than in the marine fish oils, which average 1.5 percent and range from 0.7 to 3.2 percent. The content of those fatty acids that have 20 carbon atoms and 5 double bonds is lower in fresh-water fish oils, which average 5.8 percent and range from 5.0 to 6.4 percent than in the marine fish oils, which average 9.7 percent and range from 6.7 to 13.5 percent. The content of total polyunsaturates that have 4, 5, and 6 double bonds is lower in fresh-water fish oils, which average 70 percent and range from 65 to 74 percent, than in the marine fish oils, which average 88 percent and range from 84 to 92 percent.

The variability of fatty acid content of oils from a single species is well demonstrated by the data on menhaden oils shown in Table 9. Here, the oil from even the very large batches of menhaden, with each batch representative of thousands of fish, varies considerably. For example, the content of the fatty acid that has 22 carbon atoms and 6 double bonds ranges from 3.3 to 5.5 percent.

(2) Fatty acids in phospholipids.—A small, fairly constant portion of the fatty acids of most fish oils is combined as phospholipids rather than triglycerides. In those species—for example, cod—where the total content of oil is very low, the quantity of fatty acids combined as phospholipids may predominate. As has been shown by Shuster, Froines, and Olcott (1964), nearly half of the fatty acids in fish phospholipids are highly polyunsaturated and have 5 or 6 double bonds. These authors also have shown that in albacore tuna, the phospholipids consist of 65-percent phosphatidyl choline, 25-percent phosphatidyl ethanolamine and phosphatidyl serine, 5-percent sphingomelin, 1-percent phosphoinositides, and lesser percentages of sterols, cerebrosides, and unidentified components.

(3) Fatty acids in alkoxydiglycerides.—In certain species of fish, such as dogfish and certain other sharks, a substantial part of the fatty acids in the body and liver oil occurs as alkoxydiglycerides. In such compounds, two fatty acids are attached to the glycerol through the ordinary ester linkage. A third fatty acid is attached by means of an ether linkage. Upon hydrolysis, these alkoxydiglycerides yield, in addition to the usual fatty acids, so-called glyceryl ethers, such as batyl or chimyl alcohol. These compounds are of unusual biochemical interest because they raise the question of what their function is in fish or other animals. In recent years, a considerable amount of research has been carried out with these compounds as well as with the structurally somewhat similar neutral plasmalogens.

Malins and others (Malins, 1960; Malins and Houle, 1961; Malins, Wekell, and Houle, 1965) have analyzed dogfish oil to determine which fatty acids are combined in the alkoxydiglycerides, both in the ether-linked position and in the ester-linked position, and have also analyzed the fatty acids present in the triglycerides of this species. In the dogfish flesh oil, the fatty acids in the ether-linked portion are

Table 8.—Fatty acid composition of fish oils

Fatty acid chain length	Double bonds	Content of fatty acids in:																									
		Salt-water fish and components																			Fresh-water fish			Shellfish			
		Atlantic cod	Atlantic cod liver	Spiny dogfish	Spiny dogfish liver	Pacific halibut	Pacific herring	Mackerel	Menhaden	Striped mullet (A)	Striped mullet (B)	Ocean perch	Rockfish	Sablefish	Chinook salmon	Chum salmon	Coho salmon	Pink salmon	Pink salmon egg	Lake herring	Rainbow trout	Lake whitefish	Blue crab	Littleneck clam	Pacific oyster	Sea scallop
No. C atoms	*No. per molecule*	*Weight percent of total fatty acids*																									
14	0	1.8	2.8	2.0	1.6	2.8	7.6	4.9	8.0	4.6	7.5	4.6	4.1	4.6	3.7	2.2	3.7	3.4	2.9	5.5	2.1	2.2	2.2	3.2	2.7	1.9
15	0	0.5	0.4	0.5	0.3	0.3	0.4	0.5	0.5	6.3	4.5	0.6	0.6	0.4	0.4	0.6	0.5	1.0	0.5	0.4	0.8	0.3	0.9	0.8	0.9	0.7
	1(?)		0.2		0.4					0.5	1.1	0.3	0.4				0.3			0.3	0.3	0.3	0.4			
16	0	33.4	10.7	21.2	13.2	15.1	18.3	28.2	28.9	17.3	13.9	12.6	14.9	18.1	16.6	17.0	10.2	10.2	9.5	17.7	11.9	12.1	15.2	23.8	21.4	23.0
	1	2.4	6.9	6.0	5.7	8.9	8.3	5.3	7.9	11.0	15.5	8.0	6.6	8.0	9.2	4.1	6.7	5.0	7.0	7.1	8.2	10.5	11.2	9.6	4.6	2.0
	2[1]	0.6	1.0	0.9	1.0	0.8	1.0	0.7	0.8	3.8	6.0	0.9	1.5	1.0	1.1	0.8	1.2	1.7	1.2	0.7	1.2	1.2	1.8	0.8	1.6	0.5
17	0	0.9	1.2	1.2	1.0	0.7	0.5	1.0	1.0	0.8	1.0	1.0	2.6	0.8	1.1	1.1	0.9	1.6	0.8	0.6	1.5	1.1	1.9	1.3	1.4	0.8
18	0	4.0	3.7	2.7	4.3	3.4	2.2	3.9	4.0	5.0	5.1	3.6	6.0	3.1	5.8	3.2	4.7	4.4	2.9	3.0	4.1	4.0	7.2	5.4	4.0	5.3
	1	11.8	23.9	27.5	28.5	25.7	16.9	19.3	13.4	8.4	9.1	22.0	20.8	20.4	29.1	21.4	18.6	17.6	20.5	18.1	19.8	27.2	17.6	10.8	8.5	5.2
	2	1.2	1.5	1.3	0.7	0.9	1.6	1.1	1.1	3.2	2.2	1.5	1.6	0.8	1.1	2.0	1.2	1.6	1.5	4.3	4.6	5.5	1.9	1.4	1.2	0.6
	3	0.8	0.9	0.6	0.6	0.3	0.6	1.3	0.9	1.4	1.0	0.6	0.8	0.5	0.9	1.0	0.6	1.1	1.2	3.4	5.2	3.7	1.2	1.6	1.6	0.3
	4	1.2	2.6	0.7	0.8	3.6	2.8	3.4	1.9	3.0	3.1	1.6	1.3	1.3	1.5	2.0	2.1	2.9	1.8	1.8	1.5	1.0	0.6	3.0	4.3	1.8
19	0[2]		0.6		0.7		+		0.9	1.5	1.6	0.8	0.9	1.1	1.2		1.8	0.7	0.7					+	+	0.4
20	1	1.6	8.8	5.8	10.5	8.0	9.4	3.1	0.9	0.7	0.6	8.0	1.4	5.6	4.7	5.4	8.4	4.0	1.1	1.2	3.0	2.1	1.9	3.5	+	1.7
	2(?)		0.5		0.4				0.5	1.0	0.8		0.5	+	0.4	0.7	0.4	0.6	0.5	0.9	0.6	0.8	1.1	1.2		0.5
	3(?)	0.4	0.1		0.2			0.5		+	0.4		0.2		0.1		0.1	0.1	0.4	0.1	0.4	0.6	0.4	0.4		
	4	3.2	1.0	2.5	0.8	2.5	0.4	3.9	1.2	2.6	3.6	0.8	1.5	0.8	0.5	0.9	0.9	0.7	1.5	3.4	2.2	3.9	4.1	1.7	1.9	4.5
	5	12.4	8.0	7.9	3.7	10.1	8.6	7.1	10.2	7.5	11.8	9.3	11.7	8.5	8.2	6.7	12.0	13.5	20.6	5.9	5.0	6.4	13.4	10.0	21.5	21.3
22	1	0.7	5.3	4.1	10.3	5.1	11.6	2.8	1.7	0.7		8.7	0.8	8.9	3.6	9.4	5.5	3.5	0.4	2.8	1.3	0.5	1.5	2.6	2.6	0.2
	1(?)		1.1		0.7						0.8	0.7	0.5		1.1		1.1	1.8	2.8		2.1	0.6				
	4(?)		0.3	1.0	1.3	+	+		0.7	1.0	1.0	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.5	1.2	0.6	1.1	1.0	1.2	0.5	1.5
	5	0.6	1.3	2.3	3.1	1.6	1.3	1.2	1.6	3.9	3.2	0.6	1.6	1.8	2.4	2.3	2.9	3.1	4.6	3.3	2.6	3.3	1.1	1.7	1.0	1.0
	6	21.9	14.3	10.4	6.5	7.9	7.6	10.8	12.8	13.4	3.2	12.0	17.4	12.1	5.9	16.1	13.8	18.9	16.0	13.4	19.0	8.8	11.0	14.5	20.2	26.2
24	1(?)[3]		0.5	0.8	1.9	1.0	0.9	0.8	0.9	1.5	0.7	0.5	0.5	1.4	0.7	1.5	0.6	1.1	0.2	4.4	0.7	1.2	1.0	0.7		0.6

[1] Combined critical pair of 17:1 and 16:2; mostly 17:1 for mullet oil.
[2] Combined critical pair of 19:0 and 16:4.
[3] Amounts agree well with C_{24} acid (lignoceric acid) from chain-length analyses of hydrogenated methyl esters.

Table 9.—Variation in fatty acid content of different menhaden oil samples

Location of catch	Date of production	Fatty acid[1] content: 14:0	16:0	16:1	18:0	18:1	18:2	18:3	18:4
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Southern production[2]	Feb. 1961	15.1	24.0	16.8	3.0	11.1	1.0	0.9	0.8
Empire, Louisiana	May 1960	13.5	22.4	17.3	2.6	14.1	0.9	0.4	1.1
Fernandina Beach, Florida	May 1960	13.7	21.6	17.9	2.9	11.6	1.0	0.8	1.0
Beaufort, North Carolina	May 1960	16.3	23.5	17.3	3.1	10.7	1.3	0.7	0.9
Port Monmouth, New Jersey	May 1960	6.7	21.9	12.2	3.0	23.4	1.3	0.5	1.5
Port Monmouth, New Jersey	July 1960	10.6	23.6	14.8	3.0	12.6	1.2	1.0	0.9
Northern production[2]	Feb. 1961	12.5	19.6	14.1	2.4	19.3	1.2	1.1	1.8

Location of catch	Date of production	20:1	20:4	20:5	22:1	22:5	22:6	15:0 and 17:0	Others
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Southern production[2]	Feb. 1961	1.6	1.4	10.4	1.0	1.6	4.8	3.1	3.4
Empire, Louisiana	May 1960	1.6	0.8	13.5	0.9	1.4	3.3	2.2	3.9
Fernandina Beach, Florida	May 1960	2.4	0.7	11.9	0.8	1.4	5.0	3.5	3.7
Beaufort, North Carolina	May 1960	2.2	0.6	10.2	0.7	1.4	5.0	3.2	3.9
Port Monmouth, New Jersey	May 1960	1.9	1.2	12.9	0.9	1.1	5.1	1.8	4.4
Port Monmouth, New Jersey	July 1960	2.7	0.8	13.1	1.0	1.4	6.5	3.4	3.3
Northern production[2]	Feb. 1961	2.0	1.3	10.3	1.0	1.2	5.6	2.4	4.1

[1] Shorthand notation for fatty acids: (carbon number:number of double bonds); for example, 14:0 means 14-carbon-atom chain length with zero number of double bonds.
[2] Exact origin unknown.

predominantly saturated and monoene; oleic acid makes up about 47 percent of the total. Polyunsaturates in these fatty acids make up less than 1 percent of the total. In the fatty acids esterified in the alkoxydiglycerides, considerable amounts of polyunsaturates occur—in fact, more than in the triglyceride fatty acids. Those in the alkoxydiglycerides contain, for example, about 28 percent of their fatty acids as pentaenes and hexaenes as compared with about 15 percent in the triglycerides.

(4) Fatty acids in waxes.—Fatty acids may occur esterified with fatty alcohols—that is, in waxes. Waxes occur chiefly in marine-mammal oils (such as whale oil), which are not considered here, since this report is confined to fish. A very unusual fish, such as the oilfish *(Ruvettus pretiosus)* and the escalor *(Lepidocybium flavobrunneum)*, have their fatty acids entirely in esters of alcohols, the alcohols being mainly hexadecanol and octadecanol. Most species of fish, however, contain at most only traces of waxes, except perhaps in their roe (Kafuku and Hata, 1934).

b. Sterols and hydrocarbons.—The principal sterol in fish lipid is cholesterol. Table 10 gives the cholesterol content in several species as reported by Thompson (1964) and Kritchevsky and Tepper (1961). For individuals attempting to keep their serum cholesterol levels low, food sources having a low content of cholesterol are needed. The content of cholesterol in fish is no higher than in other flesh foods.

Several hydrocarbons occur in the liver and visceral oils of many sharks, in some specimens, the content being 50 percent or more. The most common of these hydrocarbons is squalene, a 30-carbon-atom, polyunsaturated hydrocarbon with 24 straight-

chain carbons and 6 side methyl groups. Several additional hydrocarbons occurring in appreciable quantities in shark-liver oils have been identified, notably pristane (Sorensen and Sorensen, 1949) and zamene (Christensen and Sorensen, 1951). These are 18-carbon-atom hydrocarbons. The various hydrocarbons generally occur in fish containing alkoxydiglycerides.

Table 10.—Cholesterol content of some fish and shellfish

Fish and shellfish		Cholesterol content	Reference
Common name	Scientific name		
		Mg./100 g. wet fish	
Clams, hard	*Mercenaria mercenaria*	82	1
Clams	Unstated	122	2
Cod	Unstated	43	2
Crab, blue, Eastern	*Callinectes sapidus*	98	1
Crab, blue, Southern	*Callinectes sapidus*	76	1
Crab, Dungeness (body)	*Cancer magister*	63	1
Crab, Dungeness (claw)	*Cancer magister*	52	1
Flounder	Unstated	41	2
Haddock	Unstated	25	2
Halibut	Unstated	34	2
Oysters, Eastern	*Crassostrea virginica*	58	1
Oysters, Southern	*Crassostrea virginica*	37	1
Oysters	Unstated	112	2
Salmon	Unstated	65	2
Scallops, sea	*Aquapecten grandes*	60	1
Shrimp, brown	*Penaeus aztecus*	156	1
Shrimp, white	*Penaeus setiferus*	157	1
Shrimp	Unstated	138	2
Tuna	Unstated	52	2

[1] Thompson (1964).
[2] Kritchevsky and Tepper (1961).

B. QUANTITATIVELY MINOR ORGANIC CONSTITUENTS

The minor organic constituents of economic importance are the vitamins and other miscellaneous components.

1. Vitamins

a. Oil-soluble vitamins (Vitamins A, D, and E).—Some fish-liver oils are excellent natural sources of vitamin A, and some are also excellent sources of vitamin D. Vitamin A and vitamin D to some extent can make up an appreciable part of the total lipid content of some fish-liver oils. For example, one halibut may contain as much as 90 grams of vitamin A (Lovern, 1942). With many species, oil of high vitamin A and D contents can also be obtained from parts of the viscera other than the liver. As a rule, the body oils of fish contain relatively low contents of vitamins A and D. Both liver and body oils are good sources of vitamin E (tacopherols).

Comprehensive tables of the contents of vitamins A and D in fish livers and viscera have been compiled by Butler (1946). Some of the data are summarized in Tables 11 and 12. In general, the weight of the livers of true fishes *(Teleostomi)* is between 1 and 5 percent (usually between 1 and 2 percent) of the weight of the whole fish. The livers of the sharks and related elasmobranches usually account for between 5 and 15 percent of the weight of the whole fish.

Whether or not vitamin A, vitamin D, or both can be extracted profitably from the liver of a given species depends upon the concentration of vitamins in the extracted oil, the content of oil in the liver, the relative size of the liver with respect to the size of the whole fish, and the current market price for the vitamins. In the United States, the manufacture of vitamin A or D oils from fish livers is ordinarily impractical because of the low cost of the synthetic products. Except in a few special markets where vitamin oils are sold under species names (for example, halibut-liver oil) and where there is still a small demand, even at considerably above usual vitamin prices, the vast bulk of the once very large fish-liver-oil industry in this country has ceased to exist. A small fish-liver-oil industry is still operating in Canada. In other parts of the world—for example, in Great Britain, Norway, and Japan—a large production of cod-liver oil and shark-liver oil continues.

The content of vitamin E in fish oils is higher than it was once believed to be. Analyses made by Braekkan, Lambertsen, and Myklestad (1963) show that the alpha-tocopherol content in commercial fish oils is as high as that in such vegetable oils as olive, soybean, or corn. The content of vitamin E in the flesh of the fish is closely correlated with the content of oil—an increase in oil content in the flesh is accompanied by a corresponding increase in content of alpha-tocopherol. Some of the values found by Braekkan and others (1963), expressed as micrograms of alpha-tocopherol per gram of fresh tissue (or per gram of oil, for values in parentheses), are: cod, 1.5-2.1 (560); pollock, 3.6 (507); herring, 14-16 (100); halibut, 4-13 (178); and catfish, 12.5 (360).

b. Water-soluble vitamins (Vitamins B and C).—Table 13 summarizes values from analyses made in many laboratories throughout the world for the content of B vitamins in the flesh of fish. Fish are a good source of both vitamins B_1 (thiamine) and B_2 (riboflavin), having about the same content as does beef.

Krampitz and Woolley (1944) showed that certain uncooked fresh-water fish contain an enzyme (thiaminase) that destroys thiamine and tends to produce thiamine deficiency in animals fed a diet composed largely of raw fish. The presence of thiami-

Table 11.—Vitamin A content of oils from some fishery sources[1]

Fish		Area in which fish are caught	Source of oil	Weight of liver relative to round weight	Oil concentration in liver	Vitamin A concentration	
Common name	Scientific name					Range	Average
				Percent	*Percent*	*U. S. P. units per gram*	
Soupfin shark ..	*Galeorhinus zyopterus*	Pacific	Liver	10	55-68	45,000- 200,000	120,000 (male)
		Pacific	Liver	10	65-72	15,000- 40,000	32,000 (female)
Grayfish (dogfish)	*Squalus acanthias*	Pacific-Alaska	Liver	10	67-72	2,000- 20,000	5,000
		Pacific-Hecate Strait	Liver	10	65-70	7,000- 15,000	10,000
		Pacific-Wash.-Ore.	Liver	10	50-70	8,000- 25,000	14,000
		Pacific-N. Calif.	Liver	10	62-68	12,000- 20,000	15,000
Sleeper shark ...	*Somniosus microcephalus* ..	Pacific	Liver	10-15	40-55	5,000- 15,000	7,000
Mud shark	*Hexanchus griseus*	Pacific	Liver	10-15	60-65	5,000- 7,000	7,500
Great blue shark .	*Prionace glauca*	Pacific	Liver	[2]	30-45	7,000- 27,000	20,000
Halibut	*Hippoglossus hippoglossus*	Pacific-Area 3[3]	Liver	1.5-3	8-21	40,000- 160,000	87,000
		Pacific-Area 2[4]	Liver	1-1.75	17-27	20,000- 65,000	40,000
		Pacific-Area 2	Viscera[5]	2.5-5	2-5	70,000- 700,000	200,000
Sablefish	*Anoplopoma fimbria*	Pacific	Liver	2-2.5	10-26	50,000- 190,000	90,000
		Pacific	Viscera	3-4	5-12	90,000- 150,000	125,000
Lingcod	*Ophiodon elongatus*	Pacific	Liver	1-1.5	8-20	40,000- 550,000	175,000
		Pacific	Viscera	1.8-3	4-15	10,000- 175,000	40,000
Albacore tuna ...	*Thunnus alalunga*	Pacific	Liver	1.5-2	7-20	10,000- 60,000	25,000
Bluefin tuna ...	*Thunnus thynnus*	Pacific	Liver	[2]	4-6	25,000- 100,000	75,000
Yellowfin tuna ..	*Thunnus albacares*	Pacific	Liver	[2]	3-5	35,000- 90,000	50,000
Skipjack tuna ..	*Katsuwonus pelamis*	Pacific	Liver	[2]	4-6	30,000- 60,000	40,000
Bonito	*Sarda chiliensis*	Pacific	Liver	[2]	4-12	15,000- 60,000	35,000
Swordfish	*Xiphias gladius*	Pacific-Atlantic	Liver	1.4-2.6	8-35	20,000- 400,000	250,000
		Pacific-Atlantic	Viscera	3-6	6-12	2,000- 30,000	10,000
Black sea bass ..	*Stereolepis gigas*	Pacific	Liver	[2]	13-20	100,000-1,000,000	300,000
Cod	*Gadus callarias*	Atlantic	Liver	3-5	20-60	1,000- 6,000	2,000
Ocean perch	*Sebastes marinus*	Atlantic	Waste[6]	[2]	2-4	3,000- 5,000	[2]
Rockfish	*Sebastodes* species	Pacific	Liver	1-1.5	5-25	14,000- 300,000	[2]
		Pacific	Viscera	1.5-2.5	2-15	15,000- 125,000	[2]
Petrale sole	*Eopsetta jordani*	Pacific	Liver	1-1.5	6-25	4,000- 175,000	[2]
Herring	*Clupea harengus pallasi* ..	Pacific	Body	[2]	5-25	50- 300	90
Pilchard	*Sardinops sagax*	Pacific	Body	[2]	5-25	50- 800	100
Menhaden	*Brevoortia tyrannus*	Atlantic	Body	[2]	5-20	500	[2]

[1] These data are compiled from reports of research at the laboratories of the Fish and Wildlife Service and of the Fisheries Research Board of Canada, and from articles published by representatives of commercial processors of fish livers and viscera. For the most part, the data are based on large lots of material or on samples taken over the normal season for the species.

[2] The source from which information listed here was obtained did not supply data under this heading.

[3] Area 3 is defined by the International Halibut Commission regulations as follows: "Area 3 shall include all the convention waters off the coast of Alaska that are between Area 2 and a straight line running south from the southwestern extremity of Cape Sagak on Umnak Island, at a point approximately latitude 52° 49' 30" N, longitude 169° 07' 00" W., according to Chart 8802, published January, 1942, by the United States Coast and Geodetic Survey, and that are south of the Alaska Peninsula and of the Aleutian Islands and shall also include the intervening straits or passes of the Aleutian Islands."

[4] Area 2 includes: ". . . all convention waters off the coasts of the United States of America and of Alaska and of the Dominion of Canada between Area 1B and a line running through the most westerly point of Glacier Bay, Alaska, to Cape Spencer Light as shown on Chart 8304, published in June, 1940, by the United States Coast and Geodetic Survey, which light is approximately latitude 58° 11' 57" N., longitude 136° 38' 18" W., thence south one-quarter east and is exclusive of the areas closed to all halibut fishing in Section 9 of these regulations."

[5] Viscera, unless otherwise designated, means the contents of the body cavity minus the liver, stomach, and gonads.

[6] Waste is the entire body of the Atlantic ocean perch minus the fillet or edible portion. It includes head, backbone, skin, and viscera.

Table 12.—Vitamin D content in liver oils from fishery sources

Fish		Area in which fish were caught	Vitamin D content
Common name	Scientific name		
			International units per gram of oil
Albacore tuna	*Thunnus alalunga*	Pacific	20,000-250,000
Bluefin tuna	*Thunnus thynnus*	"	20,000- 70,000
Yellowfin tuna	*Thunnus albacares*	"	10,000- 45,000
Skipjack tuna	*Katsuwonus pelamis*	"	25,000-250,000
Bonito	*Sarda chiliensis*	"	50,000
Swordfish	*Xiphias gladius*	Pacific-Atlantic	2,000- 25,000

nase accounts for the development deficiencies that fur farmers encounter in foxes and other fur-bearing animals when fed certain whole fresh-water fish. Green, Carlson, and Evans (1942) reported that foxes fed whole carp developed Chastek paralysis, a disease caused by thiamine deficiency and manifesting itself by loss of appetite, emaciation, paralysis, and death. The disease failed to develop, however, if the carp diet was supplemented with 10 milligrams or more of thiamine per day. Nor did it develop if whole carp were fed the foxes only intermittently—that is, for several days a week the carp diet was discontinued and a diet containing adequate thiamine was substituted—or if the fish were cooked before they were fed to the animals.

Table 13.—Average B vitamin content of the edible flesh of fish and shelfish

Fish and shellfish		Vitamin B content:					
Common name	Scientific name	Thiamine	Ribo-flavin	Niacin	Vitamin B_{12}	Panto-thenic acid	Biotin
		Micrograms per gram					
Anchovy	*Engraulis* species	0.06	1.2	—	0.0033	—	—
Carp	*Cyprinus carpio*	0-0.1	0.4	15	0.002	1.5	—
Clams	Various species	0.4-1.4	1.8	13	0.13-0.62	—	—
Cod:							
Atlantic	*Gadus morhua*	0.7	0.8	20	0.01	1.7	0.026
Pacific	*Gadus macrocephalus*	0.9	1.5	—	0.0009	1.5	—
Crab	*Cancer* species	—	0.9	17-28	0.13	7.1	0.098
Dogfish	*Squalus acanthias*	0.5	1.5	50	0.015	7.5	—
Drum	*Sciaenops* species	0.2	5.3	6-16	—	—	—
Flounder	*Pleuronectes flesus*	1.5	2.0	35	0.01	10	—
Groupers	*Epinephelus morio*	1.1	3.7	14	—	—	—
Haddock	*Melanogrammus aeglefinus*	0.7	1.0	40	0.015	2.5	0.048
Halibut, Atlantic	*Hippoglossus hippoglossus*	0.7	0.8	60	0.008	2.5	0.05
Herring:							
Atlantic	*Clupea harengus harengus*	0.4	3.0	40	0.1	10	0.1
Pacific	*Clupea harengus pallasi*	0.3	2.2	—	0.005-0.024	—	—
Lingcod	*Ophiodon elongatus*	0.5	0.4	—	0.18	—	—
Lobster	*Homarus* species	0.8-0.9	0.4-0.6	12-21	0.005	—	—
Mackerel:							
Atlantic	*Scomber scombrus*	1.0	3.5	75	0.1	10	0.07
Pacific	*Scomber japonicus*	—	—	—	0.009-0.015	1.6-3.2	—
Mullet	*Mugil* species	0.55	0.98	6.9-7.7	0.006-0.0025	6.9-8.3	—
Ocean perch	*Sebastes marinus*	—	0.7-1.1	20	0.01	3.6	0.01
Oysters	*Ostrea* species and *Crassostrea* species	1.2	1.8	20	2.0	1.4-5.3	0.087
Pilchard	*Sardinops sagax*	0.07	3.0	74	0.17	4.9-8.3	0.19-0.34
Pollock	*Gadus pollachius*	—	1.0	20	0.01	2.5-4.2	0.032
Red snapper	*Lutjanus blackfordii*	1.0	0.48	15	—	—	—
Rockfish	*Sebastodes* species	0.8	1.1-1.5	8	0.12	0-1.5	—
Salmon:							
Atlantic	*Salmo salar*	2.0	1.5	70	0.05	20	0.048
Chinook	*Oncorhynchus tshawytscha*	1.0	2.0	—	—	—	—
Chum	*Oncorhynchus keta*	1.0	1.0	—	—	—	—
Coho	*Oncorhynchus kisutch*	1.0	1.0	—	—	—	—
Pink	*Oncorhynchus gorbuscha*	1.5	0.5	—	—	—	—
Sockeye	*Oncorhynchus nerka*	1.5	1.0	—	—	—	—
Scallops	*Pecten* species	—	0.65	12	0.013	—	—
Seabass	*Stereolepis gigas*	1.0	0.5	24	—	—	—
Shrimp	*Pandalus borealis*	0.5	0.5	20	0.046	2.3	0.031
Shrimp	*Penneus* species	0.2	0.25	25	0.009	2.5	—
Sole, lemon	*Pleuronectes microcephalus*	1.5	2.0	35	0.01	10	—
Trout, lake	*Salvelinus* species	1.0	1.0	25	0.03	—	—
Tuna:							
Albacore	*Thunnus alalunga*	0.5	1.1	11-14	0.0017	4.2	0.03
Bigeye	*Parathunnus obesus*	0.6	0.6	143	0.005	—	—
Bluefin	*Thunnus thynnus*	2.0	1.2	85	0.04	5.0	0.05
Skipjack	*Katsuwonus pelamis*	0.60	0.40	72	0.0025-0.006	—	—
Whitefish, lake	*Coregonus clupeaformis*	1.5	1.2	27-33	—	—	—
Yellow perch	*Perca flavescens*	0.6	1.7	17.8	—	—	—
Yellow pike	*Stizostedion vitreum vitreum*	2.5	1.6	23	—	—	—

Source: Values taken from a variety of sources but especially from the compilations of Braekkan (1962).

Neilands (1947) has analyzed the thiaminase content of the muscle and viscera of 12 fresh-water and 28 salt-water fish. Except for certain shellfish, the salt-water species contained negligible amounts of the enzyme, whereas nearly all the fresh-water species contained a rather large content.

Fish roe and fish livers are rich sources of riboflavin. Billings, Biely, Fisher, and Hedreen (1941) showed that commercial fish meal contains extremely high contents of riboflavin. For example, samples of commercial pilchard, salmon, and herring meals were showed upon assay to contain between 900 and 2,200 micrograms per 100 grams of meal. Special meals prepared from the livers of salmon, tuna, pilchard, and herring contained (on a moisture- and fat-free basis) from 5,000 to 10,000 micrograms per 100 grams of meal.

Fish is a relatively poor source of vitamin C (ascorbic acid).

2. Other Miscellaneous Components

In addition to the principal nutritive components —protein, oil, vitamins, and minerals—fish contain many other substances far too numerous to list here completely.

Various nonprotein nitrogen compounds are present. In addition to free amino acids, there are certain basic nitrogen compounds. Beatty (1939) reported that the juice of press muscle of various teleost salt-water fishes contains an average of 0.31 to 0.67 percent trimethylamine oxide. Dogfish muscle contains an average of 1.25 percent, but the muscle of fresh-water fish contains none. (Trimethylamine

oxide decomposes during spoilage to give trimethylamine.) Small amounts of dimethylamine may also be present.

Zagami (1929) reported that the muscle of fish also contains creatine phosphoric acid in contents ranging from 0.1 to 0.6 percent. A correlation exists between the content of this substance and the muscular activity of the fish—those migrating over the longer distances have the highest content of phosphagen.

Small quantities of formaldehyde have been reported in fish, especially in canned fish. Early investigators attributed the presence of this substance to slow oxidation of trimethylamine, concluding that the increasing content over prolonged storage of the canned product derived from the oxidation process. Although such a reaction may take place in canned fish, formaldehyde has also been found in fresh (uncanned) fish (Lunde and Mathieson, 1934).

Pigments occur in the flesh and oils of some species of fish. Bailey (1937) reviewed the literature and added some experimental findings of his own to the general knowledge about the pigments in salmon. He identified red pigment as a form of astacin, which is also known to occur in lobsters. Bieley, Lloyd, and Chalmers (1936) suggested that the principal yellow pigment in pilchard oil is fucoxanthin. Other pigments believed to be present in small quantities in some fish include carotene and chlorophyll.

Glycogen is also present in the flesh of fish. As in mammals, it functions as a source of stored energy, yielding lactic acid through a series of reactions. Oysters contain relatively large quantities of glycogen (up to 2 or 3 percent in the meats); other species contain a few tenths percent. As a result of post-mortem changes, the content of lactic acid rises from a few hundredths percent in the living muscle to about 0.3 to 0.5 percent when full rigor mortis sets in.

The pH of the flesh of most species of fish is between 6.6 and 6.8 immediately after death. As lactic acid accumulates, the pH falls, but, owing to the excellent buffering action of the flesh, the decrease is not great. A drop to much below pH 5.8 is rare. As spoilage begins, basic end products, particularly ammonia, accumulate; the pH then begins to rise, slowly at first and then quite rapidly, until it reaches a value of 7.5 or 8.0 in extreme spoilage. In oysters, no rise in pH occurs. Spoilage in this species is manifested by souring, which is caused by the accumulation of large quantities of lactic acid and other acids that result from the relatively high content of glycogen. In extreme spoilage, the pH of oysters may fall to 4.8 or lower.

SUMMARY

This revision of Fishery Leaflet 116 *(Composition of Fish.* 1944) encompasses much of the new data on the proximate composition and the chemical constituents of American food fish.

Proximate Composition

Of the components that make up the proximate composition of fish, oil varies most noticeably from species to species, from batch to batch of the same species, and from body part to body part of the same fish. The fish's food, environment, size, age, body section, and sex all affect the content of oil, as does the season of the year.

Water content usually is inversely related to oil content; the sum of the two is usually constant at about 80 percent. The relation of oil content to protein content furnishes a method of categorizing fish. Even though some commercially important fish may temporarily fall into an atypical category at given periods in their lives, most can be put into one of the following categories: low oil—low protein (for example, razor clams), low oil—high protein (for example, cod), low oil—very high protein (for example, skipjack tuna), medium oil—high protein (for example, sockeye salmon), or high oil—low protein (for example, lake trout).

Chemical Constituents

Inorganic constituents.—Of the main inorganic constituents of fish, water predominates. Although it accounts for about 80 percent of the edible flesh, little can be removed from fresh, unfrozen fish because it is held by chemical and colloidal bonds. Thus, before appreciable amounts can be removed, some kind of alteration (heating or freezing, say) is necessary to reduce the binding force. Water in fish begins to freeze at 30.5° F.; at 22° F., about 90 percent will freeze; only at -30° will most of it freeze.

Among the 28-odd minerals that occur in amounts varying with species, sex, size, and season; iodine, calcium, iron, copper, sodium, potassium, and fluorine are the most important nutritionally. Iodine is more abundant in seafoods than in any other natural

foodstuff. Only cheese and certain nuts have more calcium than do canned sardines or bone-containing salmon; only pork liver and beef liver have more iron and copper than do oysters. The content of naturally occurring sodium varies widely from species to species, but in none is it high enough (no species contains as much as 100 milligrams per gram of fish) to run counter to the requirements of low-sodium diets. The ratio of potassium to sodium is about 5:1, by weight. The content of fluorine averages 5 parts per million, far in excess of the amount the Food and Drug Administration would allow to be added to a food; but, because it is in a form less easily assimilated during human metabolism than are the inorganic fluorides, it produces no harmful effects. The high content of copper in oysters and of arsenic in shrimp, likewise, are not assimilated appreciably by the human body.

Organic constituents.—Quantitatively major organic constituents.—Organic constituents occuring in greatest quantity are proteins, amino acids, and lipids. The three most common proteins are myosin, actin, and collagen; myosin accounts for about 50 percent of the total protein in white muscle, actin for about 20 percent.

All the amino acids essential to man are present in abundance in fish. In terms of percent of the protein, these and the most predominant others occur as follows: glutamic acid, 14-17; lysine, 8-14; leucine, 7-11; aspartic acid, 6-11; isoleucine, 4-8; valine, 4-7; threonine, 4-6; phenylalanine, 3-5; methionine, 2-4; cystine, 1-2; and tryptophane, 0 to 1. The variation in content is usually greater from protein to protein than from species to species.

Fatty acids are the chief lipids in fish oils. They are combined principally in triglycerides, but they also occur in phospholipids, in some species as alkoxydiglycerides, and (in marine mammals and a few unusual fish) in waxes. The basic difference between the fatty acids in fish oils and those in vegetable or land-animal oils is in the degree of unsaturation and the chain length of the molecules. Few fatty acids from land animals have more than 2 double bonds per molecule, and few from vegetable oils have more than 3. Yet highly polyunsaturated fatty acids with 4 or more double bonds per molecule occur commonly in fish—about one-third of the fatty acids have 5 or 6. Nevertheless, the oils from fish also contain relatively high contents of saturated fatty acids. The percentage varies from 44 in cod to 21 in rainbow trout.

The polyunsaturated fatty acids in marine fish oils are largely of the linolenic acid family rather than of the linoleic acid family. The polyunsaturates make up 52 percent of the total fatty acids in scallops; even in sea herring, where they appear in lowest content, they constitute 19 percent of the fatty acids.

Fresh-water fish oils differ from marine fish oils in that their content of linoleic acid is higher, and their content of fatty acids with 20 carbon atoms and 5 double bonds are lower, as is their content of total polyunsaturates with 4, 5, and 6 double bonds.

About half the fatty acids in fish phospholipids are highly polyunsaturated, having 5 or 6 double bonds. In such species as cod, where the total content of oil is very low, the fatty acids that are combined as phospholipids predominate.

In such fish as dogfish and certain sharks, a large part of the fatty acids are combined as alkoxydiglycerides. In dogfish, the fatty acids in the ether-linked part of the compound are largely saturated and monoene; oleic acid makes up almost half the total; polyunsaturates constitute less than 1 percent. On the other hand, large amounts of polyunsaturates appear in the ester-linked part, almost twice as many as in the triglyceride fatty acids.

Besides fatty acids, fish lipids contain sterols and hydrocarbons. The principal sterol is cholesterol, the content of which ranges from highs of 138-157 milligrams per 100 grams of flesh in shrimp to 25 in haddock, 34 in halibut, and 41 in flounder. Such contents are no longer than those in other flesh foods. The most common hydrocarbon is squalene, a 30-carbon-atom, polyunsaturated hydrocarbon with 24 straight-chain carbons and 6 side methyl groups. In the liver and visceral oils of many sharks, the content of hydrocarbons can reach as much as 50 percent. Others occurring in some quantity are pristane and zamene.

Quantitatively minor organic constituents.—Some of the organic constituents, though quantitatively meager, are economically substantial, for they are major factors in the nutritive value and the quality state of the fish. Many oils from fish liver or other parts of the viscera contain vitamins A and D. Since the livers of the Teleostomi range from 1 to 5 percent of total body weight (from 5 to 15 percent for sharks and related elasmobranchs), such fish are excellent sources of these vitamins. One halibut may contain as much as 90 grams of vitamin A.

Because both liver and body oils contain vitamin E (tocopherol), the content of this vitamin correlates directly with the content of oil in the fish—in micrograms of alpha-tocopherol per gram of fresh tissue, cod has 1.5-2.1, halibut has 4-13, and catfish has 12.5 (560, 178, and 360 micrograms per gram of oil, respectively). Alpha-tocopherol in fish oils is often as high as that in olive, soybean, or corn oil.

Fish have about the same content of vitamins B_1 (thiamine) and B_2 (riboflavin) as does beef. Freshwater fish contain rather large contents of thiaminase, a thiamine-destroying enzyme; of the salt-water species, only shellfish contain thiaminase in more than negligible amounts. Cooking destroys this enzyme. Fish roe and livers are rich in riboflavin. Fish meals contain extremely high contents—one (prepared from the livers of tuna, salmon, pilchard, and herring) contains from 5,000 to 10,000 micrograms per 100 grams of meal.

In addition to the nutritive components, fish contain various nonprotein nitrogen compounds. Trimethylamine oxide amounts to about 1.25 percent of dogfish muscle and occurs to a lesser extent in other species of fish. Also present in fish muscle are creatine phosphoric acid, in contents of between 0.1 and 0.6 percent; formaldehyde in small quantities, especially in canned fish; the pigments astacin, fucoxanthin, carotene, and chlorophyll; and glycogen, especially in oysters, where the content in the meats is from 2 to 3 percent.

Immediately after most fish die, the pH of the flesh is from 6.6 to 6.8. As lactic acid accumulates, the pH drops, though rarely to below 5.8. But as spoilage begins and such end products as ammonia begin to accumulate, the pH rises, reaching 7.5 or 8.0 when spoilage becomes extreme. In oysters, the pH pattern is different. As spoilage advances, the pH continues to fall, owing to the accumulation of large quantities of the acids that result from the oysters' high glycogen content. When a state of extreme spoilage is reached, the pH may fall to 4.8 or lower.

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Hutchings, Harvey M.
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LIST OF PUBLICATIONS FOR PREVIOUS YEARS

1955-61 Fishery Industrial Research 2(2): 43-48.

1962 Fishery Leaflet 560 (Copies available from the Bureau of Commercial Fisheries Publications, United States Department of the Interior, Washington, D. C. 20240).

1963 Fishery Leaflet 572 (Copies available from the Bureau of Commercial Fisheries Publications, United States Department of the Interior, Washington, D. C. 20240).

1964 Fishery Industrial Research 3(1): 9-21.

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SUGGESTIONS TO AUTHORS WRITING FOR *FISHERY INDUSTRIAL RESEARCH*

A. APPROACH

Write your paper for a reader who has had advanced scientific training. Organize and write it in such a way that he can read it rapidly, yet understand it the first time through.

B. COMPONENTS OF THE PAPER

1. Title

Select a title that reveals the overall purpose of your research. When appropriate, include scientific names of species.

2. Abstract

Make the abstract semidescriptive: tell what the report is about, and end with a statement of your overall conclusion. (This conclusion will answer the question stated, or implied, by your overall purpose.) Keep the abstract short, but do not use the title of the paper as the assumed antecedent of otherwise irreferable pronouns.

3. Table of Contents

Include a table of contents.

4. Introduction

In the introduction, (1) orient the reader to your overall purpose, (2) state the purpose explicitly, (3) orient the reader to the subpurposes, and (4) end with a listing of the subpurposes.

Include in each orienting discussion all the important words that will occur in the subsequent statement of purpose. Avoid unnecessary reviews and economic data.

When stating the overall purpose, include a word such as "purpose" so that the reader can quickly identify the statement for what it is.

5. Main Divisions

Do not use such generalized divisions as "Experimental." Instead, be specific by making the main divisions of the paper correspond to the main divisions of your research—Experiment I, Experiment II, and so on. Give each experiment a specific title so that the reader will gain immediate insight into the scope of the experiment.

For main divisions, do not use "Materials," "Procedures," and "Results" (except when, as is rare, your paper reports only a single unit of research, such as Experiment I); instead, use these headings for minor divisions. When you use them, consider the following suggestions:

a. Materials and methods.—Describe in detail the materials and the methods used in your first experiment. If the materials and methods used in succeeding experiments are similar to those in the first, merely describe the differences when you report the succeeding experiments.

If a method includes several closely consecutive steps, number them and write out the steps; use the active voice—for example, "In the separation of acids from the aqueous phase, the analyst:

1. Neutralized a 1-milliliter portion of the aqueous layer to a pH of 10 with 0.1 N NaOH.
2. Transferred the neutralized solution to Flask A.
3. Placed Flask A in a bath . . . ."

b. Results.—Report all numerical data in tables and graphs—avoid cluttering the text with numbers. In the discussion of results, do not repeat the data that are contained in the tables and graphs. Instead, analyze the data by pointing out significances and implications. Use summary tables; do not overwhelm the reader with unnecessary tables of raw data.

6. Conclusions

Draw conclusions from your results. Make sure that the overall conclusion and the subconclusions correspond with your overall purpose and subpurposes. Present the conclusions in logical sequence.

7. Summary

End the report with a summary. Make the summary quantitative, not merely descriptive. If the report is short, end it with "Summary and Conclusions." If it is long, separate the two.

8. Acknowledgment

Avoid titles of individuals—such as mister, doctor, or professor. Simply acknowledge the assistance received.

9. Literature Cited

Make your citations complete and accurate so the reader can find the original with ease. Follow the format used in *Fishery Industrial Research.*

C. MECHANICS

1. Abbreviations

Avoid abbreviations unless you have compelling reason to use them—for example, if you lack space in your tables. If you use abbreviations, use the ones standard in your discipline. End the abbreviation with a period. See the latest issue of *Fishery Industrial Research.*

2. English Usage, Punctuation, and Capitalization

Meticulously follow established practice in grammar, punctuation, and capitalization. For precise, forceful statements, use personal pronouns where appropriate and thereby avoid illogical constructions or ambiguities.

3. Headings

Use the system of headings shown in the latest edition of *Fishery Industrial Research.*

4. Numbers

Use Arabic numbers unless you have a compelling reason to use Roman numbers or to write the numbers out. See the latest issue of *Fishery Industrial Research.*

5. Tables and Graphs

a. Tables.—Number each table and give it a title. (The title, placed at the top of the table, is a brief statement of such applicable referents as the nature, classification, or chronology of the information presented, and the political division, geographical area, or physical plant to which the data refer. These points are sometimes referred to as the "what," "how classified," "when," and "where" of the table.) Do not place a period at the end of the title. When headings apply to information in more than 1 column, word them so that they reveal the meaning of the data in all columns covered. Place all units of measurement over figure columns, and underline. Separate all columns with vertical lines, but use horizontal lines and footnotes sparingly. Place each table on a separate page. See the latest issue of *Fishery Industrial Research.*

b. Graphs.—Number each graph. Place the title at the bottom of the graph, and end it with a period. In wording the title, follow the suggestions for titles of tables. Frame all 4 sides of the graph. Place tick marks on the inside of the frame at only the left and bottom sides unless you have compelling reason to do otherwise. Identify ordinate and abscissa; capitalize all letters in the identification. Place units of measurement in parentheses, and print them in lower case. Unless it clutters the graph, label each curve directly instead of using a legend or a key. Place each graph on a separate page. See the latest issue of *Fishery Industrial Research.*

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