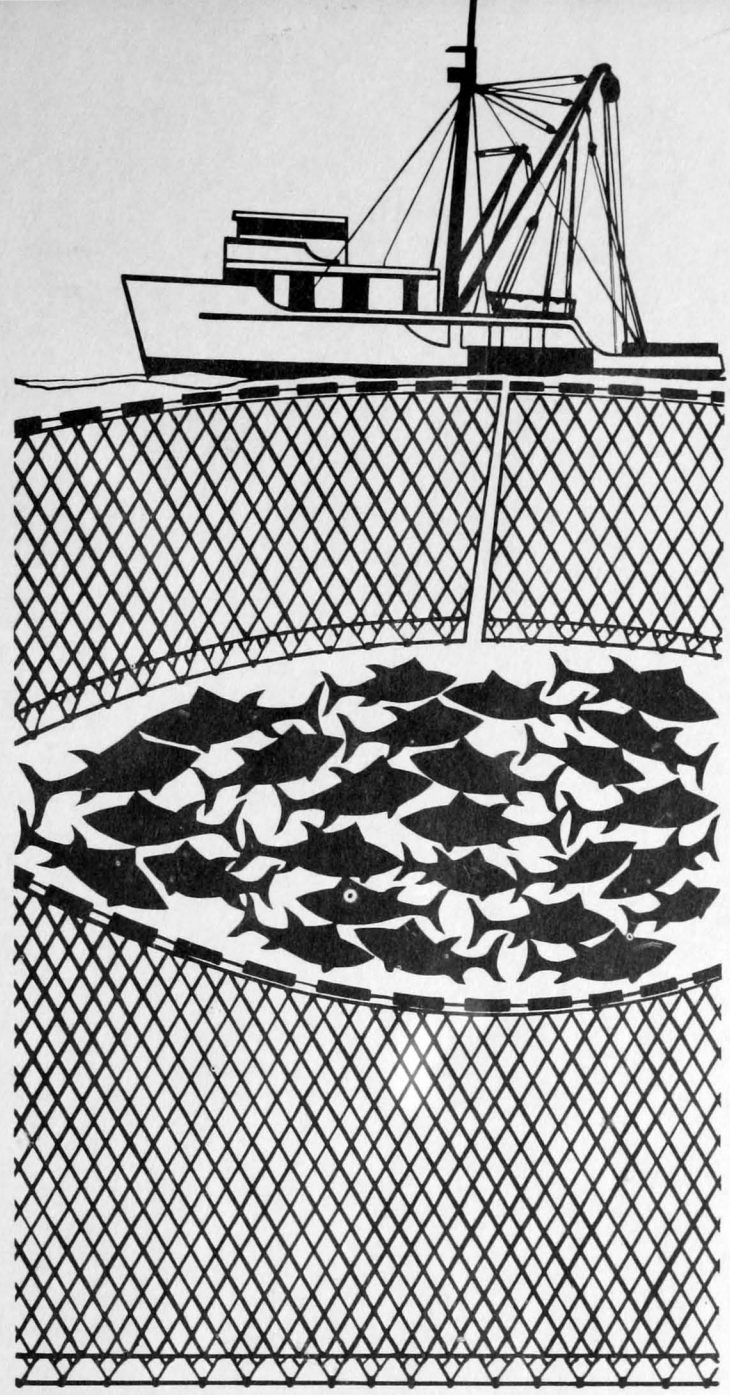

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VOLUME 2 NO. 3

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Created in 1849, the Department of the Interior—a department of conservation—is concerned with the management, conservation, and development of the Nation's water, fish, wildlife, mineral, forest, and park and recreational resources. It also has major responsibilities for Indian and Territorial affairs.

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FREE LIQUID CONTENT OF GULF OYSTERS AND SUGGESTED CHANGE IN STANDARDS

by

Arthur F. Novak, Ernest A. Fieger, and Joseph A. Liuzzo

ABSTRACT

Data obtained in 1957-62 on the free liquid content of Gulf oysters are submitted; changes in the definition and standards for shellfish are suggested based on these data.

INTRODUCTION

The present standard (Federal Register, Subdivision i, 1946), relating to the free liquid content of oysters, states:

1. That oysters shall not, during the washing process after shucking, be in contact with water or salt water for more than 30 minutes.
2. That oysters shall be "thoroughly drained" before being packed into consumer containers.

Whether or not oysters are "thoroughly drained" may be determined by one of two tests:

1. By evenly distributing for less than 5 minutes, the oysters over a skimmer having a draining surface of not less than 300 square inches per gallon of oysters.
2. By draining the oysters by any other method so that when the oysters are tested within 15 minutes after being packed, not more than 5 percent of liquid is removed by such draining.

At a joint meeting of the Oyster Institute of North America and the National Shellfisheries Association (Novak, Carritt, Ballard, Levine, and Kleinfeld, 1958), technical, industrial, and governmental representatives agreed (1) that the present oyster standard was unenforceable and (2) that extensive plans should be made immediately to investigate the bleeding characteristics of oysters in order to arrive at accurate conclusions on the extent to which, and the conditions under which, oysters "bleed" after being packed. It was proposed that the oyster industry—represented by the Oyster Institute of North America, the United States Fish and Wildlife Service, and the Food and Drug Administration (FDA)—undertake cooperative research to determine the best means for arriving at the scientific facts. Upon completion of the study, a modified standard was to be promulgated.

For several years prior to this decision, the problem of the free liquid content of Gulf oysters had been under investigation in our laboratory. The purposes of this report therefore are to submit the data on the free liquid content of Gulf Oysters, which we collected during a 5-year period between 1957 and 1962, and to suggest changes in the definition and standards for shellfish, based on these data.

EXPERIMENTAL

For 5 years, the facilities of two commercial oyster packing plants in New Orleans, have been made available to us. These two plants are above average in size for the Gulf coast. They operate throughout the year. For our tests, oysters were shucked by their regular shuckers, and samples were taken by random collection of oysters brought into the rooms set aside for washing and packing.

Monthly determinations were made by the following procedures: Freshly shucked oysters were obtained immediately after being shucked, and 1-gallon portions of the unwashed oysters were weighed. Each gallon was then washed in running tap water for 2 minutes and allowed to drain for a designated period of 1, 3, or 5 minutes. All draining was on FDA approved stainless steel skimmers, which had an area of not less than 300 square inches per gallon of oyster drained, and which had perforations of at least 1/4 inch in diameter located not more than 1-1/4 inches apart. The oysters were distributed evenly over the draining surface of the skimmer but were not otherwise agitated during the draining period. After the oysters were washed and drained as described above, each gallon-can of oysters was weighed, allowed to stand for 15 minutes, drained for 2 minutes in the same way as described above, and reweighed.

Samples were taken for the determination of the solids contents of (1) the unwashed oysters and of (2) the oysters after the final weighing. From the data obtained, the percent solids of the unwashed oysters and of the drained washed oysters were calculated, and the drained liquid content of each gallon was also calculated.

Author note.—Arthur F. Novak, *Professor and Head;* Ernest A. Fieger, *Professor Emeritus;* and Joseph A. Liuzzo, *Associate Professor,* Department of Food Science and Technology, Louisiana State University, Baton Rouge, La.

RESULTS

Table 1 lists the range in percentage of free liquor of the oysters drained 2 minutes which had been subjected to 3 and 5 minutes draining periods during packing (as outlined under "experimental"). Results are presented in ranges to show the monthly minimum or maximum deviations from the 5 percent liquor allowances. The percentage of oyster samples not meeting present FDA liquor allowances after processing by recommended procedure are shown in table 2. The range in percentage of solids of the oysters drained 2 minutes which had been subjected to 3- and 5-minute draining periods during packing (as outlined under "experimental") is given in table 3.

Table 1.—Range in percentage of drained liquor from oysters processed by official procedure

Time of year	Amount of liquor from oysters drained for:	
	3 minutes	5 minutes
Month	*Percent*	*Percent*
January	2.46 - 6.00	2.88 - 5.92
February	2.26 - 4.79	1.97 - 5.24
March	1.42 - 4.35	2.02 - 4.41
April	1.82 - 5.39	1.81 - 7.10
May	1.18 - 6.55	1.99 - 5.27
June	2.43 - 6.89	2.57 - 6.97
July	1.94 - 8.35	2.18 - 8.70
August	5.06 - 9.70	4.67 - 10.11
September	5.05 - 8.62	4.63 - 10.08
October	4.61 - 8.12	4.27 - 11.25
November	3.40 - 7.49	2.82 - 7.42
December	2.69 - 8.64	3.19 - 8.01

Note: These data were obtained in 1957-62

Table 2.—Percentage of oyster samples not meeting presnt FDA liquor allowances after being processed by official procedures

Time of year	Samples used in each draining time	Relative number of groups not meeting allowance when the draining time was:		
		1 minute	3 minutes	5 minutes
Month	*Number*	*Percent*	*Percent*	*Percent*
January	10	80	40	50
February	10	60	0	30
March	10	20	0	0
April	10	20	10	10
May	14	35	15	15
June	13	55	38	30
July	11	88	88	88
August	10	90	100	90
September	10	100	100	80
October	10	100	90	90
November	10	90	70	70
December	9	100	78	66

Note: These data were obtained in 1957-62

Table 3.—Range in percentage of solids in oysters processed by official procedure

Time of year	Amount of solids in oysters drained for:	
	3 minutes	5 minutes
Month	*Percent*	*Percent*
January	11.11 - 18.14	9.01 - 16.27
February	9.71 - 16.25	9.77 - 16.67
March	10.81 - 19.05	12.20 - 19.57
April	12.43 - 19.38	12.15 - 19.53
May	10.12 - 17.89	10.18 - 17.92
June	11.29 - 14.99	11.91 - 15.64
July	11.16 - 19.62	10.70 - 19.73
August	9.07 - 15.22	9.48 - 15.15
September	10.84 - 13.79	10.25 - 13.23
October	10.05 - 14.41	8.81 - 16.13
November	9.11 - 17.48	10.18 - 16.79
December	9.80 - 17.07	10.19 - 14.46

Note: These data were obtained in 1957-62

DISCUSSION

During the period of heavy spawning in the summer and continuing until the start of cooler weather, Gulf oysters cannot meet the present FDA standard. Depending upon environmental conditions, such as temperature, this period extends from June or July to November, December, or January. March was the only month during which all of the samples drained for 3 and 5 minutes met the present FDA liquor allowances after being processed by official procedures.

Generally, a 5-minute drain time did not result in a lower free liquid content or a higher dry-matter content than did a 3-minute drain time. The average dry matter content of the 3- and 5-minute drained samples were practically identical.

Fieger, Novak, and Burnett (1962) discussed results of a method for determining the transfer of water into and out of oysters by using tritiated water and liquid scintillation spectrometry. As short a contact with water as 2 minutes resulted in a transfer of one-third of the volume of oyster fluid content out of the oysters and an almost corresponding inflow of wash water. Increasing the length of draining time after washing had little effect in reducing the amount of wash water remaining in the oysters. The drained liquid has essentially the same constituents as the fluid in the oyster body. Draining beyond the time required for removal of the free liquid surrounding the oysters results in loss of fluid from their tissue.

On the basis of these observations, the following changes are suggested for definitions and standards for shellfish (21CFR Section 36.10 (c) (2) (ii) Federal Register 1946):

> The oysters are drained by any method other than that prescribed by subdivision (i) of this subparagraph whereby liquid from the oysters is removed so that when the oysters are tested within 15 minutes after packing by draining a representative gallon of oysters on a skimmer of the dimensions and in the manner described in subdivision (i) of this paragraph for 2 minutes, not more than 10 percent (instead of present 5 percent) of liquid by weight is removed from such draining.

Under the Federal Food, Drug, and Cosmetic Act, a regulation promulgating a standard of identity for a food should of course be reasonable. Accordingly, regulatory changes should be adopted that will enable oyster dealers to pack and sell the product available in their area.

SUMMARY

Data on the free liquid content of Gulf oysters over a 5-year period are presented, and changes are suggested in the definition and standards for shellfish.

To determine free liquid content of freshly shucked oysters, 1-gallon portions of unwashed oysters were

weighed, washed in running tap water for 2 minutes, and allowed to drain for a period of 1, 3, or 5 minutes. Each gallon of drained oysters was weighed, allowed to stand for 15 minutes, drained for 2 minutes and reweighed. The free liquid content was calculated for each sample. Percent solids was determined on samples of the unwashed oysters and of the oysters after final weighing.

During the period from June or July to November, December, or January, Gulf oysters cannot meet the present FDA standard. March was the only month during which all of the samples drained for 3 and 5 minutes met the present FDA liquor allowances after being processed by official procedure.

On the basis of these results a regulatory change has been suggested that will enable oyster dealer to pack and sell the product which is normally available in their area.

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MS #1227

COMPARISON OF CHEMICAL AND SENSORY TESTS FOR ASSESSING STORAGE LIFE OF ICED CALICO SCALLOPS (*Pecten gibbus*)

by

Melvin E. Waters

ABSTRACT

Various objective methods of assessing the freshness of iced calico scallops were compared critically. In the study, trimethylamine, volatile acids, volatile bases, pH, and picric acid turbidity tests were conducted on iced samples over a 23-day period and compared with sensory evaluations. The sensory judgments rated the scallops as being inedible after 16 days of storage. Chemical tests correlated closely with these results. The sensory evaluation, however, revealed the onset of spoilage long before the chemical tests did.

INTRODUCTION

Though numerous studies have been made on methods of detecting quality changes in raw and canned fish, only a few studies have been made using shellfish.

In the various studies, many tests have been described —each investigator primarily comparing the results of his method with sensory evaluations, inasmuch as quality changes are most readily detected by sensory means. Variations, however, in taste and judgment of the various workers in recording flavors and odors make one test difficult to compare with another.

Although the degree of fish spoilage has been estimated by various objective tests—such as changes in pH and presence of volatile acids or bases—the significance of many of these tests is questionable. A test, for example, may work well with one species but not with another, or with fresh fish but not with frozen fish. The research worker thus has long felt the need for a reliable, independent, objective method to check sensory judgments.

Research workers generally agree that while the flesh is still in rigor, adverse changes in quality do not proceed to a measurable extent. After rigor has worn off, however, changes produced by autolytic and bacterial action become apparent. A measurement of the chemical products released or used up as a result of this degradation forms the basis for chemical indices that are subsequently correlated with sensory evaluations.

A review of the literature shows that no single satisfactory test exists for detecting the onset of spoilage in fresh scallops. In fact, there are almost no literature references on the subject of spoilage in scallops.

Many methods are used, however, to determine the quality of fish and shellfish of similar composition. Kurtzman and Snyder (1960) described the picric acid turbidity (PAT) test as a rapid objective freshness test for the meat of blue crab. Farber and Ferro (1956) reported on the use of volatile reducing substances (VRS) in canned fish and compared VRS with trimethylamine nitrogen and total volatile nitrogen as a measure of spoilage. Sigurdsson (1947) described Friedmann's procedure for determining volatile acids in canned fish and recommended its use. The Nessler test has been described (Anonymous, 1961); however, as described, it is not quantitative, and the color developed is unstable. Duggan and Strasburger (1946) used the concentration of indole as a criterion of quality in shrimp. Kamasastry (1957) and Shewan and Liston (1957) reported favorably on the tetrazolium bromide reduction test for assessing the quality of fish. Of all the tests for detecting the spoilage of fish and shellfish perhaps the one used most universally is that for trimethylamine. Many other chemical methods are also employed, however, including volatile bases, hydrogen sulfide, hydrogen ion concentration, and free fatty acids.

An increase in total bacterial counts is correlated with progressive spoilage, but high counts do not always mean that the product is spoiled. Bacterial counts have been reported to be valueless as a measure of the degree of spoilage in fresh fillets (Castell, Anderson, and Pivnick,

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1948). Work by Iyengar, Visweswariah, Moorjani, and Bhatia (1960) shows that bacterial counts alone are unreliable in differentiating shrimp of different qualities. Other investigators concluded that the total count cannot be correlated with the physical condition of the product. Bacterial methods, therefore, have not been entirely reliable.

In view of the many methods available, with each author claiming the validity of his method, my approach was to compare the most promising tests on each specific product and then use the data as a basis for determining the reliability of these tests. Calico scallops were selected for study because they are of potential commercial importance in the Gulf and South Atlantic areas, will largely be held and transported in crushed ice, and have an unknown storage life as an iced product. The purposes of the work reported here therefore were:

1. To search for a definite relation between objective chemical tests and subjective sensory tests as a means of measuring the freshness of iced scallops.
2. To search for an existing chemical test that is reliable and is relatively simple, rapid, and accurate.
3. To determine the maximum storage life of iced calico scallops, utilizing the data obtained in both subjective and objective tests.

SAMPLES

The calico scallops used in this experiment were taken from the Cape Canaveral, Fla., beds. The meats were shucked immediately after being brought on deck and were placed in iced sea water. After enough meats had been accumulated, they were washed on a screen and packed into ½-gallon containers. The containers, in turn, were packed in crushed ice and transported to the laboratory. Upon arrival, the scallops were divided into two lots. The first lot was placed in polyethylene bags (8 oz. each bag) and frozen immediately at -40° C. for use as a frozen reference control. The second lot was packed in the same way as was the first lot but was placed in crushed ice and held at an ambient temperature of 5° C. for 23 days. Each day, the iced lot was repacked and covered with ice. Analyses were begun within 84 hours after capture of the scallops.

Duplicate subsamples of iced scallops and a single control subsample were analyzed at intervals of 2 or 3 days. Each subsample was divided into two parts. Part 1 was used for sensory evaluation. Part 2 was blended in an electric blender for 2 minutes, and portions then were taken from the blender slurry for analyses to evaluate the various chemical methods.

SENSORY TEST

The quality of both iced and frozen scallops was determined by an experienced taste panel of five members. A score of 5 represented high-quality scallops; a score of 1 represented decomposed scallops. Sensory values were arbitrarily set between these limits; thus, 4.0 to 4.9 represented good quality; 3.0 to 3.9, fair quality; 2.0 to 2.9, borderline quality; and 1.0 to 1.9, inedible quality. A product with a score below 3 was considered as being organoleptically unacceptable.

The taste panel rated the scallops under test as being of "high quality" at the start, of "good quality" on the 5th and 7th days, of "fair quality" on the 9th and 11th days, of "borderline quality" on the 14th day, and of "inedible quality" on the 16th day (figs. 1-5). After the 7th day of storage, the "sweet" flavor normally associated with good fresh scallops was absent. The very slight spoilage odor that was detected on the 9th day increased gradually through the 14th day. Hydrogen sulfide odors, often present in fresh scallops, were disregarded when the odor scores were assessed. Flavor and texture were not assessed after the 9th day. Textural changes were noted on the 9th day when the scallops became mushy or gummy. Heavy putrid odors had developed by the 16th day.

CHEMICAL TESTS

Trimethylamine

Trimethylamine (TMA) determination was carried out according to the method described by Dyer (1959). Results were expressed as mg. TMA per 100 g. sample.

The TMA content remained less than 1 mg. per 100 g. of scallops until the 14th day. It then began to increase and rose rapidly from the 16th day throughout the remainder of the storage period (table 1). Figure 1 shows the relation between the sensory test and the TMA test. Days of storage in ice (caught age), as shown in each figure, include the 84 hours in transport to the laboratory. Although the sensory test detected the onset of spoilage before TMA values increased significantly, TMA could be used to confirm spoilage in its advanced stages. These conclusions agree with those of Bethea and Ambrose (1962) for indices of iced shrimp quality. They also parallel the conclusions drawn by Hillig, Shelton, Loughrey, and Fitzgerald (1960) that TMA shows a high degree of correlation with organoleptic judgment on the

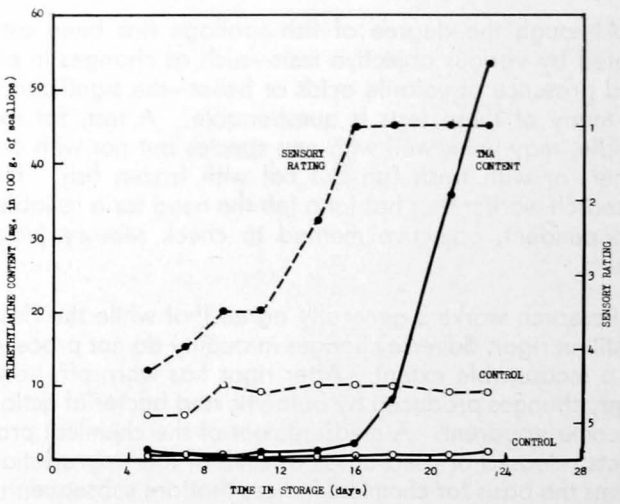

Figure 1.—Trimethylamine content and sensory test values of scallops during storage.

Table 1.—Trimethylamine colorimetric data on the concentration of TMA in the scallops during storage

Storage time	Sample designation (C=control)	Volume of extract used	Optical density				Concentration of TMA[1]
			Duplicates		Average of duplicates	Net average of A + B	
			1	2			
Days		*Ml.*					*Mg./100 g.*
5	A	2	.061	.071	.071	.066	.504
	B	2	.066	.066	.066		.504
	C	2	.066	.066	.066		
7	A	3	.084	.120	.102	.118	.576
	B	3	.135	.130	.133		.584
	C	3	.112	.121	.117		
9	A	3	.112	.082	.098	.078	.384
	B	3	.054	.060	.057		.456
	C	3	.095	.088	.092		
11	A	3	.136	.137	.137	.136	.680
	B	3	.151	.120	.136		.352
	C	3	.071	.065	.068		
14	A	3	.199	.220	.209	.235	1.18
	B	3	.245	.277	.261		.560
	C	3	.113	.110	.112		
16	A	3	.450	.520	.490	.420	2.08
	B	3	.345	.355	.350		.600
	C	3	.107	.130	.119		
18	A	1	.540	.560	.550	.540	8.04
	B	1	.520	.550	,530		.656
	C	3	.138	.123	.131		
21	A	0.3	.750	.725	.738	.722	35.76
	B	0.3	.725	.685	.705		.696
	C	3	.140	.140	.140		
23	A	0.1	.380	.370	.380	.360	53.53
	B	0.1	.350	.330	.340		.800
	C	3	.150	.170	.160		

[1] Formula used: Amount of TMA present = $\frac{\text{graph reading}}{\text{amount of sample used}}$ x 2.4, where 2.4 represents ratio of TCA used per g. of sample.

quality of ocean perch. TMA content of control samples remained less than 1 mg. per 100 g. of scallops throughout the entire storage period.

Volatile Acids

Volatile acids were determined by the Friedmann method as recommended by Sigurdsson (1947). Results are expressed in mg. NaOH per 100 g. sample.

Volatile acid values increased at about the same rate as did TMA. The volatile acid number (VAN) for the control was 5 or less during the storage period; iced samples began to increase sharply in VAN after 16 days of storage (fig. 2). VAN did not increase significantly until the iced samples were judged inedible by sensory test. VAN cannot be used to detect early stages of spoilage, but like TMA, can be useful in verifying decomposition.

Hydrogen-ion Concentration

The pH was determined using a 1:5 dilution (sample: distilled water). The pH of iced scallops ranged between 6.55 and 6.65 until the sample was judged inedible (16th day), then the pH increased steadily, reaching 7.65 on the 23rd day (fig. 3). After spoilage had occurred, the pH exceeded 6.65. The control ranged from 6.00 to 6.65. Thus, in this study, a pH greater than 6.65 indicated that the scallops were decomposed.

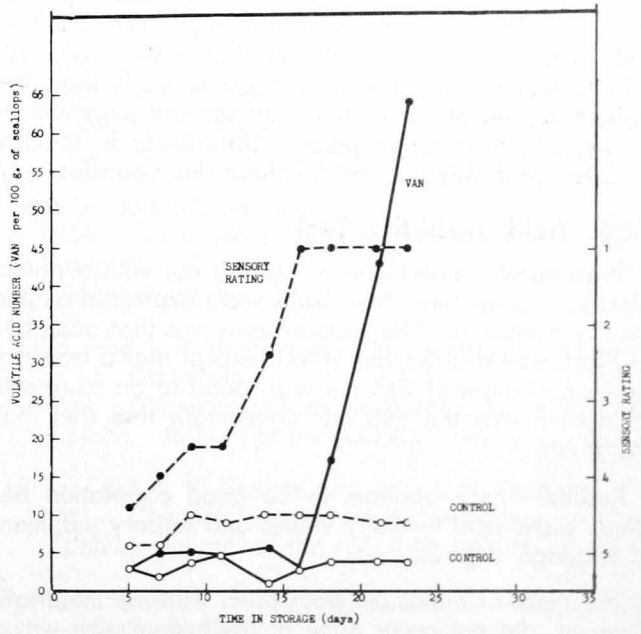

Figure 2.—Volatile acid number and sensory test values of scallops during storage.

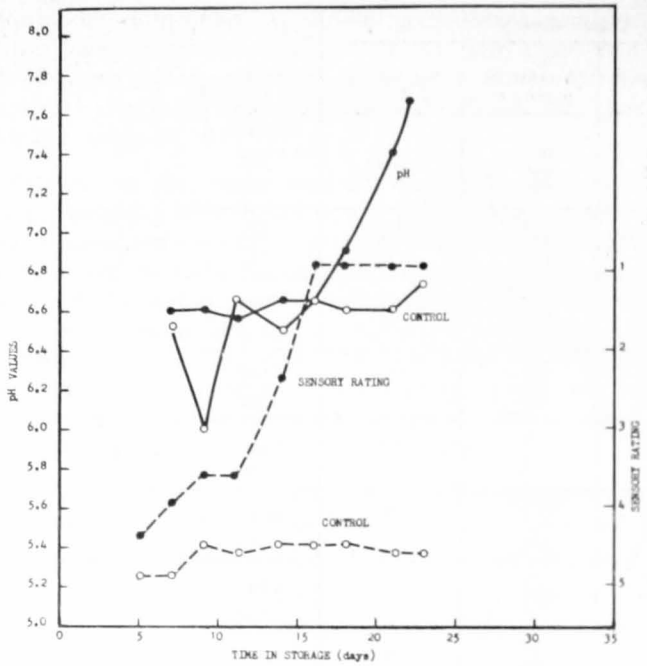

Figure 3.—pH and sensory test values of scallops during storage.

Volatile Bases

The method reported by Gagnon and Fellers (1958) was used for estimating ammonia and other volatile bases. The results were calculated as mg. NH_3 per 100 g. of scallop meats.

Values for the volatile bases (VB) were erratic both for the control and for the iced scallops (fig. 4). Shewan and Ehrenberg (1957) reported that VB content of North Sea cod muscle does not serve as a precise index of eating quality. Contrary to this finding, Hillig, Shelton, and Loughrey (1961) concluded that VAN, TMA, VB, volatile amines, and formic and acetic acids show the highest degree of correlation with sensory judgment of decomposition in ocean perch. Differences in species, however, probably account for these discrepancies.

Picric Acid Turbidity Test

Procedure.—Analyses were carried out with a photoelectric colorimeter. The results were expressed as percent transmission. The method used was that described by Kurtzman and Snyder (1960) except that a transmission wavelength of 545 mμ was found to be more suitable than was the 540 mμ wavelength that they had suggested.

Results.—There appears to be good correlation between picric acid turbidity values and sensory judgment of spoilage (fig. 5).

The peak of maximum absorption with my materials, however, did not occur quite at the transmission wavelength of 540 mμ found by Kurtzman and Snyder (1960). Several experiments were conducted in an effort to determine the maximum, and 545 mμ gave the most consistent results.

Percent transmission of iced scallops increased, indicating that the samples became less turbid as storage continued. This trend is the opposite to that reported by Bethea and Ambrose (1962) and Kurtzman and Snyder (1960) for shrimp and crab meat, respectively. Saffle, May, Hamid, and Irby (1961) noted that optical density (OD) of beef extract increased (percent transmission decreases) with time of storage. I found, however, that the OD decreased with storage time in the case of the calico scallops studied here. As yet, the nature of the product(s) measured by the turbidity is unknown, so it is difficult to assess reasons for the difference in observations.

Whatever the explanation, the percent transmission increased after 5 days of storage (iced scallops) and then increased substantially after 16 days, correlating fairly well with changes noted in sensory evaluations. The control remained quite constant throughout the experiment.

STORAGE LIFE

In a previous experiment in which the scallops were iced in cloth bags, the maximum storage was organoleptically determined to be 12 days. Melting ice tends, however, to wash away enzymes, bacteria, and spoilage odors. Accordingly, the iced-polyethylene-bag method of storage was selected in the present study to minimize this washing effect and thereby increase the sensitivity of the tests to the effects of storage time.

The maximum storage life of scallops iced in the polyethylene bags was found to be 9 days. It was observed that these scallops deteriorated very rapidly as the result of enzyme action.

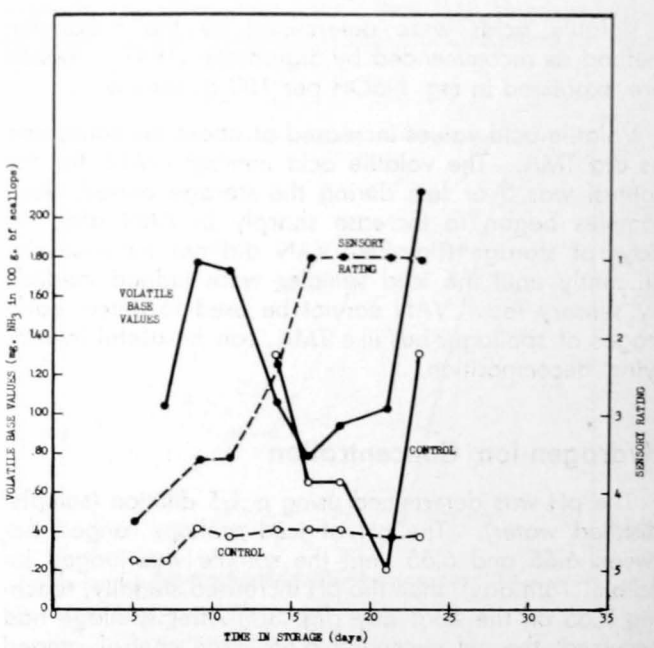

Figure 4.—Volatile bases and sensory test values of scallops during storage.

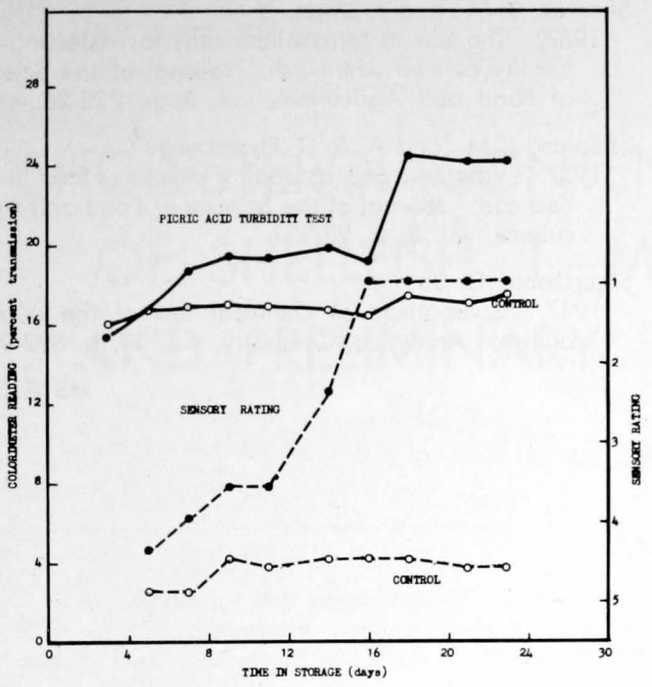

Figure 5.—Picric acid turbidity and sensory test values of scallops during storage.

CONCLUSIONS

1. a. Trimethylamine and volatile acid number appeared to offer a means of judging decomposition in scallops.

   b. A pH greater than 6.65 indicated that the scallops were decomposed.

   c. Volatile base results were erratic and therefore did not appear useful in predicting the quality of the iced scallops.

   d. Picric acid turbidity test correlated quite closely with sensory judgment.

2. Sensory judgments still offer the most reliable means of detecting early spoilage; chemical tests did not indicate spoilage until it was well under way (or until the scallops had already reached an inedible stage).

3. Scallops held in polyethylene bags had a maximum storage life of 9 days.

SUMMARY

Biochemical and organoleptic methods were studied relative to the selection of an objective test for assessing the quality of iced calico scallops.

Trimethylamine (TMA), volatile acids (VAN), pH, volatile bases, picric acid turbidity (PAT), and taste panel scores were determined on samples of iced scallops over a 23-day period and on a frozen sample used as the control. TMA and VAN showed an increase in value only after the taste panel had rejected the scallops. PAT closely correlated with the sensory test, particularly after the 16th day, and confirmed decomposition in its advanced stages. When the pH had increased to above 6.65, the scallops were judged inedible. Volatile base values could not be used to assess quality, as they were erratic. All in all, sensory evaluations were the most reliable means for detecting spoilage in the scallops, since the chemical analyses did not indicate spoilage until it was well advanced.

As a result of the foregoing tests, the maximum storage life of the scallops stored in iced polyethylene bags was judged to be 9 days.

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MS #1342

CHOLESTEROL CONTENT OF VARIOUS SPECIES OF SHELLFISH. 1.--METHOD OF ANALYSIS AND PRELIMINARY SURVEY OF VARIABLES

by

Mary H. Thompson

ABSTRACT

A method for the determination of total cholesterol is described. The method allows the recovery of 97% of the cholesterol material with a relative mean error of -0.03 mg. cholesterol per 100 g. of sample and a relative standard deviation of 0.045 mg./100 g.

Preliminary total cholesterol values are reported for eastern and southern blue crabs, clams, Dungeness crabs, eastern and southern oysters, scallops, brown shrimp, and white shrimp. In addition, comparisons are made (1) between the total cholesterol content of white body meat and claw meat of Dungeness crabs and (2) between blue crabs from the same geographical area caught in September and in November.

INTRODUCTION

Values reported in the literature for the total cholesterol content of shellfish meats differ considerably for individual species. The total cholesterol content of oysters has been given variously as 112 mg./100 g. of meats (Kritchevsky and Tepper, 1961), 130 mg./100 g. (Idler and Fagerlund, 1955), and 230 mg./100 g. (Mayo Clinic, 1961). Clams have been reported as having 122 mg./100 g. (Kritchevsky and Tepper, 1961) and 230 mg. of total cholesterol/100 g. of meats (Idler and Fagerlund, 1955).

The shellfish for which values are given usually are not further identified as to species or as to area or season of catch. The possibility therefore arises that differences in reported values may be due to differences in (1) geographical location of catch, (2) season of catch, (3) species analyzed, (4) portion of body analyzed, or (5) a combination of any or all of these variables.

The determination of the effect of these variables on total cholesterol content requires a large number of analyses, which, in turn, makes it desirable that the analytical method not only be as precise and accurate as possible but also quick and easy to use. The digitonin precipitation techniques described previously in various modifications of the Schoenheimer-Sperry method (Foldes and Wilson, 1950; Sperry and Webb, 1950) require an overnight precipitation. Vahouny, Borja, Mayer, and Treadwell (1960) eliminated this time-consuming aspect by using aluminum chloride as a gathering agent for the rapid precipitation of the cholesterol digitonide. This method called for determination of the digitonide complex with anthrone reagent, the complete assay being performed in 4 hours. Accurate results were recorded with anthrone; however, it was preferred to determine the complex by the Liebermann-Burchard color reaction, as it is the most widely accepted method today.

The objectives of the long-range program of which this study is a part are (1) to develop a reliable and quick method for determining total cholesterol in fish and shellfish, (2) to determine the significance of geographical location of catch, season of catch, species analyzed, and body portion analyzed on the total cholesterol content of fish and shellfish, and (3) to determine the total cholesterol content of various species of fish and shellfish.

This present report is primarily concerned with the first of these objectives—the development of a reliable and quick method of analysis. To test the practicality, precision, and accuracy of the method developed, a number of samples were analyzed, which resulted in the opportunity to obtain data relating to objective 2.

PROCEDURE

Materials

Samples of shellfish were collected, frozen, and shipped in dry ice to the Bureau of Commercial Fisheries Technological Laboratory in Pascagoula, Mississippi. All

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samples were frozen when received. They were stored at 0° F. until analyzed.

Specific geographical location and dates of catch as well as species and portion of meat analyzed are listed in tables 1 and 2. Samples of eastern blue crab, eastern

Table 1.—Recovery of total cholesterol and experimentally added cholesterol from blue crab, *Callinectes sapidus*, "white" body meat[1]

Sample	Total cholesterol	Deviation	Sample	Total cholesterol			
				Average	Added	Found	Recovery
No.	*Mg./100 g.*	*Mg./100 g.*	*No.*	*Mg./100 g.*	*Mg./100 g.*	*Mg./100 g.*	*Percent*
1	87	+1	1	86	50	127	93
2	81	-5	2	86	49	125	93
3	87	+1	3	86	50	134	99
4	92	+6	4	86	50	133	98
5	86	0	5	86	54	141	101
6	82	-4	6	86	50	136	100
Mean	86	2.8				133	97

Standard deviation: 3.9 mg./100 g.
Relative standard deviation: 0.045 mg./100 g.
Standard error: 1.6 mg./100 g.
95% confidence limits: 86 ± 10 mg./100 g.

Standard deviation: 3.5 mg./100 g.
Relative standard deviation: 0.027 mg./100 g.
Mean error: -4 mg./100 g.
Relative mean error: -0.03 mg./100 g.

[1] The crabs were collected 9/13/62 from upper Chesapeake Bay. The oil content was 1.2%; the moisture content, 81.6%.

oysters, and hard clams were obtained by personnel of the Bureau of Commercial Fisheries Technological Laboratory, College Park, Md., from the upper Chesapeake Bay area. Sea scallops were obtained commercially from the Gloucester, Mass., area. Dungeness crab samples were from a catch made off Westport, Wash. The remaining species—southern blue crab, southern oyster, brown shrimp, and white shrimp—were samples of catches obtained off the Mississippi coast from Pascagoula to Biloxi. All samples were obtained in November and January, with the exception of the eastern blue crab samples that were used for the recovery experiment and that were collected in September (table 1).

Sample preparation: Samples were thawed and, if necessary, cleaned in a manner resembling commercial practice. Clams, eastern oysters, southern oysters, and scallops had already been shucked. The clams and the oysters were ground together with their exuded liquor, since they were dry packed and the liquor that formed on thawing was actual body fluid. The samples of eastern and southern blue crabs represent that portion of the body contained within the carapace commonly known as "white" meat. Both the claw meat and the white meat of the Dungeness crabs were analyzed—specifically to provide an indication of the variation in cholesterol content to be expected in the two types of meat. The shrimp were headed and peeled but not deveined (no evidence of egg material was present). The samples were reduced to a homogenous mass in a ball-mill grinder, and duplicate samples were taken for extraction.

Methods of Analysis

Duplicate samples of each extract were analyzed for cholesterol content through digitonin precipitation and the Liebermann-Burchard color reaction.

The method of total cholesterol analysis is presented here in some detail, since it is a combination of several different methods and since it provides a relatively quick and reliable estimation of total cholesterol content in shellfish.

The procedure used consists of (1) extracting the lipid material containing the cholesterol with a three-phase system of chloroform, methanol, and water; (2) precipitating the cholesterol by the accelerated method of Vahouny, Borja, Mayer, and Treadwell (1960); and (3) measuring the color developed by the Liebermann-Burchard reaction according to Sperry and Webb (1950). Oil and moisture content were determined according to the Association of Official Agricultural Chemists' standard methods (1960).

Reagents.—

(a) Stock cholesterol standard (5 mg./ml.)—Weigh 0.5000 g. cholesterol and place in a 100-ml. volumetric flask. Dissolve in 1:1 ethanol-acetone and dilute to mark.

(b) Working cholesterol standard (0.5 mg./ml.)—Dilute 1 ml. of stock cholesterol standard to 10 ml. with 1:1 ethanol-acetone.

(c) 0.5% digitonin—Weigh 0.50 g. digitonin and dissolve in 100 ml. of 50% aqueous ethanol; if necessary, heat to 45° C. to effect solution. Prepare fresh biweekly.

(d) 3.5% HCl—Dilute concentrated HCl; 1 volume HCl with 9 volumes distilled water.

(e) 50% KOH—Dissolve 50 g. of reagent-grade KOH in 100 ml. of distilled water.

(f) 10% $AlCl_3$—Dissolve 10 g. of $AlCl_3 \cdot 6H_2O$ in 100 ml. of distilled water.

(g) 20:1 acetic anhydride-sulfuric acid—Add 20 parts acetic anhydride to a flask set in an ice bath; slowly add 1 part concentrated H_2SO_4; and mix. Allow to stand until ice-cold before using. Prepare immediately prior to use.

Extraction of cholesterol.—The procedure of Bligh and Dyer (1959) was adapted for the extraction of cholesterol, as follows:

1. Blend a 10-g. sample of homogenized shellfish for 30 min. in 10 ml. of chloroform and 20 ml. of methanol (that is, if the moisture content of the sample = 80 ± 1%; otherwise adjust the proportions to 0.8 parts water, 1 part chloroform, and 2 parts methanol) with the aid of a magnetic stirrer. Disperse the sample mass with a stirring rod, if necessary.

2. Add 10 ml. chloroform to the mixture and blend 30 sec.; add 10 ml. distilled water and blend 30 sec. (If the moisture content is not 80 ± 1%, adjust proportions to 1.8 parts water, 2 parts chloroform, and 2 parts methanol.)

Table 2.—Total cholesterol content of various species of shellfish

Name of shellfish		Date caught	Location caught	Oil content	Moisture content	Sample	Total cholesterol content			
Popular	Scientific						Aliquot 1	Aliquot 2	Average	Grand average
				Percent	*Percent*	*No.*	*Mg./ 100 g.*	*Mg./ 100 g.*	*Mg./ 100 g.*	*Mg./ 100 g.*
Blue crab, eastern	*Callinectes sapidus*	11/13/62	Upper Chesapeake Bay	1.1	78.5	1	96	94	95	98
						2	97	104	101	
Blue crab, southern	*Callinectes sapidus*	1/4/63	Mouth of Pascagoula River	1.2	82.5	1	73	78	76	76
						2	74	76	75	
Hard clam	*Mercenaria mercenaria*	11/25/62	Upper Chesapeake Bay	2.0	86.6	1	82	77	80	82
						2	86	79	83	
Dungeness crab, body	*Cancer magister*	1/4/63	Westport, Wash.	1.2	81.0	1	62	65	64	63
						2	63	58	61	
Dungeness crab, claw	*Cancer magister*	1/4/63	Westport, Wash.	1.0	80.3	1	52	52	52	52
						2	50	54	52	
Oyster, eastern	*Crassostrea virginica*	11/25/62	Upper Chesapeake Bay	2.0	90.2	1	57	60	59	58
						2	54	57	56	
Oyster, southern	*Crassostrea virginica*	1/4/63	Biloxi, Miss.	2.4	89.4	1	35	40	38	37
						2	35	35	35	
Scallop, sea	*Aquapecten grandis*	1/5/63	Gloucester, Mass.	1.6	80.4	1	60	57	59	60
						2	61	61	61	
Shrimp, brown	*Penaeus aztecus*	11/14/62	Mouth of Pascagoula River	1.1	76.8	1	146	146	146	156
						2	165	165	165	
Shrimp, white	*Penaeus setiferus*	1/4/63	Mouth of Pascagoula River	1.2	78.2	1	156	159	158	157
						2	153	156	155	

3. Filter the mixture through glass wool in a Buchner funnel, rinsing with small amounts of chloroform; press out last of chloroform and transfer to a separatory funnel.

4. Allow a few minutes for adequate separation; draw off chloroform layer, and evaporate to oily residue.

5. Take up residue in 1:1 ethanol-acetone, and make to 50 ml. in a volumetric flask.

Precipitation of cholesterol.—The accelerated digitonin precipitation method of Vahouny, Borja, Mayer, and Treadwell (1960) was utilized as follows (for total cholesterol):

6. Take 2 ml. of extractant from step 5, place in a tube, add 2 drops of 50% KOH, and mix. Place in a water bath at 45° C. for 30 minutes.

7. Neutralize to phenolphthalein end-point with 3.5% HCl.

8. Form a series of standards using 0.5, 1.0, and 1.5 ml. of working cholesterol standard (equivalent to 0.25, 0.50, and 0.75 mg. of cholesterol).

9. Add 1 drop of 3.5% HCl, 1 ml. of 0.5% digitonin in 50% aqueous ethanol, and 1 ml. of 10% $AlCl_3$ to all tubes, mixing between each addition.

10. Heat at 45° C. for 15 min., let stand for 1 min. to cool, centrifuge at 1000 x gravity for 20 min., discard supernatant, and drain for 1 min.

11. Add 2 ml. methanol, and dissolve precipitate by warming and mixing; add 1 drop 3.5% HCl and 2 ml. 10% $AlCl_3$, and mix; proceed as in step 10.

12. Repeat recrystallization given in step 11.

13. Add 2 ml. acetone to all tubes, and disperse precipitate; centrifuge at 1000 x gravity for 5 min.; decant supernatant.

14. Add a blank tube to the series. Add 1 ml. glacial acetic acid to all tubes, and dissolve the precipitate by warming and mixing.

Color reaction.—The Liebermann-Burchard reaction according to Sperry and Webb (1950) was adapted as follows:

15. Prepare acetic anhydride-sulfuric acid (20:1) reagent in an ice bath. Let stand until the reagent is ice-cold.

16. Add 4 ml. of ice-cold acetic anhydride-sulfuric acid reagent at regular intervals (1 min. is suitable) to each tube, mix well, and allow to stand at 25° C. in a dark place.

17. Read the optical density of known standards and of unknowns against the blank at the predetermined regular interval between 30 and 40 minutes (30 minutes for this investigation) after adding the reagent at 625 mμ in a spectrophotometer.

Calculations.—The calculations are made as follows:

18. Determine the value of cholesterol per ml. of unknown by interpolation using the optical density of the known standards.

19. Using this figure multiply by the dilution factor; divide by the number of grams in the sample; and multiply by 100. The results will then be expressed as mg. of cholesterol per 100 g. of sample.

EXPERIMENTAL WORK

Six aliquots of a blue crab "white" meat sample were extracted and analyzed for total cholesterol. A further series of six aliquots was taken from the same sample of crab meat. An amount of cholesterol equal to 50 mg./100 g. was mixed with the flesh and then extracted in the usual manner.

In a second series, samples representative of various types of shellfish were also extracted in duplicate, and duplicate analyses for total cholesterol content were made. In this series the total cholesterol contents of the claw and "white" body meat of the Dungeness crab were compared, as were those of Chesapeake Bay and Mississippi blue crab "white" meat and oyster. Two species of shrimp were also analyzed.

RESULTS AND DISCUSSIONS

The results of the recovery experiment are listed in table 1. The mean total cholesterol for the series of six samples without added cholesterol was 86 mg./100 g. The standard deviation of this series was 3.9; thus 95% of the values obtained should lie within 7.8 mg. of the true mean, and 99.7% of the values within 11.7 mg. The standard error of this series was 1.6. Therefore, in 95% of the samples, the mean value will approach the true mean within 3.2 mg.; and in 99.7% of the samples, within 4.8 mg. The 95% confidence interval shows that the true mean lies within the range of 86 ± 10 mg./100 g.

The recovery of added cholesterol is also shown in table 1. Recoveries ranged from 93% - 101% with a mean recovery of 97%. The recovery data are based on the mean value of the first series of six samples. A mean error of -4 mg./100 g. of cholesterol is noted, signifying that at this level of total cholesterol (132 mg./100 g.), a loss as high as 4 mg./100 g. may be expected. The relative mean error of -0.03 mg. shows that for every mg. of cholesterol in a 100-g. sample .03 mg. may be lost in this procedure. A comparison of the relative standard deviation of the series of six samples without added cholesterol (0.045 mg./100 g.) and with added cholesterol (0.027 mg./100 g.) indicates that any variation in results obtained will not be influenced by the total amount of cholesterol present.

The reliability and speed of this procedure prompted its use on several other species of shellfish. The results of this preliminary study on the total cholesterol content of various species of shellfish are presented in table 2. The precision of the method for duplicate analysis of each extract for digitonin-precipitable-Liebermann-Burchard-positive material is evident, since the widest spread in cholesterol values is 7 mg./100 g., and most values are much closer. The precision of the extraction procedure is evidenced by the nearly equal values for all extracts from a given sample, with the possible exception of the brown shrimp.

The standard curves from day to day (over a period of 8 days) varied but little from the average. In order that the accuracy of the entire procedure could be checked with material of known high cholesterol content, the yolk of a chicken egg was analyzed. The literature revealed that the cholesterol content of egg yolk varies somewhat according to the diet of the chicken (Long, 1961). A value of 0.29 g. cholesterol per 18.2-g. yolk is given by Long (1961), which is equal to 1,595 mg./100 g. In comparison, the value for egg yolk obtained with the above method was 1,570 mg./100 g. The value for the cholesterol content of egg yolk by the procedure described in this paper is within one standard deviation from the literature value and within the range of error as determined by the use of the relative standard deviation and relative mean error listed in table 1. This finding would indicate that the method as utilized gives an accurate value for total cholesterol.

There has been some question as to seasonal and geographical influences on the cholesterol content of shellfish. It can be seen that there is indeed a difference between the cholesterol content of eastern and southern blue crab white meat of the same species and eastern and southern oysters of the same species. Unfortunately, samples were obtained at different times of the year, so all that may be pointed out is that differences do occur in cholesterol content within a species. The closeness of the values for brown and white shrimp may be purely fortuitous, especially since the shrimp were obtained during different seasons, although the geographic location was the same. A difference in total cholesterol content of the white meat of eastern blue crab caught in the months of September and November is noted. September crabs average 86 mg. of cholesterol per 100 g. of flesh, whereas November crabs caught in the same area average 98 mg./100 g. The difference between these two means is significant at the 95% level, indicating that at least for these samples, seasonal changes in cholesterol content may be expected. Differences were found in the total cholesterol content of white body meat and claw meat of the Dungeness crab, the body meat being nearly 18% higher in cholesterol content.

Further work is contemplated to show the effect of geographic location and seasonal variation on the total cholesterol content of shellfish and will be reported in a subsequent communication.

SUMMARY

This study was undertaken to develop a reliable and quick method for determining the total cholesterol content of fish and shellfish. To test the practicality of the method developed, however, required that a number of samples be analyzed, which yielded the opportunity to collect preliminary data on the cholesterol content of seven important species of shellfish.

Briefly, the analytical method used consists of (1) extracting the cholesterol-containing lipid material with a three-phase system of chloroform, methanol, and water, (2) precipitating the cholesterol, and (3) measuring the color that develops when the precipitate is treated with a mixture of acetic anhydride and sulfuric acid. Experiments indicate that an average recovery of 97% of the total cholesterol is obtained with a relative mean error of -0.03 mg. cholesterol per 100-g. sample. A relative standard deviation of 0.045 was obtained.

Differences in cholesterol content of both eastern and southern blue crab "white" meats and eastern and southern oysters were found, which may be due to either seasonal or geographical influences. A seasonal difference in the total cholesterol content of the "white" body meat of eastern blue crab was noted. Differences in the total cholesterol content of the "white" body meat and the claw meat of the Dungeness crab were also evident. Future work in this project will be concerned with the variation in the total cholesterol content of fish and shellfish due to seasonal and geographical influences.

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MS #1325

EVALUATION OF THE MICRO-DIFFUSION METHOD FOR THE DETERMINATION OF TERTIARY VOLATILE BASE IN MARINE PRODUCTS

by

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ABSTRACT

When small amounts of trimethylamine are determined, errors resulting from reagents, glassware, titration, and trimethylamine hydrolysis can result in poor accuracy and precision.

The large magnitude of these errors in the micro-diffusion method make it unsuitable for routine use in quality control.

INTRODUCTION

The amount of tertiary volatile bases (TVB) found in fish flesh constitutes an important index of its quality. The method used to determine these bases are (a) the micro-diffusion method of Beatty and Gibbons (1936) and later modified by Stansby, Harrison, Dassow, and Sater (1944) and (b) the colorimetric method of Dyer (1945), which is specific for trimethylamine (TMA).

The micro-diffusion method for determining TVB is based on the technique developed by Conway and Byrne (1933) and involves the diffusion of the volatile base into a standardized acid solution with a subsequent back titration of the acid. Many investigators who have reported TVB nitrogen values obtained by the micro-diffusion method give only a brief description of it, leaving the impression that accurate results can routinely be obtained using only normal care, regardless of the amount of nitrogen in the sample.

I and others have noticed that when the micro-diffusion method is used to determine TVB in marine products, triplicate analyses run on the same aliquot often vary widely. Furthermore, when TVB values obtained by the diffusion method are compared with TMA values determined by the Dyer method, the relation between the two frequently is poor. This lack of agreement is disconcerting because at least 95 percent of TVB in fish is TMA.

Because of these variations in analytical results and the lack of close agreement with TMA, it appeared to me that errors in technique were involved. The purpose of the work reported here therefore was to determine what errors are likely to occur and what precautions should be taken if valid results are to be obtained when this method is used routinely.

The errors studied were those involved in titration, incompletely cleaned glassware, incomplete ammonia bonding, and such miscellaneous sources as the indicator, the alkali, and the hydrolysis of TMA.

ERRORS IN TITRATION

The amount of TMA nitrogen in commercially available raw and frozen fish generally ranges from 0 to 10 mg./100 g. With these quantities of nitrogen, very dilute solutions of acid and base are used in the micro-diffusion method, the order of normality being 0.005. Accordingly, 1.0 ml. of 0.005 N HCl (which is the amount of acid required in the center dish) is equivalent to 0.070 mg. of nitrogen. Since the size of sample in this determination is generally only 0.32 g. of fish (40 g. of fish flesh in a volume of 250 ml.; 2 ml. are taken for analysis), the amount of nitrogen available for detection generally ranges from 0 to 0.032 mg. Thus, for a sample in which TMA nitrogen is 2.0 mg./100 g., only 0.0064 mg. of nitrogen would be available for detection; and this amount would require a back titration difference of only 0.1 ml. of 0.005N NaOH for its measurement. Accordingly, every 0.01 ml. error in burette reading would be equivalent to 10 percent of the TVB.

Using a micro-burette (2 ml.; automatic delivery; graduated in 0.01 ml.) and cleaning the inner dish according

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to Conway, I determined TMA at two different concentrations in samples of known TMA content. These determinations were carried out in quadruplicate, with the results shown in table 1.

Table 1.—Recovery of small quantities of trimethylamine using the micro-diffusion method

Replicate	Volume of 0.005 N NaOH titrated with:		
	Blank	0.01 mg. TMA	0.02 mg. TMA
	Ml.	*Ml.*	*Ml.*
1.	0.870	0.785	0.665
2.	0.880	0.745	0.675
3.	0.880	0.765	0.660
4.	0.875	0.775	0.670
Average	0.876	0.767	0.667
TMA nitrogen		0.0091 mg.	0.0168 mg.
Recovery		91%	84%

Unless extreme care is taken, errors in titration range from 10 to 20 percent, or possibly more. These errors cannot be avoided simply by the use of more dilute standardized alkali, because an indecisive end point results and the precision is not increased.

ERRORS DUE TO INCOMPLETELY CLEANED GLASSWARE

I hypothesized that one source of error in the method might be the absorption of TMA by grease on imperfectly cleaned glassware. Since no special precautions were used in cleaning the outer dish and lids in the previous determinations, a new series was set up in which a thin layer of excess grease (Dow-Corning stop-cock grease) was left adhering to the outer dish and lids. The sample used for this series was halibut containing 8.0 mg. of TMA nitrogen, as measured by the Dyer method. The results of these determinations are shown in table 2.

Table 2.—Effect of greasy glassware on trimethylamine recovery in halibut

Replicate	Volume of 0.005 N. NaOH titrated with:	
	Greasy-glass samples	Clean-glass samples
	Ml.	*Ml.*
1.	0.635	0.610
2.	0.665	0.600
3.	0.630	0.600
Average	0.643	0.603
TMA nitrogen	6.0 mg.	7.2 mg.

The erroneously low result with the greasy glass is probably due to absorption of TMA by the grease. In Conway's original work, the micro-diffusion method was used to determine ammonia nitrogen, which probably has less affinity for lubricants than does TMA. Furthermore, in the concentrations we are measuring, he did not always use a titration method. With nitrogen contents of 0.014 mg., for example, he recommended Nessler reagent for accurate work. With low amounts of nitrogen (under 0.014 mg.), he recommended that the center titrating dish be cleaned as follows:

1. Wash with cold water.
2. Wash with hot water.
3. Wash with several changes of distilled water.
4. Air dry and never touch the inner surface with anything.
5. Store in 0.001 N acid with some indicator in it.
6. Rinse with distilled water before use.

ERRORS DUE TO INCOMPLETE AMMONIA BONDING

An experiment was conducted to determine what error might be expected if the operator forgot to swirl the dish after the addition of formalin. In a series of determinations, 0.05 mg. of ammonia nitrogen was added to 0.02 mg. of TMA nitrogen, and the dish was not swirled after the addition of the formalin. Nitrogen values on three samples varied highly as follows:

1. 0.023 mg.
2. 0.028 mg.
3. 0.026 mg.

OTHER ERRORS

Indicator

Doubling the amount of neutralized indicator from 0.1 cc. to 0.2 cc. increased blank titrations approximately 10 percent. Accurate measurements of the indicator into the center dish is best accomplished by adding the indicator directly to the standardized acid.

Alkali

The effect of absorbed CO_2 was not determined, although absorption of CO_2 is a problem when dilute-alkali-titrating solutions are used. Conway states that the most serious error encountered as the amount of detectable ammonia decreased was that of CO_2 contaminating the alkali. With nitrogen contents under 0.014 mg., Conway (1940) sometimes used $Ba(OH)_2$ as the alkaline titrant because it gave sharper end points. This titrant was not tried by me, as the question of CO_2 absorption obviously becomes an even more serious problem with $Ba(OH)_2$.

TMA Hydrolysis

Beatty (1936) found that some TMA oxide is hydrolized by the alkali during the incubation period, yielding erroneously high results. He found that errors of more than 10 percent sometimes occurred with fish containing less than 2.0 mg. TMA N/100 g. Hydrolysis rates of TMA oxide were not studied in my evaluation, but it can readily be seen that uneven oven temperatures could cause large errors in this determination. It has also been shown that the TMA oxide content between species of fish varies as much as 100 percent and also varies with the season (Jones and Shewan, 1957). Errors due to hydrolysis could possibly be even more serious than those found by Beatty.

CONCLUSIONS

1. Considerable error results with the micro-diffusion method unless rigid precautions are taken in regard to glassware, reagent, and contamination of the titrating solution. Titration errors of 10 to 20 percent or more are difficult to avoid when small quantities (0.01 mg.) of nitrogen are measured. (These errors, however, can doubtlessly be minimized by the use of ultramicro burettes.)

2. Although I did not study the effects due to laboratory fumes, oven temperatures, etc., these factors probably can be important sources of error.

3. At the concentrations in which tertiary volatile bases are meaningful (0 to 2 mg./100 g.) for quality judgments of raw and frozen marine products, the micro-diffusion method becomes difficult to use routinely. Although experienced analysts may be able to devise means to cope with the uncertainties of the method at these concentrations, it is not particularly suitable for use in quality-control laboratories in which periodic analysis of TVB are required to supplement sensory quality judgments.

4. Owing to the difficulties involved in the use of the micro-diffusion method when the quantity of TVB nitrogen is less than 2 mg./100 g., analysts contemplating the routine use of the method should consider alternative approaches, such as use of the Dyer TMA method.

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MS #1351

PREPARATION OF CHILLED MEAT FROM ATLANTIC BLUE CRAB

by
David H. B. Ulmer, Jr.

ABSTRACT

A survey of 180 crab plants along the Atlantic and Gulf coasts in 1959 provide a description of the practices employed in the production of fresh crab meat. Most plants follow a basic pattern of pressure steaming, cooling, hand picking, and packaging in 1-pound containers, but many modifications exist. These practices and also some recent innovations are described.

Tests on the main variables in processing were made at experimental, pilot-plant, and commercial-plant levels. They showed that cooking drastically reduces bacterial content but that gross reinfection can occur in plants having poor sanitation. Cooking for 5 minutes effectively reduced the bacterial flora, but cooking for 10 minutes produced optimal yields of crab meat. Steam boiling produced a significantly higher yield than did pressure cooking and resulted in a product with equal organoleptic quality. Variation in the yield occurred with season, biological character of the crabs, use of machines for picking, post-cook handling, and unidentified variables.

Maximum yield was obtained by steam boiling male crabs for 10-15 minutes, debacking, washing, and storing overnight under refrigeration prior to picking.

INTRODUCTION

HISTORICAL DEVELOPMENT

The blue crab (*Callinectes sapidus*, Rathbun 1885) occurs in abundance and is harvested commercially from coastal and estuarine waters of all the Atlantic states from New Jersey to the Florida Keys and in all the states bordering the Gulf of Mexico.

It was in fact so abundant and easily caught that in the early days of the fishery, the only market for blue crabs was in the big cities. Prior to 1878-79, all crabs were sold as hard crabs (for about 10 cents a dozen) or as the much more highly prized soft crabs. The latter were such a delicacy that according to Goode (Goode and Associates, 1887), about 550 men fished the waters of northern New Jersey in 1880 to supply the New York City market alone. Goode reported that at least as early as 1855, there was an important soft crab fishery in New Jersey and that by 1876, soft crabs were being taken in Chesapeake Bay for shipment to the markets in New York, Philadelphia, and Baltimore.

As already indicated, however, prior to 1878, all crabs, either hard or soft, were shipped alive and sold by the dozen. There was no production of cooked, picked blue crab meat. About 1876, James McMenamin, observing the success of commercial canning of lobster meat in New England, began to experiment with the canning of crab meat; and on March 10, 1878, he began actual canning operations at Norfolk, Va., marking the first attempt to sell picked crab meat (McMenamin, 1884). The following year he moved to Hampton, Va., and a year later, T. T. Bryce had opened a second crab cannery in Hampton, and another cannery had started at Oxford, Md.

This Oxford plant, Goode writes, employed 170 men and used 12 to 15 thousand crabs daily. In these days of minimum wages of $1.15 per hour, it is interesting to note that the canneries then paid the pickers 2 to 3 cents a pound; although a few could pick 25 pounds per day, the average production was about 16 pounds, equivalent to a daily wage of 35 to 50 cents.

Shortly after this first production in 1878 of cooked, picked crab meat for canning, it was found practical to ice the picked meat and sell the fresh product. As a result the commercial production of blue crabs increased from about 7.5 million pounds in 1880 to almost 155 million pounds in 1960 (table 1).

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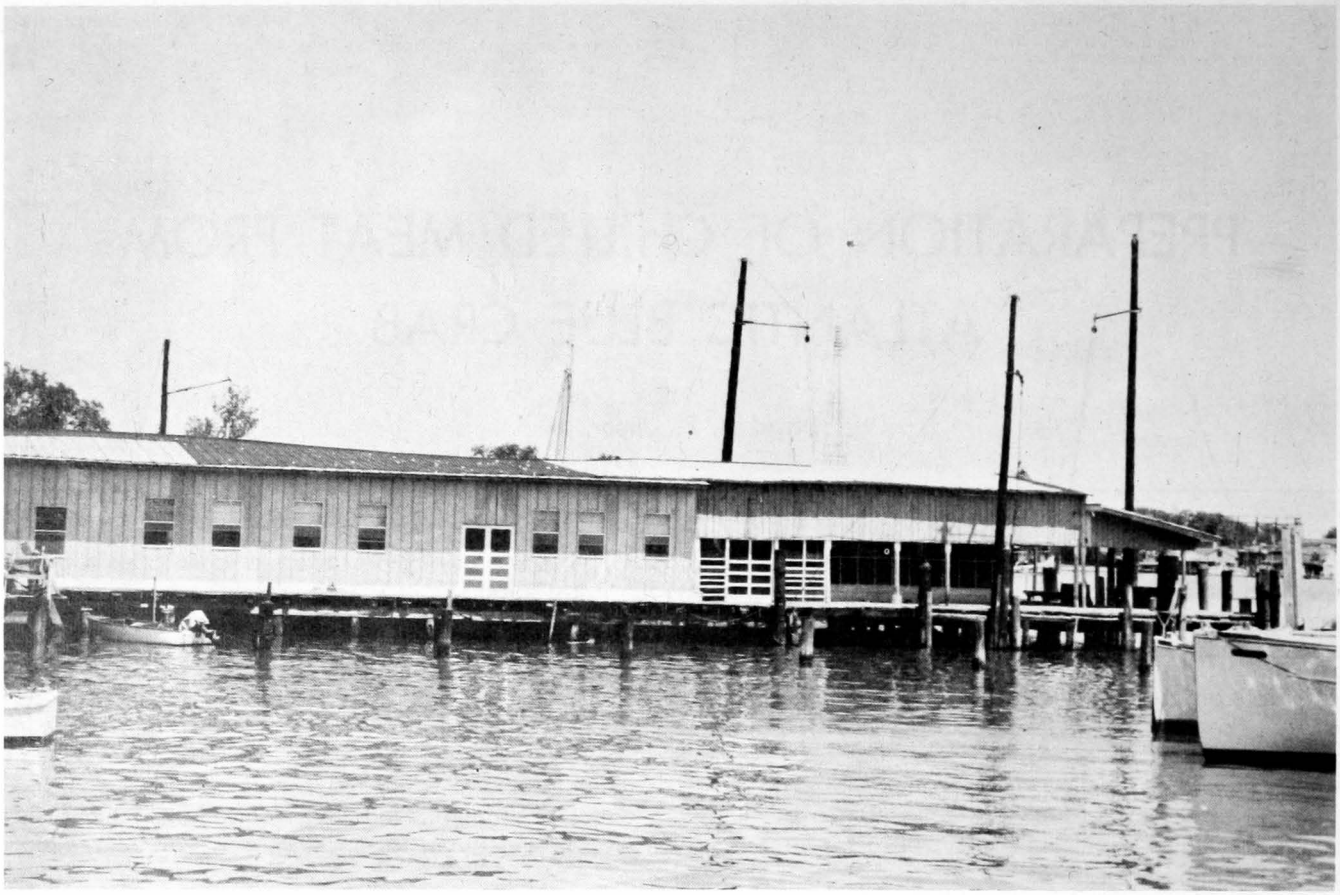


The oldest blue crab meat packing plant in the country, located at Hampton, Va., since 1885.

Although in the crab producing states the crab industry is outranked in value by two other shellfish—shrimp and oysters—it is nevertheless of substantial value. In 1900, the catch of blue crabs in the Middle Atlantic states was roughly 12 million pounds, with a value of $85,000. In 1930, the catch of 55 million pounds of blue crabs in Maryland and Virginia amounted to 88 percent of the total production of blue crabs. By 1960, the catch of blue crabs in the two Chesapeake Bay states had increased to 70.7 million pounds, but landings elsewhere had increased to a total of 154.7 million pounds, so that this amounted to only about 46 percent of the total catch. In 1960, the products of the blue crab industry included canned regular meat and specialty products valued at over $1.2 million, fresh and frozen regular meat valued at almost $14.4 million, frozen specialty products valued at over $7.3 million, and meal and scrap worth $0.34 million, for a total product value of $23.3 million.

Table 1.—Catch of crabs and production of blue crab meat, 1960

State	Catch of live crabs		Picked blue crab meat	
	Hard crabs	Soft crabs		
	Million lbs.	*Million lbs.*	*Million lbs.*	*Million dollars*
New Jersey	1.53	0.02	-	-
Delaware	2.11	0.04	-	-
Maryland	27.07	2.79	4.40	3.87
Virginia	39.27	1.59	3.48	3.31
North Carolina	14.94	0.09	1.28	1.11
South Carolina	7.12	-	0.16	0.16
Georgia	15.77	-	1.63	1,62
Florida	25.61	1/	2.86	2.66
Alabama	0.50	-	0.07	0.06
Mississippi	2.81	1/	0.37	0.37
Louisiana	10.05	0.51	0.51	0.53
Texas	2.87	1/	0.39	0.39
Total	149.64	5.05	15.14	14.07

1/ Less than 10,000 pounds.

TECHNICAL LITERATURE

The technical literature on the processing of fresh chilled crab meat from blue crab can be divided into three main categories. As illustrated by the following selected examples, these are (1) descriptive accounts of various phases of the industry (Cronin, 1949; McHugh and Ladd, 1953; Quittmeyer, 1957), (2) recommendations based primarily on observations (Szabo, 1955; Young, 1957), and (3) results of experimental work (Punochar and Pottinger, 1954[1]; Anzulovic and Reedy, 1942; Littleford, 1957). More experimental studies on the various phases of the industry are needed, and our basic knowledge must be increased before the production of meat from the blue crab becomes truly efficient.

[1] J. F. Puncochar and S. R. Pottinger. Commercial production of meat from the blue crab. U. S. Fish and Wildlife Service. Unpublished paper.

OBJECTIVE

The producers of crab meat are vitally concerned with obtaining a maximum yield of meat that has satisfactory bacteriological, organoleptic, and storage properties. Accordingly, the industry was surveyed by laboratory personnel, who visited all of the crab plants to determine what the fundamental problems are. Based on this survey, preliminary experimental studies and pilot-plant as well as commercial-plant tests were carried out to ascertain optimum processing conditions.

The objective of this paper is to report, first, the results of the survey and, second, the findings of the tests.

RESULTS OF SURVEY

Presented in this section are (1) a brief account of the plants and their locations, (2) a description of the plants, (3) the procedures used in processing, (4) the regulations of the various states, and (5) a summary of the fundamental problems.

PLANTS AND THEIR LOCATIONS

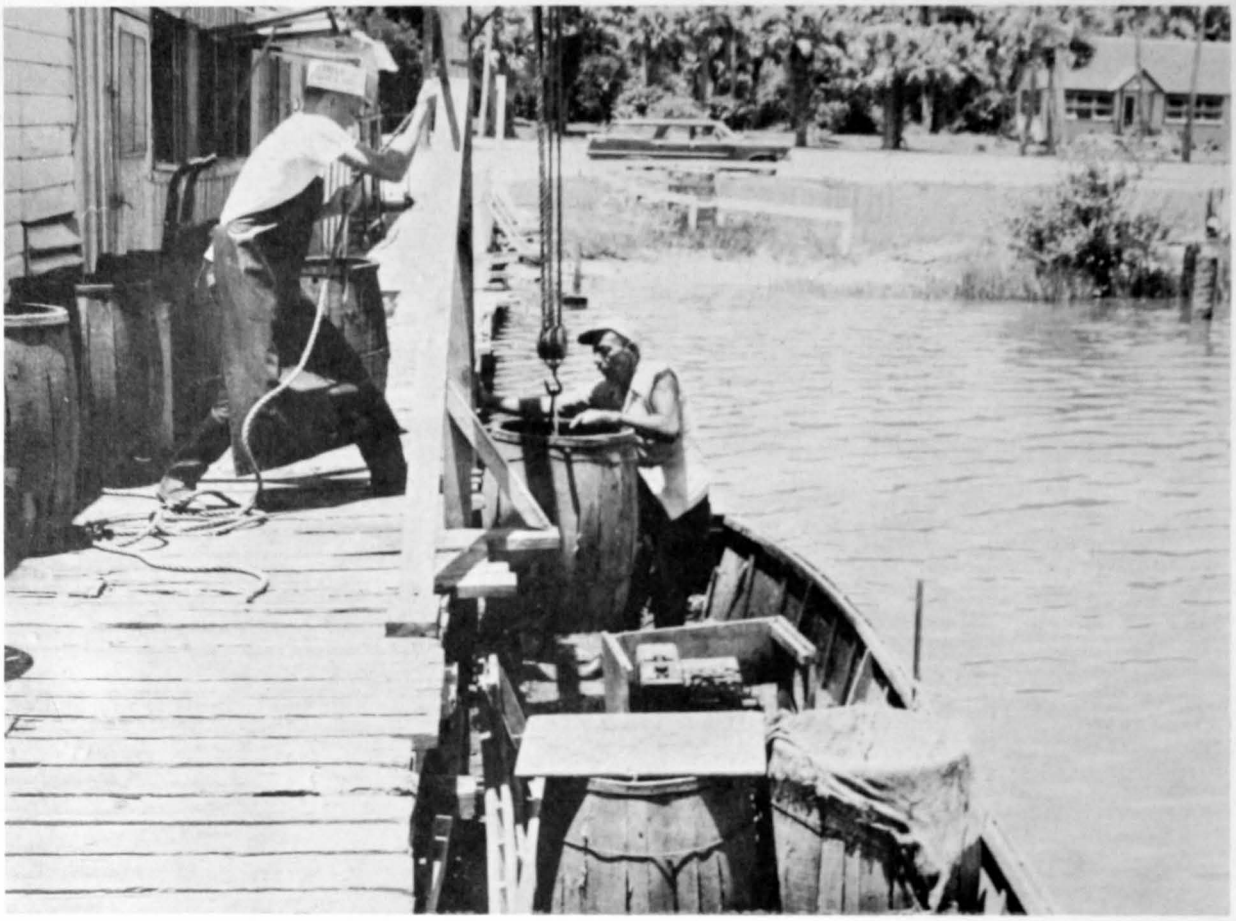
A survey in 1959 revealed that the industry consisted of about 180 separate plants in the nine states from Maryland to Louisiana. The number of blue crab meat packing plants in each state was as follows: Maryland, 55; Virginia, 37; Florida, 34; North Carolina, 19; Louisiana, 10; Mississippi, 7; Alabama, 6; Georgia, 6; and South Carolina, 6.

DESCRIPTION OF PLANTS

Plants ranged in size from a one-man operation in a 10- by 15-foot building to plants that covered half an acre and employed 100 or more workers.

The plants are divided into rooms, or occasionally into work areas, where each of the several operations involved in processing crabs is carried out. Whether transported by boat or by truck, the crabs are received almost universally at a dock or a similar loading platform. Cooking devices are usually located in a room immediately adjacent to the receiving dock, if they are not actually installed on the dock. Procedures for handling the cooked crabs vary greatly; consequently, the physical

Annapolis, Maryland's capital, reflects the crab influence. Here are crab boats tied up in Spa Creek with the Capitol dome in the background.



Typical unloading dock at a small Florida crab plant. Wooden barrels are still the most commonly used container for live crabs, and manpower operates the hoist.

setup associated with them also varies. All crabs, however, must be cooled prior to being picked, and cooling rooms are a part of every installation. Where cooking areas are large, the crabs may be cooled in their respective cooking containers in a designated area of the same room. This practice is especially true where the cooking room is a large, screened enclosure. In many plants, the cooling rooms are artificially refrigerated. Fans, air conditioners, and commercial refrigeration units are variously utilized. When debacking (removal of carapace or back shell) is a standard procedure, crabs are commonly debacked in the same room in which they are cooled. These rooms usually are not refrigerated.

After being cooked, the crabs are transported to a picking room, where the meat is removed from the shell. Since hand picking requires many workers, the picking room is characteristically the largest room in the plant. Adjacent to it in most plants is a much smaller packing room with a portal through which the pickers pass the cans of picked meat to be weighed, tallied, and prepared for shipment or for further processing. In a few plants, a portion of the picking room, separated by a table or counter but not actually walled off, suffices as a packing room. After being weighed and packaged, the chilled meat is packed with crushed ice in barrels or boxes either for immediate shipment or for temporary refrigerated storage.

PROCEDURES USED IN PLANTS

After the crabs are unloaded, they are weighed and then dumped into the cooking receptacles. Most of these receptacles are circular retort baskets of various depths that are used in vertical retorts, or they are wheeled carts of various designs used with horizontal rectangular steamers. Where large male crabs are available, they are first sorted out for sale as "steamers," at a premium price.

Baskets of crabs go into the cooker as rapidly as the cooking equipment and the procedure permit. Most cookers accommodate from 800 to 1,200 pounds per cook. One thousand pounds is a realistic average, but capacities range from 1,500 down to 100 pounds. Cooking temperatures vary from 212° F., where boiling is employed, up to 250° F., where steam pressure is employed. Cooking times of 15-20 minutes are usually used at 212° F., and 3-20 minutes are used at 250° F. in addition to the time required to bring the temperature and pressure in the cooker up to the desired level. Table

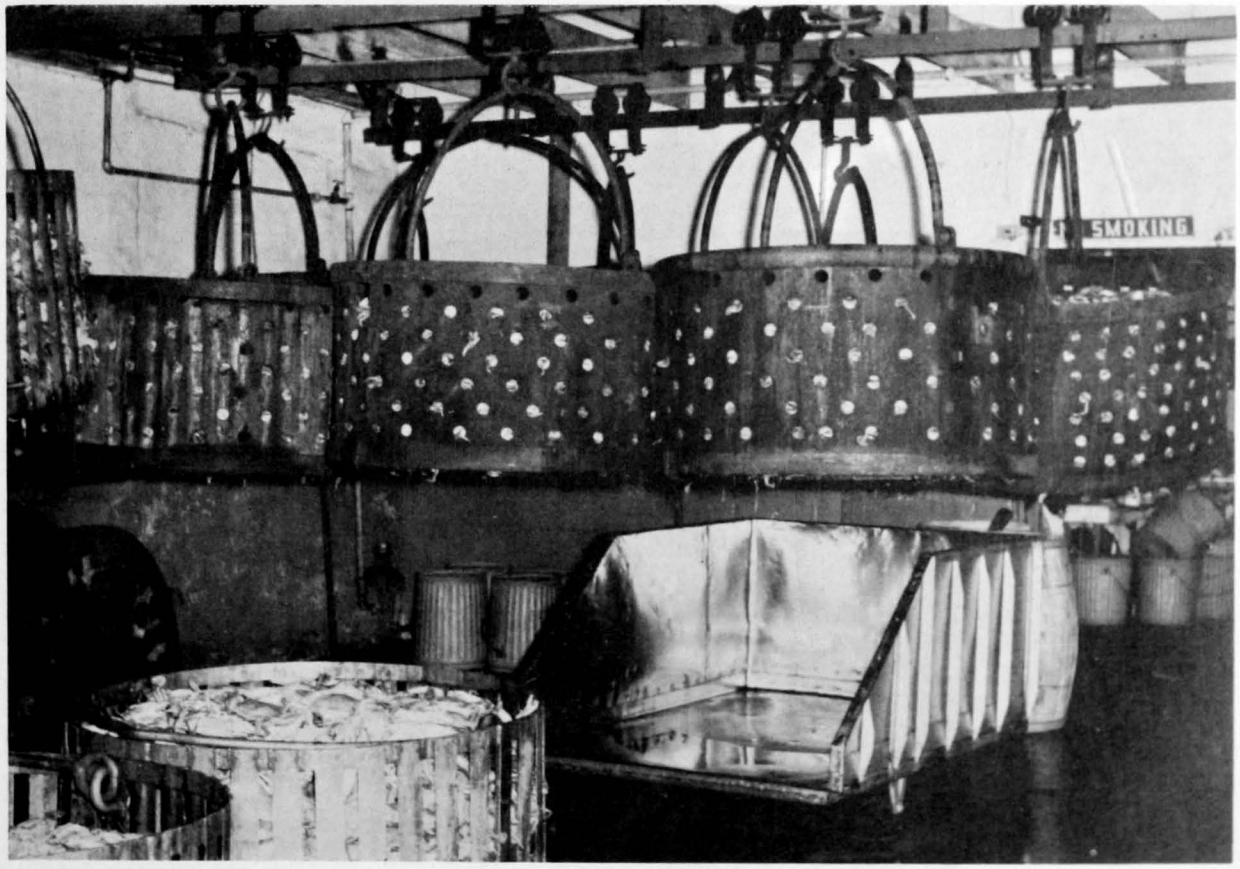
2 shows the variations in cooking equipment used by 165 packers in this industry. The vertical retort is by far the most numerous.

All operations to which crabs are subjected from the time they are cooked until the time the meat is picked are referred to as post-cook handling. Table 3 summarizes the major variations in post-cook handling operations.

Cooked crabs are always allowed to cool initially at atmospheric temperature—at least until they can be handled with bare hands. Some crabs are held overnight, and the rate of cooling may be speeded by large fans. In an increasing number of plants, the partly cooled crabs are moved into an artificially cooled room or refrigerator and held until they are picked.

Table 2.—Cooking equipment used in 165 blue crab plants

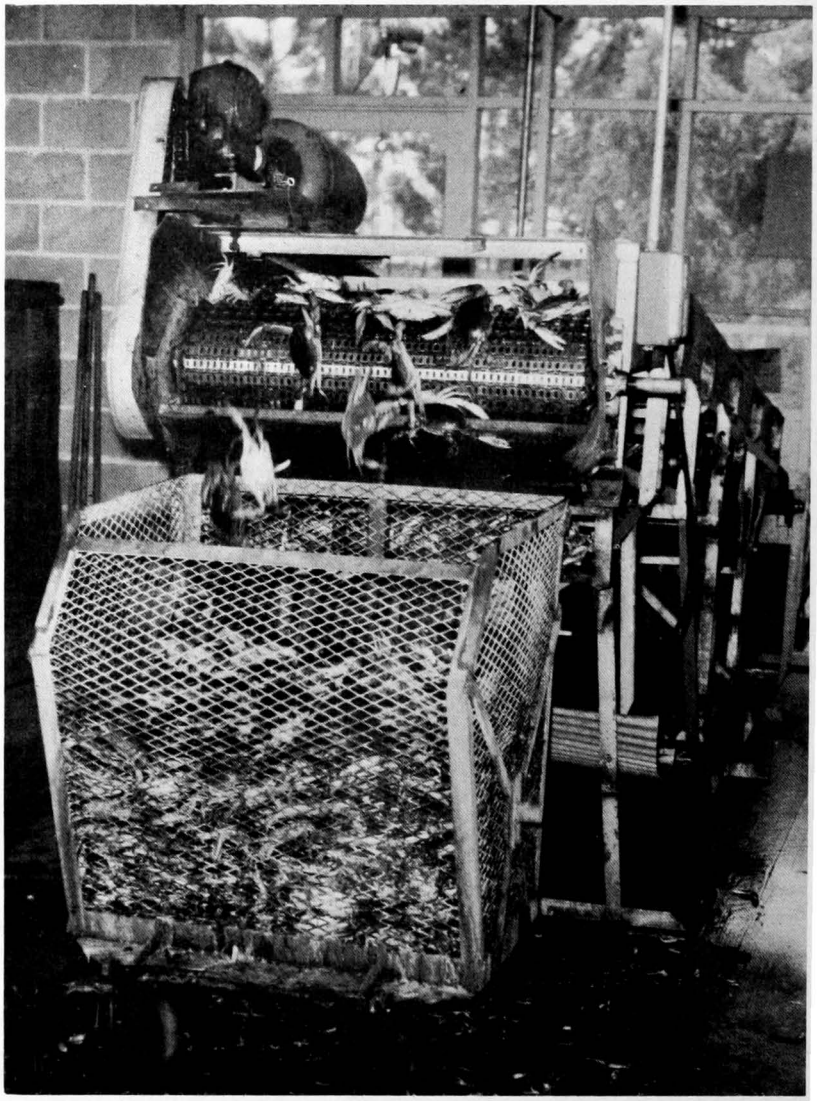
Cooking method	Kind of equipment	Plants using equipment
		Number
Steam pressure	Typical vertical retorts	103
	Special vertical retorts	2
	Top-loading rectangular boxes	4
	Horizontal rectangular boxes (short and wide)	21
	Typical oyster steam boxes (long and slender)	10
	Horizontal retorts	5
Boiling	Rectangular metal vats — closed coil	3
	Rectangular metal vats — perforated coil	2
	Rectangular metal vat — coil type unknown	4
	Rectangular metal vat — wood fired	1
	Steam-jacketed soup kettles	2
	Iron syrup vats — oil fired	2
	Shrimp cooker — steam coils	1



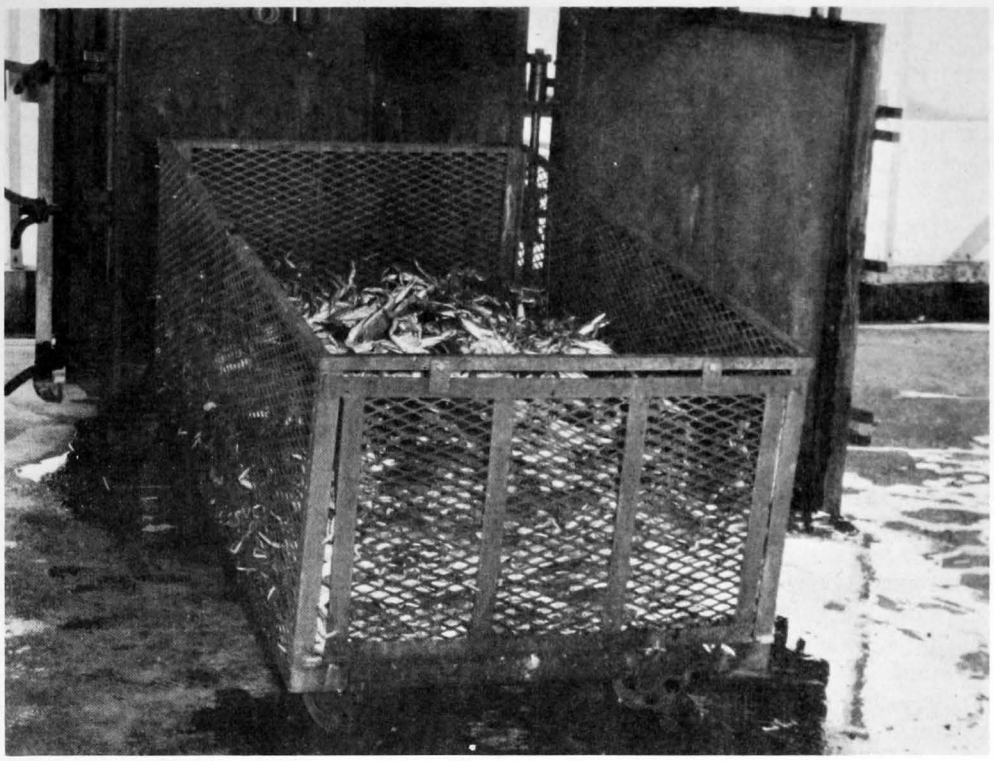
Crabs are suspended to air cool in the baskets in which they are cooked. The monorail facilitates moving the baskets, which may hold 500 pounds of crabs. The stainless steel cart, foreground, is used to transport the cooled crabs to the pickers.

Table 3.—Post-cook handling procedures in 165 blue crab plants

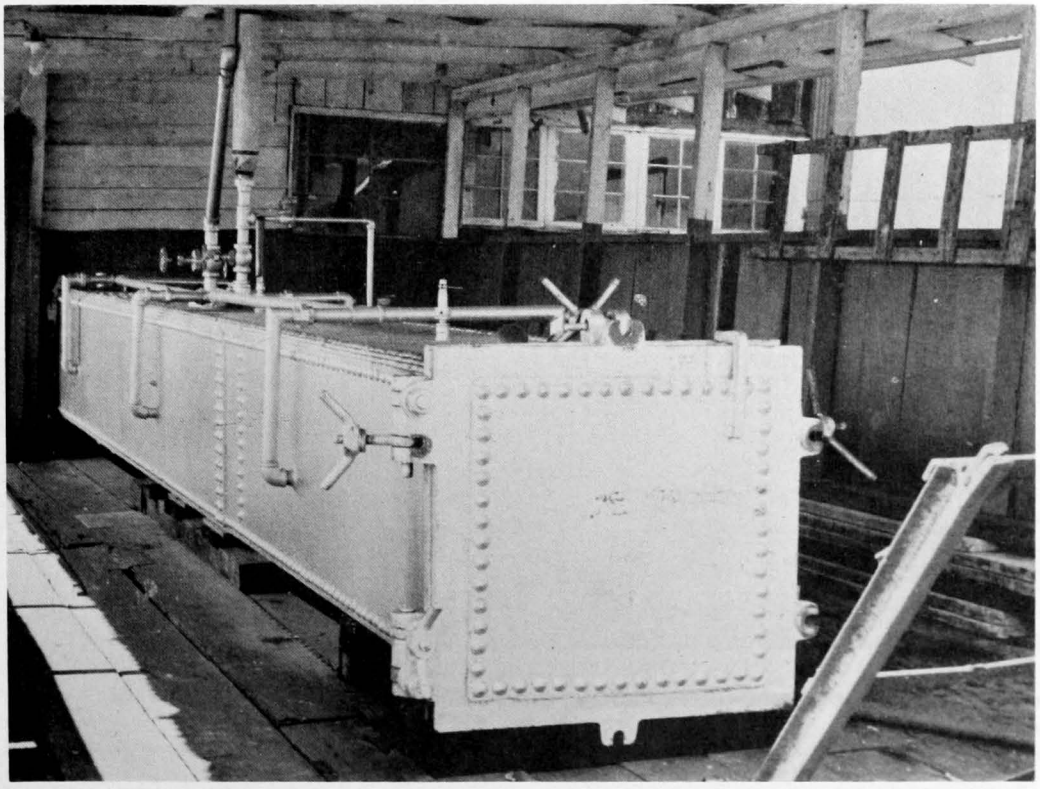
Processing variations	Procedures	Plants using procedure
		Number
Debacking	Deback a.m., and refrigerate overnight (unwashed in one plant)	15
	Deback p.m., room temperature overnight unwashed	3
	Hold at room temperature overnight, deback a.m., and refrigerate	5
	Hold at room temperature overnight, deback a.m., and pick	2
	Refrigerate overnight, deback a.m. by pickers	5
	Declaw and refrigerate overnight, deback a.m. by pickers	1
	Deback and wash by debackers, and pick immediately	2
	Deback and wash by pickers, and pick immediately	2
	Combinations of above	5
Washing	Flume	5
	Revolving drum	6
	Spigot and sink	6
	Hose and trough or sink	8
	Brine tub	1
	Chlorine dip	1
	Practices unknown	9
Whole crab cooling	Refrigerate overnight	40
	Hold at room temperature overnight	40
	Pick immediately	12
	Combinations of above	11
	Practices unknown	22



Steel cart is filled with crabs from the outside receiving-wash tank. This special cooking basket is designed for a large-diameter horizontal retort.



Another type of cooker car and horizontal retort-cooker in background, designed to take one car at a time.



This three-car horizontal cooker will take 1,500 pounds of crabs at a load.

Many operators deback and clean the crabs during this initial cooling period. This operation consists of removing the claws, the back or carapace, and the viscera, including gills or "dead man's fingers," vital organs, and glandular tissue. The claws are saved separately, the other material being discarded as waste, and the crab bodies or "cores" usually are washed. The cleaned cores are quickly moved into a refrigerator unless they are picked immediately.

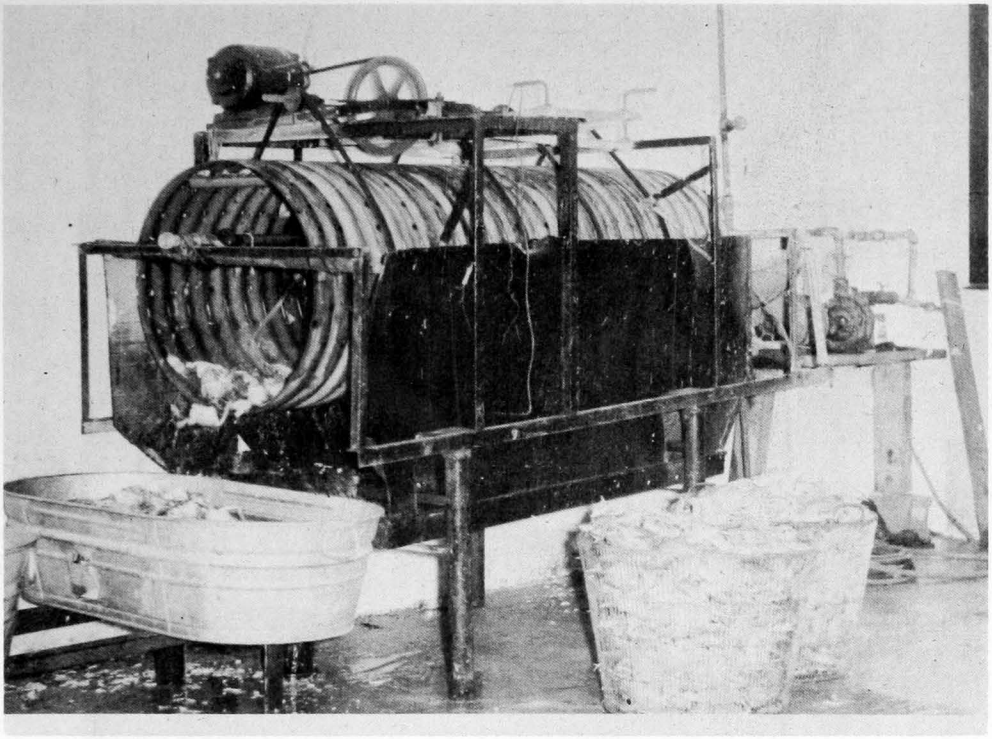
Combining all handling variations enumerated in table 3, one finds that common practices are as follows: Refrigerate overnight, 68 plants; hold at room temperature overnight, 54; pick immediately, 21. This breakdown is derived from the same 165 packers presented in table 2, but 22 are omitted for lack of information. Of this group, 125 do not deback.

Crabs are picked (almost exclusively by hand) at tables that accommodate from 4 pickers to rows of 25 pickers on each side. Pickers may occasionally stand, but they usually sit. A wide variety of chairs, stools, and benches are provided. As the meat is picked, it is separated into three categories: (1) "Lump"—the premium product—is the muscle from the large hindmost body segment, which controls the swimming paddles or "backfins"; (2) "regular" or flake white meat is the muscle from the rest of the body segments; and (3) "claw meat." Consistent with the large variation in the size of plants, the plants employ from 4 to 100 pickers, with the average plant employing from 20 to 40. Picked meat is delivered to the packing room in small quantity, usually 5 pounds, but may be 4 or 6 pounds. This amount represents about an hour's production for many of the pickers. Delivering the meat in small units aids in the prevention of excessive buildup of bacteria by getting the meat packed and iced in a relatively short time. Bacterial recontamination of the meat occurs most heavily during the picking operation, so good sanitation is essential. Handpicking is supplemented in a few plants by mechanized picking. Machines that combine hammer mills with brine-tank flotation are in use, but since the crab meat produced is inferior in texture and flavor, most owners use these machines only for picking claws.

Picked meat is packaged in a variety of containers, but the bulk of it goes into 1-pound cans with snap-lock lids for sale as fresh-pack crab meat. Half-pound and 12-ounce cans are also used. Frequently, meat in excess of immediate demand is packed in sealed cans and pasteurized. Meat for institutional use or for further manufacturing frequently is frozen, and for this purpose, the use of sealed plastic bags that usually hold 5 pounds of crab meat is increasing. All crab meat is cooled with crushed ice immediately after it has been weighed and packaged.

Sanitation is important in the operation of all crab plants. Waste is removed from the picking tables at frequent intervals and from the plant no less often than daily. Much of the waste from plants in isolated locations is dumped overboard. Elsewhere, it must be hauled away. In many localities throughout the industry, it is hauled to a dehydration plant and manufactured into crab meal. In addition to the disposal of scrap, all equipment must be cleaned up at the end of each day's work, if not oftener. For this purpose, most picking and packing rooms or, in some places, the entire plant, are washed down with a hose.

A worker is debacking crabs and scraping out viscera into the drum below. Basket of crabs on the right is cooling.

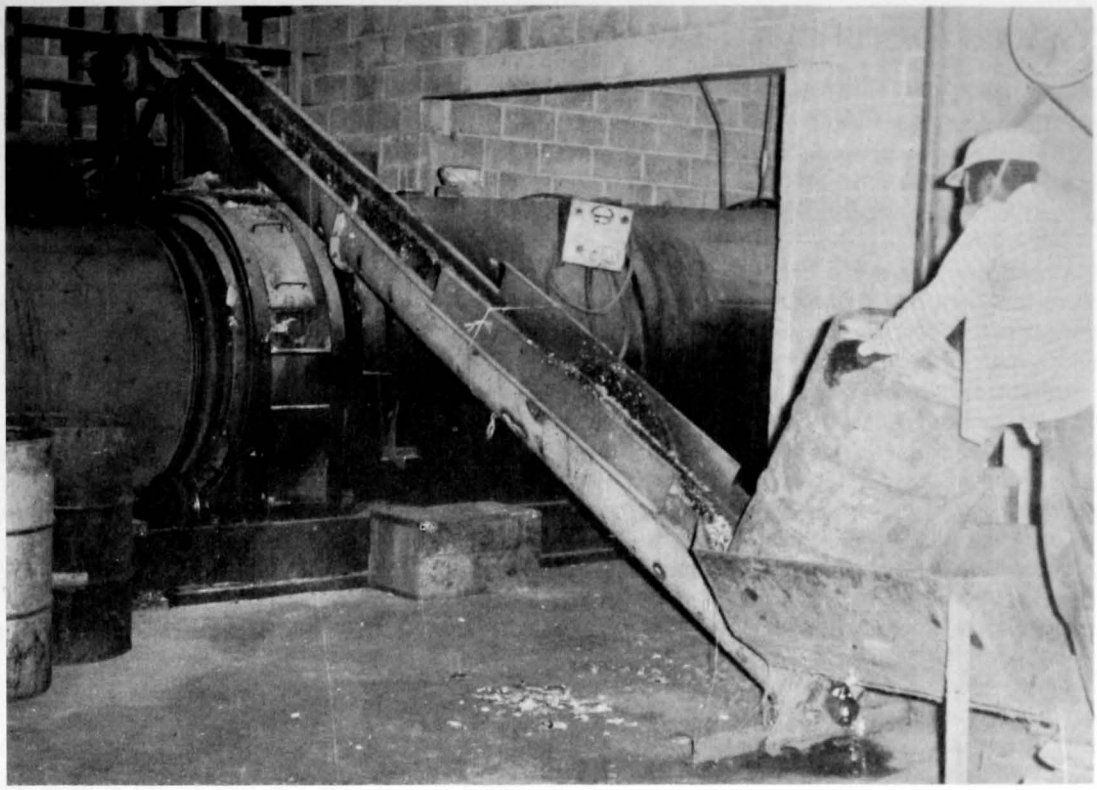


This is a continuous rotary washer for the crab cores, in use in a Gulf coast plant.

Typical picking room in a Chesapeake Bay crab plant.

Packing room of a Virginia plant. Here the picked meat is examined for shell before being packed in the cans.

Packing room of another plant in the Chesapeake Bay region. Tile walls and stainless steel tables, scales, etc., make it easy to keep the packing room spotlessly clean.



Crab scrap is dumped into hopper of screw conveyor and carried up into the rotary, direct-heat dryer in left background. At right is the air-heating chamber.

REGULATIONS

Commercial production of crab meat is regulated in all states in which crabs are processed. The states require a permit to operate, and reserve the right to revoke it when circumstances indicate that this action is necessary. Virginia, North Carolina, Georgia, and Florida require a certificate of health from all plant employees. All states but one specify that in-plant water supplies are to be approved by a regulatory authority. Some states specify the size of wire-mesh screening to be used in plants. Adequate lighting and smooth, easy-to-clean wall surfaces are specified by most states. Type of flooring for ease of sanitation and number of personnel per toilet are also specified. State authorities either specify the use of washing solutions and chlorine dips at concentrations up to 200 parts per million or simply require the use of an approved bactericide. Several states require that a steam cabinet or comparable device be used for sterilizing all picking equipment and other utensils used for handling meat.

The Maryland State Department of Health has set up standards for permissable numbers of bacteria in crab meat. Maximums of 100,000 bacteria per gram and an *Escherichia coli* most probable number (MPN) of 50 per 100 grams of crab meat are allowed. With the pasteurized product, the maximums are 25,000 bacteria per gram and no *E. coli*. Bacterial counts are determined by the Health Department's standard plate count (SPC), which involves counting the number of colonies that develop after incubation at 35° C. for 48 hours on sterile petri plates that have been inoculated from a crab meat suspension and coated with an accepted agar culture medium. In order that a countable plate can be obtained, serial dilutions by tenths are made from a 10-gram sample of crab meat. The most probable number (MPN) method is a standard method almost universally accepted for *E. coli* determinations. It involves testing for gas production by bacteria, by (1) inoculating from a series of 10-fold dilutions of crab meat suspension into a culture medium containing a sugar and (2) incubating at 45.5° C. Test tubes rather than petri dishes are used for this determination.

In New York City, the Health Department, in addition, makes a determination on differential culture media for staphylococci of the food-poisoning type. The U. S. Food and Drug Administration checks interstate shipments for *E. coli*. If *E. coli* are found, and if, concurrently, the plant is in an unsanitary condition, condemnation proceedings may be instigated.

Maryland does not permit crabs to be boiled, nor does Virginia, but in Virginia steaming without pressure is allowed. States that definitely do permit boiling of crabs are Louisiana, Mississippi, Alabama, Georgia, and South Carolina.

SUMMARY OF FUNDAMENTAL PROBLEMS

The major current problems in processing of crab meat are (1) attainment of maximum yield, (2) production of a high-quality product with respect to bacterial population and organoleptic properties, and (3) maintenance of high quality during storage and shipment of the product.

In processing, yield is primarily a function of the temperature to which live crabs are subjected and the length of time they are cooked. Cooking accomplishes three main things: (1) It consolidates the meat by coagulating the protein and loosens the meat from the shell so that picking is facilitated; (2) it produces the flavor characteristic of cooked crab meat; and (3) it destroys most of the micro-organisms associated with the live crab. Properly cooked crabs are those that have received sufficient heat to destroy spoilage organisms without causing excessive loss of moisture and shrinkage of tissue. Decreased yields result from either overcooking or undercooking. Cooking problems also arise from overloading the retort, from having insufficient steam-boiler capacity or inadequate steamlines, and from improper venting of air and steam from the retort.

Post-cook handling procedures also influence yield. Debacking and washing or refrigerating prior to picking have been demonstrated to increase yield. A combination of the two, together with proper cooking, generally produces the highest yields.

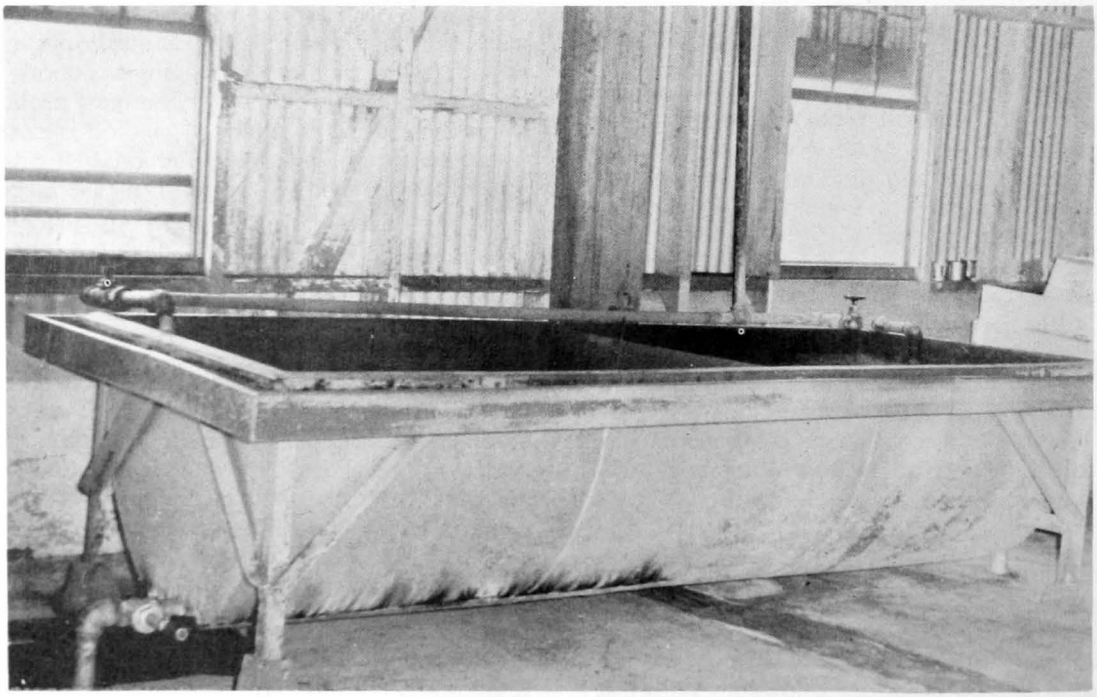
Bacterial population is a major factor in quality throughout the life of the product. It influences organoleptic properties of crab meat during storage and largely determines shelf life. Meat of high quality can be produced only by adhering to the strictest sanitary practices. In this regard, the Maryland State Department of Health and most of the agencies in the other states concerned not only stipulate maximum allowable bacterial counts but also stipulate minimum sanitary regulations, and picking and packing procedures intended to avoid unacceptable bacterial counts. In spite of these measures, however, controls are not perfect. Improvements must await more knowledge and better methods.

FINDINGS OF TESTS

This section of the report is concerned with results obtained from preliminary experimental studies and from the pilot-plant and commercial-plant tests based upon them.

PRELIMINARY EXPERIMENTAL STUDIES

Since cooking is both the first and most critical processing operation in the production of blue crab meat, it was the hub of all studies except those few dealing exclusively with the microbiology of crab meat. Early studies on heat penetration were followed by extensive studies on yield and shelf life. For this purpose 75 different combinations of cooking medium, cooking time, and post-cook handling procedures were tested. The criterion throughout for the evaluation of shelf life was the bacteriological standard plate count (SPC) described on page 31.



This open tank, heated by a bottom steam coil, is used in a Louisiana plant for cooking crabs by boiling. The trough carries off foam and overflow.

Accordingly, the following factors were studied: (1) penetration of heat into crabs during cooking, (2) cooking in relation to the destruction of bacteria, and (3) variables affecting yield and bacterial count, including cooking temperature, cooking time, post-cook handling, season, and source.

Heat Penetration into Crabs During Cooking

As would be expected, the penetration of heat into crabs during cooking was considerably slower with cold, winter crabs than with warm, summer crabs. When crabs were cooked at 250° F. for 5, 10, and 15 minutes, internal temperatures of winter crabs and summer crabs were, respectively, as follows: 137° and 211° F.; 188° F. and 234° F.; and 210° and 246° F. To obtain more information on the penetration of heat into crabs during cooking, 75 random cooks of 100 pounds of crabs at 212°, 213°, 227°, 239°, and 250° F. for 5, 10, and 15 minutes were made. In this experiment, which is referred to later in the discussion on variables affecting yield and bacterial count, three of the whole crabs in each retort basketful were equipped with thermocouples inserted into the body at the rear of the carapace or back. Internal temperatures from the time of installation of the thermocouples until the end of the cook were recorded. The results are summarized in table 4, both as ranges and as averages based on a minimum of 15 thermocouple readings, 3 thermocouples per each of 5 tests. The results presented there are indicated temperatures and not absolute, as sources of error were known to be present. All thermocouples, however, were subject to the same errors, and the results are significant relative to one another. Most obvious in this regard are the influence of the temperature in the cooking vessel on the rate of heat penetration and the variations in rate of heat penetration at each of these temperatures.

When the crabs are placed in the cooker, a drop in temperature occurs. The cooking period begins when the cooking medium has returned to the desired temperature. (This reheating to temperature required, on an average, 4-1/2 minutes with the laboratory equipment used but may take as long as 20 minutes with some commercial equipment.) During this period, frequently referred to as "come-up time," some crabs nearest the heat sources are actually cooked. The internal temperature of many crabs, however, does not reach 165° F. in 5 minutes, even at a retort temperature of 227° F. Such crabs are undercooked and have a raw taste. An uneven distribution of heat in the retort results in a wide range in rates of heat penetration, and those retorts that do not provide uniform cooking temperature will overcook or undercook some of the crabs. In a properly installed retort, uneven distribution of heat

Table 4.—Penetration of heat into crab cooked at different temperatures

Cooking medium and temperature	Cooking time	Measure	Internal temperature of crab after:		
			5 Minutes	10 Minutes	15 Minutes
	Minutes		° *F.*	° *F.*	° *F.*
	5	Range	165-212		
		Average	205		
Water 212° F.	10	Range	125-212	155-212	
		Average	196	204	
	15	Range	180-212	204-212	195-212
		Average	208	210	210
	5	Range	153-213		
		Average	200		
Brine 213° F.	10	Range	160-213	173-213	
		Average	190	205	
	15	Range	165-213	195-213	176-213
		Average	208	211	211
	5	Range	116-226		
		Average	197		
Steam 227° F.	10	Range	153-227	193-227	
		Average	210	223	
	15	Range	122-227	184-227	213-227
		Average	199	220	226
	5	Range	148-239		
		Average	222		
Steam 239° F.	10	Range	183-239	226-239	
		Average	215	233	
	15	Range	200-239	222-239	233-239
		Average	227	236	238
	5	Range	174-250		
		Average	234		
Steam 250° F.	10	Range	191-250	224-250	
		Average	237	247	
	15	Range	200-250	242-250	248-250
		Average	234	247	249

will be at a minimum. Fortunately, a cooking time of 10 minutes, later found to produce highest yields when used in conjunction with pressure steaming, exposes the crabs to sufficient heat to ensure a complete cook. When the crabs are boiled, the distribution of heat is reasonably equitable.

Cooking in Relation to Destruction of Bacteria

Whole live crabs were prepared by removing the carapace, the abdominal flap, and the claws. The viscera, glandular tissue, and other extraneous material were scraped out, and the cleaned crabs were rinsed under the tap. The legs were cut off, and the remainder of the crab was cut into quarters. Each quarter was placed in a cheesecloth bag, and the quarters were distributed into four groups. In Experiment A, one group of uncooked quarters was retained as a control, the others were boiled for 2, 4, and 6 minutes and placed into sterilized 1/2-pound crab meat cans with snap-lock lids, then stored at 36° F. (33°-38° F. in a walk-in refrigerator). The samples were examined bacterialogically after storage for 5 days. This test was repeated in Experiment B, using an uncooked control and boiling times of 1, 2, and 3 minutes for the quarters. Results are shown in table 5.

Two more tests were carried out. In Experiment C, half of the lot of crab quarters was boiled for 2 minutes, then one-half of these were stored at 36° F. for 1 day, and the other half were stored at the same temperature for 10 days. In Experiment D, quarters from four dead crabs with different histories plus one live crab were likewise divided, and half were boiled for 2 minutes. Again, one half of these quarters were stored at 36° F. for 1 day, and the other half for 5 days. In each case, a corresponding portion of the uncooked crab quarters was retained as a control under the same conditions of storage. Results are summarized in table 6.

After 4 minutes or more at the boiling temperature, the typical flora of live crabs appears to be destroyed. All except one of the 25° C. dilution plates were blank. Two minutes appears to be the critical time, at least for a crab quarter, since large numbers of bacteria are destroyed. It is in these circumstances that the nature of the residual bacterial population, rather than the

Table 5.—Destruction of bacteria in boiled crab quarters subsequently stored at 36° F. for 5 days

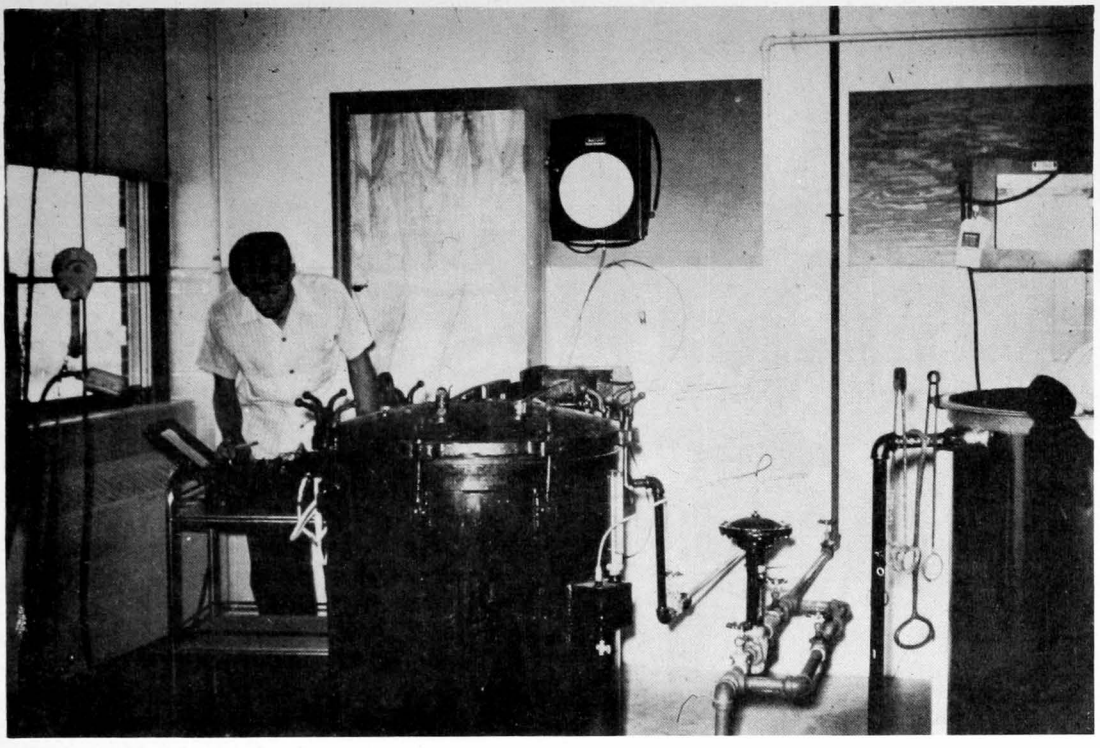
Crab	Uncooked control	Boiling time				
		1 minute	2 minutes	3 minutes	4 minutes	6 minutes
Number	*Bacteria per gram crab meat*[1]					
A 1	200,000				0	0
2	45,000		-		100	0
3	150,000		0		0	0
4	85,000		1,700		0	0
5	21,000		200		0	0
B 1	3,000	0	100	0		
2	13,000	0	1,000	0		
3	2,000	200	100	100		
4	12,000	100	100	4,000		
5	10,000	500	0	300		

[1] Incubated at 25° C.

Table 6.—Destruction of bacteria in boiled crab quarters subsequently stored at 36° F. from 1 to 10 days

Crab	Storage time	Condition of crab initially	Bacteria/gram of crab[1]	
			Uncooked crab quarter	Crab quarter boiled 2 minutes
Number	*Days*		*Number of bacteria*	*Number of bacteria*
C 1		Alive	1,200	0
2		Alive	8,000	0
3	1	Alive	2,700	0
4		Alive	30,000	0
5		Alive	1,000	0
C 1		Alive	700,000,000	12,000
2		Alive	1,600,000,000	0
3	10	Alive	1,400,000,000	0
4		Alive	1,800,000,000	0
5		Alive	1,000,000,000	0
D 1		Dead 11 days[2]	120,000	200
2		Dead 5 days[2]	26,000	0
3	1	Dead on dock	10,000	0
4		Dead in barrel	2,800	0
5		Alive in barrel	20,000	0
D 1		Dead 11 days[2]	23,000,000	0
2		Dead 5 days[2]	4,600,000	0
3	5	Dead on dock	1,200,000	800
4		Dead in barrel	7,000,000	0
5		Alive in barrel	1,700,000	0

[1] Determined at 25° C. incubation temperature.
[2] Kept in walk-in refrigerator held at about 36° F.



The laboratory experimental retort is provided with a recording thermometer on wall (rear). Laboratory aide at left checks internal temperature of crabs during cooking with potentiometer and thermocouples.

simple tabulation of numbers of colonies, becomes important. To the eye of one who has examined thousands of colonies on hundreds of crab meat dilution plates, these colonies fell into a familiar pattern. The few scattered colonies that developed on plates from samples cooked 3, 4, and 6 minutes were predominately flat-surfaced, densely opaque colonies, which produced white and orange pigment. Under microscopic examination, gram-stained smears from 20 colonies on 12 dilution plates were, without exception, gram-positive cocci. These organisms are not typical of the flora of live crabs, although they do occur on platings from live crabs. They resemble staphylococci, which are universally associated with man. The ultimate source of these organisms on plates from live-crab tissue and of those from packed meat may be the same as the source of those scattered colonies appearing on plates in these experiments. In the case of samples boiled for 2 minutes, however, this phenomenon did not always appear. In two notable instances, the colonies produced were typical spoilage organisms, and all colonies on the plates were composed of these organisms.

Of interest is the fact that one live crab (table 6, No. D5), which was included in a sense as a control to provide contrast with the four dead crabs, produced a flora that was both quantitatively and qualitatively similar to the flora typical of the dead crabs. This crab was surrounded in the barrel by dead crabs, one of which was also included in this experiment.

Variables Affecting Yield and Bacterial Count

The effects of several variables on yield and on shelf life as determined by bacterial count were investigated. Most extensive was the statistically designed, 75 random-cook experiment in which 5 temperatures, 3 cooking times, and 5 post-cook handling procedures were cross tested. Through earlier experiments, some effects of season and source as variables were also tested.

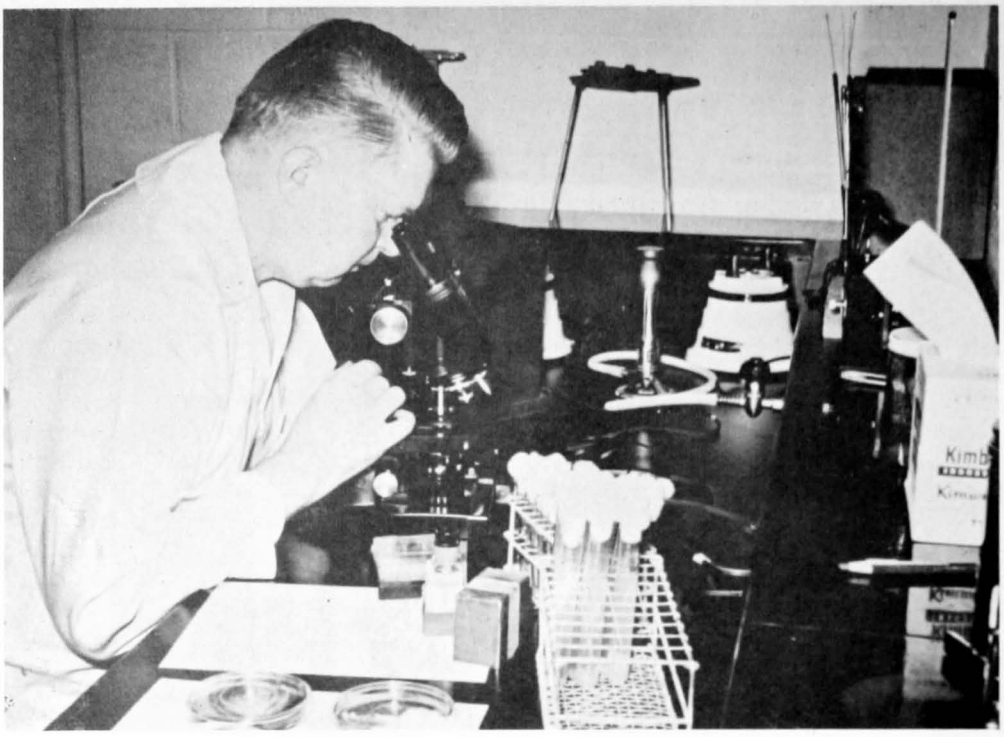
Cooking temperature.—The 5 temperatures selected for the 75 random cooks ranged from 212° to 250 °F. in tap water, brine, and steam under pressure. To determine the effect of temperature on the yield of picked meat from crabs cooked at these temperatures, data for all cooking times and post-cook handling procedures at each temperature were combined. Significantly higher yields were obtained at 212° F. in tap water than at higher temperatures. Results are shown in table 7.

Table 7.—Yield of picked meat as affected by the cook

Temperature and medium	Average yield[1]
	Percent by weight
212° F., steam-boiled[2] in tap water	14.9
213° F., steam-boiled in 3 percent brine	14.3
227° F., steam at 5 p.s.i.	14.1
239° F., steam at 10 p.s.i.	13.6
250° F., steam at 15 p.s.i.	13.4

[1] Yield based on 75 lbs. live crabs each cook; yields are average of 30 cooks for each treatment.

[2] Steam-boiling is achieved by discharging live steam into the cooking water.



Slides prepared from agar slant cultures are being examined microscopically to reveal the different types of bacteria that make up the complex flora of the live crabs.

Shelf life was considered to be equal to yield in importance, but analysis of the influence of cooking temperature on shelf life revealed no significant differences. The findings are presented, along with those for the effect of time on shelf life, in table 9.

Cooking time.—The three intervals selected for the 75 random cooks were 5, 10, and 15 minutes. In this instance, to determine the effect of time alone on yield, data for all cooking temperatures and post-cook handling procedures at each time interval were combined. Significantly higher yields were obtained after a 10-minute cook than with either a longer or a shorter cooking time. These results are presented in table 8 in the extreme right-hand column. Throughout the range of temperature employed, however, from 212° to 250° F., no direct linear relation with yield occurred. A breakdown of yield at each of the five temperatures is also presented in table 8.

Investigations were carried out at an earlier date (Littleford, 1957), one concerning the effect of season on yield in which cooking times of 5, 10, and 15 minutes were used and one on the yield from crabs from different habitats in which cooking times of 8, 12, and 20 minutes were used. In both experiments, one cooking temperature, 250° F. with 15 p.s.i. of steam, and one post-cook procedure, holding overnight whole in the refrigerator, were used. The average yields derived from the two experiments produced complementary results. They are presented in table 8 in the left-hand column.

The highest yields from steam-pressure cooking were produced using steam at 250° F. with cooking times of from 8 to 10 minutes. With boiling water at 212° F., the cooking medium that produced the highest yields of all, maximum yields were produced with cooking times

Table 8.—Yield of picked meat as affected by cooking time

Cooking time	Yield in Littleford's 1957 studies[1]	Yield in 75 cooks—for all post-cook procedures—at:					
		250° F. 15 p.s.i.	239° F. 10 p.s.i.	227°F. 5 p.s.i.	213° F. brine	212° F. water	All temperatures[2]
Minutes	*Percent by weight*	*Percent by weight*	*Percent by weight*	*Percent by weight*	*Percent by weight*	*Percent by weight*	*Percent by weight*
5	15.0	14.7	14.3	13.9	13.8	14.2	14.2
8	15.5						
10	16.0	14.4	13.9	14.1	15.0	15.2	14.5
12	14.3						
15	14.2	11.2	12.7	14.4	14.2	15.3	13.5
20	13.9						

[1] 1 barrel (100+ lbs.) live crabs each cook, average of 24 or 40 cooks per cook time.
[2] Average of 50 cooks per cooking time, 10 for each individual temperature.

of 10-15 minutes. The presence of salt in the boiling water (3 percent brine) appeared to make the cooking time required to obtain the highest yield more critical.

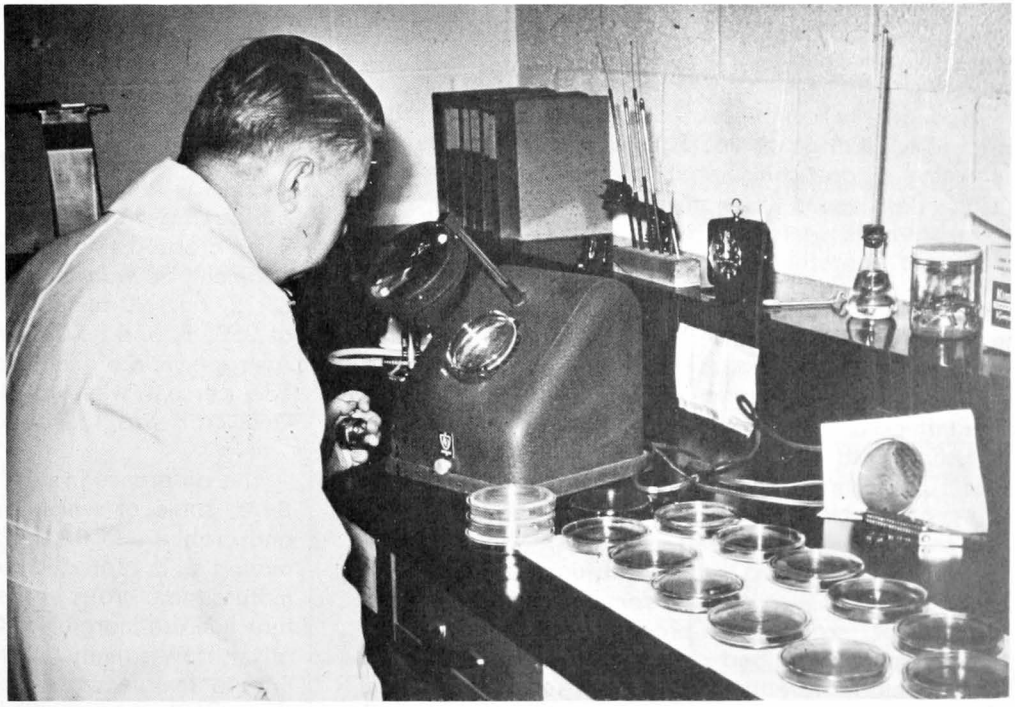
Bacteriological studies in conjunction with the processing tests brought interesting facts to light. Among these was the indication that the organisms that spoil crab meat are introduced into the packing plant by way of the live crabs and later, following cooking, are inoculated back into the crab meat primarily during the picking process. These bacterial populations in packed crab meat have a rather consistent pattern of growth behavior and, consequently, were used for determining shelf life. The criterion for determining the acceptibility or unacceptibility of a crab meat sample was the Maryland standard plate count (SPC) method described on page 31. Samples with counts of 100,000 colonies or less per gram of crab meat were considered to be acceptable. Those with counts in excess of 100,000 colonies were considered to be unacceptable. SPC determinations on the 75 random cooks, in duplicate (150 cooks) for the various times and temperatures employed revealed, in terms of percentage of acceptable samples, no significant differences after storage of samples for 1 week. The combined data for each of the four cook temperatures and three time intervals are presented in table 9.

Any influence exerted upon the bacterial population of the crabs by cooking temperature or time could be expected to be reflected subsequently in the picked meat and the bacteriological plate counts from that meat. Since no significant differences were observed, it might be concluded that cooking crabs for 5 minutes at 212° F. kills so many bacteria that any additional reduction achieved by increasing the time or temperature of the cook is insignificant. This interpretation, however, is not the only possible one. It may be that bacterial recontamination after cooking and inoculation during picking were gross enough to overwhelm a light residual population, however varied it might be among the treatments. There is also the possibility that there are factors affecting the shelf life of crab meat, other than simply the destruction of bacteria, which is influenced

Table 9.—Shell life, based on bacterial population of crab meat, as affected by the temperture and the time of the cook

Crab-cooking[1] treatment	Relative number of samples of crab meat with acceptable Maryland standard plate counts, after storage at 36° F. for:		
Temperatures for all cooking times	Initial	1 week	2 weeks
°F.	*Percent*	*Percent*	*Percent*
212	97	81	23
227	93	78	31
239	97	83	35
250	93	80	38
Times for all cooking temperatures			
Minutes			
5	98	78	28
10	96	85	42
15	94	79	24

[1] Seventy-five pounds live crabs each cook, average 30 to 60 cooks per treatment.



Bacteriologist is determining the standard plate count on dilutions made from samples of freshly picked crab meat. Counter is in his left hand.

by cooking. Although differences in shelf life were not significant after 1 week of storage, the number of samples from crabs cooked for 10 minutes that were acceptable after 2 weeks, suggests that the 10-minute cook beneficially influenced shelf life.

It should be noted that all references to cooking time are exclusive of "come-up" time. Crabs arriving at the packing plant may vary substantially in temperature from season to season. Each cook was timed from the moment the cooker arrived at the chosen temperature.

Post-cook handling.—The five post-cook handling variables incorporated into the 75 random-cook study were as follows: (1) Pick the crab immediately. (2) store whole overnight at room temperature, (3) refrigerate whole overnight, (4) deback and pick immediately, and (5) deback and refrigerate overnight. Among these variables, none was found to differ sigificantly from the others in their effect on yield. In contrast, the effect on shelf life was found to be quite significant. Evaluations of shelf life, based on bacterial population as determined by the Maryland SPC described on page 31, are presented in table 10.

Table 10.—Shelf life of crab meat stored at 36° F. as effected by post-cook handling procedures

Post-cook treatment[1] of the crabs	Samples passing Md. SPC[2] after storage for:		
	Initial	1 week	2 weeks
	Percent	*Percent*	*Percent*
Pick immediately	94	73	40
Store whole overnight at room temperature	94	61	19
Refrigerate whole overnight	100	87	33
Deback and pick immediately	100	85	17
Deback and refrigerate overnight	98	95	50

[1] Seventy-five pounds of live crabs each cook, values are average of 30 cooks for each treatment.
[2] Maryland standard plate count.

Based on the numbers of acceptable samples after refrigerated storage at 36° F., both debacking and refrigerating as post-cook handling procedures were beneficial. Best results were produced by combining these two procedures.

Season.—The packer has little control over several of the factors that affect yield. Some of these factors have not been identified, but it is helpful to consider the more important of those that have been. One such factor is the influence of season, which Littleford (1957) studied at Crisfield, Md. Thirty batches consisting of 1 barrel (over 100 pounds of live crabs per barrel) per batch were processed during each of the four seasons. Seasonal categories were divided as follows: winter crabs—dredged crabs procured through February to mid-March; spring crabs—those procured from early May to mid-June; summer crabs—those procured from early August to mid-September; and fall crabs—those procured through October to early November. Ten batches were cooked for 5 minutes; 10 batches, for 10 minutes; and 10 batches, for 15 minutes. All 30 batches were cooked at 250° F., and all were held overnight whole in the refrigerator.

Regardless of cooking time, the poorest yields were consistently obtained from winter crabs. Best yields varied. After a 5-minute cook, a decidedly better yield was obtained from spring crabs. With both 10- and 15-minute cooking periods the difference in yield between spring and summer crabs was insignificant. Average yields of meat per hundred pounds of live crabs were as follows: winter, 14.3 percent; spring, 15.7 percent; summer, 15.4 percent; and fall, 15.0 percent.

Although the study was not conducted the year around, yields from the 75 random-cook experiment were averaged by month in order to provide a basis for comparison. The results of both the seasonal and the random-cook studies are presented in table 11.

Although the above experiments are not entirely comparable, certain observations can be made, and the disparities observed. In Littleford's seasonal study, the lowest yields were obtained from winter crabs; whereas in the 75 random-cook study the highest yields were obtained from winter crabs. It should be noted that the crabs are classified as winter crabs in both instances essentially because all were dredged crabs. In the case of the 75 cooks, however, the crabs were taken at the start of the dredging season, shortly after beginning hibernation. In Littleford's study, the crabs were taken in late winter toward the end of the season. Littleford's study also showed highest yields in spring and early summer with a consistent decline through late summer and fall. The yields from the 75 cooks were likewise high in early summer with a decided drop by September, but the cooks then produced a gradual but steady increase through the fall to a maximum in December, as described above. Season has a definite influence on yield, although a clear pattern has not been revealed.

Source.—Another pertinent variable was the influence of habitat. Because of the competitiveness of the industry, a majority of packers have little control over the source of their live crabs. Accordingly, an experiment was conducted during July and August 1957, comparing the yields from Tangier Sound and Choptank River crabs (Littleford, unpublished data). In this experiment, 36 batches of crabs were cooked, 12 each at 8, 12, and 20 minutes. All of the crabs were cooked at 250° F. and held overnight whole in the refrigerator. Average yield of meat from the Tangier Sound crabs was 13.9 percent, whereas the average yield from Choptank River crab was 15.2 percent.

This difference in yield results from crab behavior patterns, some of which are familiar to veteran packers and crabbers in the locality. Behavior associated with mating and reproduction results in a concentration of mature male crabs in the upper reaches of the estuaries that line the margins of Chesapeake Bay—waters of relatively low salinity. During the summer, after mating, mature female crabs begin a gradual migration back down the bay toward the Virginia Capes and the ocean. Consequently, throughout the summer, crabs taken from Tangier Sound ranged from 50 to 100 and averaged about 70 percent adult females. In contrast, those taken

Table 11.—Comparison of seasonal variations in yield from two experiments

Seasonal study[1]		75 random cooks[2]	
Season	Yield	Time of year	Yield
	Percent by weight	*Month*	*Percent by weight*
Winter (Feb. and 1/2 Mar.)	14.3	December	16.3
Spring (May and 1/2 June)	15.7	June	15.3
Summer (Aug. and 1/2 Sept.)	15.4	September	12.4
Fall (Oct. and 1/4 Nov.)	15.0	October	13.6
		November	14.4

[1] Intermittently tested from February to November 1956.
[2] Continuously tested from September to December 1957, completed June 1958.

from the Choptank River were 90 to 100 percent adult males during the test period. It might also be noted that all crabs in the Choptank were taken by the trotlines, whereas the Tangier Sound crab were taken entirely by crab pots. The Choptank River male crabs are, on the average, larger than those from Tangier Sound; and in addition, the male crab has a proportionately larger claw than the female.

In this study, as in all others, yields were based on all meat, including lump and flake white body meat as well as claw meat. Although many biological factors, such as the physical condition of the crabs and their metabolic status, can be involved in yield differences, in this instance at least, the primary factor was the sex of the crabs.

PILOT-PLANT STUDIES

Based on the findings of the preliminary studies, a series of experiments was carried out at the pilot-plant level. The most extensive of these was the test at the Seafood Processing Laboratory comparing two distinct crab-processing methods. Carried out over a period of 5 consecutive weeks, this test, which was statistically designed, consisted of 4 individual 100-pound cooks each day, for a total of 80 cooks: (1) two different methods of cooking—(a) steam boiling and (b) pressure steaming—were compared in combination with (2) two distinct methods of post-cook handling. This study was followed by (3) an evaluation of yields from several batches of crabs boiled consecutively in the same cook water. Incorporated into the experiment was (4) a comparison of yield and bacterial population from crab claws picked by hand with claws picked by machine.

Steam Boiling vs. Pressure Steaming

The cooking methods compared were: boiling at 212° F. and steaming at 250° F. Boiling was accomplished in a retort into which the live steam was discharged from a perforated spreader directly into the cook water. This method, which percolates the steam through the water, agitates the water and continuously replenishes the cooking medium. The method is referred to as steam boiling. Pressure steaming was accomplished in the same vessel with the top secured and under 15-p.s.i. pressure. The cooking time for each cook was 10 minutes. Forty cooks each for both steaming and boiling were accomplished using the same cooking method for all four cooks conducted on the same day, and the days were randomized. Disregarding post-cook handling methods, yield of picked meat per 100 pounds of live crabs was 17.6 percent from boiled crabs compared with 15.9 percent from pressure-steamed crabs. Details concerning the yield are presented in table 12. The factors of moisture content and bacteriological quality were considered concurrently. They are discussed at the end of the following section.

Store at Room Temperature Overnight, Whole vs. Refrigerate Overnight, Debacked

The crabs cooked by each of the two methods just described were subjected to two different post-cook

Table 12.—Yield of crab meat as affected by method of cooking and post-cooking handling

Cooking method	Overnight post-cook procedure	Yield[1]				
		Regular	Lump	Total white	Claw	Total yield
		Percent by weight	*Percent by weight*	*Percent by weight*	*Percent by weight*	*Percent by weight*
Pressure-steamed 250° F. 10 mins.	Room temp., whole	8.2	4.3	12.5	2.8	15.3
	Refrigerator, debacked	8.7	4.5	13.2	3.3	16.5
Steam-boiled[2] 212° F. 10 mins.	Room temp., whole	9.3	3.9	13.2	3.9	17.1
	Refrigerator, debacked	9.5	4.1	13.6	4.4	18.0

[1] Average of 20 cooks per treatment, 100 pounds of live crabs each cook.
[2] Steam boiling is achieved by discharging live steam into the boiling water.

handling procedures. Twenty of the 100-pound batches that were steam boiled were held overnight at room temperature without further handling, and the other 20 were debacked, washed, and refrigerated overnight. The same procedure was followed with the pressure-steamed crabs. From each day's four cooks, two batches were selected randomly for debacking, and two were left whole. Disregarding cooking methods, yield of meat per 100 pounds of live crabs was 17.3 percent for debacked and refrigerated crabs compared with 16.2 percent for whole crabs held at room temperature. These data on yield are also presented in table 12.

With this additional evidence that higher yields were obtained from boiled crabs than from pressure-steamed crabs, the moisture content of the meat became significant. Consequently, meat from crabs cooked by both methods was compared by a series of tests for total solids. The results are presented in table 13.

Table 13.—Solids content of crab meat

Kind of meat	Cooking method	Overnight post-cook procedure	Total solids from: Individual procedure	Total solids from: Average of two:
			Percent by weight	*Percent by weight*
White meat, flake and lump	Pressure-steamed 250° F. 10 mins.	Room temp., whole	25.8	24.4
		Refrigerator, debacked	23.0	
	Steam-boiled 212° F. 10 mins.	Room temp., whole	23.6	23.1
		Refrigerator, debacked	22.6	
Claw meat	Steam-boiled 212° F. 10 mins.	Room temp., whole	24.0	24.0
		Refrigerator, declawed	24.0	

The above data indicate that meat from the boiled crabs contained less solids, and therefore more moisture, than meat from the steamed crabs. The higher level of moisture in the boiled crabs, however, did not account for all of the increase in yield. Meat from crabs that were debacked, washed, and refrigerated overnight had a higher moisture content than crabs held whole at room temperature overnight without further handling or washing. This finding was true with meat from both methods of cooking, but the difference between the two was considerably greater with meat from steamed crabs than with meat from boiled crabs similarly handled. These results indicate that pressure steaming actually dries the meat. This indication was investigated further in connection with tests made at commercial plants.

The bacteriological quality of the crab meat produced by the various processing methods under comparison was determined by plating representative samples at various intervals using the Maryland standard plate count (SPC) method. In contrast to all previous experiments in which stored crab meat was held on shelves in the walk-in refrigerator at a temperature of 36° F. (actually 33°-38° F.), cans of these samples were packed in crushed ice and held at a temperature of 32°-33° F. The findings are presented in table 14.

An examination of the data reveals some observations of interest, although plate-count range and acceptable samples do not tell the whole bacteriological story. All 1-day-old samples were bacteriologically acceptable as expected, with the average SPC being relatively low throughout. At 1 week, many samples showed a decreased SPC over 1-day samples. This is a phenomenon familiar to many bacteriologists and others concerned with sanitation and regulation of shellfish industries. Range of counts at this time, however, showed an increased spread, which continued until the final platings

Table 14.—Bacteriological quality of crab meat after storage at 33° F.[1] as affected by method of cooking and post-cook handling

Cooking method	Overnight post-cook procedure	Storage period	Bacteriological analysis of samples based on Md. standard plate count (SPC): Md. SPC	Acceptable samples[2]	samples Total
		Days	*Bacteria per gram*	*Number*	*Number*
Pressure-steamed 250° F. 10 mins.	Room temp., whole	1	22,000- 32,000	2	2
		7	6,000- 920,000	4	8
		14	37,000- 11,000,000	3	7
		21	20,000- 300,000,000	4	19
	Refrigerator, debacked	1	19,000- 29,000	2	2
		7	6,000- 38,000	8	8
		14	57,000- 12,000,000	1	7
		21	43,000- 85,000,000	1	19
Steam-boiled 212° F. 10 mins.	Room temp., whole	1	11,000- 57,000	2	2
		7	6,000- 1,000,000	4	9
		14	71,000- 94,000,000	1	5
		21	100,000-1,000,000,000	1	16
	Refrigerator, debacked	1	4,000- 66,000	2	2
		7	7,000- 400,000	7	9
		14	82,000- 45,000,000	2	5
		21	160,000- 770,000,000	0	16

[1] Storage temperature lowered from walk-in refrigerator average of 36° F. to 33° F. by packing cans in crushed ice.
[2] Refer to text for description of "acceptable" under Md. SPC.

were made at 3 weeks. Steam-boiled samples revealed a wider spread in range than did pressure-steamed samples. But on the basis of both plate counts and acceptable samples after storage, steaming showed little or no bacteriological advantage over boiling. Also of interest is the fact that the initial advantage, up to 1 week, of debacking and refrigerating overnight compared to holding overnight whole at room temperature has been lost by the end of 2 weeks. Because the bacteriological objectives of this pilot-plant study were secondary, the design of the experiment did not include sufficient bacteriological samples for a statistical evaluation.

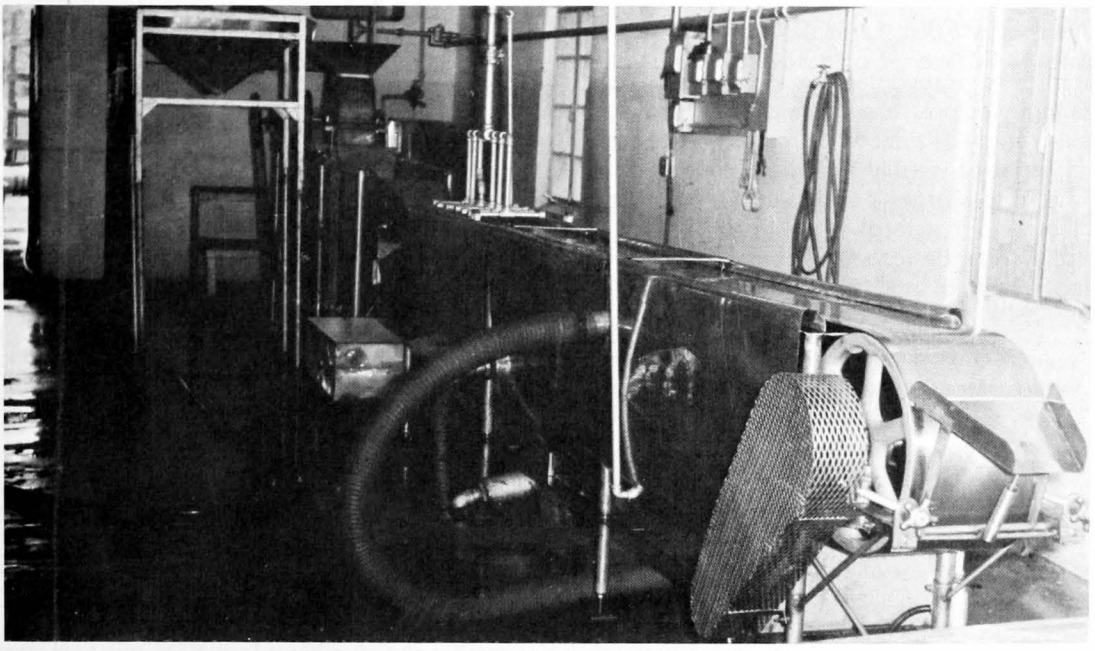
The yield data from the above pilot-plant experiment were re-evaluated to determine the effect of successive boilings in the same water and to compare this effect with the yield from successive steamings. Repeated boiling in the same water, at least up to four cooks, had no effect on yield, and the average yield from four lots, boiled successively in the same water was actually more consistent than the yield from four successive steamings (table 15).

To investigate further, a second pilot-plant-scale test in which ten 100-pound batches of crabs were successively boiled in the same water was carried out. Every third cook (1, 4, 7, and 10) was picked to determine the yield, and the picked meat was tested bacteriologically by SPC. Neither yield nor bacterial count showed significant differences from cook to cook (table 16).

Table 15.—Comparison of successive yields[1] by cook order, steamed crabs vs. boiled crabs

Cooking method	Overnight post-cook procedure	Yield			
		First cook	Second cook	Third cook	Fourth cook
		Percent by weight	*Percent by weight*	*Percent by weight*	*Percent by weight*
Pressure-steamed 250° F. 10 mins.	Room tem., whole	15.3	15.5	15.4	14.9
	Refrig., debacked	17.1	16.2	16.4	16.1
	Average	16.4	15.7	15.9	15.6
Steam-boiled[2] 212° F. 10 mins.	Room temp.	17.0	17.1	17.2	17.1
	Refrig., debacked	18.3	18.2	17.7	17.9
	Average	17.5	17.5	17.4	17.7

[1] Average of 3 to 7 cooks for each post-cook procedure, grand average of all 10 for each cooking method.
[2] Steam boiling is achieved by discharging live steam into the boiling water.



The Harris claw picking machine. The large hose (center) provides suction to remove moisture from the washed meat on the conveyor belt.

Table 16.—Yield and bacterial count of meat from batches of crabs cooked successively in the same water.

Cook	Yield	Maryland standard plate count
Number	*Percent by weight*	*Bacteria per gram*
1	18.9	3,900 to 12,500
4	17.6	3,700 to 7,700
7	18.6	14,700 to 20,500
10	17.7	12,500 to 20,500

Machine Picking vs. Hand Picking of Claw Meat

As an accessory of the pilot-plant study, the yield from machine-picked claws (Harris machine)[2] was compared with the yield from hand-picked claws. On 2 consecutive days, a day of boiling and a day of steaming, the four cooks were divided as usual. Two cook-lots were declawed at the time they were debacked and were held overnight in the refrigerator. The other two were declawed in the morning after being held whole overnight at room temperature. One of each was machine picked and the other was hand picked. Machine picking produced both higher yields and higher bacterial counts (table 17).

COMMERCIAL-PLANT STUDIES

Any significant increase in yield of crab meat is of interest to the packer. After discussing the research findings with members of the industry and pertinent state and Federal agencies, we decided to make further tests in a commercial plant.

All previous studies have revealed the yield-producing superiority of boiling over pressure steaming. To project this observation to a study of the commercial significance of the findings, a series of weekly runs were carried out at the plant of one of the larger packers in the industry, throughout the summer for a total of 12 tests. The experiment was statistically designed. The same cooker was used for steam boiling and for pressure steaming.

[2] Mention of a specific commercial product does not constitute endorsement by the U. S. Department of the Interior.

For boiling, the retort was equipped with a stainless-steel collar; and as the fluid level was continuously raised by condensing steam, foam and detritus overflowed and were carried away by a trough to a drain.

In these tests, several aspects of steam boiling and pressure steaming were compared, including: (1) yield, (2) moisture content, (3) bacteriological quality, and (4) organoleptic properties.

Yield

Previous experiments had demonstrated no significant change in yield between cooking times of 10 minutes and 15 minutes when boiling in water was employed. For better control in this experiment, all lots were boiled (212° F.) for 15 minutes. Pressure steaming was, as usual, at 250° F. (15 p.s.i.) for 10 minutes. Although differences in yield due to the method of cooking were small in some trials, overall the superior yield of boiling over pressure steaming was again demonstrated. Details on the yield are presented in table 18.

Moisture Content

As with the pilot-plant study, a knowledge of the relation of moisture to solids in the meat was desirable, and a series of determinations of total solids was run (table 19). As before, analyses were made on regular flake and backfin lump (white meat) and claw meat (dark meat) from both boiled and steamed crabs. As a positive control in this instance, an additional set of samples were run on raw, unprocessed muscle tissue from the same lot of crabs. The implication of the earlier tests was substantiated. The consolidation of the meat through cooking, by heat precipitation of the protein, actually removes water from the tissue. In so doing, pressure steaming has a greater drying effect on the crab meat than does steam boiling.

Bacteriological Quality

The bacteriological quality of the product is always important in the production of crab meat. Therefore, although post-cook handling procedures were not of direct concern in the design of this experiment, post-cook temperatures were. All cooked crabs were held overnight whole in their respective cooking containers. Most were held at atmospheric temperature, which at times approached 90° F., but several lots were refrigerated

Table 17.—Yield of machine-picked and hand-picked claw meat and bacterial count after storage at 36° F. for 10 days

Cooking method	Overnight post-cook procedure	Hand-picked meat		Machine-picked meat	
		Yield	Md. SPC	Yield	Md. SPC
		Percent by weight	*Bacteria per gram*	*Percent by weight*	*Bacteria per gram*
Pressure-steamed	Room temp., whole	2.8	22,000	3.7	660,000
	Refrig., declawed	3.0	-----	4.2	------
Steam-boiled	Room temp., whole	3.8	420,000	4.4	1,200,000
	Refrig., declawed	4.2	18,000	5.0	231,000
Average		3.5	153,000	4.3	687,000

Table 18.—Yield as affected by cooking method—commercial plant tests

Date	Cooking method	Live crabs	Yield of picked meat per batch				
			Regular	Lump	Claw	Total	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*
6/8	Steam[1]	402	36.8	22.0	13.4	72.2	18.0
	Boil[2]	402	40.0	23.0	17.0	80.0	19.9
6/15	Steam	467	40.0	21.8	16.6	78.4	16.8
	Boil	467	56.0	21.5	19.8	87.3	18.7
6/22	Steam	425	38.9	22.0	15.8	76.7	18.0
	Boil	425	43.8	17.7	17.6	79.1	18.7
6/29	Steam	407	35.9	21.5	15.3	72.7	17.9
	Boil	407	38.4	19.1	17.9	75.4	18.5
7/5	Steam	356	32.5	17.0	13.4	62.9	17.7
	Boil	356	36.7	17.4	17.5	71.6	20.1
7/13	Steam	362	32.0	13.4	8.2	53.6	14.8
	Boil	362	34.4	10.3	8.2	52.9	14.6
7/20	Steam	296	27.6	13.3	11.0	51.9	17.5
	Boil	296	28.8	13.3	13.1	55.2	18.6
7/28	Steam	439	28.8	14.0	10.5	53.3	12.1
	Boil	438	34.0	11.0	11.9	56.9	13.0
8/4	Steam	249	26.4	10.0	8.0	44.4	17.8
	Boil	249	28.1	9.5	10.6	48.2	19.4
8/11	Steam	380	34.1	16.4	12.9	63.4	16.7
	Boil	380	37.6	14.5	15.0	67.1	17.7
9/1	Steam	325	32.3	18.5	14.3	65.1	20.0
	Boil	325	33.5	16.5	16.1	66.1	20.3
9/15	Steam	300	27.3	13.5	9.9	50.7	16.9
	Boil	300	31.4	14.8	13.5	59.9	19.9
Total	Steam	4408	393	203	150	745	
	Boil	4407	433	189	177	799	
Average	Steam	367	32.8	16.9	12.5	62.1	16.9
	Boil	367	36.1	15.8	14.8	66.6	18.2

[1] Steam = pressure-steam at 15 p.s.i.—250° F. for 10 minutes.
[2] Boil = steam-boil (steam discharged into boiling water)—212° F. for 15 minutes.

Table 19.—Solids content of fresh crab meat

Type of meat	Treatment of crabs	Solids content
		Percent by weight
Claw	Raw	18.0
	Steam boiled	20.3
	Pressure steamed	21.5
Regular white	Raw	19.6
	Steam boiled	20.8
	Pressure steamed	21.9
Backfin lump	Raw	19.6
	Steam boiled	21.0
	Pressure steamed	22.0

at approximately 38° F. On several occasions the meat from steam-boiled crabs produced disturbingly high plate counts. These high counts, however, dropped rapidly during refrigerated storage and were within a range normal for crab meat after only a few days. An investigation revealed that the bacteriology was being complicated by the presence of many spore-forming bacteria, particularly of the *Bacillus subtilis* group. These organisms are not normally associated with crabs when taken from the water, but they are common in soil and dust. They are destroyed by pressure steaming at 250° F. but not by boiling at 212° F. Although this factor would compound the problems of regulation, it can be controlled. These excessively high counts in meat from crabs held overnight at room temperature were prevented from developing by overnight refrigeration. The findings are presented in table 20.

Table 20.—Bacterial counts of stored crab meat from steamed-boiled and pressure-steamed crabs

Test	Cooking method	Storage temperature of cooked crabs	Md. standard plate count after storage of meat at 38° F. for:	
			1 day	8 days
Number		° *F.*	*Bacteria per gram*	
1	Steamed[1]	38	24,000	20,000
	Boiled[2]	38	143,000	60,000
2	Steamed	Room	40,000	57,000
	Boiled	Room	23,000	241,000
3	Steamed	38	18,000	30,000
	Boiled	38	11,000	67,000
4	Steamed	Room	180,000	120,000
	Boiled	Room	2,900,000	870,000
5	Steamed	Room	31,000	28,000
	Boiled	Room	1,600,000	330,000
6	Steamed	Room	45,000	50,000
	Boiled	Room	660,000	120,000
7	Steamed	38	106,000	2,100,000
	Boiled	38	19,000	44,000

[1] Steamed = pressure-steamed at 15 p.s.i.—250° F. for 10 minutes.
[2] Boiled = steam-boiled (steam discharged into boiling water)—212° F. for 15 minutes.

Organoleptic Properties

Organoleptic characteristics of experimentally produced crab meat were taken into account from the start of the program. When samples were opened for bacteriological testing, they were examined organoleptically by one or more members of the laboratory staff. Visual appearance and aroma were noted, and all samples not graded "poor" or worse than poor were tasted. Such testing, although useful, however, was not scientifically controlled. Consequently, as a contribution to the commercial-plant test program, the Bureau of Commercial Fisheries Technological Laboratory at College Park, Md., carried out controlled organoleptic comparison tests on boiled and steamed crab meat from the first six experimental trials. Three styles of crab meat—lump, regular, and claw—were tested. The triangular (three-sample) test method was used with a 12-member panel. Their conclusion was that no significant differences existed among the lots of crab meat tested. Often no preference was expressed, because of the similarity of the samples. Where a preference was expressed, boiled meat was preferred more often than was the steamed meat.

CONCLUSIONS

1. The cooking process very markedly reduced the bacterial population in crabs.

2. Experimental evidence indicated that spoilage bacteria are brought into the packing plant on the live crabs and are reinoculated into the crab meat after it is cooked. A high order of plant sanitation is essential.

3. Cooking for 5 minutes, either by steam boiling at 212° F. or pressure steaming at 250° F., was sufficient to reduce bacterial populations to acceptable levels.

4. Pressure steaming crabs at 250° F. (15 p.s.i.) for 10 minutes produced higher yields than did pressure steaming for either longer or shorter periods.

5. Steam boiling crabs at 212° F. in tap water for 10 to 15 minutes produced higher yields than did pressure steaming at 250° F. for 10 minutes. The boiling time is considerably less critical than is steaming time.

6. Successively steam boiling several baskets of crabs, at least up to 10, in the same water had little effect on yield or bacterial counts of picked meat.

7. Machine-picked crab claws produced about 25 percent more yield of meat than did hand-picked claws, but the meat also had higher bacterial populations.

8. Natural variables, such as season and source, and biological factors, such as physiological condition and sex of the crabs, have a distinct influence on yield. Data were inadequate, however, to show that any definite yield pattern is produced by these variables.

9. Refrigeration of crabs overnight, after they had been properly cooked, increased both yield and shelf life. Refrigeration was essential during hot weather.

10. Debacking and washing properly cooked crabs prior to overnight storage also increased yield. Highest yields were obtained when a combination of debacking and refrigeration was employed.

11. Crab meat produced from boiled crabs could not be distinguished organoleptically from crab meat produced from steamed crabs. When a preference was indicated, it was more frequently for boiled meat than for steamed meat.

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Charles F. Lee, Food Technologist on the staff of the Bureau of Commercial Fisheries Technological Laboratory, College Park, Md., has served as coordinator and liaison officer between the Bureau and the laboratory from the start of the contract.

George W. Wharton, former head of the Department of Zoology, University of Maryland, College Park, and at that time Director of the Seafood Processing Laboratory, Crisfield, Md., had a major influence on the content and direction of the research program and participated in the design of all experiments.

L. F. Hobbs of the Maryland State Department of Health, supervised the commercial plant tests, with observers from the Seafood Processing Laboratory. Staff members of the Bureau's College Park laboratory assisted the participants from the above organizations in the design and the evaluation of results of this plant test series.

Vincent Schultz, formerly of the University of Maryland, College of Agriculture, assisted in the statistical design, and Richard Highton, Department of Zoology, supervised statistical analysis, of the random cook and pilot plant experiments.

R. A. Littleford, formerly in charge of the Seafood Processing Laboratory, in addition to the two studies cited in the text, initiated the random cook project. This was later taken over by the author.

C. F. Dunker, former Director of the Seafood Processing Laboratory succeeding G. W. Wharton, and M. A. Benarde, former staff member, assisted in compilation of data and preparation of an earlier draft of this report. Most of the multitude of bacteriological examinations were made by John Cox, laboratory bacteriologist. Paul Dorsey, Samuel Williams, James Dennis, Dorothy Collins, and Kay Taylor assisted in the processing and laboratory work.

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MS #1297

OBSERVATIONS OF THE "BLUEING" OF KING CRAB, *Paralithodes camtschatica*

by

Herman S. Groninger and John A. Dassow

ABSTRACT

Blood coagulum from heat-processed king crab was used to study the dark discoloration called "blueing." It was shown that the blueing reaction requires oxygen and is inhibited by ascorbic acid. The blued product was found to have some properties that are similar to those of copper proteins and biuret complexes.

INTRODUCTION

Blueing is a term used to describe the discoloration that sometimes occurs in heat-processed crabmeat. The discoloration can range from blue-gray to black and usually occurs in coagulated blood and in blood vessels and other tissue containing blood in an appreciable amount. This defect in quality is called "blueing," since the phenomenon is not sufficiently understood to permit a more precise terminology. In the present report, it is assumed that the blueing observed in heat-processed and frozen products from different species of crab constitutes the same or similar phenomena.

The correlation between the presence of blood and the occurrence of blueing in processed crab meat has prompted a number of investigators to suggest procedures for the reduction of residual blood prior to or during processing (Elliott and Harvey, 1951; Farber, 1953; Tanikawa, 1959).

The question arises as to what basically is the cause of blueing. Oshima (1932) suggested the following four possible substances as causes of the blue discoloration in canned crab meat: (1) iron sulfide, (2) copper sulfide, (3) melanin, and (4) the biuret complex. Later, Fellers and Harris (1940) suggested that the blued discoloration in heat-processed crab *(Callinectes sapidus)* was due to copper-ammonia complexes and to some extent to sulfides. Bailey, Fieger, and Novak (1960b) indicated that melanin is probably not a cause, since they found that tyrosinase activity was absent from the blood of the blue crab. Krishnan (1955) found that the tyrosinase activity of the blood of the green crab *(Carcinus maenus)* varied from slight at the moulting and the soft-crab stages, to moderate at the paper- and the hard-shell stages, and to high at the peeler stage. There are, however, no reports on the tyrosinase activity of king crab blood, nor is any evidence reported showing that blueing is caused by tyrosinase in any species of crab.

During the past decade, the occasional occurrence of blueing in crab meat has created a quality-control problem in the important king crab fishery in Alaska. The work reported here was undertaken in an effort to better understand the characteristics of the blueing reaction and the nature of the blued product.

CHARACTERISTICS OF THE BLUEING REACTION

Blueing does not occur in uncooked king crab. If it occurs at all, it occurs after cooking; and if the crab is frozen immediately following cooking, then a portion of the white coagulated blood (coagulum) becomes blue when the crab thaws. This discoloration can be inhibited by holding the material at a temperature just above 0° C. and by reducing the oxygen level with a blanket of CO_2. White coagulum from a lot of processed crab with a history of blueing then can be used as a system to study the blueing reaction.

Materials

In the present study, two kinds of materials were used: crab legs and crab blood.

Crab legs.—Frozen raw crab legs and frozen cooked crab legs were obtained from a local processor. Both the raw and cooked legs were from freshly butchered crabs. The cooked legs were prepared by cooking in boiling water for 24 minutes and freezing. The cooked crab legs were sawed lengthwise, and the white coagulum was collected from the areas where it accumulated in the joints and between the meat and the shell. The

Authors Note.—Herman S. Groninger, *Research Chemist*, and John A. Dassow, *Supervisory Chemist*, Bureau of Commercial Fisheries Technological Laboratory, U. S. Fish and Wildlife Service, Seattle, Wash.

coagulum was kept just above 0° C. and blanketed with CO_2 during mixing in a blender. This coagulum was used in two types of experiments, as follows:

1. The coagulum was divided into portions of equal weight. One set of portions was extracted with 0.2 M citrate buffer immediately, and the other set was extracted after blueing occurred.

2. The coagulum was separated into supernatant and residue fractions by centrifugation. The residue then was washed three times with cold distilled water to remove soluble material.

Crab blood.—A sample of pooled crab blood was obtained from live crabs by a processor in Alaska. It was frozen and held at -29° C. until used.

Methods

Copper determination.—Total copper was determined by the method of the Association of Official Agricultural Chemists (1955).

Nitrogen determination.—Nitrogen was determined by the method of Hawk, Oser, and Summerson (1954).

Electrophoresis.—Starch-gel electrophoresis was carried out following the method of Smithies (1955).

Phenolic determination.—Phenolic materials in crab were determined by the method of Malek (1961).

Oxidation-reduction measurements.—Oxidation reduction measurements were made using a pH meter equipped with platinum and calomel electrodes. The meter was standardized internally.

Reducing power.—Reducing power was measured by a method based on the reduction of cupric to cuprous ion in the presence of 2,2-biquinoline. The extract to be tested (about 2 ml.) was placed in a small separatory funnel and treated with 2 ml. of 10-percent trichloracetic acid, 1 ml. of $CuSO_2$ (100 micrograms) solution, and 4 ml. of 0.05-percent 2,2-biquinoline in isoamyl alcohol. The isoamyl layer was dried over anhydrous Na_2SO_4, and the absorbence was measured at 540 mμ.

Tyrosinase.—Tests for tyrosinase were made by using the manometric method described by Bailey, Fieger, and Novak (1960a) and by watching for a color change after mixing a solution of 0.01 M phosphate buffer, pH 7.4, and aqueous extract of crab or crab blood in a spot plate.

Results and Discussion

Production of blueing.—The extent of blueing in commercial packs of frozen king crab is not known. Normally, there are small sporadic occurrences, but occasionally, there are occurrences of greater extent. A high incidence of blueing has been attributed to underheating during processing. Many experienced operators of crab-processing plants insist that because blueing develops during cooking, its presence indicates the need for a longer cook. Plant observations have shown, however, that an increased cook does not necessarily solve the problem.

Attempts to produce blueing under laboratory conditions were not always successful. The main effort was based on the premise that blueing occurs as a result of undercooking. In these trials, king crab blood was heated at various temperatures from 65° to 100° C. and for various periods from 5 to 25 minutes. It was found that a bluelike product was produced by heating the blood at 74° C. for 9 minutes but that the discoloration could not always be produced. Attempts to produce blueing in raw crab legs by undercooking likewise were unsuccessful.

Melanin and cupric ion oxidation of polyphenols as causes of blueing.—As was indicated earlier, the melanoidlike character of the blueing product has suggested tyrosinase as a cause of blueing. The absence of tyrosinase activity in king crab blood and in the blueing product and the absence of fluorescence in the blueing product, however, showed that melanin is not a cause.

The cupric ion oxidation of polyphenols also was ruled out as a cause of blueing when polyphenols could not be demonstrated in the blood coagulum.

Effects of specific reagents on the blueing reaction.—The coagulum and the residue and supernatant fractions prepared from the coagulum of commercially processed crab were used as a system to study the nature of the blueing reaction. The centrifugation scheme for obtaining the fractions and some of the simple reactions of these fractions are given in figure 1. The blueing reaction requires the presence of all three of the following: (1) the residue fraction, which is primarily denatured protein, (2) the supernatent fraction, which constitutes the soluble constituents of the blood, and (3) oxygen.

A number of reagents were used in the above reaction in an effort to determine what types of substances were participating and how they might be related.

1. *Reduction*·—Ascorbic acid inhibited the blueing reaction and decreased the intensity of the color of the blueing product slightly if it was added after blueing occurred. Treatment of the residue fraction with ascorbic acid and subsequent removal before reaction with the supernatant fraction did not inhibit the blueing reaction. This means that the system or component sensitive to ascorbic acid is in the supernatant fraction.

Sulfur dioxide was used as a reducing agent, since an excess can easily be removed. Treatment of either the supernatant or residue fractions before mixing them together inhibit the blueing reaction. Bubbling oxygen through the supernatant treated by SO_2 did not return it to its original condition, which would permit participation with the residue fraction to cause blueing. The effect of this treatment is not understood.

2. *Oxidation*·—The blueing reaction was inhibited with 0.01 M H_2O_2 and removal did not inhibit the blueing reaction. This result means that the system or component to H_2O_2 is in the supernatant fraction.

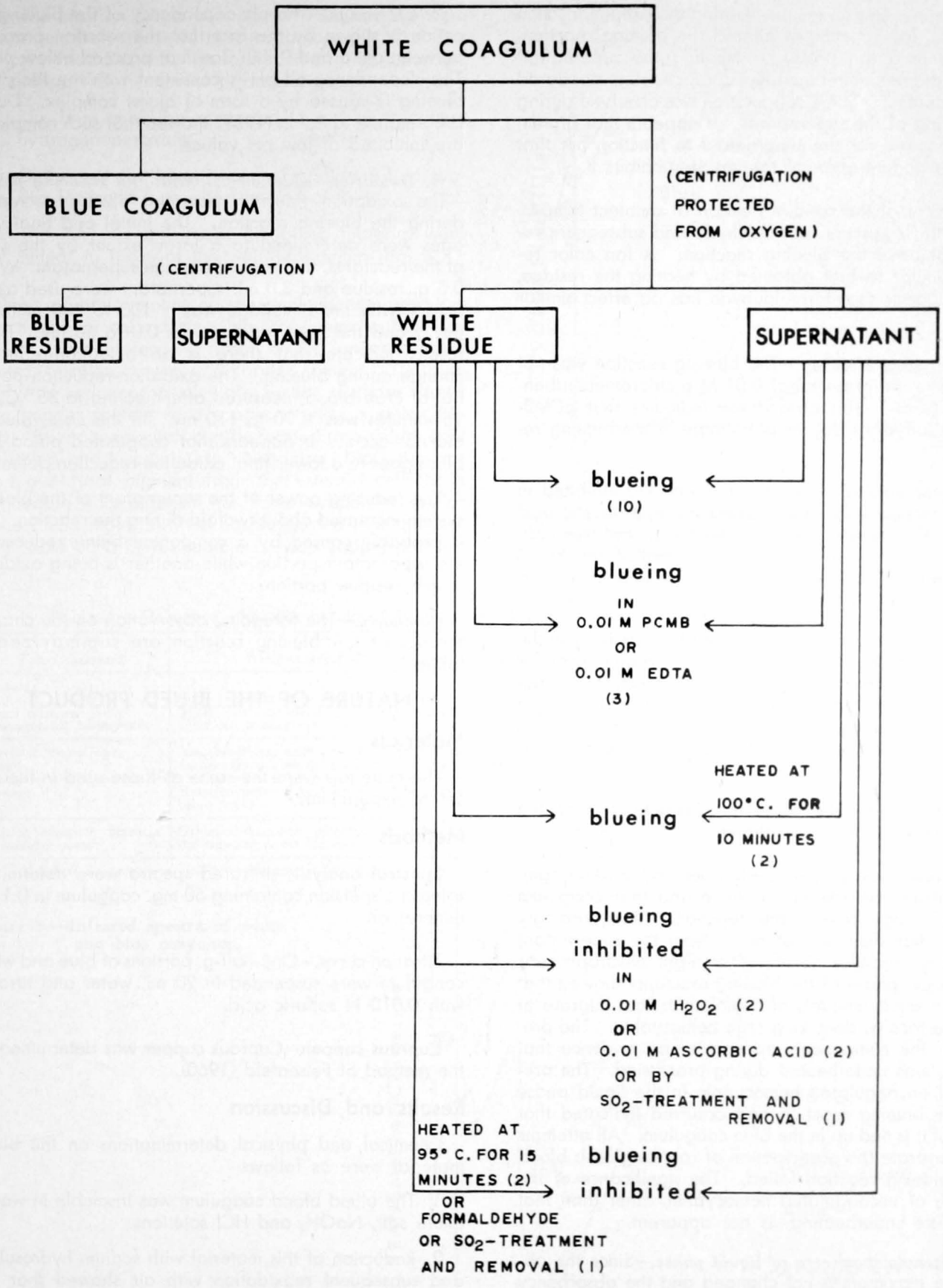


Figure 1.—Scheme for obtaining coagulum fractions and the effect of various treatments on the blueing reaction. (Note: numbers in parenthesis indicate the number of trials.)

3. *Protein denaturation.*—Heating the residue fraction at 95° C. for 15 minutes altered the blueing reaction, resulting in a tan product. Heating the supernatant fraction did not inhibit the blueing reaction but appeared to accentuate it. Some coagulation was observed during the heating of the supernatant. It appears that protein is not required for the supernatant to function but that excessive denaturation of the residue inhibits it.

Treatment of the residue fraction at ambient temperature with 37-percent formaldehyde and subsequent removal inhibited the blueing reaction. A tan color resulted, similar to that obtained by heating the residue, which suggests that formaldehyde has an effect similar to heat.

4. *Sulfydryl blocking.*—The blueing reaction was not inhibited in the presence of 0.01 M p-chloromercuribenzoate (pCMB). This observation indicates that pCMB-sensitive sulfydryls do not participate in the blueing reaction.

5. *Metal binding.*—The reaction was not inhibited in the presence of 0.01 M ethylenediaminetetraecetic acid (EDTA). This observation indicates either that free copper is not required by the reaction, or that at the pH 6.6 of the reaction, sufficient copper is unchelated to participate in the reaction.

The blueing reaction was inhibited by 0.01 M cyanide, which is evidence in favor of a copper requirement for the reaction. Removal of copper from the residue fraction by dialysis against 0.1 M cyanide gives a product that did not participate in the blueing reaction, which is additional evidence indicating a copper requirement for the blueing reaction.

Characteristics.—The observed characteristics of the blueing reaction were as follows:

1. *Components of system.*—Copper and total nitrogen in the citrate extracts of the white and blue coagulum do not change during the reaction. It accordingly appears that they do not move from the supernatant to residue and vice versa. Starch-gel electrophoresis of the liquid phase of the blueing reactants showed that there are small amounts of components that migrate at the same rate as does king crab hemocyanin. The presence of the components appears to be evidence that the crab was underheated during processing. The presence of uncoagulated hemocyanin in the liquid phase after the blueing reaction had occurred indicated that not all of it is tied up in the blue coagulum. All attempts to demonstrate the participation of raw king crab blood in the blueing reaction failed. The significance of the presence of uncoagulated hemocyanin, other than that it suggests underheating, is not apparent.

2. *Ultraviolet spectra of liquid phase.*—Since the absorbance maximum is not changed and the absorbency at 265 mμ remains constant during the reaction, it appears that compounds absorbing at this wavelength do not move from the supernatant to the residue and vice versa.

3. *pH range.*—The pH dependency of the blueing reaction is shown by the fact that the reaction proceeds between pH 5 and 9, but does not proceed below pH 4. This dependency on pH is consistent with the idea that blueing is caused by a form of biuret complex. Datta, Leberman, and Rabin (1959) showed that such complexes are inhibited at low pH values.

4. *Oxidation-reduction potential and reducing power.*—The oxidation-reduction potential always decreased during the blueing reaction. The initial and final voltages were determined to a large extent by the ratio of the reactants, the residue, and the supernatant. When 0.5 g. residue and 3.0 ml. supernatant were used as reactants, the initial voltage was + 100 to 200 millivolts (mv.), and the final reading was 0.0 to 50 mv. These results indicate that there is an oxidation-reduction change during blueing. The oxidation-reduction potential of crab blood measured after heating to 85° C. for 15 minutes was + 90 to 110 mv. In this case, blueing did not occur. It appears that coagulated blood that blues goes to a lower final oxidation-reduction potential.

The reducing power of the supernatant of the blueing system increased about twofold during the reaction. This is probably caused by a component being reduced in the supernatant portion while another is being oxidized in the residue portion.

Summary.—The foregoing observation on the characteristics of the blueing reaction are summarized in table 1.

NATURE OF THE BLUED PRODUCT

Materials

The materials were the same as those used in the first set of experiments.

Methods

Spectral analysis.—Infrared spectra were determined using a dispersion containing 50 mg. coagulum in 0.1 ml. mineral oil.

Titration curve.—One-half-g. portions of blue and white coagulum were suspended in 20 ml. water and titrated with 0.010 N sulfuric acid.

Cuprous copper.—Cuprous copper was determined by the method of Felsenfeld (1960).

Results and Discussion

Chemical and physical determinations on the blued material were as follows:

1. The blued blood coagulum was insoluble in water, dilute salt, NaOH, and HCl solutions.

2. Reduction of this material with sodium hydrosulfite and subsequent reoxidation with air showed that the blued material has a redox property. This property is common to copper proteins such as hemocyanin, laccase, and ceruloplasmin and suggests that the blued material could be a copper-protein complex.

3. The titration curves between pH 7.02 and 2.5 were similar for the white and blue coagulum (fig. 2). This similarity indicates that the formation of blue color did not change the number of titratable groups.

4. The blue could be converted to tan by treatment with hydrogen peroxide.

5. Dialysis of the blued material against 0.1 M cyanide did not appear to alter the material.

6. The infrared spectra of the blued material were very similar to those of the white coagulum (fig. 3).

Only a small amount of chemical change produces the change in color from white coagulum to blue coagulum. This inference is based on the similar infrared spectra, titration curves, and copper content. The blue color and redox properties are similar to those shown by a copper protein or a copper-peptide complex (biuret). Biuret compounds can be formed at a mildly acid pH (Rising and Yang, 1933). Needham (1960) has isolated a natural pigment from the esteroid cells of a centipede. This pigment has some properties similar to the blued material. He has suggested that the pigment could be a biuret complex. Most copper proteins

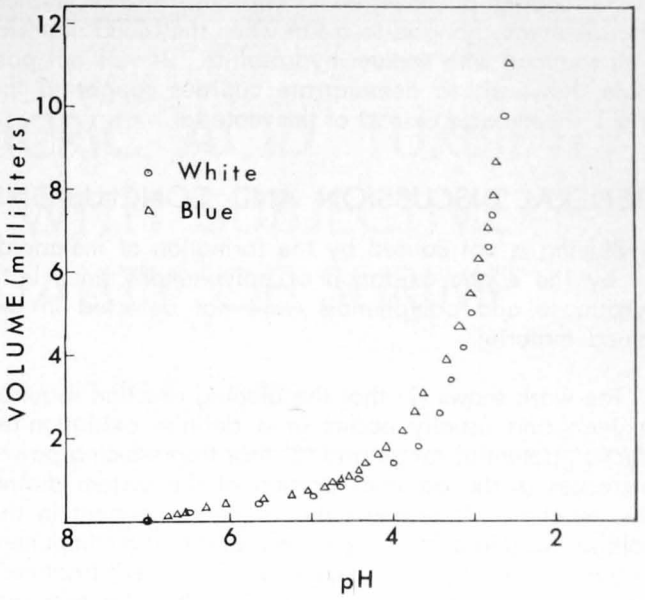


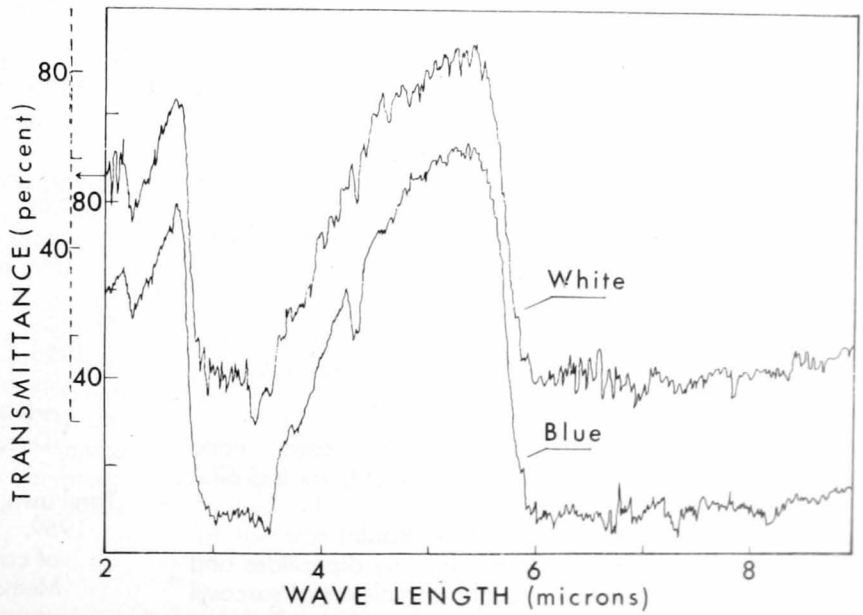
Figure 2.—Titration of white and blue coagulum (0.5 g. coagulum suspended in 20 ml. water and titrated with 0.102 N H_2SO_4).

Table 1.—Observed characteristics of blueing reaction

Factor measured	White coagulum $\xrightarrow{O_2}$ Blue coagulum
Reactants:	
Copper	Copper content does not change in citrate extract. (3)
Total nitrogen	Total nitrogen content does not change in citrate extract. (3)
Uncoagulated hemocyanin	Unaltered hemocyanin is present in supernatent of both. (2)
Ultraviolet absorption spectra	Absorbance maximum of aqueous extract remains at about 265 millimicrons throughout the reaction. Absorbance remains constant. (3)
pH range	Reaction proceeds between 5 and 9, but is inhibited at pH 4 and below. (1)
Oxidation-reduction potential and reducing power	Oxidation-reduction potential decreased during the reaction and the reducing power increased. (2)

Note: Numbers in parentheses indicate the number of trials.

Figure 3.—Infrared spectra of white and blue coagulum.



change from a blue to yellow color when reduced, and cupric copper is converted to cuprous. In our studies, the blue was changed to a tan when the blued material was reduced with sodium hydrosulfite. It was not possible, however, to demonstrate cuprous copper in the trichloracetic acid extract of this material.

GENERAL DISCUSSION AND CONCLUSIONS

Blueing is not caused by the formation of melanoids or by the cupric oxidation of polyphenols, since both tyrosinase and polyphenols were not detected in the blued material.

The work shows (1) that the blueing reaction requires oxygen and usually occurs in a definite oxidation-reduction potential range and (2) that the reducing power increases in the aqueous portion of the system during this reaction. It appears that some component in the solid or residue portion is oxidized and that a component in the aqueous portion is reduced. Since heat treatment or formalin treatment appears to inhibit the reaction, it is possible that a certain level of coagulation or denaturation favors the reaction but that an excess level inhibits the reaction. Sulfydryl groups sensitive to p-chloromercuribenzoate are probably not involved in this reduction, since pCMB does not inhibit blueing. Also, free cupric ion is probably not involved, because ethylenediaminetetracetic acid does not inhibit the reaction. The inhibition of blueing by ascorbic acid is probably due to the reduction of an important component of the system.

The chemical characteristics of the blued product were very similar to the white coagulum from which it was formed. The blued product had some properties that are similar to those of copper proteins or biuret complexes, which suggests that the blued product is probably a type of biuret complex.

ACKNOWLEDGMENT

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MS #1354

COMPARISON OF THE PICRIC ACID TURBIDITY AND NESSLER TESTS WITH SUBJECTIVE EVALUATIONS OF QUALITY OF SHRIMP

by

Mary E. Ambrose, Charles F. Lee, and Frank T. Piskur

ABSTRACT

In developing and testing the U. S. Standards for Grades of Frozen Raw Shrimp, 72 samples of raw headless shrimp were graded according to the standards. Two objective tests for freshness—the picric acid turbidity test and the Nessler test—were then applied to these shrimp. The purpose was to determine the adequacy of these tests to reflect quality of shrimp as evaluated by the sensory (subjective) ratings and grades of the samples. The relation of these test results to the numerical deductions for various factors was also studied.

INTRODUCTION

The development of standards for grades of various fishery products by the U. S. Department of the Interior is part of a general program to aid the industry in marketing products of consistently good quality. Generally, a standard consists of a rating for flavor and odor plus a numerical score for factors relating to quality and workmanship. The rating for flavor and odor is determined subjectively because there is no entirely satisfactory objective test to accomplish the same purpose. Certain chemical and bacteriological tests have been found useful for indicating quality at some particular stage of iced storage (Sigurdsson, 1947; Tarr, 1954), but few tests are satisfactory for determining relative quality through all stages from prime freshness to definite spoilage. Furthermore, in the past, no satisfactory test has been developed that is sufficiently simple, rapid, and accurate for routine commercial use.

Recently, a procedure known as the picric acid turbidity (PAT) test has been developed for evaluating the freshness of raw shrimp (Kurtzman and Snyder, 1960). Also recently, the Nessler test for ammoniacal nitrogen was satisfactorily applied to rapid evaluation of the quality of raw shrimp (Edwards, personal communication). Such tests would be of great value to inspectors of shrimp as a corroboration of their subjective judgments of flavor and odor, particularly in cases of borderline quality of the product. It may be that one of these objective tests could determine the degree of freshness of raw shrimp as well as, or better than, the combined quality evaluations in the standards, and could possibly replace subjective testing entirely.

Both the PAT test and the Nessler test have been applied only to limited laboratory and in-plant trials with special lots of shrimp and not to lots of shrimp in the market. In the present study, both tests were performed on 72 samples of frozen raw headless shrimp of different species and varying quality that were purchased from the wholesale market and graded according to the U. S. Standards for Grades of Frozen Raw Headless Shrimp (Anonymous, 1960).

The purpose was to determine the adequacy of the PAT test and the Nessler test in reflecting the quality of market shrimp as evaluated by flavor and odor ratings and the grades of the samples, and to study the relations of the results of the chemical tests to the numerical deductions for various factors included in the grading system of the Standards.

EXPERIMENTAL PROCEDURE

Samples

Seventy-two samples were obtained from wholesalers. Most of the samples were 5-pound packages; but five samples were 2-pound packages. Two samples were composites of four 10-ounce packages; this is the method specified in the Standards for handling small packages. Usually, two or three packages of the same brand and size of shrimp were purchased at the same time. No attempt was made to average the data for the "replicate" samples, because it was not known whether they were actually replicates from the same lot of shrimp. In fact, one package contained a different species from that in two other packages of the same brand purchased at the same time.

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The samples consisted of brown shrimp (*Penaeus aztecus*), white shrimp (*P. setiferus*), and several species of shrimp imported from Mexico and Central America. Determining the species of shrimp is practically impossible after the heads have been removed. These imported shrimp were blue, pink-spotted, and a few samples were mixed in color. The mixed samples consisted of at least two species and ranged in color from a bluish-white to a deep maroon within the same sample. The pink shrimp (*P. duorarum*), caught by U. S. fishermen, is seldom found on the market in the Washington area and thus was not included in the samples.

Grading the Samples

The samples were graded according to the U. S. Standards for Grades of Frozen Raw Headless Shrimp. The relation between grade, score, and flavor and odor ratings is as follows: Grade A, 90 - 100 and good flavor and odor; Grade B, 80 - 89 and at least reasonably good flavor and odor; Grade C, 70 - 79 and at least reasonably good flavor and odor; and Substandard, failure to meet the requirements of Grade C. The numbers 1 to 4 were assigned to Grades A to Substandard, respectively, which permitted statistical analysis of the data.

Flavor and odor were evaluated by a panel of experienced laboratory personnel, usually four but occasionally five. Scores of 5, 3 and 1 were assigned to the good, reasonably good, and substandard categories of flavor and odor. (Substandard evaluation signified the presence of objectionable off-flavors and odors in shrimp of borderline quality but not yet spoiled.) An average of the panel scores was taken as the rating of the sample.

Twenty-five of the samples were used for evaluating variations in the judgments of the taste panel. Two subsamples of each were prepared and served to the taste panel at two different times, usually on different days. Variations obtained in these data would also include variation within the samples as well as any variation due to the time of day of the taste tests.

Ten factors are rated in the scoring system of the Standards. Point deductions are made for each factor, and the total of the deductions is subtracted from the maximum score of 100. In the samples tested, the scores ranged from 100 to 30. The 10 factors can be divided into two categories: Those related to defects of the shrimp material and those related to defects of workmanship. The factors related to shrimp-material defects are dehydration, deterioration, black spot on shell or loose membrane only, black spot on the meat, and texture of the cooked shrimp. The factors related to workmanship defects are broken or damaged shrimp, or pieces of shrimp; legs, loose shell, and flippers; heads and unacceptable shrimp; extraneous material; and nonuniformity of size. The deductions incurred for each of the two groups of factors were calculated for comparison with the objective test results. For the purpose of statistical analysis, deductions were grouped from 1 to 10, 11 to 20, 21 to 30, and over 30. Numbers 1 to 4 were then assigned to these respective groups.

Objective Tests of Quality

After a sample had been graded subjectively, from 6 to 20 of the shrimp, depending on their size, were selected at random for use in the chemical quality tests. If the shrimp could not be tested immediately, they were refrozen and stored at -20° C.—a procedure that previous work at this laboratory (Kurtzman and Snyder, 1960) had shown did not affect the response to either one of the objective tests. The tests were conducted within a few days of grading. No differences had been found in the results of the quality tests performed upon different segments of the same shrimp; therefore, sections were cut at random for use in these objective tests after discarding a slice of the meat exposed at the head end. For convenience, the shell was included in the part taken for the Nessler test, but the sections taken for the PAT tests were peeled and deveined to exclude any influence of the contents of the sand veins (intestinal tract). Thus the two objective tests were performed upon parts of the same random sample of shrimp from each package.

The picric acid turbidity test.—Twenty-five grams of the peeled, deveined shrimp was disintegrated for 30 seconds with 100 ml. of 70-percent ethanol in a blender. Then 25 ml. of saturated aqueous picric acid solution was added, and the blending was continued for 20 seconds. The resultant slurry was filtered immediately through Whatman number 41 filter paper, and about 10 ml. of the filtrate was collected in a Klett test tube.

The turbidity of the filtrate was measured with a Klett-Summerson colorimeter, using a number 54 filter (green) to compensate for the color of the picric acid. The filtrates were considered clear when the colorimeter readings were 30 or less (scored 1), slightly turbid between 31 and 100 (scored 2), and very turbid when the readings were over 100 (scored 3). Increase in turbidity of the filtrates corresponded with decrease in quality of the shrimp.

The Nessler test.—The segments of shell-on shrimp were weighed and disintegrated in a blender with nine parts of water to one part of shrimp. After being blended 3 minutes, the slurry was allowed to stand 10 minutes. A small amount of the liquid that separated under the foam of the slurry was removed with a pipette, and 2-drop portions of it were placed in several of the cups of a spot plate. Two drops of Nessler solution were added to each, and the resulting color was compared within 1 minute to a set of five color standards that increase from Nessler number 1, a pale yellow tint, to Nessler number 5, brownish-orange. These standards may be compared to quality of shrimp and the Munsell classification of color (Munsell, 1929) as shown in table 1.

The results of the PAT test and the Nessler test for the entire group of samples were each compared by statistical procedures with flavor and odor ratings, grades, and deductions incurred for each of the two groups of factors of the grading system of the Standards. The correlation between the results of the two objective tests was also calculated.

The data from the shrimp samples were then divided into three species classifications: brown shrimp, white shrimp, and a group of "other" species including all the imported shrimp of undetermined species. The same comparisons between the results of the objective tests and subjective ratings were made for these smaller groups as for the entire group.

Table 1.—Relation of Nessler number to sensory evaluation and Munsell classification

Nessler number	Quality of shrimp	Munsell Classification		
		Hue	Value	Chroma
1	Good	27.5	9	3
2	Reasonably good	25.0	9	6
3	Fair	22.5	8	8
4	Spoiled	22.5	8	12
5	Badly spoiled	17.5	8	8

RESULTS AND DISCUSSION

All Samples Grouped Together

Table 2 presents the correlation coefficients found between the objective and subjective evaluations for all samples of shrimp. No correlations were found between the objective test results and deductions for defects of workmanship. All other correlations were significant at the 1-percent level except the one for PAT test results and grades of samples. This correlation was significant at the 5-percent level.

Table 2.—Correlation coefficients between objective and subjective evaluations of quality of frozen raw headless shrimp

Test results compared	Correlation coefficients obtained with:	
	PAT	Nessler
Grades	0.274[1]	0.374[2]
Flavor and odor, uncorrected	0.412[2]	0.378[2]
Flavor and odor, corrected[3]	0.613[2]	0.563[2]
Defects of shrimp material	0.408[2]	0.543[2]
Defects of workmanship	0.090	0.163
Nessler	0.596[2]	------

[1] Significant at the 5-percent level.
[2] Significant at the 1-percent level.
[3] Correlation coefficient between judgments of the panel at two different times was 0.446.

The correlation coefficient found between judgments of the panel on the same sample at two different times was 0.446. This low value was partially due to the wide variations within the samples, which are inherent in this product. Shrimp is held on ice on the fishing vessel until a full load is caught, which may take a week. When the boat is unloaded, and again during grading for size, the shrimp caught at different times become thoroughly mixed, resulting in much variation in freshness in each package. Any variation of the panel judgments due to the time of day of the taste test was also included in the correlation coefficient, since it was not always possible to serve the samples at the same time of day.

With this low correlation coefficient between judgments of the panel, no very high correlations with panel results could be expected. For this reason, an attempt was made to remove panel inaccuracy and variation within the sample by dividing the correlation coefficients for flavor and odor ratings by the square root of the coefficient between panel judgments (Kramer and Harrison, personal communication). After this correction had been made, the objective quality test results correlated, in descending order of significance, with the flavor and odor ratings, deductions for defects of shrimp material, and grades of the samples. This order indicates that the objective tests are actually measuring freshness of the shrimp, because freshness is the primary basis for the flavor and odor ratings. Freshness, however, is only a part of the evaluation of shrimp material and accounts for even a lesser part of the grades of the samples that also include defects of workmanship.

Samples Grouped as to Species

Table 3 presents the correlations found between the objective and subjective evaluations of the samples grouped by species. Correlations existed at the 1-percent level of significance between the two objective tests for each species of shrimp, but the correlation coefficient was considerably lower for the brown shrimp than for the others.

For the brown shrimp, the PAT test results gave a highly significant correlation with flavor and odor ratings, but no significant correlations with other subjective evaluations. This apparent inconsistency is explained by the fact that although almost half of the samples received a good flavor and odor rating, only 12 samples were Grade A, 9 were Grade B, 10 were Grade C, and 18 were Substandard. The PAT test evaluated accurately the freshness of the shrimp, but the defect deductions and grades received by the samples under the grading system were influenced by things other than freshness that were not detectable by the PAT test. Although correlations may be obtained between a chemical test for freshness and

Table 3.—Correlation coefficients between objective and subjective evaluations of quality of shrimp grouped by species

Test results compared	Correlation coefficients obtained for:		
	Brown shrimp (39 samples)	White shrimp (18 samples)	Other species (15 samples)
PAT — Nessler	0.443[1]	0.856[1]	0.784[1]
PAT — grades	0.118	0.608	0.617[2]
Flavor and odor, uncorrected	0.468[1]	0.279	0.560[2]
Flavor and odor, corrected[3]	0.702[1]	0.418	0.840[1]
Defects of shrimp material	0.253	0.759[1]	0.726[1]
Defects of workmanship	0.303	0.396	-0.157
Nessler — grades	0.208	0.470[2]	0.416
Flavor and odor, uncorrected	0.068	0.311	0.439
Flavor and odor, corrected[3]	0.102	0.466[2]	0.658[1]
Defects of shrimp material	0.430[1]	0.581[1]	0.585[2]
Defects of workmanship	-0.360	0.228	-0.275

[1] Significant at the 1-percent level.
[2] Significant at the 5-percent level.
[3] Correlation coefficient between judgments of the panel at two different times was 0.446.

factors relating to defects of shrimp material, such correlations may not necessarily be valid. No test for freshness can therefore adequately substitute for complete evaluations of these factors. Neither could a test substitute for grades of the samples, since grades also include factors of workmanship, for which no correlations were found nor could logically be expected.

The lack of correlations with the Nessler test results for the brown shrimp was not unexpected, since in-plant trials had indicated that the Nessler test did not indicate the intermediate quality of brown shrimp. The pale yellow color of good-quality shrimp persisted until spoilage was evident, when the orange or brown color appeared. The Nessler test was of no value as an indicator of freshness of brown shrimp.

No significant correlations were found between the PAT test results and flavor and odor ratings for the white shrimp samples, and the correlations between the Nessler test results and the corrected flavor and odor rating were significant only at the 5-percent level. In this group were a few samples for which the results of the taste panel were obviously at variance with those of the objective tests, probably because of variations in quality within the samples. If two odd samples were omitted, the correlations of each of the objective tests with corrected flavor and odor ratings would be highly significant. Only one of each of the objective tests was performed on each sample of shrimp. These results demonstrate the necessity of running several tests on samples of shrimp that show decided variation of quality within the sample.

The correlations between the objective test results and the corrected flavor and odor ratings for the "other" species of shrimp were highly significant. For this group of samples, all correlations were higher with the results of the PAT test than with those of the corresponding Nessler test.

The PAT test appeared to reflect satisfactorily the quality of market shrimp as evaluated by a taste panel. The instances in which it was not satisfactory point out the necessity for running replicate tests on samples showing marked variation in quality. The Nessler test was of limited value when applied to brown shrimp, since it indicated only definite spoilage.

Further study of these objective tests with commercial lots of shrimp is needed to determine their ultimate value to the industry and to the U.S.D.I. Inspection Service.

SUMMARY

Two objective tests of quality—the picric acid turbidity (PAT) test and the Nessler test—were performed on 72 samples of raw headless shrimp of different species and varying quality. These samples were also graded according to the U. S. Standards for Grades of Frozen Raw Headless Shrimp. The results of the objective tests were compared statistically with each other and with flavor and odor ratings, grades, deductions for defects of shrimp material, and deductions for defects of workmanship of the samples. After allowance was made for variation in judgments of the taste panel, the results of the objective tests correlated most highly with the flavor and odor ratings, indicating that the objective tests were measuring freshness of the shrimp. The samples were regrouped by species into brown shrimp, white shrimp, and a group of "other" species of imported shrimp. Except for a few typical samples of white shrimp of mixed quality, the results indicated that the PAT test was useful in determining quality from "good" to "spoiled" of all species tested. The Nessler test was similarly useful for all species of shrimp tested except brown shrimp, for which the test indicated only the onset of spoilage.

ACKNOWLEDGMENT

Sue Nealis performed the statistical computations.

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MS #1326

ECONOMIC STUDY OF SEA SCALLOP PRODUCTION IN THE UNITED STATES AND CANADA

by

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and Charles L. Vaughn

ABSTRACT

The sea scallop industry of the United States, centered at New Bedford, Mass., presents in microcosm many of the problems characteristic of our resource-based industries.

It now faces its most severe competitive challenge from the rapidly growing Canadian sea scallop industry, centered in the Province of Nova Scotia. Although the New Bedford industry has adjusted well to prior competition and continues to prosper, the Canadian industry after only 6 years almost equals the New Bedford industry and threatens soon to surpass it.

This report presents an assessment of the competitive position of the sea scallop industries of the United States and Canada. By description and analysis of the industries and of the social and economic milieux in which they operate—with special attention to those forces directly affecting production and revenue—the report attempts to isolate the factors that account for the competitive position of each.

Vessel-construction subsidies from the Canadian Government and lower operating costs furnish the Nova Scotia scallop industry with a competitive advantage. This study suggests that giving attention to manning regulations, layover requirements, insurance costs, and trip expenditures could improve the competitive position of the scallop fishery in New Bedford.

INTRODUCTION

In this era of expanding world trade and intense competition between foreign and domestic producers, the competitive position of domestic industries is important both to the nation involved and to those people whose labor and capital are involved.

The primary industries of the United States have experienced severe competition because of the lower costs of labor and capital available to their foreign competitors. Also in an economically advanced nation such as ours, the primary industries (1) account for but a small part of the total employment and output and (2) face internal competition from secondary industries seeking labor and capital.

The sea scallop industry presents one of the few bright spots in the otherwise dark picture of New England commercial fisheries. In an era of declining production, vanishing markets, increasing prices, and soaring costs, the sea scallop industry has expanded its production and markets and has kept pace with a growing economy.

The favorable position of the sea scallop producer has not escaped the notice of New England's strongest competitor in the fishing industry. Canada—specifically, Nova Scotia—is building its own sea scallop industry, which threatens to surpass the New England industry in productive capacity.

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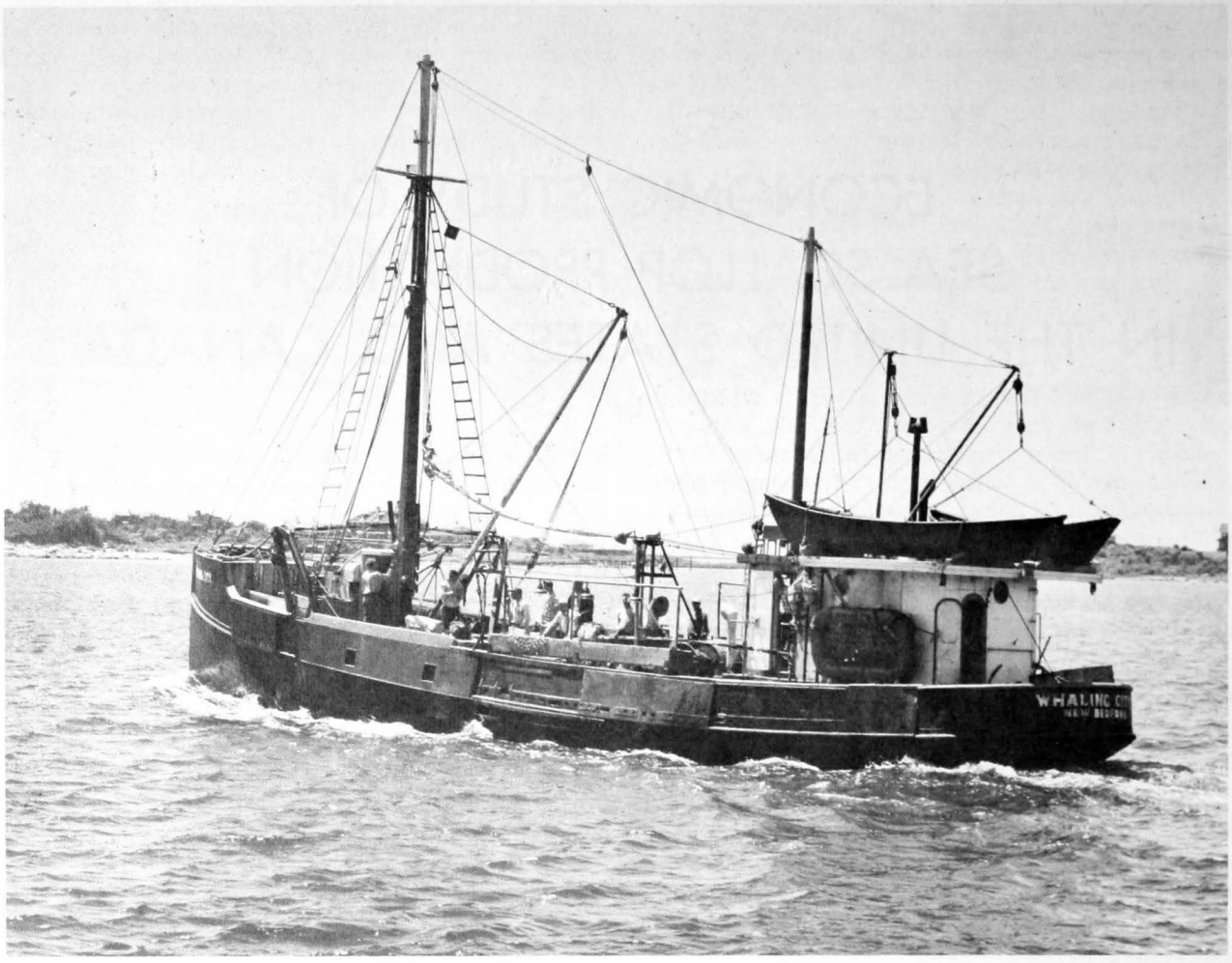

Scallop dragger Whaling City — New Bedford, Mass.

The growth of the Canadian industry has taken place since 1956. Before that time, the scallop industry was confined to an inshore small-boat fishery centered at Digby, Nova Scotia. Offshore scalloping by larger vessels on St. Pierre and Georges Bank was sporadic.

In 1956, however, larger Canadian vessels were converted to scalloping and began to operate on Georges Bank. Nova Scotia scallop landings, which had never been more than 1.5 million pounds in any year, increased to more than 2.3 million pounds. Since then, annual landings have increased steadily.

This constant increase in Nova Scotia scallop landings has been accompanied by a corresponding increase in exports to the United States. The Canadian scallop industry, like the Canadian groundfish industry, depends primarily on the export market. From 1956 to 1962, Canadian landings grew from 2.3 million to 14.0 million pounds; in the same period, exports of scallops to the United States increased from 1.3 million to 11.4 million pounds. Thus, imports from Canada, never more than 6 percent of the total U. S. supply before 1956, have risen sharply since then to almost 32 percent of that supply (table 1).

Table 1.—Imports of Canadian scallops related to the total domestic U. S. supply, 1951-62

Year	U. S. landings	Canadian imports	Total landings and imports	Canadian imports relative to the total
	Million pounds	*Million pounds*	*Million pounds*	*Percent*
1951	18.7	0.2	19.0	1.3
1952	18.6	0.4	19.0	2.0
1953	23.6	0.7	24.3	2.7
1954	17.6	1.1	18.8	6.0
1955	22.1	0.7	22.8	3.0
1956	20.1	1.3	21.3	6.0
1957	21.0	2.5	23.5	10.5
1958	19.0	2.4	21.4	11.1
1959	24.6	3.2	27.8	11.4
1960	26.6	6.3	32.9	19.2
1961	27.5	8.7	36.2	23.9
1962[1]	24.3	11.4	35.7	31.9

[1] Preliminary.
Sources: U.S. Department of the Interior (1951-60) and Department of Fisheries of Canada, Monthly review of Canadian fisheries (1961-62).

This increase in scallop imports has caused concern among U. S. scallop producers, who have seen imports of Canadian groundfish increase and now overshadow the U. S. groundfish industry (Canadian-produced groundfish account for two-thirds of the U. S. domestic supply and thus dominate the U. S. market).

This report will examine the Canadian and New England sea scallop industries in terms of their history, structure, organization, and operations; it will analyze their social and economic differences, and assess their competitive futures.

The report is divided into two main sections—the first section surveys the United States and Canadian sea scallop industries and the second section surveys the competitive positions of the two scallop industries and studies and compares costs, earnings, and operations.

SEA SCALLOP INDUSTRY--UNITED STATES AND CANADA

In this section of the report, we first discuss the U. S. sea scallop industry and then the Canadian.

UNITED STATES

The U. S. sea scallop industry began in 1883, when several beds of scallops were found along the New England coast. Initially, the Maine ports of Portland and Rockland were the leading scallop producers because the other New England ports were more concerned with groundfish—especially cod and haddock.

In the 1920's, scallop beds were discovered off Long Island. Part of the industry then shifted to Middle Atlantic ports, as a number of New England vessels moved their base of operations to that area. Landings of scallops never exceeded 430,000 pounds a year until the 1930's, however, so this industry did not attain any great commercial significance.

With the discovery in the mid-1930's of large scallop beds on Georges Bank, the scallop industry returned to New Bedford, since then the major scallop producer in the United States. In 1931, the Middle Atlantic States (New York and New Jersey) produced 1.3 million pounds of sea scallop meats, while New England produced only 1.1 million pounds. By 1937, however, New England production amounted to 5.7 million pounds, whereas the Middle Atlantic States produced only some 3.0 million pounds.

With the exception of Rockland and Portland, scallops are landed only sporadically at New England ports other than New Bedford. Scallop landings at Boston have been insignificant, except in 1960 (the large increase in landings at Boston in 1960 was due to New Bedford scallopers seeking other ports to land larger catches and avoid long layovers between trips).

Thus, the sea scallop industry in the United States is concentrated in New Bedford and is the mainstay of that port (table 2). This situation is characteristic of the groundfish industry of New England, where each port tends to specialize in one species (Lynch, Doherty, and Draheim, 1961).

Importance

Nationwide.—The sea scallop catch before 1946 accounted for less than 1 percent of the total poundage of sea foods landed annually in the United States. Since then scallops have accounted for 2 to 3 percent of the total value of all fish and shellfish landed in this country.

Owing primarily to the high value of scallops, New Bedford has been the second-ranking port in the nation for the past 3 years with respect to value of landings, although the volume of fish and shellfish landed is much less than that at other leading ports.

Table 2.—Quantity and value of scallops and all other species landed at New Bedford, 1951-62

Year	Landings of:				Total landings		Landings of scallops relative to total	
	Scallops		All other species				Quantity	Value
	Million pounds	*Million dollars*	*Million pounds*	*Million dollars*	*Million pounds*	*Million dollars*	%	%
1951	12.6	5.6	66.7	6.3	79.3	11.9	15.9	47.3
1952	12.1	7.2	63.1	5.9	75.2	13.1	16.1	54.9
1953	16.3	7.2	58.7	4.6	75.0	11.8	21.7	60.8
1954	13.8	6.2	57.7	4.1	71.6	10.3	19.3	60.3
1955	14.0	7.3	69.1	4.6	83.0	11.9	16.8	61.2
1956	14.2	7.7	73.7	4.6	88.0	12.3	16.2	62.6
1957	16.5	8.0	87.9	5.1	104.3	13.1	15.8	61.2
1958	15.3	7.4	96.4	6.4	111.7	13.8	13.7	53.7
1959	18.8	9.1	89.1	6.6	108.0	15.7	17.4	57.8
1960	19.4	6.7	65.8	6.4	85.1	13.2	22.7	51.3
1961	20.6	7.8	79.8	7.0	100.4	14.8	20.5	52.7
1962[1]	19.3	7.9	100.3	8.9	119.6	16.7	16.1	47.0

[1] Preliminary.
Sources: U. S Department of the Interior (1951-60) and O'Brien (1961a).

New England.—Prior to 1946, scallops constituted a very small part of the New England fishing industry. Only some 4 million pounds were landed annually, and these landings accounted for only 4 to 5 percent of the total value of all species. From 1945 to 1946, however, the New England scallop landings increased from 4 million to 9 million pounds, and the value quadrupled—from $1.3 million to $5.4 million. In 1946, scallops constituted 8.6 percent of the value of all fish and shellfish landed in New England. Since that time, they have remained a prime segment of the fishing industry, accounting annually for some 15 percent of the value of the catch landed at New England ports.

New Bedford Sea Scallop Industry

Landings and value.—Scallop landings have not, except in 1960-61, constituted more than one-fifth of the landings at New Bedford (table 2). But because of their high value per pound, they have accounted for 50 to 60 percent of the total value of all species landed at New Bedford over the years. This figure dropped below 50 percent in 1962 only because of the record landings of yellowtail flounder in that year.

The importance of the sea scallop fishery to the New Bedford area is best illustrated by the estimate that it contributes more than $50 million to the economy (National Fisherman, 1962). In addition to providing employment and capital opportunities in its own operations, the fishery supports the local scallop processing industries, provides business for the four local shipyards, and spends millions annually with the local businesses that provide it with the food, fuel, ice, and fishing equipment that it uses.

The Vessels.—The New Bedford scallop fleet has about 60 vessels. Because, however, of the difficulties of scalloping in winter, some of these vessels convert to finfishing during that season, so the year-round fleet usually numbers somewhat less than 50.

Since 1956, there has been a noticeable decline in the size of the scallop fleet. The seasonal fleet declined from 79 in 1956 to 60 in 1962, and the year-round fleet dropped from 56 to 47 over the same period (table 3). Significantly, however, during this same period, 12 new boats were added. Thus, although it may appear that the scallop fleet has been undergoing a process of decreasing capital investment, in reality it has been going through a period of replacement and modernization.

Table 3.—New Bedford's sea scallop fleet, 1956-62

Year	Vessels	
	Year-round	Seasonal
	No.	*No.*
1956	56	79
1957	52	81
1958	55	70
1959	52	70
1960	50	64
1961	46	63
1962	47	60

Source: O'Brien (1961b, 1963)

It is significant that the new vessels are larger and more efficient than are those they replaced. Of 59 vessels in the fleet in 1960, 34 (about 58 percent) were under 80 feet long (table 4). This size characteristic was typical of the fleet, which has always been composed mainly of vessels 70 feet or less in length. The 12 boats built since 1956, however, are in the 80- to 85-foot class, with high horsepower and modern equipment. Thus, it appears that at the end of 1962, about two-thirds of the New Bedford scallop fleet were vessels over 80 feet long.

The increase in landings from 14 million pounds in 1956 to almost 30 million pounds in 1962, with fewer vessels in 1962, shows that the New Bedford fleet is more efficient.

Of 55 vessels in the fleet in 1960, the average age was about 15 years. Of these vessels, 44 (80 percent) were less than 20 years old and 14 (25 percent) were less than 10 years old (table 4). With the addition of the new vessels over the years, the average scallop vessel is now only 10 to 12 years old, and more than one-third of the vessels in the fleet are less than 10 years old. These figures bear out the generally held opinion that the New Bedford sea scallop fleet is the most modern and efficient of any fishing fleet in New England.

The new vessels built in the past few years cost $110,000 to $150,000. The replacement cost of the New Bedford scallop fleet has been estimated to be in excess of $6.5 million (National Fisherman, 1962). This estimate would place the value of the average scallop vessel at well over $100,000.

All of the new scallop vessels have been built entirely with private capital (the scallop industry is not eligible for the U. S. Government Vessel Construction Subsidy). This use of private capital contrasts with the situation in the groundfish fleet, in which only two new vessels have been added in the past 15 years, one of which was built with the aid of the subsidy.

Employment and labor force.—Unlike the situation in other New England ports and fisheries, employment on fishing vessels in New Bedford has been relatively stable over the past 10 years. The average number of fishermen engaged annually in New Bedford increased by only 100 from 1952 to 1962 (table 5), but dropped during 1952 to 1954 when the number fell to 738, and then rose gradually to 1,000 and 1,100 in 1961 and 1962, respectively.

The figures for employment on New Bedford vessels represent both scallop fishermen and groundfishermen. Separate data on the number of people employed in each fishery are not kept. About two-thirds of the active fishermen regularly sailing from New Bedford, however, are engaged in scalloping. In 1962, it was estimated that 650 men were employed on scallop vessels (National Fisherman, 1962).

Although total employment on all vessels in New Bedford has remained relatively stable over the past 10 years, it appears that the number of scallop fishermen has increased. This inference is based on interviews with people in the industry and on the increased trip activity of scallop vessels. In 1960, for instance, scallop vessels made about 200 more trips than they did in 1954 (O'Brien, 1961b). This number of trips would have provided job opportunities for the year for 96 men, on the assumption of about 25 trips per man per year.

Table 4.—Length and age of New Bedford scallop vessels, 1960

Length or age of vessel	Vessels		
	Of given length or age	Cumulative	
Length: *Feet*	*No.*	*No.*	*% of total*
70 & under	13	13	22.0
71 - 75	14	27	45.8
76 - 80	7	34	57.6
81 - 85	13	47	79.7
86 - 90	9	56	94.9
91 - 95	1	57	96.6
96 -100	0	57	96.6
101 & over	2	59	100.0
Age: *Years*			
5 & under	8	8	14.5
6 - 10	6	14	25.5
11 - 15	10	24	43.6
16 - 20	20	44	80.0
21 - 25	8	52	94.5
26 - 30	1	53	96.4
31 & over	2	55	100.0

Source: Records of the New Bedford Seafood Producers Association, 1961.

Table 5.—Average annual total employment on fishing vessels in New Bedford, 1951-62

Year	Men employed
	No.
1952	940
1953	913
1954	738
1955	781
1956	816
1957	862
1958	961
1959	1,013
1960	1,007
1961	1,022
1962	1,050[1]

[1] Estimated.
Source: Commonwealth of Massachusetts, Division of Employment Security, Research and Statistics Department.

Table 6.—Employment on fishing vessels in New Bedford, monthly, 1959-61

Month	Employed on vessels in:		
	1959	1960	1961
	No.	*No.*	*No.*
January	894	955	960
February	890	894	928
March	940	985	967
April	1,001	1,031	1,045
May	995	1,024	1,067
June	1,032	1,045	1,074
July	1,101	1,078	1,064
August	1,100	1,087	1,067
September	1,075	1,058	1,062
October	1,097	1,031	1,032
November	1,050	985	1,011
December	986	912	963

Source: Commonwealth of Massachusetts, Division of Employment Security, Research and Statistics Department.

Most of the men who sail from New Bedford are members of the New Bedford Fishermen's Union. In December 1962, the Union had 900 members in good standing. Significantly, the Union had been taking in about 10 new members a month over the prior 2 years, yet the total membership in December 1962 was not appreciably greater than it was a couple of years earlier and may have been somewhat less. It appers that there is considerable turnover in the total supply of fishermen, especially scallop fishermen.

Another characteristic of the fishery is the seasonal nature of operations, which keeps more fishermen available than may be employed continuously. Employment in the summer, for example, averages 100 or more above that in the winter (table 6). The customary employment contract under which every trip is a separate venture and a man's employment may be as short as one trip is partially the cause of this.

Although scallop fishermen account for only about 1 percent of the New Bedford area's labor force of 63,000, the scallop fishery is important because it provides a stable source of employment in an area of persistent, substantial unemployment.[1]

With the good earning opportunities in scalloping (discussed later), it would seem that the local labor force would be a ready source of vessel crews; however, the records of the Fishermen's Union indicate that much of the new blood in the industry in recent years has come from abroad. In autumn 1962, between 200 and 240 members of the Union were immigrants from Europe, principally from Norway. More significantly, about two-thirds of the 120 new members that the Union has admitted annually have been from Scandinavian countries, and only about one-third have come from New Bedford.

The principal reasons that young natives of New Bedford do not generally seek employment in the scallop fleet seem to be that scalloping is arduous and requires spending much time at sea, away from home and family. It also appears that those from New Bedford who do enter the fishery come from families that traditionally have earned their living in this industry.[2]

On the whole, however, it appears that the combination of the immigrant fishermen and the fishermen drawn to the prosperous scallop fishery from other New England ports[3] has been and will be sufficient to man the scallop fleet. One consequence, however, of the failure of many young New Bedford natives to enter the fishery may be a gradual increase in the average age of scallop fishermen[4] in the future.

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[1] The unemployment rate in the New Bedford labor market area in January 1963, was 9.2 percent. A year earlier, it stood at 10.2 percent. (U. S. Department of Labor, 1963.)

[2] Other than for foreign fishermen, the recent young entrants to the scallop fishery have been second-generation fishermen, especially the sons of captains.

[3] Because fishing industries in Gloucester and Boston have not been as attractive as in New Bedford, some fishermen, especially younger men, have moved from the former ports to New Bedford.

[4] Scallop fishermen at present average less than 33 years of age, and many are 17 to 25 years old.

Earnings.—Earning opportunities in scalloping are quite good compared with employment ashore in work requiring comparable skill. In this area of high unemployment, $3,500 would be considered good annual earnings ashore, assuming full employment throughout the year and skill requirements comparable to those involved in scalloping. Admittedly, the effort level in other industries might be less, the work less arduous, and the workers would not have to brave the rigors of the sea and leave home and family for extended periods. Nevertheless, on the New Bedford vessels for which data were obtained in this study, average annual earnings for regular scallop fishermen ranged from $5,630 in 1956 to $6,970 in 1959. They dropped to $5,390 in 1960, a poor year. In the more favorable years of 1961 and 1962, earnings would have been appreciably better, and the Union agreed that about one-fourth of the men in scalloping in 1962 averaged about $9,000 for steady fishing[5]. The earnings of New Bedford scallop fishermen are analyzed in detail later.

In addition to the opportunities for relatively high earnings, many of the younger men get chances to become part owners of a boat; ashore, few of them would ever be able to develop such an equity investment. In fact, several owners have a policy of gradually acquiring working partners in their vessels, eventually letting an aggressive young man become captain and, through his earnings, gradually acquire outright ownership of the vessel (see footnote 5).

CANADA

Fishery

The Canadian sea scallop industry is centered in the Province of Nova Scotia, which has 98 percent of scallop landings in Canada. The industry comprises two "segments"—the inshore fishery and the offshore fishery. Although both fisheries produce the same product, they will be discussed separately because of differences in size and operation.

Inshore.—The Canadian sea scallop industry began about 1920, with the development of a fleet of small boats to fish the inshore areas. Active inshore fisheries developed in the Bay of Fundy along the south shore of Nova Scotia, and in the Gulf of St. Lawrence.

The largest and most productive scallop beds for this fishery are along the Digby shore of the Bay of Fundy. They lie between 3 and 12 miles offshore and extend along the shore for a distance of about 30 miles in 30 to 60 fathoms of water (MacPhail, 1954).

Although the inshore fishery is widely dispersed along the Nova Scotia shoreline in the Bay of Fundy, the principal inshore fishery is located at Digby, on the southwest coast. Digby has become the center of this fishery because the town is situated midway along the scallop-bearing areas and affords the only sheltered harbor in the long rocky coastline.

In 1960, there were about 33 draggers in the inshore scallop fishery, the great majority of them operating out of Digby. These vessels ranged from 45 to 60 feet in length, carried a crew of three to five men, and landed an average daily catch of 500 pounds of scallop meats[6].

Until recent years, the inshore fishery accounted for the bulk of Nova Scotia scallop landings. With the recent expansion of offshore scalloping on Georges Bank, however, the offshore fishery now dwarfs the inshore fishery. Though there is evidence that the inshore fishery has increased its annual landings to a level of 1.5 million to 2 million pounds, this fishery now accounts for only about 20 percent of the total Nova Scotia catch of scallops (see footnote 6).

We cannot predict future inshore operations. Until 1961, inshore landings had continued to increase, although the growth of the offshore fishery overshadowed this increase. At some stage, the offshore development may act as a damper on the growth of the inshore fishery and may suppress it entirely.

The future of inshore scalloping will depend, among other things, upon the scallop price structure that emerges as offshore landings expand and upon the relative costs of inshore and offshore operations in relation to scallop price. In any event, if present trends continue, it appears that future inshore landings will be but a minor part of total Nova Scotia landings.

Offshore.—The large-boat offshore fishery is a recent development. Prior to 1956, offshore fishing for scallops in Nova Scotia was irregular. Subsequently, this fishery grew rapidly and came to dominate the Canadian scallop industry—now it accounts for about 80 percent of all scallop landings in Nova Scotia.

Analysis of scallop landings at Nova Scotia ports indicates that 1956 was the year in which the offshore fishery became firmly established. (Offshore landings, which had remained at about 250,000 pounds per year for the prior 3 years, increased by 500,000 pounds in 1956, as contrasted with an estimated increase in inshore landings of only 300,000 pounds.)

Vessels.—The early offshore fleet was composed mainly of large, older vessels designed for groundfishing and converted to scalloping. Information from the Canadian Department of Fisheries indicates that in 1956, the offshore fleet consisted of 11 older vessels that had been converted to scalloping and 9 new ones built between 1953 and 1956.

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[5] Information is from interviews with Union officials on November 23, 1962. One informed observer who is close to the industry in New Bedford stated that he had two brothers scalloping, one 20 years old who had just started and one 26 years old who had been a scallop fisherman for 6 years. He pointed out that each could make over $400 a month scalloping—more than twice what they could make ashore.

[6] R. E. S. Homans. "Sanitary and quality control of the Canadian scallop industry." Paper presented before the fourth National Shellfish Sanitation Workshop, Nov. 28-30, 1961, Washington, D. C.

With the addition of 12 new vessels between 1957 and 1961, the offshore scallop fleet had 32 vessels in the latter year. These ranged in length from 65 to 130 feet, but the majority of them were in the 90- to 95-foot class. They carried a crew of 12 to 14 men in the 65- to 80-foot class and 18 to 21 men in the 90- to 130-foot class (see footnote 6).

The expansion of the offshore fleet received its greatest impetus in 1961 and 1962 when Parliament passed subsidy acts (Canada. Parliament, 1961, 1962) that provided outright government capital grants of 40 percent of the cost of constructing vessels of 100 gross tons or over and 50 percent of the cost of constructing steel fishing trawlers 75 feet or more in length.

Although government subsidies prior to this legislation, in the form of low-interest loans and accelerated depreciation allowances, had helped the offshore scallop fleet expand, the construction subsidy was the first direct aid to the scallop fishermen, and they quickly took advantage of it. Between October 1961 and October 1962, 16 scallop vessels were constructed under the 40-percent subsidy provision, all of them between 92 and 100 feet in length, at costs ranging from $140,000 to $207,000 (Canadian Fisherman, 1962). The Fisherman's Loan Board of Nova Scotia reported in June 1962 that 21 such vessels entered the scallop fleet in 1962 and a minimum of 8 more would be entering the fleet in 1963. Thus, in 1962, the Nova Scotia offshore scallop fleet had 53 vessels, practically all of them over 90 feet long, with an average age of between 5 and 10 years. With the addition of 8 more in 1963, the fleet will comprise more than 60 vessels, rivalling the size and performance of the New Bedford scallop fleet.

Employment and earnings.—The employment of some 13,000 men in the fisheries of Nova Scotia is of great importance to the Province, which depends heavily on its primary industries. If we include employment in fish processing, fully 7 percent of the Nova Scotia labor force is engaged in the fisheries (Canada. Dominion Bureau of Statistics, 1960).

Because it depends on the primary industries, the Nova Scotia economy suffers from cyclical and seasonal fluctuations and has chronic unemployment problems. In 1960, for example, Nova Scotia contributed in great part to the 11-percent unemployment rate that prevailed in the Atlantic Provinces (Canada. Dominion Bureau of Statistics, 1962). In such a depressed economy, the sea scallop fishery provides an opportunity not only for stable employment but also for relatively high earnings.

Of 13,000 men engaged in the primary fisheries in Nova Scotia, only some 1,000 were employed on deep-sea vessels in 1960. Although employment on sea scallop vessels and on groundfish vessels is not reported separately, on the basis of the number of vessels scalloping in 1960 and the average crew size, a good estimate of the number of scallop fishermen was about 500 in 1960.

The earnings of these scallop fishermen appear quite high compared with earnings of other Nova Scotia industry workers. The average fisherman on the Canadian boats studied earned only $2,670 in 1956. This increased to $6,190 in 1959, however, and decreased to $4,620 in 1960, when the average production worker in Nova Scotia earned about $3,500. Thus, in an area of high unemployment and low earnings levels, the scallop industry provides an opportunity not only for stable (and increasing) employment, but also for relatively high earnings.

Landings and value.—Unlike the U. S. scallop industry, which is concentrated in one port, the offshore industry in Nova Scotia is dispersed among four major ports: Lunenburg, Shelburne, Yarmouth, and Saulnierville—Lunenburg being the chief port in terms of poundage landed (table 7). Only in recent years have scallops become important in these ports, which had previously been primarily concerned with groundfish. Since 1956, scallop landings and values have become a major part of the fishery in each port. In 1960, although accounting for only 10 percent of the total poundage landed at the four ports, scallops represented 42 percent of the value, ranging from 31 percent of the value in Lunenburg to more than 92 percent in Saulnierville (table 8).

Table 7.—Scallop landings, by ports.[1] Nova Scotia, 1951-61

Year	Landings at:					
	Lunenburg	Shelburne	Yarmouth	Saulnierville	All other ports	Total landings
	Thousand pounds					
1951	12	--	20	--	426	458
1952	9	4	144	--	659	816
1953	6	--	252	--	1,076	1,334
1954	8	--	227	--	1,180	1,415
1955	47	23	193	--	1,259	1,522
1956	521	--	150	45	1,598	2,314
1957	1,129	31	72	173	1,758	3,163
1958	1,813	49	155	298	917	3,232
1959	2,749	251	718	587	517	4,822
1960	2,751	858	1,628	955	1,464	7,656
1961	3,099	1,079	2,646	1,516	2,028	10,368

[1] Data are for the Fishing District in which the named port is located.
Source: Canadian Department of Fisheries.

Structure.—The Nova Scotia scallop industry like the Canadian groundfish industry, is typified by vertical integration (Lynch, Doherty, and Draheim, 1961). In each of the four ports, the major scallop producers largely own or control the scallop processing facilities. This fact gives the producer-processor an opportunity for controlling prices, since he "buys from himself."

Concentration of ownership—although not as strong as in the groundfish industry—is another characteristic of the Nova Scotia industry. Of 28 vessels in the 1961 fleet, 8 were owned or controlled by one producer, and 6, 5, 5, and 4 vessels, respectively, were owned or controlled by four other principal producers.

Union organization of scallop fishermen is unknown in the Province. This is due in part to the dispersion of the scallop ports. Two other factors, however, are more important: (1) Nova Scotia is a labor surplus area and (2) legal impediments to organization exist.

Table 8a.—Landings and value of fish and shellfish, Nova Scotia,[1] 1960

Product landed	Landings and value at:									
	Yarmouth		Lunenburg		Shelburne		Saulnierville		All four ports	
	Thousands of pounds	*Thousands of dollars*	*Thousands of pounds*	*Thousands of dollars*	*Thousands of pounds*	*Thousands of dollars*	*Thousands of pounds*	*Thousands of dollars*	*Thousands of pounds*	*Thousands of dollars*
Scallops	1,628	407	2,751	714	858	232	955	233	6,192	1,586
Groundfish	1,336	51	34,345	1,204	1,872	76	13	--	37,566	1,331
All other	6,788	397	6,721	414	422	29	1,657	19	15,588	859
Totals	9,752	855	43,817	2,332	3,152	337	2,625	252	59,346	3,776

[1] Data are for the fishing district in which the named port is located.
Source: Economics Branch, Department of Fisheries, Halifax, Nova Scotia

Table 8b.—Relative landings and value of fish and shellfish, Nova Scotia ports,[1] 1960

Product landed	Relative landings and value at:									
	Yarmouth		Lunenburg		Shelburne		Saulnierville		All four ports	
	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value
	Percent									
Scallops	16.7	47.6	6.2	30.6	27.2	68.7	36.4	92.2	10.4	42.0
Groundfish	13.7	6.0	78.4	51.6	59.4	22.6	0.5	0.1	63.3	35.3
All other	69.6	46.4	15.4	17.8	13.4	8.7	63.1	7.7	26.3	22.7
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1] Data are for the fishing district in which the named port is located.
Source: Economics Branch, Department of Fisheries, Halifax, Nova Scotia

Because Nova Scotia has basically a primary economy, it is subject to seasonal unemployment and underemployment, which make it difficult to organize workers in the primary industry.

A legal impediment to organizing the scallop fishermen is that under the Nova Scotia Labour Relations Act, deep-sea fishermen are classified as joint venturers, rather than employees; therefore, they do not come within the provisions of the Act. (The Act was so interpreted by the Nova Scotia Supreme Court (1947)). In the Fishermen's Federation Act, the Nova Scotia Legislature (1954) provided a form of collective bargaining for deep-sea fishermen. This Act, however, requires that the bargaining agent represent the majority of the fishermen resident in the country. Since the number of scallop fishermen is small, this provision tends not to make it worthwhile to organize a group, owing to the relatively high cost per fisherman in having a labor representative travel a large area. Thus, although there is no theoretical legal barrier to organization, the small size of the scalloping work force and the geographic dispersion of deep-sea fishermen operate as barriers to organization under the Federation Act.

These characteristics of the Nova Scotia scallop industry—integration, concentration, and lack of labor organization—have a direct effect on costs and prices.

Obviously, to reduce the processing cost, the producer-processor has an interest in keeping ex-vessel prices as low as possible. The more vessels he owns the more influence he has to exert to keep scallop prices and operating costs down.

Also, the Nova Scotia producer-processor not only can react quickly to fluctuations in market conditions, but he also can influence these market conditions directly by withholding supplies when prices are low and releasing them when market prices are high.

This degree of control of costs and prices by the producer-processor also serves to insulate him from drastic changes in market conditions. In times of falling prices, he can freeze and hold scallops—thus restricting supply—and can await a price increase before releasing them. Conversely, in times of rising or high prices, he can restrict the flow into the market to avoid a price-reducing oversupply.[7]

Labor Force

The expansion of the Nova Scotia sea scallop fleet raises the question of the availability of fishermen in the labor supply of the Province. If in 1962 the average crew of the 53 scallop vessels had 15 men, then some 800 men were needed. Evidently, this number was sufficient to man the fleet through 1962. On this basis, the addition of eight more vessels to the scallop fleet in 1963 will require that the fleet employ over 900 men.

The available evidence does not indicate either a present or anticipated shortage of men for the Nova Scotia scallop fleet. Two factors militate against any shortage of scallop fishermen in Nova Scotia, at least in the immediate future. First, the population has increased in the four counties in which the principal scallop ports are located (Digby, Lunenburg, Shelburne, and Yarmouth); between 1956 and 1961, these counties showed an increase of 2,700 persons. Second, the high earnings of the scallop industry will continue to attract men from lower-wage industries, including the groundfish industry.

[7] There is some evidence that one large Nova Scotia processor did this in 1962; that is, scallops were withheld throughout the summer in anticipation of a price rise, which occurred in the autumn when the holdings were then exported to the United States.

RELATIVE COMPETITIVE POSITIONS

In this part of the report, we consider the following two main topics:

1. Costs, earnings, and operations of New Bedford and Canadian scallop vessels.

2. Cost advantages in Nova Scotia.

Although the vessel samples on which the cost data are based are not probability samples, the data obtained are interesting and useful for analysis.

COSTS, EARNINGS, AND OPERATIONS

The performance of the individual fishing units of the New Bedford scallop fleet is affected by several interrelated and mutually independent factors. The fleet is a heterogeneous group of vessels differing in age and size. The vessels are owned or operated or both by individuals with differing managerial skills. The natural availability of fish during a given year, the vessel, the captain, and the crew are the major determinants of the relative productivity of the fishing units. A well-equipped vessel, a capable captain, and a good crew, of course, make for a highly efficient productive unit. A good captain with a poor outfit will see a way to improve performance; a poor captain will have difficulties even with a good outfit. (Bottomanne, 1959; Food and Agricultural Organization of the United Nations, 1958).

There is some danger, then, in treating all fishing units of a particular fleet as homogeneous and then analyzing "average" performance. In the study of receipts, expenditures, and returns of New Bedford scallop vessels, we therefore paid particular attention to the ownership, captain, and crew in selecting vessels upon which the analysis would rest. The original sample consisted of 18 vessels drawn from a list supplied by the New Bedford Seafood Producers Association. These 18 were chosen as representative of the fleet, in age and size of vessel and of managerial skill of the owner or operator.

Financial and operating data for the years 1956-60 were requested for each vessel. Only 5 of the 18 vessel owners furnished the information for all 5 years, but 9 furnished data for at least 1 year. To ensure that a significant number of vessels were included in the cost analysis, we requested this information from the owners of vessels other than the 18 originally selected. A number of them cooperated (table 9). Thus, the analysis of the New Bedford scallop industry is based on data obtained for 7 vessels in 1956, 10 vessels in each year from 1957 through 1959, and 12 vessels in 1960.[8]

[8] The complete results of the analysis of data for all vessels for the 5-year period are in table 10. Portions of this table are extracted throughout the report whenever the relevant financial or operation category is discussed.

New Bedford

Earnings.—Between 1959 and 1960, the New Bedford scallop vessel owners lost money. New Bedford scallop vessels had an average operating loss of $1,515 per vessel in 1960. In 1959, scallop vessels had an average pre-tax profit of $7,716. In 1960, the owner's average share before depreciation ($5,944 per vessel) was approximately $7,000 less than in 1959 ($12,937 per vessel) and $2,000 below 1956 ($7,834 per vessel). Thus, between 1959 and 1960, the owner's share per vessel fell by 54 percent. Moreover, of the 12 vessels furnishing information, only 3 reported an operational profit before taxes (table 11).

Returns to the fishermen also fell appreciably in 1960. The average earnings per man in 1960 were $5,390. This income was 22.7 percent lower than in 1959 and the lowest of the entire period, 1956-60 (table 12).

Landings and prices.—Dollar productivity depends not only on landings but also on prices. The average landings per New Bedford scallop vessel were higher in 1960 (325,000 lbs.) than in any other year, but scallop prices were significantly lower. The 1960 ex-vessel price for scallops ($37.18 per 100 lbs.) was 20.6 percent below the 1959 price ($46.85 per 100 lbs.) and 29.2 percent below the 1956 prices. Thus, the average dollar productivity of New Bedford scallop vessels in 1960 was only $121,169—the lowest of any year.

Trip expenditures.[9]—Average trip expenditures, though increasing from $21,102 per vessel in 1956 to $23,513 per vessel in 1958, fell to $22,457 per vessel in 1960. Higher expenditures for ice and for scallop bags, plus added expenses for an advertising fund and welfare contributions, offset a substantial reduction in both food and fuel costs. Food expense per vessel per trip was lower in 1960 than in any other year (table 13). The purchase of a local oil business by a cooperative of vessel owners has resulted in substantial savings in fuel expenditures (table 13).

[9] Trip expenditures include outlays for food, fuel, ice, bags, welfare contributions, and similar items but do not include crew wages and commissions to captains.

Table 9.—New Bedford scallop fleet: total fleet versus vessels participating in the study 1956-60

Year	Participating vessels	Total year-round flet[1]	Participating vessels relative to the total year-round fleet
	No.	*No.*	*Percent*
1956	7	56	12.5
1957	10	52	19.2
1958	10	55	18.2
1959	10	52	19.2
1960	12	50	24.0

[1] O'Brien (1961b).

Table 10.—Average receipts, expenditures, and returns per vessel, New Bedford scallop vessels, 1956-60

Item	1956	1957	1958	1959	1960
No. of vessels	7	10	10	10	12
Trips	23	25	26	27	28
Average length trip (days)	9.1	9.0	9.0	8.6	8.1
Crewmen	10.9	11	11	11.1	11.2
Man days at sea	2,297	2,471	2,588	2,606	2,582
Landings	235,900	285,800	279,700	314,400	325,900
Price ($/cwt.)	52.50	46.75	48.10	46.85	37.18
Receipts	$ 123,837	$ 133,589	$ 134,519	$ 147,314	$ 121,169
Trip expenditures:					
Food	6,609	7,344	7,813	7,481	7,041
Fuel and lubrication	9,381	10,401	9,827	7,956	7,802
Ice and icing[1]	2,283	2,732	2,779	2,721	3,033
Other	2,829	3,249	4,094	4,688	4,581
Subtotal	21,102	23,726	24,513	22,846	22,457
Repair and maintenance:					
Gear	5,824	6,004	6,693	6,502	3,498
Hull and engine	12,263	11,070	10,437	10,900	9,394
Subtotal	18,087	17,074	17,130	17,402	12,892
Fixed charges:					
Interest	1,034	1,136	915	801	1,221
Insurance	6,996	7,122	7,802	7,840	8,024
Taxes (employee)	1,816	2,348	2,598	2,940	2,963
Administrative	1,107	1,430	1,152	1,082	2,906
Subtotal	10,953	12,036	12,467	12,663	15,114
Total cash expenditures	50,142	52,836	54,110	52,911	50,463
Share to labor and capital:					
Wages	61,372	66,366	66,174	77,327	60,313
Captain's commission	4,489	4,743	4,651	5,065	4,451
Owner's share	7,834	9,644	9,584	12,937	5,942
Total share expenditure	73,695	80,753	80,409	95,329	70,706
Depreciation	4,736	6,707	6,573	5,176	7,457
Net return before taxes	3,098	2,937	3,011	7,761	(1,515)

[1] Includes bags.

Table 11.—Number of vessels reporting profit[1] or loss, 1956-60, New Bedford

Year	Vessels reporting:		Total vessels reporting
	Profit	Loss	
1956	4	3	7
1957	6	4	10
1958	6	4	10
1959	8	2	10
1960	3	9	12

[1] Before taxes.
Source: Calculated from information furnished by the vessel owners.

Table 12.—Average annual wages of New Bedford scallop fishermen, 1956-60

Year	Wages
	Dollars/man
1956	5,630
1957	6,030
1958	6,020
1959	6,970
1960	5,390

Source: Computed from information furnished by vessel owners. See table 11 for the number of vessels involved.

Table 13.—New Bedford average food and fuel expenditures per vessel per trip, 1956-60

Year	Food	Fuel
	Dollars/vessel/trip	
1956	287	408
1957	293	416
1958	300	378
1959	277	294
1960	252	279

Source: Computed from information furnished by vessel owners. See table 11 for the number of vessels involved.

Repair and maintenance.—The average total exp iture for repair and maintenance fell perceptibly in 1 with the average expenditure for the repair and m tenance of hull and engines decreasing almost co ually. Gear expenditures per vessel increased 1956 to 1958 but decreased thereafter.

Fixed charges.—In sharp contrast, average fixed ch es per vessel increased continually. Average mo insurance expenditures per vessel rose from $6,98 1956 to $8,024 in 1960. Protection and indemnity insurance for the three vessels for which this informa was furnished from $3,447 per vessel in 1956 to $4 per vessel in 1960 (table 14).

In 1956-60, employee social security taxes rose ste and administrative expenditures per vessel incre sharply between 1959 and 1960.

Table 14.—Average cost of hull and protection indemnity (P&I) insurance per New ford vessel. 1956-60

Type of insurance	Vessels	Average cost of insurance in:				
		1956	1957	1958	1959	1
	No.	*Dollars/vessel*				
Hull	3	3,592	3,784	4,000	4,000	4,
P & I	3	3,447	3,460	4,574	3,899	4,

Source: Information furnished by the vessel owners.

Despite the increased fishing effort and heavier landings, the financial results of the 1960 New Bedford scallop fishing operations were the most unsatisfactory in the period 1956-60. The returns to the New Bedford owners and crew were lower in 1960 than in any other year in the period. This decline was caused by low vessel receipts in 1960, not by any substantial increase in cash expenditures.[10] The problem that faced the New Bedford scalloping enterprises in 1960 was the substantial reduction in the average "ex-vessel" price of scallops.

Nova Scotia

Since detailed information on the size and composition of the Canadian offshore scallop fleet was not available, all known owners of Canadian scallop vessels now fishing on Georges Bank were requested to supply financial and operating data comparable with those furnished by New Bedford owners.

In all, information was obtained for six Canadian vessels: three vessels supplied information for 1956-60; two additional vessels supplied information for 1957-60; and one vessel supplied information only for 1960. Thus, the analysis of the Canadian scallop industry is based on three vessels in 1956, five vessels in each of the years 1957-59, and six vessels in 1960[11]. The analysis was further limited by the fact that none of the Canadian vessels reported depreciation charges or administrative expenditures.

The six Canadian scallop vessels included in the 1960 analysis averaged 96 feet long and 7 years old and were built at a cost of $139,000 per vessel.[12] These vessels generally were built for other fishing activities in the early fifties and later were converted to scallop vessels.

Earnings.—The earnings of the owners and fishermen tended to increase in 1956-60. In 1960, the average owner's share, before depreciation and taxes, was $26,609 per vessel. This was five times the average owner's share in 1956 of $5,100 per vessel. Average annual earnings of crew members likewise increased from $2,670 per man in 1956 to $4,620 in 1960 (table 16).

Landings and prices.—From 1956 to 1960, average annual landings per Canadian scallop vessel increased from 190,100 pounds to 615,900 pounds, and during

10 This is not to say that there has been no substantial changes in vessel expenditures, for fixed charges were significantly higher in 1960, but rather that on balance, 1960 total cash expenditures per vessel are no higher than in other years.

11 The complete results of the analysis of data for all vessels for the 5-year period are contained in table 15. Portions of this table are extracted throughout the report whenever relevant financial or operating categories are discussed.

12 All Canadian offshore scallop vessels are not this large (Proskie, 1960). The other smaller vessels are not included because they are not comparable with the New Bedford vessels.

Table 15.—Average receipts, expenditures, and returns, Nova Scotia scallop vessels, 1956-60

Item	1956	1957	1958	1959	1960
No. of vessels	3	5	5	5	6
Trips	13	18	19	20	21
Average length of trips	13	13	13	12.5	12.2
Crewmen	14	14.5	14.6	14.6	16.3
Man days at sea	2,275	3,379	3,572	3,648	4,156
Landings	190,100	315,500	361,000	475,600	615,900
Price ($/cwt.)	46.55	39.50	38.73	39.44	26.83
Receipts	89,510	124,647	139,821	189,967	165,247
Trip expenditures:					
Food	4,002	5,599	6,008	6,713	7,190
Fuel and lubrication	7,667	11,154	11,597	12,158	8,917
Ice and icing[1]	1,736	2,729	2,835	3,263	4,437
Other	3,856	1,419	2,696	2,607	2,801
Subtotal	17,261	20,901	23,136	24,741	23,345
Repair and maintenance:					
Gear	5,409	9,824	8,909	9,470	10,361
Hull and engine	13,579	15,888	13,074	15,615	14,372
Subtotal	18,988	25,712	21,983	25,085	24,733
Fixed charges:					
Interest	363	691	1,363	1,092	169
Insurance	5,545	5,672	6,118	6,748	8,498
Taxes	[2]	[2]	[2]	[2]	[2]
Administrative	[2]	[2]	[2]	[2]	[2]
Subtotal	5,908	6,363	7,481	7,840	8,667
Total cash expenditures	42,157	52,976	52,600	57,666	56,745
Share to crew and owner:					
Wages	37,394	54,578	60,177	90,413	75,262
Captain's commission	4,830	6,599	6,674	9,468	6,631
Owner share	5,129	10,494	20,370	32,420	26,609
Total share expenditure	47,353	71,671	87,221	132,301	108,502
Depreciation	[2]	[2]	[2]	[2]	[2]

1 Includes bags.
2 Not reported.

Table 16.—Average annual earnings per Nova Scotia scallop fishermen, 1956-60

Year	Earnings
	Dollars/man/year
1956	2,670
1957	3,760
1958	4,130
1959	6,190
1960	4,620

Source: Information furnished by owners of six vessels.

the same period, average prices per 100 pounds of scallops fell from $46.55 to $26.83, a drop of 42 percent. The reduction in prices received was more than offset, however, by the threefold increase in average landings. As a result, average vessel receipts increased from $88,510 per vessel in 1956 to $165,256 per vessel in 1960.

The Canadian scallop vessels, like their New Bedford counterparts, were affected by the substantial reduction in scallop prices in 1960. Prices received by Canadian scallop vessels in 1960, $26.83 per 100 pounds, were 32 percent under the 1959 price of $39.44 per 100 pounds. Thus, despite an increase of 140,300 pounds in average landings per vessel, average receipts per vessel in Canada fell from $189,967 in 1959 to $165,256 in 1960.

Trip activity, fishing effort, and expenditure.—*Activity and fishing effort.*—In 1956-60, the annual effort of the Canadian vessels increasde substantially. The average length of each trip of Canadian scallop vessels declined from 13 days in 1956 to 12.2 days in 1960; however, both the number of trips and size of crew increased significantly. From 1956 to 1960, the number of trips per vessel per year increased from 13 to 21, and the number of men carried per vessel per year increased from 14 to 16.3. Consequently, the average annual effort of the Canadian vessels rose from 2,275 to 4,156 man days at sea per vessel over the 5-year period, an increase of 83 percent.

Expenditures.—The average annual trip expenditures of the Canadian scallop vessels were at least $23,000 per vessel in 1958-60, 33 percent higher than the average annual trip expenditure of $17,261 per vessel in 1956. The increase was not surprising in view of the increased annual number of trips and crew sizes of the Canadian units. Average food expenditures per trip of the Canadian units increased slightly in each year, reflecting the trend toward larger crews (table 17). On the other hand, fuel expense per trip, which had remained relatively unchanged in 1956-59, dropped suddenly in 1960 (table 17).

Repair and maintenance.—Repair and maintenance expense increased continually throughout the period, reflecting the sharp rise in gear expense. Average gear expense almost doubled from $5,409 per vessel in 1956 to $10,361 per vessel in 1960.

Fixed charges.—The increase in the average fixed charges of Canadian vessels was a direct result of an increase in marine insurance. The average cost of marine insurance per vessel was $8,498 per vessel in 1960 but was only $5,595 per vessel in 1956.

Despite a continued decline in ex-vessel scallop prices and rising average total cash expenditures per vessel, the earnings of both owners and crew members of Canadian vessels were significantly higher in both 1959 and 1960 than in earlier years because average annual landings per vessel increased markedly.

1959 and 1960 Operations

From 1956 to 1959 there was a marked improvement in the landings, receipts, and cash returns to owners and crew members of both the New Bedford and Canadian scallop fishing units. In 1960, there was a sharp drop in the average ex-vessel price of scallops. As a result, the 1960 average receipts per New Bedford and Canadian vessel were significantly below those of 1959. The fall in scallop prices so depressed the average receipts at New Bedford that the returns to the owner and crew members were lower in this year than in any other. On the other hand, the 1960 cash returns to the owner and crew members in the Canadian scallop fishery, although lower than those of 1959, were nonetheless significantly higher than the average cash returns of all other years.

The most apparent reason for the unsatisfactory results of the New Bedford scallop fishery in 1960 and the substantial difference between the results in New Bedford and in Canada was the high operating expenditures in relation to the vessel receipts in the New Bedford scallop fishery (tables 18 and 19).

In 1959, the total cash expenditures of the New Bedford scallop fishery accounted for only 35.9 percent of vessel receipts; in 1960 they accounted for 41.6 percent. As a result, the share of receipts available for distribution among the New Bedford owners and crew members fell from 64.1 percent in 1959 to 58.4 percent in 1960. In Canada too, average total cash expenditures accounted for a higher share of vessel receipts in 1960 than in 1959 (34.3 percent in 1960 vs. 30.4 percent in 1959).

The owners and crews of the Canadian vessels have an advantage over the New Bedford owners and crews because the total cash expenditures per Canadian vessel account for a significantly smaller share of vessel receipts. In 1960, only 58.4 percent of vessel receipts were available for distribution among New Bedford owners and

Table 17.—Food expense per trip and fuel expense per trip per vessel day at sea, Nova Scotia scallop vessels, 1956-60

Year	Food expense	Fuel expense
	Dollars/trip	*Dollars/vessel/day*
1956	308	592
1957	311	622
1958	316	610
1959	331	611
1960	342	420

Source: Computed from information furnished by owners of six vessels.

crew, whereas the Canadian owners and crew members received 65.7 percent of vessel receipts. These same tables reveal that the Canadian vessel owner benefits from a much more favorable sharing arrangement. In 1960 with 58.4 percent of receipts available, the New Bedford crew received 49.8 percent, the captain 3.7 percent, and the owner 5.0 percent. In Canada, with 65.7 percent of vessel receipts available, the crew received 45.5 percent, the captain 4.0 percent, and the owner 16.1 percent.

Table 18.—Percentage distribution average vessel receipts, expenditures, and returns, New Bedford scallopers, 1956-60

Item	1956	1957	1958	1959	1960
Receipts	% 100.00	% 100.00	% 100.00	% 100.00	% 100.00
Trip expenditures:					
Food	5.34	5.50	5.81	5.08	5.81
Fuel and lube	7.58	7.79	7.31	5.40	6.44
Ice and icing[1]	1.84	2.04	2.07	1.85	2.49
Other	2.28	2.43	3.03	3.18	3.77
Subtotal	17.04	17.76	18.22	15.51	18.51
Repair and maintenance:					
Gear	4.71	4.49	4.98	4.41	2.89
Hull and engine	9.90	8.29	7.66	7.40	7.75
Subtotal	14.61	12.78	12.64	11.81	10.64
Fixed charges					
Interest	.83	.85	.68	.54	1.00
Insurance	3.63	5.33	5.80	5.32	6.62
Taxes (employee)	1.47	1.76	1.98	2.00	2.44
Administrative	.90	1.06	.86	.73	2.39
Subtotal	8.83	9.00	9.27	8.59	12.45
Total cash expenditures	40.48	39.54	40.13	35.91	41.60
Share to labor and capital:					
Wages	49.66	48.99	49.19	52.49	49.77
Captain's commission	3.62	3.55	3.46	3.44	3.67
Owner	6.22	7.92	7.22	8.17	4.96
Depreciation	3.82	5.02	4.89	3.51	6.15
Total share expenditures:	59.50	60.46	59.87	64.10	58.40
Net return before taxes	?	?	?	?	?

[1] Includes bags.
Source: Computed from information supplied by vessel owners. See table 11 for number of vessels involved.

Table 19.—Percentage distribution average vessel receipts, expenditures, and returns, Nova Scotia scallopers, 1956-60

Item	1956	1957	1958	1959	1960
Receipts	% 100.00	% 100.00	% 100.00	% 100.00	% 100.00
Trip expenditures:					
Food	4.52	4.49	4.30	3.54	4.35
Fuel and lube	8.67	8.95	8.29	6.40	5.40
Ice and icing[1]	1.96	2.19	2.03	1.71	2.68
Other	4.35	1.14	1.93	1.37	1.69
Subtotal	19.50	16.77	16.55	13.02	14.12
Repair and maintenance:					
Gear	6.11	7.89	6.37	5.00	6.27
Hull and engine	14.21	12.75	9.35	8.22	8.70
Subtotal	20.32	20.64	15.72	13.22	14.97
Fixed charges:					
Interest	.40	.50	.90	.57	.10
Insurance	6.26	4.55	4.38	3.55	5.14
Taxes (employee)	[2]	[2]	[2]	[2]	[2]
Administrative	[2]	[2]	[2]	[2]	[2]
Subtotal	6.66	5.05	5.28	4.12	5.24
Total cash expenditures	46.48	42.46	37.55	30.36	34.33
Share to crew and owner:					
Wages	42.55	43.79	43.04	47.39	45.54
Captain's commission	4.66	5.30	4.78	4.98	4.01
Owner	6.31	8.45	14.63	17.07	16.12
Depreciation	[2]	[2]	[2]	[2]	[2]
Total share expenditure	6.31	8.45	14.63	69.64	65.67
Net return before taxes	?	?	?	?	?

[1] Includes bags.
[2] Not reported.
Source: Computed from information supplied by owners of six vessels.

COST ADVANTAGES IN NOVA SCOTIA

The previous subsection was concerned with the performance of the Nova Scotia and New Bedford scallop industries as separate entities during 1956-60. Such an analysis, although describing the internal functioning of each of the industries, tells us nothing of the interrelation between the two, of their effect upon one another, or of the underlying differences between the two that give rise to their disparate costs and operations.

The purpose of this subsection is to point out the interrelation of the two industries, their effect on each other, and the underlying differences between them, and to show the effect of these factors upon costs and operations in each industry. The basis for this analysis will be a comparison of the average performances of Nova Scotia and New Bedford scallop vessels.

That the average Nova Scotia scallop vessel can produce at a lower cost than its New Bedford counterpart was pointed out previously. A major source of the lower costs in Nova Scotia is the greater production per vessel. This greater production alone, however, does not explain the continuing cost differential between Nova Scotia and New Bedford, so we must look at the operations of each industry.

Effort per Vessel

The amount of effort expended by a fishing vessel is determined by the number and length of trips (boat days at sea) and the size of the crew. A measure of the average total annual effort is man days at sea per vessel. Table 20 shows the substantial difference in the effort prevalent in each area, and the rapid and substantial growth in the annual effort per Nova Scotia vessel.

The growth in the effort of the Nova Scotia vessels resulted primarily from an increase in the use of the vessel (boat days at sea) and secondarily from an increase in the average size of crew. Effort of the Nova Scotia vessels is much higher than that of the New Bedford vessels because Nova Scotia crews are larger. The increased use of the vessel—from an average of 169 boat days at sea per vessel in 1956 to 256 boat days in 1960—resulted in the great increase in the average annual effort and physical output of the Nova Scotia vessel in 1956-60 (table 21). Similarly, the larger crews of the Nova Scotia vessel—16.3 men as compared with 11.2 men in the New Bedford vessel—are the cause for the substantial differences between the annual efforts of the Canadian and New Bedford vessels[13] (table 22).

Although the rapid growth in the physical output of Nova Scotia unit is a result of an increase in both capital (vessel) and labor (crew) inputs, the difference between the output of the Nova Scotia unit and of the New Bedford unit results primarily from the different labor input. In terms of individual vessels, Nova Scotia scallopers fish more intensively than do the New Bedford enterprises.[14]

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[13] The difference in the average crew size in Nova Scotia and New Bedford does not fully indicate the magnitude of real differences. In New Bedford, all vessels and all trips carry 11 men—in some instances 12 men; in Canada, however, individual units may carry as many as 23 men.

[14] If the number of men per vessel were solely dependent upon the size of the vessel, then the substantial differences in the size of crews on the Canadian and New Bedford vessels could be explained in terms of the differences in the average size of the vessels. (Canadian vessels studied were on the average both larger and newer than New Bedford vessels.) This, however, is not the case. Certain Canadian vessels included in this study were not substantially larger than those of New Bedford; these Canadian vessels had a much larger average crew size than did the New Bedford vessels (16 vs. 11 men in 1960). Furthermore, the Canadian scallop vessels made several trips during 1960 with crews as large as 21 men. There are, then, other factors that account for the substantial differences in the average size of the crews of Canadian and New Bedford vessels.

Table 20.—Average annual effort per vessel, New Bedford and Nova Scotia, 1956-60

Year	Effort by crews at:					
	New Bedford			Nova Scotia		
	High	Low	Average	High	Low	Average
	Man days at sea per vessel					
1956	2,670	1,350	2,297	[1]	[1]	2,275
1957	2,770	2,090	2,471	3,900	2,808	3,379
1959	2,920	2,380	2,588	4,095	2,366	3,572
1959	2,920	2,280	2,606	4,095	2,717	3,648
1960	2,990	2,180	2,582	4,824	3,570	4,156

[1] Data were obtained from only three vessels.
Source: Computed from information furnished by owners.

Table 21.—Average number of boat days at sea per vessel, New Bedford and Nova Scotia, 1956-60

Year	Effort by vessels at:					
	New Bedford			Nova Scotia		
	High	Low	Average	High	Low	Average
	Boat days at sea per vessel					
1956	260	125	204	[1]	[1]	169
1957	252	192	225	260	221	234
1958	260	220	234	270	182	244
1959	255	207	232	273	209	250
1960	265	198	227	273	234	256

[1] Data were obtained by only three vessels.
Source: Computed from information furnished by vessel owners.

There can be no doubt that both the Nova Scotia and New Bedford vessels benefitted from a substantial increase in scallop stocks on Georges Bank. The Canadian vessels appear to have benefitted more from the increased productivity than did the New Bedford vessels; at least the increase in landings per man per vessel day at sea was greater for the Nova Scotia vessels (table 23).

Two New Bedford units and one Canadian unit furnished specific information on landings, crew size, days at sea, and days fished on a trip-by-trip basis. These data indicate that, although the landings per man per day at sea of the Canadian vessels increased greatly during these years, New Bedford vessels still retain an advantage albeit much reduced (table 24)[15]. These same data illustrate another factor that contributes to higher annual landings of the Nova Scotia boats: namely, the apparent ability to spend a greater proportion of time at sea actively engaged in fishing (table 25).

Organization

New Bedford scallopers have made no effort to fish more intensively. If they wished to do so, however, their ability to increase their efforts would be limited by union-management agreements. In contrast, the Canadian vessel owner can increase or decrease the size of the crew from trip to trip and can extend trips to 15 or 16 days.

[15] Canadian vessels use a larger dredge (12- or 13-foot) than do the New Bedford vessels (10- or 11-foot), which, according to biologists, theoretically could produce a 10-percent difference in catch per tow (New Bedford vessels are limited to having not more than two tow catches on deck at any one time). It is possible, however, that New Bedford scallop fishermen, being "old-time" fishermen, are sufficiently more efficient for at least the best of them to maintain some advantage on a day-fished basis.

Table 22.—Average number of men per vessel, New Bedford and Nova Scotia, 1956-60

Year	Vessel crews at:					
	New Bedford			Nova Scotia		
	High	Low	Average	High	Low	Average
	Men per vessel					
1956	11.0	10.0	10.9	[1]	[1]	14.0
1957	11.0	11.0	11.0	15.0	12.0	14.5
1958	11.0	11.0	11.0	15.0	13.0	14.6
1959	11.4	11.0	11.1	15.0	13.0	14.6
1960	11.5	11.0	11.2	18.0	15.0	16.3

[1] Data were obtained by only three vessels.
Source: Computed from information furnished by vessel owners.

Table 23.—Average landings per man per vessel day at sea, New Bedford and Nova Scotia, 1956-60

Year	Landings at:					
	New Bedford			Nova Scotia		
	High	Low	Average	High	Low	Average
	Pounds per man per vessel day at sea					
1956	116	91	102	[1]	[1]	84
1957	131	101	116	102	72	93
1958	133	101	109	110	82	101
1959	151	93	121	135	122	124
1960	160	101	126	160	125	147

[1] Data were obtained for only three vessels.

Table 24.—Landings per man per vessel day fished, New Bedford and Nova Scotia, 1956-60

Place and item	1956	1957	1958	1959	1960
New Bedford:					
Man days at sea	2,426	2,170	2,525	2,486	2,380
Landings per man, per day at sea (pounds)	101	117	107	141	151
Man days fished	1,656	1,650	1,766	1,814	1,679
Landings per man, per day fished (pounds)	148	154	152	193	213
Number of vessels	2	2	2	2	2
Nova Scotia:					
Man days at sea		3,606	3,909	3,630	4,824
Landings per man, per day at sea (pounds)		92	104	123	155.5
Man days fished		2,992	3,330	3,030	3,998
Landings per man, per day fished (pounds)		110	122	147	187
Number of vessels		1	1	1	1

Source: Computed from information furnished by vessel owners.

Table 25.—Man days fished as a percent of man days at sea, New Bedford and Nova Scotia

Year	Man days fished relative to man days at sea at:	
	New Bedford	Nova Scotia
	Percent	*Percent*
1956	68	--
1957	76	83
1958	70	85
1959	73	84
1960	71	83

Source: Computed from data in table 26.

The 1958 agreement between the New Bedford Fishermen's Association and New Bedford vessel owners (New Bedford Fisherman's Association and Seafood Producers Association of New Bedford, 1958), although not mentioning a maximum size of crew, refers repeatedly to boats with 11 men and boats with 10 men or less. Thus, there was an implicit agreement regarding the maximum size of crew for each scallop vessel.

The 1961 agreement explicitly states:

"A vessel shall in no event carry in excess of twelve (12) men and one (1) shacker[16] (if any) and a bunk must be furnished for each man aboard including the shacker (Article VI, Section (8).)"

Past and present union-owner agreements also control the annual activity of the New Bedford vessels by limiting fishing time and requiring rest ashore between trips.

The 1958 Union-Management agreement, Article IV, Section (a) states:

"The Owner and the Union agree that crews shall receive one (1) day of rest ashore for each 250 pounds of scallops per man landed or for each 48 hours of fishing time year round, in order to assure the quality of the catch."

The 1961 Union-Management agreement, Article IV, Section (a) states:

"The Owner and the Union agree that each member of the crew shall receive four (4) days rest ashore for every six (6) days of fishing time or part thereof in any one trip, except on a "broker."[17] In addition, each member shall receive an additional one-half day rest ashore for each day fishing time in excess of six (6)."

To illustrate the effect of these provisions, we constructed table 26. The assumptions underlying this presentation are as follows: (1) that regardless of the length of trip there is a so-called 4-day layover between trips; (2) that vessels sail on the 4th day rather than on the 5th, so that there are only 3 days of idle time; (3) that there are 2 days running time to and from the banks; and (4) that there is a 360-day work year, taking holidays into account. Under these assumptions, annual days at sea and days fished were computed under varying conditions of average trip lengths. The table demonstrates that (1) total days at sea and total days fished are higher for a vessel making fewer but longer trips and (2) the longer trip permits more fishing time.

Table 26.—Relation between length of trip and fishing time

Average length of trip	Maximum trips possible	Maximum time at sea	Maximum time fished	Days fished relative to days at sea
Days	*No.*	*Days*	*Days*	*Percent*
14	21	294	252	89.5
12	24	288	240	83.3
10	28	280	224	80.0
8	33	264	198	75.0

Source: Computed from information furnished by the owners.

The New Bedford scallop vessel owners are aware that a few long trips are more profitable than frequent short ones. The 1961 Union-Owner agreement allows the owner to make (1) 8-day trips—6 days fishing and 2 days running time—with a 4-day layover, sail on the 4th day; or (2) 10-day trips—8 days fishing and 2 days running time—with a 5-day layover, sail on the 5th day. We understand that vessel owners are choosing the 10-day trip.

Under the other assumptions used to construct table 26, the decision to make 10-day trips with 5-day layovers allows a maximum of 26 trips; per year ($10 + 4 = 14$; $360 \div 14 = 25.7$ or 26 in round numbers)—260 days at sea per year and 208 days fished per year. The 8-day trip, as indicated in table 27, permits 33 trips a year—264 days at sea and 198 days fished. Thus, the decision to make 10-day trips increases the amount of time (annual fishing time) of the New Bedford vessels.

The operators of the Canadian vessels, in the absence of an organized labor force, are able to conduct a relatively unlimited scallop fishery. The restraints on the New Bedford scallop vessels reduce effort levels and landings and thus make the scallop fishery of New Bedford a "high cost" one relative to the intensive scallop fishery of the Canadian scallop vessels.

As the present contract does not expire until March of 1964, there is little possibility of a substantial increase in the average annual effort of New Bedford vessels. Moreover, recent and proposed additions to the New Bedford fleet are no larger than the vessels currently in the fleet, nor is more bunk space being provided.

New Bedford scallop vessel owners apparently do not plan any substantial change in existing agreements, as neither party is unduly concerned about the present arrangements. There also appears to be some general agreement, particularly among Union officials, that the past and present contractual limitations on fishing time are good for the resource and are necessary for maintaining scallop meat quality.

[16] "Shacker" is a beginner who may not use the crew's scallop boxes—that is, the shacker cannot use the area where the crew works protected from the weather.

[17] A "broker" is a trip that failed to make expenses. (Expenses include a minimum of $12 a day to each crew member.)

Wages

The New Bedford scallop vessel owner has always operated at a disadvantage because the wage rate of the New Bedford fisherman exceeds that of the Canadian fisherman. Although the increase in the average annual crew share of the Canadian scallop fisherman has been substantial, there is no evidence that there has been any great change in the wage rates of Canadian fishermen, nor has there been any narrowing in the difference between prices paid for labor in Canada and in New Bedford. Despite the substantial increase in annual crew share of the Canadian scallop fisherman, the Canadian scallop vessel owners still enjoy significant advantages because of lower labor costs.

Although the general level of earnings of Canadian scallop fishermen has improved considerably both in relation to their own past earnings and to the present earnings of the New Bedford scallop fishermen, one should remember that the earning potential of the New Bedford scallop fishermen has been and still is much greater than that of Nova Scotia fishermen (table 27). Moreover, wage rates (crew share per man per vessel day absent) of the Nova Scotia fishermen have changed hardly at all (table 28). In fact, the differential in the average crew share per pound landed by the Nova Scotia fishermen and by the New Bedford fishermen actually has been increasing. In 1956 the net price per 100 pounds landed received by New Bedford crew members was 23 percent higher than that paid the Canadian crew members. In 1960, the net price received by New Bedford fishermen was 34 percent higher than that paid the Canadian crew members (table 29).

Table 27.—Range in average annual crew share per man, New Bedford and Nova Scotia, 1956-60

Year	Crew share at:					
	New Bedford			Nova Scotia		
	Low	High	Average	Low	High	Average
	Dollars/man/year			*Dollars/man/year*		
1956	4,500	6,500	5,600	--	--	2,700
1957	4,900	7,900	6,000	2,700	4,500	3,800
1958	4,700	6,900	6,000	2,200	4,900	4,100
1959	5,400	8,500	7,000	4,900	6,700	6,200
1960	3,800	7,800	5,400	3,200	5,300	4,600

Source: Computed from information furnished by the owners.

Table 28.—Range in crew share per man per vessel day absent, New Bedford and Nova Scotia, 1956-60

Year	Crew share at:					
	New Bedford			Nova Scotia		
	Low	High	Average	Low	High	Average
	Dollars/man/year			*Dollars/man/year*		
1956	22	35	27	--	--	16
1957	22	33	27	13	22	16
1958	23	31	26	14	21	17
1959	27	36	30	23	27	25
1960	17	30	23	15	22	18

Source: Computed from information furnished by vessel owners.

Table 29.—Labor cost of landings, New Bedford and Nova Scotia, 1956-60

Year	Data relating to crew share and landings at:					
	New Bedford			Nova Scotia		
	Crew share	Landings	Ratio of crew share to landings	Crew share	Landings	Ratio of crew share to landings
	Dollars/man/yr.	*Lbs./man/yr.*	*Dollars/cwt.*	*Dollars/man/yr.*	*Lbs./man/yr.*	*Dollars/cwt.*
1956	5,600	21,600	25.92	2,700	13,600	19.85
1957	6,000	26,000	23.08	3,800	21,700	17.51
1958	6,000	25,400	23.65	4,100	24,700	16.60
1959	7,000	28,300	24.73	6,200	32,600	19.02
1960	5,400	29,100	18.55	4,600	37,800	12.17

Source: Computed from data furnished by the vessel owners.

Differing lay (sharing) arrangements cause some of the differences in the prices received by New Bedford and Canadian crew members. The lay arrangements in New Bedford is controlled by union-management agreements. Basically, it calls for a 65 percent:35 percent sharing of vessel receipts after the deduction of certain joint expenditures from the crew's 65 percent share. In Canada the current agreement is 40 percent for the boat and 60 percent for the crew, who pay for bags, fuel, ice, and in some instances for the maintenance of the gear. There are no joint expenditures.

The effect of the differences in the sharing arrangements on the distribution of vessel receipts was pointed out earlier. The existing sharing agreements operate in favor of the Nova Scotia operator because he is able to retain a larger proportion of the vessel receipts. In addition, since the sharing arrangements in each area involve the sharing of dollars, not pounds, prices received by Canadian crew members would always be lower than those paid to New Bedford crew members.

Ex-Vessel Prices

The overriding concern of both owners and crew members of New Bedford scallop vessels was the existing differences between the "ex-vessel" prices in Canada and New Bedford. The cash return to both owners and crews of the New Bedford vessel were lower in 1960 than in any other year, not because New Bedford vessels were "high cost" producers in this year, but rather because they received less revenue from greater landings because of a substantial fall in price.

The Union and the owners of New Bedford scallop vessels are primarily concerned over the "ex-vessel" prices of scallops in Canada, for it is their opinion that lower Canadian prices are quickly reflected in lower ex-vessel prices in the United States.[18] The Union and owners of the New Bedford vessels are particularly concerned regarding the price differentials that exist because they feel that Canadian buyers impose "artificial" restraints on the prices received by the Canadian scallop vessels. They contend that prices are lower than they would be in an entirely free market.[19]

Many reasons can be given to explain the lower ex-vessel price in Canada, not the least of which is the much greater landings of the Canadian fishery. Considering the different socio-economic climates within which the Canadian and New Bedford industries operate—employment opportunities for both capital and labor are more limited in Canada than in New Bedford—it is to be expected that the price paid in Canada will be lower than that paid in New Bedford. Unlike the New Bedford processors, the Canadian processors are dealing exclusively in a frozen product. This difference in final product would also result in a somewhat different price structure.[20] Furthermore, the lower ex-vessel price paid by Canadian scallop processors may result from the unmarketability of a portion of the scallops landed, owing to poor handling.[21]

Structure

The Canadian scallop industry organization differs from the New Bedford industry—to a degree that affects the price and return to both the owners and crew members of the Canadian scallop vessels. None of the New Bedford buyers own scallop vessels, and all sales are made in the Union selling room, where scallops are sold to the highest bidder. In sharp contrast, the Canadian scallop industry is scattered in four principal areas, and there is one major buyer in each area. Canadian scallop processors generally are part owners in the scallop vessels and are dealing with an unorganized labor force.

As partial owner of the fishing vessels and as sole buyers within an area, the Canadian processors have the opportunity and ability to establish prices. When the Canadian processor-vessel owner exerts this influence, he affects the prices received by the vessel and the return to owners and crew members and thereby affects in a large measure the costs of the raw product.[22] This policy would automatically reduce the cash returns to the processor who is vessel owner and also reduce the return to other individuals who might be part owners of the vessel but not of the processing firm. This situation poses problems in price setting. New Bedford fishery people state that the Canadian processor vessel-owner overcomes this difficulty by giving the captain a cash bonus in excess of his usual share. They state that this practice exists regardless of whether the captain is an owner or not.[23]

Other Costs

Food expenditures.—The analysis of expenditures for food on Canadian and New Bedford scallop vessels shows a distinct cost advantage for the Canadian vessel (table 30). These differences probably result from the strong buying power of the Canadian fleet owner who, because he buys in quantity, can command lower prices

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[18] New Bedford buyers believe that the price break in 1960 is a long-run asset, since it encouraged food chain stores to handle scallops and, consequently, enlarged the market. The buyers would like to have scallop prices at levels that would permit retailers to sell at 50-60 cents per pound. At higher prices, they feel the chain stores would lose interest, for then scallops would be competing with higher priced meats.

[19] New Bedford has several buyers; however, one major buyer reportedly purchases over 60 percent of New Bedford scallop production. When one major processor decided to retire, there was some question of how free the New Bedford market was to be. The entrance of a new major scallop buyer, however, has alleviated the fears of the New Bedford vessel owners.

[20] New Bedford processors estimate that over 40 percent of the domestic production is sold fresh. Moreover, New Bedford processors agree that the ex-vessel prices paid for the product do influence decisions on how (fresh or frozen) the final product will be sold.

[21] We feel that the Canadian scallop processor may face a real problem of quality because of handling difficulties.

[22] The report of the Royal Commission (Canada. Royal Commission on Price Spreads of Food Products, 1959) implies that bargaining over prices is one-sided in favor of buyers. Moreover, the commission recommended legislation to allow the fishermen to bargain more effectively over prices.

[23] Canadian scallop fishermen are earning more than ever before. The captain, however, does receive a larger share or vessel receipts than he ordinarily would, if we assume that all captains in Canada receive 10 percent of the owner's share of 40 percent.

than can the New Bedford vessel owner who has a single vessel. It is uncertain whether part of the difference is attributable to food of lower price on Canadian vessels as compared with New Bedford vessels.

Table 30.—Average food expenditure per man per vessel day at sea, New Bedford and Nova Scotia, 1956-60

Year	Food expenditure at:	
	New Bedford	Nova Scotia
	Dollars/man/day	
1956	2.87	1.69
1957	2.97	1.65
1958	3.02	1.64
1959	2.87	1.84
1960	2.73	1.72

Source: Computed from information furnished by vessel owners.

Insurance.—Canadian vessels have a substantial advantage over New Bedford vessels in terms of insurance costs. The average expenditure per man for protection and indemnity (P & I) insurance in New Bedford ranged from $315 in 1956 to $450 in 1960 (table 31). Canadian vessel owners pay only $1,000 per vessel crew for the statutory limit of $50,000 coverage of P & I insurance and can obtain additional coverage of $150,000 for an additional cost of only $500.[24] Thus, total cost to the Canadian vessel owner for $200,000 of P & I coverage for 16 men amounts to approximately $94 per man, which is far less than the P & I costs to New Bedford vessels.

The heavier costs of insurance coverage for New Bedford vessels is largely attributable to the differing legal situations in the fishing industries of Canada and the United States. Canadian fishermen are covered by that country's Workmen's Compensation Act, which expressly spells out the vessel operator's liability. New England fishermen, however, are excluded from coverage under a workmen's compensation system. They are included, however, under the Jones Act, which subjects the vessel operator to unlimited liability, often determined by jury trial. The New Bedford operator, therefore, must maintain insurance with high coverage limits.

Repair and maintenance.—Repair and maintenance expenditures are much higher in Nova Scotia than in New Bedford. This may appear surprising because the Canadian vessels are newer than the New Bedford vessels. Whereas repair and maintenance expenditures are discretionary with the New Bedford owner, however, and may be deferred, the Canadian vessel's hull must be inspected annually, and its engine, every 4 years (Canada. Department of Transport, 1956). In addition, Candian vessels, because of their greater activity, experience more wear.

[24] Correspondence with General Manager of Lunenburg Sea Products, dated July 10, 1962.

Depreciation.—The absence of normal depreciation policies among New Bedford vessel owners and the failure of the Canadian operators to furnish any information on depreciation costs or policies, preclude any meaningful analysis of such costs within or between the two industries.

In New Bedford, many vessel owners depreciate both hull and engine jointly at a rate of 4 percent a year; others depreciate both at 10 percent; and still others depreciate them separately at rates ranging from 6 to 15 percent for the hull and 10 to 25 percent for the engine.

Canadian vessel owners do benefit, however, from accelerated depreciation policies allowed by their Government. Under these policies, a new or recently converted vessel can be depreciated at rates ranging up to 33-1/3 percent in a single year (Proskie, 1958).

Table 31.—Average protection and indenmity insurance per man, New Bedford vessels 1956-60

Year	Insurance expenditure
	Dollars per man
1956	318
1957	315
1958	416
1959	350
1960	450

Source: Computed from information furnished by owners.

SUMMARY AND DISCUSSION

The U. S. sea scallop industry, centered at New Bedford, Mass., since the 1930's, has grown in landings and receipts in recent years, while many other fisheries —especially groundfish—have declined.

The attractiveness of the sea scallop fishery, however, has induced New England's traditional competitor, Canada, to build its own sea scallop industry and in recent years the Canadian industry, centered in Nova Scotia, has grown to rival the New Bedford industry in fleet size and annual landings.

Vessels

The Canadian scallop industry began in the 1920's as an inshore fishery in the Bay of Fundy. Not until the mid-1950's did the large-boat offshore fishery come into prominence. Since that time, the offshore fleet has grown to some 40 vessels, mostly of the 90- to 100-foot class, all of which fish the Georges Bank scallop grounds, as do the New Bedford vessels.

Subsidy.—The growth of the Canadian offshore fleet was stimulated by the passage in 1961 and 1962 of Federal Subsidy Acts that provide a grant of 40 percent of the cost of constructing new scallop vessels. In 1962, some 20 new boats were constructed under this Act, and at least 8 more will be built under the Act in 1963.

The result of this expansion in Canada has been a growth in Canadian scallop landings to a level of some 14 million pounds in 1962, of which 82 percent (almost 12 million pounds) was exported to the United States.

Lower cost operation.—The Canadian industry has a lower operating cost than the New Bedford industry. The cost differences spring mainly from the different social and economic environments in which the two industries operate.

The New Bedford industry is characterized by a high degree of labor organization and competitive bidding on ex-vessel price. The major items of cost are controlled by the union-management agreement between the New Bedford Fishermen's Union and the Seafood Producers Association. The vessels and processing plants are owned by different individuals, and selling price is determined by supply and demand.

The Canadian industry, on the other hand, is dispersed among four major ports—Lunenburg, Yarmouth, Shelburne, and Saulnierville. In each port, there is one primary owner of vessels and processing plant; consequently these owners have a great influence over the establishment of the ex-vessel price for the catch. The crew members are precluded from organization both by legal impediments and by economic conditions in the Province, therefore, they can exercise little, if any, control over the price and their share of the catch and, consequently, their wages.

Although the lay on scallop vessels is substantially the same in Nova Scotia and New Bedford, the lower Canadian price means that the labor costs to the Canadian operator are lower.

Fishing effort.—The Nova Scotia operator also has greater flexibility in regulating the amount of fishing effort of the vessel. The discretionary power enjoyed by the Nova Scotia operator enables him to increase or decrease the size of the crew from trip to trip and to undertake trips as long as 15 to 16 days. In contrast, the New Bedford operator enjoys no such discretion, for he is bound by limitations on crew size and by the layover requirements of the union-management agreement.

Capital.—The Nova Scotia operator perhaps has a major advantage over the New Bedford operator because he utilizes his capital more intensively; that is, he uses more labor per unit of capital without any significant reduction in physical output per man per day. To the extent that the collective bargaining agreement prevents the New Bedford operator from greater utilization of the vessel, the agreement constitutes a cost handicap to that port's owners and fishermen. But it must be understood that the problem involved is not one of too much capital per worker or fisherman in the sense that the boats are too big. This is not the case. It is true that the New Bedford industry continues to benefit by adding newer vessels to the fleet. The principal problem is that the existing fleet might be utilized more efficiently by adding one more man per boat. Furthermore, if this were done, the increased physical production would mean lower cost per pound of scallops. Provided the market for scallops could absorb the additional product without any significant diminution in price, both vessel owners and scallop fishermen would benefit in an economic sense.

One warning: the cost of production depends largely upon the availability of scallops. Thus, if they become scarcer and more fishing time must be spent on the banks, then increased utilization of the vessel may be dissipated by the increased cost of fishing. Because biological data on the size and location of the scallop resource are incomplete, no definite statement can be made at this point.

Crew Size

The New Bedford industry could compete better with Canadian operators if at least one more man were used per vessel. He would, of course, function as a shucker. To expand production, the output of existing vessels should be increased by adding men whenever possible rather than by expanding the fleet. If the capital can be obtained, it would be desirable in New Bedford to continue the current policy of introducing a new vessel while withdrawing an older, less efficient vessel. This statement does not imply that the crews of the scallop vessels or the size of the vessels could be indefinitely expanded without encountering diminishing returns. The present type of New Bedford vessel could carry at least one more man without decreasing the average productivity of each crew member. We imply no criticism of either the Union or of the vessel owners. Perhaps differences in the quality of scallop meats landed and the use of more vessels and fewer men than what we consider the most efficient number per vessel, offset to some extent the quantitative disadvantages of an owner's using fewer men per boat. But in an increasingly competitive milieu —and it seems certain that Nova Scotia will give New Bedford more and more competition as time goes by— the New Bedford industry may needlessly be handing Nova Scotia a cost advantage that New Bedford can ill afford.

Optimum Fishing Time

Closely related to the question of crew size is the question of fishing time. Under the 1961 Union-Management agreement in New Bedford, fishing time provisions resulted in trips averaging 8 days of fishing time, with 5 days home between trips. Under the preceding agreement, actual fishing time per trip was about 6 days. The increase in fishing time under the 1961 agreement, however, resulted in a more than proportionate increase in average landings per vessel, probably due in part to the greater abundance of scallops on the fishing grounds.

The increased landings emphasized that from the standpoint of the vessel and crew, production costs were lowest per pound and earnings per man and per vessel highest, when the vessel made the longest trips and largest catch consistent with the maintenance of high quality. If longer trips became the practice the ratio of fishing time to running time would increase, per unit costs would drop, and the New Bedford industry would be better able to compete. This proposal, however, requires fishermen to spend longer periods away from home, to which some object. We merely point out that

if the parties find it advantageous to achieve lower costs, whether they are motivated by a desire for higher income or merely to stay abreast of competition, one way they can do this is by making longer trips.

Specific Cost Differences

Besides its greater utilization of vessels and men, the Nova Scotia scallop industry has certain other advantages, as shown by the analyses of differences between the two industries in specific cost categories.

Wages.—In 1960, wages to fishermen were considerably higher in New Bedford than in Nova Scotia. The average crewman on a Nova Scotia scallop vessel landed 37,800 pounds of scallops and received $4,600 in wages. The average New Belford crewman received $5,400, yet he landed only 29,100 pounds of scallops. This higher rate of payment in New Bedford reflects the differences in the economies of the two areas and the bargaining powers of the crews. But it must be kept in mind that although Nova Scotia scallop fishermen's wages are low relative to New Bedford's, they are much higher than wages in many other forms of employment in Nova Scotia.

The Canadian operator has a cost advantage because wages represent only about 45 percent of his receipts, whereas they account for 50 percent or more of the New Bedford operator's receipts. Furthermore, whereas the Canadian operator can partially control wages, the New Bedford operator's wage-cost factor is fixed by agreement.

Trip expenditures.—In the matter of trip expenditure (food, fuel, ice, and similar items) the Nova Scotia scallop fishery has an advantage over New Bedford. Trip expenditures on New Bedford vessels as a percent of receipts remained at a relatively constant 18 percent over 1956-60. In Nova Scotia, not only are these costs lower—representing only some 14 percent of receipts—but they have decreased from some 20 percent of receipts in 1956 to about 14 percent in 1960. This decrease is partly accounted for, of course, by the increased activity of the Nova Scotia vessels during the period. It is also attributable, however, to the large-scale purchasing of vessel supplies by the Canadian operator, who buys in quantity for a fleet, unlike the New Bedford owner, who buys for a single vessel. The purchase of a local oil business by a group of New Bedford vessel owners, however, has enabled them to realize substantial savings in fuel costs. Similar cooperative effort among the vessel owners in the purchase of other items also might effect considerable cost savings.

Repair and maintenance.—Repair and maintenance expenditures are higher for Canadian scallopers than for New Bedford vessels. This is the only cost category in which New Bedford has an "advantage" over Canada. But the reasons behind this show that it may not really be an advantage to New Bedford and may in fact be a disadvantage.

For the New Bedford owner, repairs and maintenance are a discretionary and deferable cost item. In Canada, however, there is compulsory inspection of hull and engine. Thus, the Canadian vessel owner must reserve and spend part of his annual receipts for this purpose, whereas the New Bedford owner may or may not do so.

To the extent that the New Bedford vessel owner defers repair and maintenance, he incurs higher costs in the form of increased insurance and decreased efficiency of the vessel. Thus, this temporary "saving" will be eaten up by increased costs elsewhere.

Insurance.—The Canadian owner is, in effect, insulated against the high insurance costs of the New Bedford owner by the fact that fishermen in Canada are covered by workmen's compensation, whereas New Bedford fishermen are not. Thus, for example, the cost of protection and indemnity (P & I) coverage per man to the Canadian owner is approximately $94, whereas the average New Bedford operator must pay some $400 per man for P & I insurance.

It is obvious, therefore, that Canada enjoys a distinct advantage in insurance costs. If this cost is reduced for the New Bedford industry, whether by extending the coverage of workmen's compensation or by other means, the scallop industry will be in a better competitive position vis-a-vis Canada.

Ex-Vessel Price

The difference in costs of production analyzed in this report lead to a constant differential of 5 to 10 cents per pound between the ex-vessel prices of scallops in Nova Scotia and New Bedford. The feeling in New Bedford is that lower Canadian prices are quickly reflected in a lowering of New Bedford ex-vessel prices.

This concept is difficult to substantiate, however. In 1961, for example, both domestic landings and imports of scallops increased sharply. Yet, in the face of this increase in supply, ex-vessel prices rose in New Bedford and in Nova Scotia. And as total supply (domestic landings plus imports) continued to increase, ex-vessel prices, rather than decreasing, remained at high levels.

The difficulty in measuring the impact of increased supply on ex-vessel prices lies in the fact that little is known about the markets for scallops. It might not be amiss to raise the question here whether Nova Scotia scallops do compete with New Bedford scallops, or whether the two industries are operating in entirely separate markets. How much of domestically produced scallops are marketed fresh and how much frozen? What is the geographic market for scallops, or are Canadian scallops sold only in the mid-West, and New Bedford scallops only on the Atlantic Coast? Until these and other questions are answered, no meaningful answer can be given to the question as to the effect of the ex-vessel price differential between Canada and New Bedford.

The lower ex-vessel price in Canada does mean, however, that the Canadian industry would be less affected than New Bedford by a decline in the level of scallop abundance on the banks. In such a situation, the Canadian operator could cut both his capital and labor costs to a level that would give him an adequate return at a lower level of ex-vessel price. The New Bedford owner would be precluded from such an adjustment because of the inflexible nature of his costs and operating requirements. But it must be remembered that in this situation, ex-vessel prices are reacting to resource and market conditions, not causing them.

Market Expansion

Although little is known of the market for scallops, it is obvious that the market has expanded in recent years to absorb the increased supply. This expansion has resulted in large part from the agreement reached in 1957 by the Union and the Seafood Producers Association to deduct from the gross stock of each trip a certain percentage to be used as a promotional fund. In 1962, the 1-percent deduction provided a fund of about $70,000.

In January of 1962, representatives of the Association were successful in inducing Canadian sea scallop buyers and packers to join the program. Canadian participation is expected to add about $15,000 to the fund in 1963.

It has been estimated that U. S. consumption of scallops has increased 62 percent in the past 5 years. Although expenditure of the Seafood Producers Council fund has contributed to this growth in the market, the Council should investigate the effectiveness of its promotional efforts, not only as an audit, but also to give it a better idea of how to spend future promotional funds.

CONCLUSIONS

The expanding Nova Scotia sea scallop industry threatens to displace New Bedford as the leading scallop producer in the world. The Nova Scotia industry has the dual advantage of lower production costs and liberal construction subsidies from the Canadian Government.

To remain competitive with the Nova Scotia industry, the New Bedford industry must find ways of utilizing more effectively both capital and labor so costs can be cut wherever possible. We suggest that the Union and the Seafood Producers Association give increased attention to the impact of manning regulations and layover requirements on the production costs outlined in this report.

We also suggest that the parties investigate ways of reducing insurance costs either by governmental action to extend workmen's compensation insurance to fishermen, or possibly by programs of self-insurance.

The industry should also give attention to the possibility of cooperative action on trip expenditures similar to that of forming a cooperative for the purchase of fuel oil. In this way, they can realize economies by concentrating their buying power.

The policy of replacement and modernization—rather than fleet expansion—evident in New Bedford in recent years, should be encouraged. This policy should ensure profitable operations or, at the least, adequate returns in times of resource scarcity or adverse market conditions that cause the ex-vessel prices to decrease.

Further efforts should be devoted to ascertaining the market for scallops by the industry, the government, or both, since the current lack of information about the market in which the domestic industry operates hinders efforts to enhance its competitive position relative to the Canadian industry.

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