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UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

STUDIES ON THE HANDLING OF FRESH MACKEREL

(Scomber scombrus)

RESEARCH REPORT No. 1

UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

FISH AND WILDLIFE SERVICE
Ira N. Gabrielson, Director

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(*Scomber scombrus*)

By

M. E. STANSBY and J. M. LEMON

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ABSTRACT

THE MACKEREL (*Scomber scombrus* Linnaeus) is one of the most important food fishes of the United States. In 1935 the mackerel fishery ranked eighth in volume and seventh in value among the food fisheries of this country. Owing to prevailing methods of handling and shipment, however, considerable difficulty has been experienced in disposing of the entire catch at a profit. Studies of this fishery were conducted as a basis for recommendations leading to increased distribution and popularity of mackerel, and improved handling methods are discussed in this report.

The fat content of mackerel varies with the season, from a minimum of approximately 2 percent in spring to a maximum of 20 percent or more late in summer and in fall. This variation is important in determining the food value of fish, since fat fish contain a considerably higher calorific food value.

Spoilage is much more complicated in mackerel than in many other species, owing to the usual high fat content. Mackerel can be kept in good condition much longer, however, if eviscerated and packed in finely crushed ice, rather than floated in the round in sea water that contains but little ice. For example, floated mackerel keep in good condition for only about 4 days, while those eviscerated and packed in crushed ice remain in edible condition for 7 to 10 days.

Marketing of the catch necessarily involves transportation, the cost of which is based upon gross weight. By shipping mackerel in crushed ice, rather than floating them in barrels, the net cost of transportation is greatly reduced.

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(*Scomber scombrus*)

By Maurice E. Stansby, *Assistant Technologist*, and James M. Lemon, *Technologist, Division of Fishery Industries, Fish and Wildlife Service*

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INTRODUCTION

The mackerel (*Scomber scombrus* Linnaeus) ranks among the more important species of food fish landed in the United States and is taken principally in the waters of the New England and Middle Atlantic

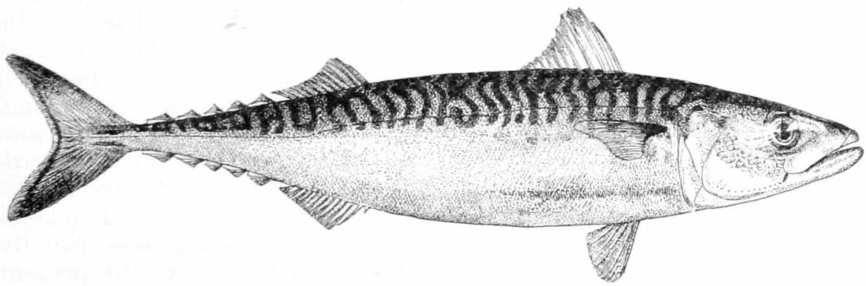

Figure 1.—Boston mackerel (*Scomber scombrus*).

States. The greater portion of the catch is marketed fresh; the remainder being frozen, salted, or smoked. Although the mackerel is considered one of the choicest food fishes of this area, it is not subject to such wide fresh distribution as many of the other species. The

Note.—The Research Reports of the Fish and Wildlife Service supersede the Investigational Reports (44) of the former Bureau of Fisheries, Technical Bulletins (711) of the former Bureau of Biological Survey under the Department of Agriculture, and Wildlife Research Bulletins (4) under the Department of the Interior. Figures in parentheses indicate last number published in each series.

In accordance with the President's Reorganization Plan No. II the Bureau of Fisheries was transferred from the Department of Commerce to the Department of the Interior on July 1, 1939; and by Reorganization Plan No. III it was merged with the Bureau of Biological Survey on June 30, 1940, to form the Fish and Wildlife Service.

reason for this has been attributed to greater difficulty in handling. Since it was believed that an investigation of the factors controlling mackerel spoilage might suggest means whereby improvement in keeping qualities could be effected, the Bureau of Fisheries made a study of this problem. The purpose of this report is to discuss the information obtained.

THE MACKEREL FISHERY

EXTENT OF THE INDUSTRY

The mackerel fishery supports one of the more important food-fish industries of the United States. In 1935, according to Fiedler (1936), the catch of Atlantic mackerel amounted to 65,086,000 pounds, valued at $1,342,000, ranked eighth in volume and seventh in value among the food fishes landed in this country, and fourth in volume and value among fishes landed on the Atlantic coast. Nearly 1,100 fishermen took part in the mackerel fishery in 1935. A total of 1,500 trips were made and approximately 100 vessels and boats were used.

Mackerel first appear in schools off the coast of New Jersey during April. The quantity of fish taken early in the season is quite small compared with the amount caught later, so that the price of the fish caught in the spring is usually quite high. As the season advances these fish appear farther north, being caught off New York and Boston, and later as far north as Newfoundland. The largest quantity of mackerel is taken during July, August, and September. After September the supply dwindles rapidly, a few being caught in late November and in some years in early December.[1] The fish then disappear until the following spring, when they reappear off New Jersey and the cycle is repeated.

FISHING METHODS

Very little is known about the earliest methods of catching mackerel. However, prior to 1700 a law was passed by the Colony of Massachusetts which prohibited the seining of these fish, and it may be assumed that the first methods probably involved some type of seine which was operated close to shore. Records also show that between 1815 and 1860 the mackerel fishery was essentially hook-and-line, although gill nets were introduced in some localities during that period.

About 1860 a notable advance was made in fishing methods applicable to those species which school during their migratory movements. This was the introduction of the purse seine. Since mackerel are schooling fish, the purse-seine method of fishing was rapidly adopted and soon superseded hook-and-line fishing. At the present time over 75 percent of the mackerel catch is taken in purse seines, about 7 percent in gill nets, and the remainder in traps.

A mackerel purse seine is usually about 250 fathoms long and 18 fathoms deep, with a small strengthened area in the upper center section which is called the "bunt." The net has a cork line attached to the upper edge to give it buoyancy and a weighted line with metal rings attached to the lower edge. A purse line of stout rope is rove through the metal rings.

[1] In 1938 and 1939 a few mackerel were caught during January and February.

When fishing for mackerel the seine is carried in a seine boat which is towed behind the mackerel seiner. When a school of mackerel is sighted by the lookouts, who are stationed at the masthead of the seiner, the vessel is maneuvered into proper position and the seine boat is hauled alongside and made fast to a towing boom which extends outboard at right angles from the deck rail about opposite the foremast. A dory is then launched, one end of the seine taken aboard, and the seiner encircles the school—towing the seine boat from which the net is payed out. When the two ends of the net have been brought together and the purse line has been hauled in, the excess netting is pulled by hand into the seine boat until the fish are concentrated within the bunt. The seiner then maneuvers alongside the bunt section, the net is made fast alongside, and the fish are brought aboard by means of a large dip-net which is operated from the deck. Each time a school of fish is sighted the entire operation is repeated until a load has been obtained or it is necessary to return to port in order to land the fish while they are in good condition.

EARLY PROCEDURE

Though the methods of handling mackerel prior to 1815 are not definitely known, the fish were probably taken in small quantities near the shore and consumed fresh shortly thereafter. Between 1815 and 1820 the process of salting was greatly expanded, and until long after the use of ice was a firmly established practice the greater portion of the mackerel catch was salted. Previous to the adoption of ice the fish were usually salted at the time of catching, although increasing quantities were being landed fresh for subsequent salting. At present the market for fresh mackerel so far exceeds the demand for the salted product that the bulk of the catch is marketed fresh.

In preparing mackerel for salting during the early days, both aboard ship and on shore, the fish were first split and cleaned and then subjected to an operation known as "plowing." This consisted of producing cracks in the flesh near the backbone for the purpose of giving the fish the appearance of being fatter than was actually the case. The reason for this operation was the fact that as the season advanced and mackerel increased in fat content, cracks would normally appear in the flesh near the backbone when the fish were split. The depth of the cracks was roughly proportional to the fatness of the fish. In the early 1800's a fat fish was considered superior to a lean one, and plowing was a common practice for increasing the sales value of the fish. This is of interest since it indicates that even at this early date the industry recognized the varying degree of the fatness of mackerel; a condition which is often lost sight of today.

Between 1850 and 1870 two drastic changes were made in connection with the mackerel industry. It was during that period that ice was first used aboard fishing vessels, and the purse-seine method of fishing began to displace the old hook-and-line fishery. With fish being taken in greater numbers and with greater ease, and with facilities for preserving them with ice, it soon became less essential and probably impractical to depend upon the former procedure of salting the fish on board the fishing vessel. However, since vessels were still slow and several days might elapse before the fish were landed, it remained common practice to dress the fish at the time of catching. The dressing operation, which was termed "gibbing," consisted of removing the viscera and gills through the gill cleft without slitting the belly wall. The gibbed fish were then washed and packed with ice in small buckets. Such importance was placed on the value of gibbing as a means of retarding spoilage that the State of Massachusetts enacted a law which required that all mackerel be gibbed at sea if they were to be landed fresh. The dressed fish were ordinarily packed in ice in small kegs, to prevent bruising, and stowed in the hold of the vessel. When the fish were landed they were often held in what was termed "dry ice." This was ordinary water ice cut by hand into thin shavings with an ice shaver. Mackerel handled in the above manner from the time of catching could be kept in good condition for a considerable period.

PRESENT PROCEDURE

Since 1900 two important developments affecting the mackerel industry have taken place. All mackerel boats have been equipped with power engines, and improved transportation facilities now permit rapid delivery of mackerel to distant points. As a result of the decrease in time required for transportation from fishing grounds to consuming markets, the industry considers the gibbing of mackerel at sea as being no longer necessary, and, with the repeal of the Massachusetts law requiring this procedure, gibbing has been discontinued. Also, the practice of packing the fish in small individual containers has been discontinued in favor of gross storage with ice in the hold of the boat.

The fish-hold of a mackerel seiner is usually divided into compartments which are known as bins, or pens. Each bin is about 4 feet long, from 6 to 7 feet deep, and tapers from about 5 feet in width at the top to about 2 feet in width at the bottom; conforming generally to the shape of the hull of the vessel. Each bin will hold from 3,500 to 5,000 pounds of mackerel.

In stowing mackerel an initial layer of ice is first placed on the floor of the bin, a layer of fish is then permitted to drop down onto the ice through manholes in the deck above, another layer of ice is added, more mackerel, etc. Boards are usually placed across the bins at regular intervals in order to relieve the weight and pressure on the fish. When the bin has been loaded a final heavy layer of ice is placed on top to prevent the possibility of the upper layer of fish absorbing heat from the deck. The hatches are only opened for the time necessary to ice down the fish.

Usually 1 ton of ice crushed to pebble size, or slightly larger, is used in each bin of fish. This averages about 12 tons to care for 60,000 pounds of mackerel. Interviews with several vessel captains on the question of how much ice they thought necessary for certain amounts of mackerel resulted in the following figures:

Pounds of fish	*Tons of ice*
80,000	15
60,000	12
50,000	12
35,000	11
23,000	6

It is the custom of most of the fishermen to take on at least 10 tons of ice for a trip. Should the catch exceed expectations and insufficient ice is on hand, such ice is used as sparingly as the outside temperature and distance from market will permit. If the vessel is within half a day's journey from market and an extra large catch is made, holds are filled and the excess is loaded on deck—sometimes without ice.

An average mackerel-seiner trip covers a period of 3 days—1 day going out, 1 day fishing, and 1 day returning. There is much variability, however, and the fish might be landed when they are from 6 to 60 hours out of the water; the average time being 12 to 24 hours.

Upon arrival in port the mackerel are removed from the hold and hoisted to the wharf by means of wire baskets. There the fish are weighed and removed to the packing house for packing and shipment.

In packing fresh mackerel for shipment they are placed in watertight wooden barrels, known as "Irish" barrels, having a capacity of about 150 pounds of fish, 45 pounds of ice, and enough sea water to float the fish. The buoyancy given by the water prevents the fish from being bruised excessively during transit. Sea water is used in preference to fresh water in order to minimize leaching, which tends to cause fading of the natural color of the skin. The barrels are covered with squares of burlap having a waterproof coating on one side. This method of packing is commonly known as floating. Packing-house shipments are usually made to wholesale dealers in the larger marketing areas, and there the fish are repacked to fill individual orders received from retail dealers. The general practice in repacking small orders is to pack the fish in wooden boxes with sufficient shaved ice to keep them in good condition. In the preparation of large orders, however, most wholesalers find it more convenient to replace the sea water in the barrels with freshly drawn sea water or brine, add a fresh supply of ice, and make delivery to the retailer in the original barrels.

A survey of stores handling fresh mackerel has disclosed the fact that in most instances the fish are sold at retail from the containers in which they were received from the wholesaler, ice being added as necessary. Also, that the majority of retailers decline to stock more mackerel than can be sold in 2 or 3 days. The adoption of these practices has enabled the retailers to market fresh mackerel with a minimum of handling and in a uniformly good condition.

In preparing mackerel for the housewife the retailer usually splits the fish down the back. (See fig. 2.) This method has the disadvantage that when the fish is baked or broiled the hottest portion of the flame, which is usually at the center of the burner, is nearest to the thin section of the fish. Recently some of the fish dealers have been splitting mackerel from the belly toward the back. (See fig. 3.) This has the advantage of placing the thickest portion of the flesh near the hottest part of the flame and insures the flesh near the backbone of being thoroughly cooked before that at the edge has become scorched.

MARKETS AND DISTRIBUTION

In a normal year over 90 percent of the mackerel caught are landed in Massachusetts, and the remainder in Maine, New York, New Jersey, and Rhode Island. About half of the mackerel from the Massachusetts fleet are received at Boston, about one-fourth at Gloucester, and the remainder at Provincetown, New Bedford, and other ports.

Most of the mackerel landed at Gloucester are shipped by truck to Boston, New York, Philadelphia, and intermediate points. Mackerel landed at Boston, and not consumed locally, likewise are shipped by truck to nearby points and by express or freight to more distant cities such as Cleveland, Chicago, and Washington, D. C.

A very large portion of the mackerel catch is consumed in cities along the Atlantic seaboard between Philadelphia and Portland, and inland as far as Albany. Unfortunately no figures are available as to the exact geographical distribution of fresh mackerel. However,

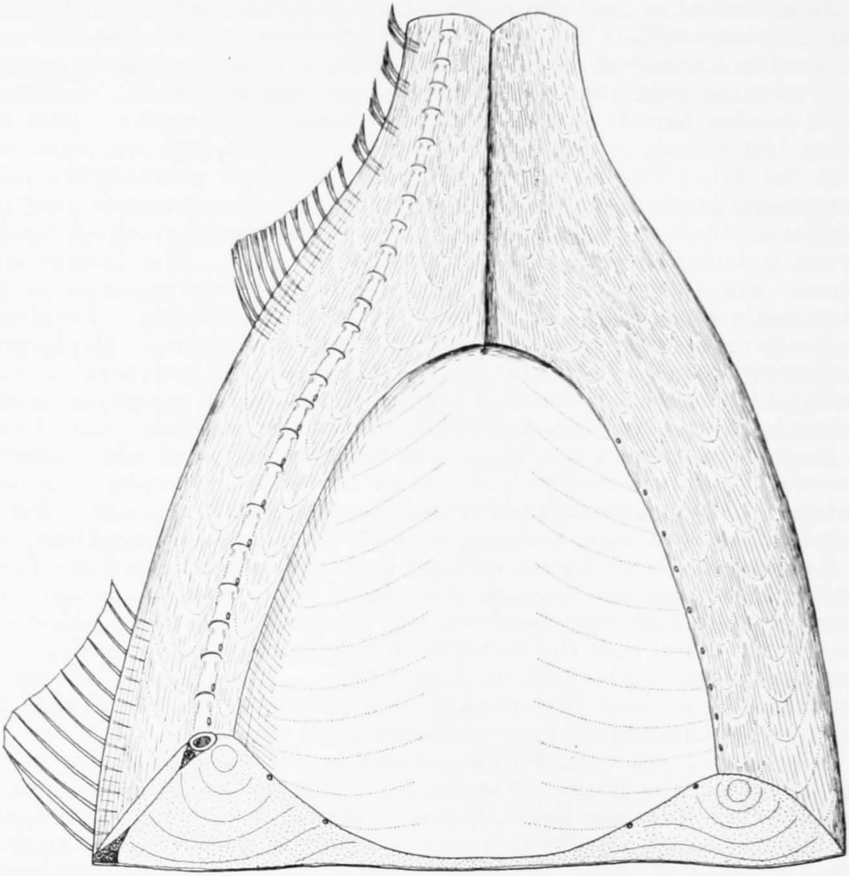

FIGURE 2.—Ordinary method of splitting mackerel which is to be broiled. In this method the thinnest portion of the fish will be subjected to the hottest part of the broiler.

the results of surveys made by Hopkinson (1921a; 1921b; 1921c; 1922a; 1922b), Fiedler (1927), and Fiedler and Matthews (1925), indicate that the common mackerel is not very well known in cities outside of the New England and Middle Atlantic Coast States. This was confirmed by one of the writers in a number of inland cities, including Cleveland, Chicago, St. Paul, and Minneapolis.

The relatively small quantities of fresh mackerel received in Cleveland and Chicago are consumed almost entirely by various foreign groups. In Minneapolis and St. Paul less than 10 percent of the mackerel receipts are sold fresh, the remainder being received frozen or salted. Apparently most of the fresh mackerel consumed in Midwestern cities is used by persons who have recently come to this country and who have been used to eating mackerel in their native countries. It is fairly certain that the average American west of the Appalachian Mountains does not include fresh Atlantic mackerel in his diet.

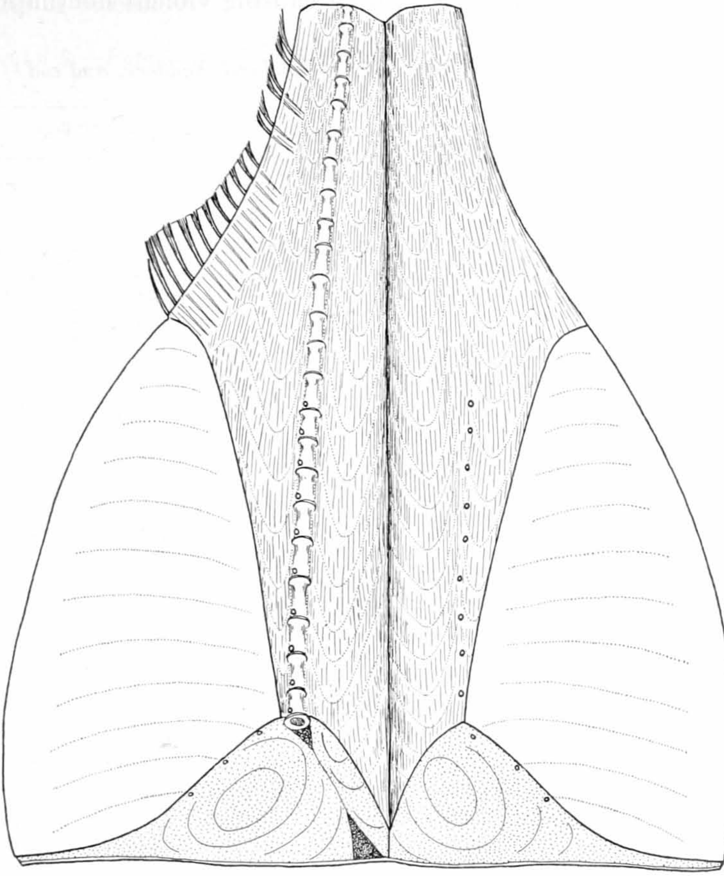

Figure 3.—Improved method of splitting mackerel which is to be broiled. In this method the thickest portion of the fish will be subjected to the hottest part of the broiler.

TRENDS IN THE WHOLESALE PRICE OF MACKEREL

During the past 20 years the average price paid to fishermen for mackerel has decreased approximately 75 percent. (See table 1.) In the period 1931–35 the average price of mackerel to the fishermen was 2.3 cents per pound, as compared with 9.6 cents for the years 1916–20. While many factors contribute to the establishment of the wholesale price of fish, making an exact determination of the cause of fluctuation from year to year impossible, the much greater decline in mackerel prices, as compared with other principal New England fish, is not without significance. Most fish fluctuate in quantity of catch and price per pound from year to year and there is a general correlation between these fluctuations; a large catch tending to lower the price, and vice versa. In the case of mackerel this correlation is much more pronounced, indicating that the value of mackerel to fishermen is more subject to the available supply than is the case with other species. For example, considerable fluctuations may occur in the catch of cod and haddock without causing violent fluctuations in prices.

TABLE 1.—*Trend in catch and price of mackerel, haddock, and cod* [1]

5-year period	Mackerel				Haddock				Cod			
	Average catch per year	Average price per pound [2]	Relation to period 1916–20		Average catch per year	Average price per pound [2]	Relation to period 1916–20		Average catch per year	Average price per pound [2]	Relation to period 1916–20	
			Catch	Price [2]			Catch	Price [2]			Catch	Price [2]
	Lbs.	*Cts.*	*Pct.*	*Pct.*	*Lbs.*	*Cts.*	*Pct.*	*Pct.*	*Lbs.*	*Cts.*	*Pct.*	*Pct.*
1916–20	24, 100, 000	9. 6	100	100	63, 500, 000	4. 3	100	100	52, 000, 000	4. 2	100	100
1921–25	26, 400, 000	7. 3	110	76	74, 500, 000	3. 1	117	70. 5	56, 800, 000	3. 2	109	76
1926–30	60, 600, 000	5. 2	252	54	154, 200, 000	3. 2	243	73	61, 400, 000	3. 4	118	81
1931–35	52, 800, 000	2. 3	219	24	175, 400, 000	2. 5	276	57	99, 700, 000	2. 1	192	51

[1] Data in table 1 were calculated from the following sources: In the case of mackerel for the period 1916–30 the statistics of Sette and Needler (1934) were used. This is the estimated total mackerel catch. For the period 1931–35, inclusive, the statistics for the total mackerel catch and value for the New England States were taken from Fishery Industries of the United States (Fiedler). For cod and haddock all data were taken from Fishery Industries of the United States. For the period 1916–30 the data used were for American fishing vessels which landed their catch at Boston and Gloucester, Mass. and Portland, Maine, and for the period 1931–35, in which such data had not been tabulated, the total catch for the New England States was used. The latter data were not available for all the years during the period 1916–30, which necessitated the use of data from a different source.

[2] Price to fishermen.

In the surveys conducted in fish markets in various cities by the Bureau of Fisheries in 1922 (previously cited) the results indicated that both haddock and mackerel were virtually unknown in inland cities. At that time a number of fish dealers attributed the lack of popularity of mackerel to its poor keeping quality. In 1936 the Bureau again conducted a survey as to the popularity of various species of fish in 61 cities in the United States (Johnson, 1938). The six most popular species were determined for each city. Data taken from the 1936 report (see table 2) show that in New England, where both mackerel and haddock are available in good condition at all times during season, the two species lead in popularity. However, in inland cities mackerel is no better known today than in 1922, while haddock has become one of the most popular species.

This great increase in the distribution of haddock since 1922 is undoubtedly due to the improved methods of handling this fish. In recent years the packaged fillet business has been greatly expanded both for fresh and frozen haddock, and this has led to a fish of much higher quality being placed on the market in cities far removed from the Atlantic seaboard. Accordingly, since mackerel is generally considered to be at least as choice a fish as haddock in cities where it is available in good condition, it would seem to follow that if better handling methods were adopted for this species a much wider distribution and a more stable price could be obtained.

Under present conditions if a large catch of mackerel is landed the surplus fish must either be absorbed by the market along the Atlantic seaboard or go into the freezers. Either alternative results in a disastrous lowering of prices, often to a point well below the cost of production. If a market was available in the Midwest, these surplus fish could be more readily disposed of without causing such drastic lowering of prices.

TABLE 2.—*Popularity of mackerel and haddock in various cities in 1936* [1]

New England States			Other States		
City	Order of preference		City	Order of preference	
	Mackerel	Haddock		Mackerel	Haddock
Boston, Mass.	2	1	Cleveland, Ohio	[2] 3	3
Fall River, Mass.	1	5	Dallas, Tex.		1
Manchester, N. H.	2	1	Denver, Colo.		4
New Haven, Conn.	2	3	Detroit, Mich.		5
Portland, Maine	2	3	El Paso, Tex.		2
Providence, R. I.	4	1	Kansas City, Mo.		1
			Milwaukee, Wis.		4
			New York, N. Y.	[3] 3	2
			Omaha, Nebr.		2
			St. Louis, Mo.		2
			St. Paul, Minn.		2
			Washington, D. C.	[2] 6	5
			Wichita, Kans.		2

[1] Johnson, 1938. [2] During June. [3] During May and June.

SCOPE OF THE INVESTIGATION

The original intent of this investigation was to determine whether or not the handling of fresh mackerel could be so improved as to reduce losses incurred by spoilage and permit a wider range of distribution. Consideration of the present methods used in handling this fish indicated that a number of relatively simple changes might lead to a considerable improvement in keeping quality. It was believed that the custom of floating the fish in sea water during transportation is especially harmful to the fish, particularly if the sea water is badly contaminated with bacteria. It also was believed that if the fish were eviscerated, rather than left in the round, the fish would keep in a much better condition for a longer period of time. As a result of these observations a series of experiments was begun to ascertain the optimum handling conditions for mackerel. It was soon realized that there were many complicating factors which had not been foreseen, and that these would have to be dealt with before the study originally started could be completed.

Early in this work it was realized that the composition of individual mackerel varies to a considerable extent. This difference is largely one of the oil content, or fat, which shows a surprisingly large variation. These variations were found to be influenced by a number of factors, chief of which was the season of the year in which the fish were caught. While the general trend of this seasonal variation of the oil content of mackerel has been known for a long time, no quantitative information as to the exact oil content of the fish at different seasons could be found. Mackerel which first appear off the Atlantic coast in early spring are very lean and as the season advances they become fatter and more oily, reaching a maximum in August, but no figures could be found to give any indications as to the amount of this variation. Consequently, a study was made of the variation in the oil content of mackerel.

It was found that the spoilage of mackerel was a much more complicated process than that of nonfatty fish. While limited information was available as to the chemistry of the decomposition of fish protein, little could be found bearing on the decomposition of fish oil while still present in the flesh. Since mackerel is a very oily species, a series of experiments was begun to determine the course of decomposition under different conditions of storage.

It was also found necessary to develop methods for determining the relative freshness of mackerel. These include tests for decomposition of both the protein and the oil. With all these facts and methods available, it was possible to store fresh mackerel under varying conditions, and, by following the course of spoilage, to determine the best handling conditions.

VARIATION OF THE OIL CONTENT OF MACKEREL

Very little reliable information has been available as to the oil content of mackerel. This is surprising, since the variation in the oil content of this fish is greater than for most other species. The most comprehensive analyses of American food fishes are those of Atwater (1888), who analyzed many different species for the various constituents, including oil, and reported in the case of mackerel an oil content varying from 2.9 to 7.7 percent, the average being 7.1 percent, which has been widely quoted. However, the data upon which these figures were based were obtained from fish caught either in the spring or late fall, at which times the oil content is at a minimum.

TABLE 3.—*Oil content of mackerel of various sizes*

Length of fish [1] (centimeters)	Probable age group [2]	Average oil content		
		June 5	Oct. 20	Nov. 17
	Years	*Percent*	*Percent*	*Percent*
30–31½	1		14.6	9.4
31½–36½	2	9.3	13.6	22.0
36½–38	3	7.0	16.5	20.1
39–42	5 and 6	4.0	17.1	16.5
41–44	7 and over	2.2		

[1] Measurements were made by Frank E. Firth, Cambridge, Mass.
[2] Information as to age groups was supplied by O. E. Sette, Cambridge, Mass.

The present work was confined largely to a determination of the seasonal variation in oil content. A considerable variation is also due to difference in size or age of the fish. Enough work was done to show that this is the case, but not sufficient to draw any definite conclusions. These results (see table 3) indicate that small fish show less variation in oil content with the season than larger ones. However, this cannot be taken as entirely conclusive until more data are obtained.

In order to minimize the effect of size, samples were taken comprising small, medium, and large fish. The samples were usually obtained directly from the fishing boats as they landed in Gloucester. The mackerel caught in early spring, which are never landed in New England, were shipped in from Cape May, N. J. All samples reported were obtained during a single season.

While there is undoubtedly some fluctuation in oil content from year to year at the same season, it is apt to be small and the general trend should be uniform. This was confirmed by making a few analyses during three other seasons, although one exception was noted with mackerel caught in tbe late fall. These fish seem to vary considerably both between different lots of fish caught in the same year, and from year to year. In some cases mackerel caught in November contained as high as 20 percent oil, while in other cases a marked decline was shown from the maximum attained during the summer.

In making the analyses fillets were cut from the fish, removing as many bones as possible. The skin was then removed, care being taken to lose as little as possible of the oil occurring next to the skin. In some cases the fish were analyzed separately to show the difference in oil content between individuals, while in other cases the fish were ground together and a single average analysis made. From 4 to 25 fish were used for each sample.

The method of analysis used was one developed especially for this work which allowed a rapid, yet reasonably accurate determination of oil. The method has been described in detail by Stansby and Lemon (1937) and will not be repeated here. The results obtained in 11 lots of fish examined are given in table 4.

TABLE 4.—*Variation in oil content of mackerel with the season*

Date fish were caught	Number of fish analyzed	Maximum oil content	Minimum oil content	Average oil content	Date fish were caught	Number of finish analyzed	Maximum oil content	Minimum oil content	Average oil content
		Percent	*Percent*	*Percent*			*Percent*	*Percent*	*Percent*
Apr. 18	[1] 13			3.9	Aug. 13	7	25.6	10.6	17.5
22	8	7.6	2.7	4.8	15	7	21.6	16.0	19.2
May 3	[1] 4			8.0	Sept. 11	20	11.4	2.0	6.5
21	[1] 4			9.0	Oct. 1	25	16.2	3.0	10.1
June 1	[1] 6			9.8	Nov. 17	12	15.2	2.2	8.2
July 23	13	17.3	6.1	10.6					

[1] These fish were analyzed as a composite sample.

With a single exception the mackerel examined showed a regular increase in oil content from a minimum average value of 3.9 percent in April to a maximum average value of 19.2 percent during August, followed by a decrease in oil content to an average minimum value of 8.2 percent in November. Since mackerel are not usually caught during the winter months, no values are available for that season. A large deviation between individual fish of the same lot also was observed. Thus, fish caught in April varied between 2.7 and 7.6 percent; those caught in August, between 10.6 and 25.6 percent; while mackerel caught in November showed the largest deviation of all, 2.2 to 15.2 percent, a difference of almost 7 times. These data, therefore, indicate a much higher oil content for mackerel than is generally believed to be present. Bodansky (1934), Leach and Winton (1920), and Sherman (1932), all list mackerel in their food charts as having an oil content of 7.1 percent, a value apparently obtained from the analysis of Atwater (1888).

Not only is the oil content of mackerel generally understated but also the calorific value is widely quoted as 630 calories per pound of flesh. This value would now appear to be too low; the true value varying from about 500 calories per pound of flesh for lean fish caught in the spring to 1,350 calories per pound for very fat fish caught in the summer, with a value of about 900 calories per pound of flesh being fairly representative for the bulk of the catch.

The effect of the seasonal variation upon the energy value expressed in calories is shown in figure 4. These values were calculated, assum-

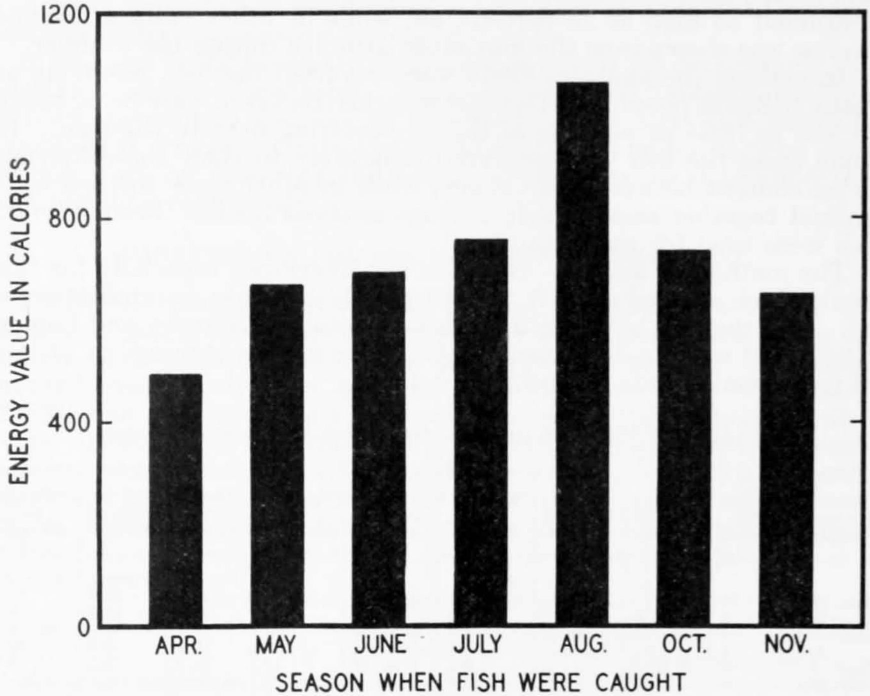

FIGURE 4.—Energy values, expressed in calories per pound of fresh fish, for mackerel caught at various seasons.

ing 4 calories per gram of protein and 9 calories per gram of fat The protein content was taken as 18 percent in all cases. The energy value of mackerel may vary by more than 3 times in extreme cases, and 1 pound of average mackerel flesh from a fish caught in August will yield more than twice as many calories as 1 pound of mackerel flesh from a fish caught in April.

THE PROBLEM OF MACKEREL SPOILAGE

THEORETICAL CONSIDERATIONS

Mackerel flesh may be considered to consist of three principal components—light muscle tissue, dark muscle tissue, and oil. The dark muscle occurs chiefly in layers between the skin and the light muscle. The oil is intermixed throughout the flesh but is not uniformly distributed about the body, the tendency being for a considerable portion to be near the surface, especially in those individuals caught during the summer months and having the highest oil content. The flesh, especially the light portion, is usually soft. This property is often accentuated by the presence of considerable oil which makes the texture semiliquid. The oil is semidrying, having an iodine number of about 167. When fresh the oil is colorless and possesses a sweet, slightly fishy odor and flavor.

DECOMPOSITION OF MACKEREL FLESH

The protein of mackerel, as with other species of fish, is decomposed by the action of bacteria as well as enzymes. Owing to the fact that this species is handled in the round, the action of enzymes is of more importance than with species from which the viscera is removed at the time the fish are caught.

Immediately after the death of the fish rigor mortis sets in. While this phenomenon is often thought of as a mere stiffening of the fish, it actually includes various other changes. During life and before rigor begins a portion of the water in the flesh can be separated from the protein by exerting a slight pressure. When rigor mortis is present, however, the water and protein "set" in a gel-like consistency from which very little water can be removed, even when the flesh is subjected to enormous pressures. Simultaneously considerable lactic acid develops which increases the acidity of the flesh to a noticeable extent. Several other phenomena occur also, such as the shortening of the muscle fibers and increases in buffer capacity, etc. These, however, have no bearing on the spoilage of the fish—so far as our present knowledge indicates.

The changes occurring during rigor mortis have a tendency to prevent, or at least minimize, bacterial action upon the flesh. The gel-like consistency of the flesh is considerably more difficult for the bacteria to penetrate than is the semiliquid condition of the flesh immediately before or after rigor mortis. The growth and action of the bacteria are also probably retarded by the increase in acidity occurring during rigor mortis. Thus, the presence of rigor mortis is not only a guaranty that the fish is in first-class condition but it also acts as a natural protection against bacterial invasion and decomposition. As long as full rigor is present, practically no bacterial decomposition can take place.

During life many natural functions, especially those associated with metabolism, depend upon the presence of various enzymes in the body. After death these enzymes begin to tear down the complex body tissue into simpler compounds. Most of the compounds so formed are harmless in themselves but cause the fish to deteriorate in quality, owing to the softening of the flesh and the fact that fish in such condition are a more ready prey to the action of bacteria. This process is known as autolysis. It can be retarded by keeping the temperature of the fish as low as possible, but even at freezing temperatures autolysis proceeds slowly.

In the case of fish handled in the round, the enzymes of the body tissues are further accompanied by those present in the visceral organs. The stomach, pyloric caeca, and other organs contain a number of enzymes for digesting the food which is eaten, and after death these enzymes break down the surrounding tissues with extreme rapidity. While bad flavors or odors do not usually accompany this early stage of autolysis, it is undesirable because it detracts from the appearance of the fish.

The beginning of autolysis and the decrease of rigor mortis overlap, and it is a disputed point as to whether the onset of autolysis causes the disappearance of rigor, or whether the disappearance of rigor allows autolysis to begin. The former view appears to be better founded, according to the experience of the writers, because occasionally fish in maximum rigor were found to show signs of extensive autolysis, especially where the tissue enzymes were supplemented by those of the viscera.

Shortly after autolysis is under way, and rigor mortis has disappeared, bacterial decomposition of the fish commences. The first stage in the bacterial decomposition is usually a further break-down of the protein. Bacteria, however, do not stop at the formation of intermediate compounds but continue to decompose these compounds into still simpler ones.

The most frequently formed end product is probably ammonia, but various other nitrogen compounds, such as amines, are often found simultaneously in the early stages of decomposition. The evolution of ammonia is very slow at first, so that the resulting odor is not objectionable, and, being mixed with other substances, is often not even recognized as such. In advanced stages of decomposition, however, comparatively large quantities of ammonia are given off and the sharp, penetrating odor is easily discernible.

Fish protein contains cystine and other amino acids which have sulfur as one of their constituents. During bacterial decomposition hydrogen sulfide is evolved. Ordinarily the quantity liberated is so small that its effect upon the odor of the fish is not pronounced until an advanced stage of spoilage is reached. In the handling of mackerel the fish are kept under water, and, since air cannot reach them, a condition is maintained which is favorable to the growth of anaerobic bacteria which generally promote the formation of hydrogen sulfide. Furthermore, the skin of the mackerel is more or less impervious to gases and helps to retain the gaseous hydrogen sulfide. It is often observed that immediately upon cutting open a fish a strong odor of hydrogen sulfide is evident. After only a few seconds most of the gas escapes and this odor is considerably reduced. The presence of hydrogen sulfide in fish gives it a very bad odor which is ordinarily much worse than that of ammonia and similar compounds. Consequently every effort should be made to avoid its formation.

Although most of the nitrogen in fish occurs as protein, a small part is present in other compounds. Among these may be mentioned various free amino acids, lecethin, and trimethylamine oxide. The free amino acids may be expected to decompose and contribute to spoilage in a manner similar to the protein. Trimethylamine oxide is not usually decomposed by the action of enzymes, but it is readily attacked by bacteria. It is of especial interest since it readily breaks down into trimethylamine, which is one of the compounds principally responsible for the odor of stale fish, and although trimethylamine oxide occurs in rather minute quantities in fish, it may be of considerable importance in contributing to spoilage.

DECOMPOSITION OF MACKEREL OIL

An entirely different type of fish spoilage is involved in changes in the oil. As has previously been stated, mackerel is an extremely oily fish in which the oil content may be as high as 25 percent or more. When this is the case the amount of oil exceeds that of every other constituent of the fish except water, and consequently deterioration of the oil is of considerable importance. As with the protein, the oil is decomposed by bacteria and enzymes although it can decompose spontaneously without the aid of either. Decomposition occurs chiefly in two ways. The first type of change results in splitting the oil into glycerine and fatty acids, and is called hydrolysis. The second change involves the oxidation of the oil with the resultant formation of numerous products which lead to rancid flavors and odors. Hydrolysis is usually accelerated by the presence of either bacteria or enzymes. Oxidation may be hastened by the presence of suitable enzymes but it is less influenced by bacteria.

Hydrolysis of oil tends to give it a bitter flavor which is probably caused by the presence of the acids formed. The odor of the oil remains practically unchanged so long as hydrolysis is the only reaction occurring. Even the development of the somewhat bitter flavor is rather slow, so that this type of change is not very serious except in extreme cases.

Oxidation is the more important type of change occurring in mackerel oil and deserves primary consideration. Fish oils as a class are of the type chemically known as unsaturated. This indicates that such oils can combine with considerable quantities of oxygen from the air. A familiar example of the oxidation of an oil is the drying of paints or varnishes. In this case the hard external coating which forms upon standing is due to the addition of oxygen from the air to the oil in the varnish. Similarly, mackerel oil when exposed to the air combines with the oxygen and changes from a clear, thin liquid to a viscous mass—in extreme cases even becoming solid. In fact, owing to its high degree of unsaturation, mackerel oil is sometimes used in the manufacture of paint. As the oil becomes more and more viscous the color changes progressively from almost colorless through various stages of yellow to an orange brown. Simultaneously the flavor, and to a less extent the odor, of the oil develops the characteristics of rancidity.

Fresh mackerel oil has a sweet odor and flavor which leaves an oily sensation, but little or no aftertaste, when eaten. As rancidity develops, the oily sensation evident after eating is accompanied by a sharp, rather unpleasant flavor which persists for a considerable period. As rancidity increases this aftertaste becomes more and more unpleasant, and in advanced stages of rancidity it may endure for an hour or more after the oil has been tasted. When these rancid flavors are mixed with the flavors of the fish protein they become difficult to recognize with certainty, but owing to the persistent aftertaste of the oil they can readily be detected long after the protein flavor has disappeared.

Rancidity is of less importance in fresh mackerel than in the salted or frozen product. In many cases no rancidity is evident before the fish is eaten. The relative importance of rancidity in the spoilage of mackerel is dependent upon a number of factors. Thus, in fish which

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have a very low oil content, rancidity plays a small role in the spoilage of the product; whereas in fish containing 20 to 30 percent oil a very definite rancid aftertaste may develop before the fish is completely inedible.

The layer of oil next to the skin of the mackerel becomes rancid much sooner than that contained in the deeper portions of the flesh. The closer the oil is to the surface the more ready access it has to the oxygen in the air. Very little oxygen penetrates to the center of the fish so that oil in the interior of the flesh remains fresh for a much longer period of time than that near the surface. When mackerel containing rancid oil is eaten, not only is a persistent aftertaste left in the mouth but many people complain of what is termed "repeating of the mackerel." For many hours the flavor of the mackerel oil is tasted at intervals, indicating that digestion was not complete. It has been found that if the skin is removed before cooking, little trouble will be experienced with the so-called repeating. This is due to the fact that when the skin is removed most of the outer layer of oil adhering to the skin is also discarded. Since it is this outer layer of oil which contains most of the rancid products, the remainder of the oil in the fish is comparatively fresh.

PRACTICAL SPOILAGE PROBLEMS

BRUISING AND SOFTENING OF FLESH

As previously indicated, the flesh of the mackerel is exceedingly delicate and special care should be exercised in handling in order to avoid bruising it. The protein in the flesh is not only softer than that of most other fish but the presence of considerable oil also adds to its delicate nature.

Fish handled in the round normally soften more rapidly on account of the greater enzyme and bacterial activity of the viscera in contact with the flesh of the body cavity. The belly wall may become softened to such an extent that jostling the fish is apt to cause a break in the skin and expose the viscera. When this occurs the fish are unsuitable for sale because of their unsightly appearance.

If the fish are packed with large pieces of ice, the corners of the ice frequently break through the skin or leave marks on the surface. The fish also become generally softer the more handling they undergo.

The development of bruises and softness in fish is undesirable for two reasons: First, a soft fish is considered to be of inferior quality and many consumers use the degree of softness as an index to the quality of the fish, and the second and more serious result is that when fish have been bruised the flesh is more readily decomposed by enzymes and thus made more susceptible to bacterial action. Also, since the spoilage rate of fish is influenced by the number of bacteria present, any skin abrasions lead to greater bacterial contaminations of the flesh and a further acceleration of decomposition.

RED FEED (*CALANUS FINMARCHICUS*)

Mackerel feed largely upon minute crustaceans, one of the most common of which is *Calanus finmarchicus*. This crustacean often occurs in vast swarms and is called red feed by the fishermen because of its reddish-orange appearance. It is the contention of those engaged in the handling of mackerel that fish which contain large quantities of the red feed do not keep as well as those in which it is absent. Observations of the writers bear out this contention and indicate that spoilage of two types accompanies the presence of considerable quantities of the red feed.

The first type is apparently an extremely rapid autolysis. Only a few hours after the fish are caught the flesh around the backbone softens. After about 24 hours the flesh is entirely broken down in this region so that upon dressing the fish the bones are exposed free of flesh. Frequently mackerel containing much red feed exhibited more evidence of autolysis near the backbone only 24 hours after catching than other mackerel which did not contain red feed and which had been kept in ice for more than 2 weeks. It should be emphasized that it is not only the presence of red feed which determines the rate of autolysis, but the amount as well. Fish which contain small amounts of the red feed have been examined and found to exhibit but slight autolysis.

The second type of spoilage accompanying the presence of red feed is a rapid evolution of hydrogen sulfide from the flesh. Even freshly caught mackerel which contain much red feed give off a perceptible hydrogen sulfide odor from the flesh when first cut open. This odor does not persist for long, however, as would be the case of a fish in which extensive decomposition had taken place. An hour or so after the fish has been cut open no hydrogen sulfide odor is evident. Also, if the fish containing red feed, which give off hydrogen sulfide immediately after catching, are packed in ice for several days the odor of hydrogen sulfide is not nearly so strong as it was in the freshly caught fish.

There are numerous other organisms of a reddish appearance upon which mackerel feed which are not the true red feed. Fish containing large quantities of these other varieties do not decompose more rapidly than fish which contain little or no food at all. The true red feed can usually be distinguished by the orange color it possesses. The other types are usually dark red or purple in color.

Another feature of the presence of red feed which is very objectionable to those who handle the fish is that such fish are said to "burn" the hands. Persons who handle such mackerel are troubled with a skin irritation which leaves small lesions upon the hands. These lesions are blamed upon the red feed in the fish. Owing to this phenomenon, red feed is sometimes termed cayenne, or red pepper. However, the writers believe this trouble is caused by bacteria present around the boats and fish wharves, which is quite independent of the red feed itself.

A number of explanations can be given for the effect of red feed on the spoilage of fish. Not enough information is available, however, to decide which theory is most likely to be correct, and there probably is a combination of several conditions which bring about the total effect. The rapid autolysis occurring when red feed is present is usually accompanied by a large evolution of hydrogen sulfide which in some cases acts as a catalyst, increasing autolytic action of enzymes. It is possible that the marked degree of autolysis accompanying the presence of red feed is due to an activation by the hydrogen sulfide of the enzymes already present in the fish.

Red feed consumes prodigious amounts of bacteria; in fact it cannot live in their absence. Therefore, fish containing much red feed would likewise contain many bacteria, some of which might be capable of producing hydrogen sulfide. Another explanation is that red feed itself contains enzymes capable of producing the rapid autolysis observed. Bond (1934) has shown that *Calanus finmarchicus* contains a protein-splitting enzyme.

Unfortunately the only remedy known for reducing the spoilage blamed upon red feed in mackerel is applicable to only a small portion of the mackerel catch. When mackerel are caught in traps it is customary for the fishermen to examine the fish to see whether they contain these organisms. If they do, the fish are left in the traps for from 24 to 48 hours. After this time the intestinal tract is usually cleared and no further trouble of this nature is experienced. However, only a very small percentage of the mackerel caught on the Atlantic coast are taken in traps, so that this method of examination and elimination of the undesirable red feed is not usually available to Atlantic coast mackerel fishermen.

EVALUATING THE GENERAL QUALITY OF MACKEREL

FACTORS CONTRIBUTING TO QUALITY

The buyer is willing to pay more for fish of high quality than for a low-quality product. For this reason it is advisable to consider the factors which influence quality and to determine which are of most importance. The housewife uses such indications as clear eyes, bright-red gills, etc., as criteria of first-quality fish. These factors, which are of no consequence in themselves, indicate that certain other conditions are apt to be present. The properties which actually mean most to the consumer are keeping quality after purchase, good appearance and odor during preparation, and palatability.

KEEPING QUALITY AFTER PURCHASE

If fish is purchased for immediate consumption the keeping quality need not be given as much consideration as when it is expected to hold it over for a day or two before cooking. However, fish are frequently purchased in the morning and placed in the household refrigerator until evening, or the following day. Prior to sale the fish was kept in crushed ice at a temperature not much above 32° F. When removed from the ice for delivery the temperature of the fish immediately rises, since no attempt is made to refrigerate it during the delivery period. In warm weather the temperature of the fish will rise considerably during this time. If the fish is not cooked immediately upon receipt from the market it is usually placed in a household refrigerator where the temperature is probably not very far below 50° F.; a temperature considerably above that at which it had previously been stored.

The spoilage rate of fish is dependent upon a number of factors, one of the most important of which is the temperature of storage. This rate increases greatly with increasing temperatures, and, according to Hess (1934), the rate of decomposition of fish stored at 41° to 50° F. (temperature of refrigerator) is over four times as great as fish stored at 32° to 41° F. (temperature of fish stored in ice). Consequently, when fish is purchased at a store and carried home and placed in a refrigerator, decomposition proceeds at a greatly increased rate. For example, a fish which would remain in good condition for 36 additional hours if kept in ice at the retail store would keep only about 9 hours in a refrigerator in the home. Thus the keeping quality of the fish after sale to the consumer is of considerable importance, since it is not so much the condition of the fish when purchased, but the condition of the fish several hours later which is of most importance.

APPEARANCE AND ODOR DURING PREPARATION

A fish of high quality must have an appetizing appearance, especially during preparation. Even though the fish meets all of the requirements of palatability, if the flesh shows evidence of decomposition the person who prepares the fish will not find it as desirable as though it had been perfectly sound.

Of even more importance is the presence or absence of decomposition odors during preparation and cooking of the fish. Many fish give off a stale or putrid odor during cooking, yet have no bad odor or flavor when eaten. In such a case all of the bad odors have been driven off during the cooking. When it is ready for serving, however, no one present during the cooking has any appetite for the fish. Furthermore, the odor of stale fish may remain about the house for hours, if not days. Many people are under the impression that such a condition is always encountered with all fish, whereas only fish of inferior quality give off bad odors when cooked.

PALATABILITY

Palatability is determined by numerous factors which can be listed as follows, the order being according to relative importance:

1. Freedom from decomposition odors and flavors.
2. Freedom from aftertaste.
3. Presence of normal flavors and odors.
4. Correct texture of fish.
5. Good appearance of cooked fish.

Anyone can distinguish fish having a stale odor, and it is at once classified as being of inferior quality. What is not so generally recognized is that when an aftertaste is left in the mouth after eating the fish, it was of low quality. Many people suppose that all fish can be tasted after it has been eaten. This is not true, since an aftertaste usually is due to rancid oil in the fish.

Even though no decomposition flavors or odors are present, the flavor of the fish may not be satisfactory. Each species of fish contains various aromatic substances which give that species its characteristic flavor and odor. Moreover, fish contain numerous mineral substances which not only contribute to the flavor but add considerably to its nutritive value. When fish are not handled properly a portion of these substances may be lost, and such fish are not of high quality.

Various abnormal textures are sometimes observed when fish is eaten. Sometimes a portion of fish is described as stringy, another as rubbery, or another as tough. While these differences are often due to improper methods of cooking, they are also caused by the fish being improperly handled.

TESTS FOR SPOILAGE

With some species of fish, for example haddock, spoilage is a comparatively simple process. In such fish there is practically no oil present and they almost invariably decompose in the same manner, giving ammonia and amines as the chief end products. When such simple types of spoilage occur one or more chemical tests often can be correlated with the decomposition, and these tests normally will be more accurate than organoleptic tests because errors due to the personal equation are eliminated. Where more complicated decomposition occurs, however, scientific tests are much less reliable because an accurate correlation between the chemical tests and the degree of spoilage is complicated by the numerous factors which have to be considered. Therefore, in the case of mackerel, organoleptic tests are more important than scientific tests.

ORGANOLEPTIC TESTS

The organoleptic tests for judging the quality of fish are based on observations relating to the appearance, odor, texture, etc., of the sample in question. No single observation can suffice by itself, however, and final judgment must be based on the fitting together of a relatively large number of properties. The following points have received consideration during this investigation:

1. Observations on round fish.
   - (*a*) Appearance—"pearlescent" color, color of stripes, appearance of eyes and gills.
   - (*b*) Firmness—rigor mortis, softening of flesh.
   - (*c*) Odor of fish and gills.
2. Observations during dressing.
   - (*a*) Appearance of flesh near backbone, yellow gloss of flesh near viscera, and viscera.
   - (*b*) Odors—permanent odors and odors which do not persist.
   - (*c*) Condition of flesh—color, texture, and odor.
3. Observations on cooked fish.
   - (*a*) Appearance.
   - (*b*) Texture.
   - (*c*) Odor—during and after cooking.
   - (*d*) Flavor of flesh and oil.

In making the various organoleptic tests it was found to be helpful to have a blank form upon which all of the observations could be noted. In this way there was less chance of omitting or overlooking any particular test. An example of the type of form used in the present study is shown in figure 5. This form also includes space for the scientific tests which will be discussed later.

It will be appreciated that in making a large number of observations, many of which are limited in scope, it is essential that some manner of evaluation be used. After observations had been made on a large number of fish in varying degrees of decomposition, and after due consideration had been given to the limitations of the various tests, the following arbitrary method of evaluating quality, based on organoleptic examination, was adopted for the actual experimental work.

It was decided that 30 percent of the rating should be attributed to appearance. This included color of stripes, condition of eyes and gills, and the rigidity or firmness of the flesh. Fifteen percent of the rating was assigned to the condition of the body cavity, 10 percent to the texture of the flesh, and 45 percent to the various tests for odors. A fish considered to be excellent in all the factors contributing to appearance, condition of body cavity, texture of flesh and odor would be rated 100 percent.

Series No.....　　　　　　　　　　Series started..........

Run No........　　　　　　　　　　Run started.......Time...

ORGANOLEPTIC TESTS	BACTERIAL COUNT
General appearance.--	....
Iridescent colors..............................	....
Green-blue stripes..............................	OIL TESTS
Firmness..............................	Normality of alkali................
Eyes..............................	Ml. alkali for free fatty acid.....
Gills..............................	Normality of thiosulfate...........
Body cavity..............................	Ml. thiosulfate for peroxide.......
Flesh.--	ELECTRICAL TESTS
Color..............................	A................................
Texture..............................	B................................
Drip..............................	HYDROGEN SULFIDE TESTS
Odor.--	A................................
Surface..............................	B................................
Flesh..............................	Remarks
Remarks	....
....	....
....	....

FIGURE 5.—Data sheet used for recording results of organoleptic and scientific tests of mackerel.

Six different classifications were selected for each type of rating. These were excellent, very good, good, fair, poor, and very poor; each decreasing one-fifth of the percentage rating in the order given. Thus, a fish having the necessary qualifications as to color of stripes, condition of eyes and gills, and rigidity and firmness, to be considered excellent, would be credited 30 points; very good, 24 points; good, 18 points; fair, 12 points; etc. However, for purpose of presentation, it was believed the reader could detect differences better by some graphical method. Therefore, in tables 7, 10, 11, 15, 19, and 20, excellent will be denoted by XXXXX, very good by XXXX, good XXX, fair XX, poor X, and very poor by 0; in which X is equivalent to one-fifth of the total rating. Under the heading of appearance X will have a weight of 6; under condition of body cavity, 3; under texture of flesh, 2; and under odor, 9.

The above method proved most useful since it not only permitted a rather definite rating of a sample at any particular time but also made it possible to obtain a rather definite idea of the time required to reach a similar condition of quality under different methods of handling.

As previously indicated, organoleptic tests, up to the present time at least, are most suitable in following the spoilage of mackerel. So many different types of spoilage may occur that numerous scientific tests would have to be made before arriving at even the approximate condition of the fish. However, such tests are useful when used in conjuntion with organoleptic tests.

TESTS FOR PROTEIN DECOMPOSITION

ELECTROMETRIC TEST

An electrometric method for the determination of fish freshness has been described by Stansby and Lemon (1933). This method, originally described for haddock, has been extended to include cod and pollock. Many tests were also run using mackerel, but the results obtained were not as reliable as with the other species. A brief description of this test follows:

Fish flesh has the ability to combine with acids to a degree varying with the degree of freshness of the fish. In the case of haddock this acid-combining power rises sharply after death of the fish, ordinarily reaching a maximum within 36 hours. It then declines slowly to a minimum of about one-half of the maximum value. Since haddock are rarely landed before they are at least 36 hours out of the water, the initial rise of the acid-combining power of the fish flesh can be disregarded for all practical purposes. The acid-combining power can be expressed as the A value, an arbitrary unit which is directly proportional to the amount of acid combining with the flesh. In the case of haddock the A value rises from about 25 at the death of the fish to a maximum of approximately 32, whereupon, as decomposition sets in, it falls to a minimum of 15, or in extreme cases 12. The fall in the A value proceeds simultaneously with what is known as primary decomposition; i. e., hydrolysis of the protein to simpler, though usually harmless compounds.

In order to determine the acid-combining power of the fish flesh, a weighed sample of the ground flesh is shaken with water, and acid is added to bring the acidity of the suspension to a pH value of 6. The amount of acid required to bring the pH to 4.3 is then determined. The latter amount of acid, calculated according to certain empirical rules, is the A value. The first step, the addition of acid to pH 6, gives another value which varies with fish spoilage. The amount of acid used in this stage is called the B value and is more or less proportional to the development of secondary decomposition or the collection of undesirable end products which are basic in nature. The B value for haddock falls from an initial value of about 7 or 8, to a minimum of 2 to 5 soon after the fish is caught, and then as bacterial decomposition occurs it rises again to a maximum of 16 or more in extreme decomposition. Since the initial drop in B value generally occurs before haddock is landed commercially, it is usually disregarded. By comparing both the A and B values, a knowledge as to the condition of the fish is obtained. Neither value alone, however, is useful in predicting the quality of the flesh.

Several hundred samples of mackerel were obtained, in varying degrees of decomposition, and the electrometric test applied. When the results were summarized the following differences were noted between the method as applied to mackerel and to haddock:

1. The A and B values for haddock correspond quite closely to the same condition of the fish throughout the year. With mackerel the table, as prepared (see table 5), is valid only for fish of a fairly high fat content; i. e., those caught between June and September. For fish caught at other times the test is not to be recommended, since values obtained often do not correspond to the condition of the fish.

2. For mackerel caught during the summer the electrometric method cannot be considered as a final test. Other types of decomposition, such as hydrogen sulfide formation or changes in the oil, sometimes occur simultaneously and are not shown by the test. In such cases, however, the results of the electrometric test together with the other tests are valuable in appraising the condition of the fish. The A value is less affected by these other types of decomposition than is the B value.

TABLE 5.—*Condition of mackerel as indicated by electrometric test*

A value	Extent of primary change	Extent of secondary change—B values			
		B=less than 2	B=2-5	B=5-8	B=over 8
30-40	None	None	None	Slight	Considerable.
25-30	Slight	do	Slight	Definite	Do.
20-25	Considerable	do	do	Considerable	Extreme.
Under 20	Extreme	do	Definite	Extreme	Do.

NOTE.—These values apply only to mackerel caught between June and September.

HYDROGEN SULFIDE TEST

Hydrogen sulfide often forms during decomposition of mackerel. Numerous tests are available for determining the amount of hydrogen sulfide in food products. It was believed that in the case of mackerel the relatively simple test of Ebers (1897) would serve as a basis for a very suitable, rapid test. In working out this test it was decided to make use of the fact that during the early stages of decomposition hydrogen sulfide may collect in the fish and give off a bad odor when cut open, even though advanced spoilage is not present. By determining the amount of hydrogen sulfide when the fish is first cut open, and then incubating the fish for a further period, two values are obtained. A positive test for hydrogen sulfide in the first step indicates only that some small amount of decomposition has occurred, and unless it is also strongly positive in the second step, the condition of the flesh is not necessarily poor.

The following method was used: Strips of filter paper 1 inch wide were dipped for 3 to 5 minutes in a 10 percent lead acetate solution and were then allowed to dry thoroughly at room temperature. Twenty-five gm. of thoroughly ground mackerel flesh were weighed to within a few tenths of a gram into a 250 ml. Erlenmeyer flask. Fifty ml. of 6N hydrochloric acid were then added and a strip of the lead acetate paper, moistened with water, was placed across the mouth of the flask and the flask loosely stoppered with a wad of cotton. The flask was placed in an incubator for exactly 10 minutes and then withdrawn. The lead acetate strip was then replaced with a fresh one, the original one being set aside. The flask was restoppered and placed once more

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in the incubator and after 110 minutes the lead acetate strip was removed.

A large number of samples of mackerel of known history, and representing different degrees of decomposition, were tested in this way and the strips of lead acetate paper were saved. They were then classified into 11 groups according to the intensity of the black or brown spot of lead sulfide on the paper. The 11 degrees of intensity were numbered from 0 to 10. No. 0 was perfectly white; No. 1 was slightly yellowish; No. 2 was a faint yellow ring, etc.; up to No. 10, which was a black circle.

The amount of hydrogen sulfide corresponding to each strip was next determined so that it would be possible to duplicate the set of strips at any time in preparing a set of standards. A solution of sodium sulfide was made up, standardized with iodine, and then diluted with hydrogen-sulfide-free water. Varying amounts of this standardized sodium sulfide solution were placed in Erlenmeyer flasks containing hydrochloric acid. The flasks were stoppered with cotton, a lead acetate paper placed in the neck, and the solution boiled. This was repeated with suitable amounts of the sodium-sulfide solution until 11 strips were obtained which matched the 11 groups of paper obtained from the fish tests (see table 6).

TABLE 6.—*Test papers for hydrogen sulfide determination*

Strip No.	Discoloration	Sulfide (S)
		Milligrams
0	No trace of yellow	0.000
1	Faint yellow color	[1].001
2	Yellow, concentrated in ridges	.002
3	Light yellow-brown color in indefinite rings	.004
4	Yellow-brown in fairly definite rings	.005
5	Brown in definite rings	.006
6	Brown in definite, fairly solid rings	.007
7	Brown in definite, solid rings	.008
8	Brown (with black predominating over yellow tinge) solid rings	.009
9	Dark brown, nearly black, solid rings	.010
10	Practically black solid rings; edges tapering off to brown	[2].010

[1] Or less. [2] Or more.

In making this test it is important that the fish be filleted and ground as rapidly as possible. The sample must be weighed immediately, the acid added, the strip of paper and stopper put in place, and the test started. Otherwise, the first test strip obtained after a 10-minute incubation will be meaningless, since much of the hydrogen sulfide would have escaped before the test was under way.

Two lead sulfide strips were obtained by this test. The first one resulting from 10-minute incubation will be designated A, while the second will be designated B. High values of A indicate that some decomposition has occurred, so that hydrogen sulfide has collected in the flesh. However, unless B is also high no extensive decomposition has taken place.

TESTS FOR OIL DECOMPOSITION

As stated in the discussion of the problems of mackerel spoilage, the principal types of fat, or oil decomposition are hydrolysis and oxidation. The method for measuring the degree of hydrolysis—the free fatty acid value—in which a known quantity of oil is neutralized with an alkali solution of known strength is quite generally standardized. The matter of measuring oxidation, however, is rather more complicated, since primary interest in the oxidation of the fat or oil of a food product pertains to its relation to rancidity. In most practical cases the principal concern is incipient rancidity, rather than readily detectable "off" flavors and odors. While rancid odors and flavors are generally attributed to oxidation, not all off flavors and odors are specifically the result of oxidation alone. Consequently numerous tests have been suggested in an attempt to correlate some chemical change in the fat or oil with the development of rancid odors and flavors. For the present investigation the writers selected a method which is quite commonly known as the peroxide test. It is based on the assumption that peroxides which can be readily broken down in the presence of potassium iodide with the liberation of iodine are found as an intermediate step during the oxidation of the oil.

In studying oil decomposition in a product such as mackerel it is necessary to separate the oil from the other body constituents. In the present investigation the method described by Stansby (1935) was used. It may be given briefly as follows:

The mackerel flesh, free of skin and bones, is ground thoroughly in a meat grinder. Twenty gm. of the flesh is weighed into a 150-ml. oil sample bottle, and 25 gm. of anhydrous sodium sulfate and exactly 100 ml. of ethyl ether are added. The bottle is shaken for exactly 30 minutes in a shaking machine and allowed to stand until the solids settle to the bottom. Twenty ml. of the clear ether solution of oil is pipetted through a filter into a weighed beaker, and the filter washed with two 5-ml. portions of ether. The ether is evaporated on a steam bath and the beaker and oil weighed. Meanwhile two further 20-ml. portions of the ether solution are pipetted into two Erlenmeyer flasks. To one of them is added 20-ml. of ethanol (neutral to phenolphthalein) and the solution is titrated with standard sodium hydroxide solution to a pink color, permanent for at least 15 seconds after the addition of the last drop of alkali solution.

The other 20-ml. aliquot is treated with 20 ml. of chloroform and 30 ml. of glacial acetic acid. One ml. of a saturated potassium iodide solution is added immediately from a pipette, the solution shaken for exactly 1 minute, and 100 ml. of a 0.05-percent starch solution is added. The liberated iodine is then titrated with standard sodium thiosulfate to the disappearance of the blue color. A blank determination is always run, using all the reagents and the same procedure but omitting the oil. The value found for the blank is then subtracted from the titration value found for the oil. From these data the percentage of free fatty acid (as oleic) and the peroxide number according to Wheeler (1932) are calculated. The peroxide number has a fair degree of correlation with the degree of rancidity, especially at lower temperatures of storage. This fact has been demonstrated by experiments (not included in this report) on the storage of mackerel body oil at different temperatures. For mackerel packed in ice or floated, a peroxide number of 0 to 1 corresponds to an imperceptible degree of rancidity. Peroxide numbers up to 20 indicate a slight degree of rancidity while values of 20 to 40 are definitely rancid. Peroxide numbers greater than about 40 and running up to 200 or more indicate extremely rancid fish.

STUDIES ON THE KEEPING QUALITY OF FRESH MACKEREL

This portion of the work consisted of experiments to test the feasibility of improving present commercial methods of handling fresh mackerel. Experimental runs were made on methods of packing mackerel for shipment and upon the effect of various methods of dressing the fish. Experiments also were run to determine the effect of the size of mackerel upon the rate of spoilage.

GENERAL STORAGE CONDITIONS

Fish were obtained as fresh as possible from the commercial mackerel fishery and were divided into lots and dressed and packed according to the storage method being studied. When the fish were floated care was taken to reproduce, as nearly as possible, standard commercial practice. The regular Irish barrels were employed, and the fish were floated with the same proportions of ice and water as is done commercially. Care also was taken to see that an adequate supply of ice remained in the barrels at all times.

For packing fish in ice, boxes such as are employed for packing haddock were used. The mackerel were packed with an ample supply of finely crushed ice which was replaced at suitable intervals as it melted. All containers were stored at room temperature, usually about 75° F. The temperature of the fish was maintained at about 33° F.

EFFECTS OF METHODS OF PACKING FOR SHIPMENT

A number of experiments were run to determine the relative merits of several methods of packing fish for shipment. Whole fish were used—one lot being floated, another packed in ice, and in some cases eviscerated fish were packed in ice for comparative purposes. Organoleptic tests of these fish were carefully made after varying periods of storage, and at the same time the various scientific tests also were run.

Fish floated in the regular commercial manner kept in good condition for at least 1 day (see table 7). Beginning on the second or third day, however, a pronounced hydrogen sulfide odor developed. After 4 days the mackerel were usually in very poor condition. Whole fish packed in ice remained in excellent condition for a period of at least 4 days, and even after storage of 1 week were usually quite edible. A comparison of the keeping quality of fish packed by the two methods is shown in figure 6. Fish packed in ice kept for more than twice as long as those which were floated.

The hydrogen sulfide and oil tests were the most significant of the scientific tests made. The electrometric test also was run, and in general it confirmed the organoleptic tests.

Hydrogen sulfide formed much sooner and in larger quantities in the floated fish than in those packed in ice (see table 8.) The amount of hydrogen sulfide present in the flesh when the fish were first cut open was nearly as great in the floated fish after 3 days of storage as it was in the fish packed in ice after 2 weeks. Since the presence of hydrogen sulfide in fish is one of the factors detracting from its value, the large difference found is highly significant.

TABLE 7.—*Effect of methods of storage on the keeping quality of mackerel*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Series	Sample	Time stored	Condition as indicated by organoleptic observation: Whole fish—floated: General appearance	Whole fish—floated: Body cavity	Whole fish—floated: Texture of flesh	Whole fish—floated: Odor	Whole fish—floated: Numerical rating	Whole fish—packed in ice: General appearance	Whole fish—packed in ice: Body cavity	Whole fish—packed in ice: Texture of flesh	Whole fish—packed in ice: Odor	Whole fish—packed in ice: Numerical rating	Eviscerated fish—packed in ice: General appearance	Eviscerated fish—packed in ice: Body cavity	Eviscerated fish—packed in ice: Texture of flesh	Eviscerated fish—packed in ice: Odor	Eviscerated fish—packed in ice: Numerical rating
		Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
Bc 173	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	3	XXXX	XX	XX	XXX	61	XXXXX	XXX	XXXX	XXXX	83	XXXXX	XXX	XXXX	XXXXX	92
	C	7	X	X	X	X	20	XX	XX	XXXX	XXXX	62	XXXX	XXXXX	XXXX	XXXX	83
	D	10	X	…	…	…	6	XX	X	X	XX	35	XXX	XXXXX	XXXX	XXX	68
	E	15	…	…	X	…	2	…	X	XXX	X	18	XXX	XXXXX	XXXXX	XXXX	79
Bh 25	A	0	XXXX	XX	XXXXX	XXX	67	XXXX	XX	XXXXX	XXX	67	XXXX	XX	XXXXX	XXX	67
	B	1	XXX	XX	X	XXX	53	XXX	XX	X	XXX	53	…	…	…	…	…
	C	2	XX	XX	X	XX	38	XXX	XX	X	XXXX	62	…	…	…	…	…
	D	4	XX	XX	X	X	29	XX	XX	X	XXXX	56	XXXX	X	XX	XXXX	67
	E	9	…	…	…	…	…	…	…	…	…	…	XXXX	XX	XXXX	XXX	65

Analyses of the oil of mackerel packed by the 2 methods (see table 9) show that the free fatty acid formation is considerably retarded by packing the fish in ice, whereas little actual difference in peroxide

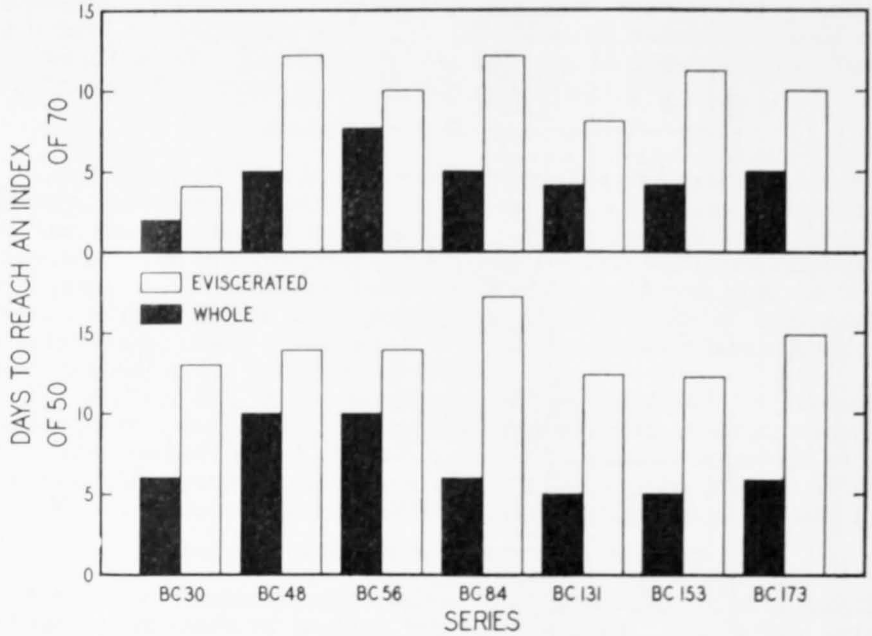

FIGURE 6.—Comparative keeping qualities of whole and eviscerated mackerel packed in ice, determined organoleptically. An index of 70 corresponds to a condition in which the fish, though not strictly fresh, are in fairly good condition. An index of 50 corresponds to incipient decomposition.

number could be shown for the different packing methods. The floated mackerel showed a sharp rise in free fatty acid to a maximum value of 85 percent after 2 weeks, while the ice-stored fish contained less than 8 percent free fatty acid in the oil after a like period. On the other hand, no definite correlation between packing method and peroxide number could be demonstrated. The peroxide number

TABLE 8.—*Hydrogen sulfide formation in floated and iced mackerel, in parts per billion*

Sample	Time stored	Hydrogen sulfide content [1]			
		Floated mackerel		Iced mackerel	
		When opened	After 2 hours	When opened	After 2 hours
A	0	0	0	0	0
B	3	320	160	0	40
C	7	400	360	0	160
D	10	<400	<400	160	320
E	14	<400	<400	360	<400

[1] Expressed as sulfide sulfur in parts per billion.

varied considerably from one fish to another, but with no marked difference in favor of the floated or ice-stored fish.

One reason for the widespread custom of floating mackerel is the belief that this method reduces bleaching of the color from the surface of the fish. Observations were made as to this point during the course of the experiments. After 3 days' storage no difference in bleaching of the colors could be detected between the floated and iced fish. After storage in ice for 1 week the mackerel were definitely lighter in color than when freshly iced—the stripes being more or less faded, the background a greyish hue, and the pearlescent colors had completely disappeared. Mackerel which had been floated for 1 week did not show such a marked bleaching but were usually very stale, if not definitely decomposed.

TABLE 9.—*Effect of method of packing mackerel upon oil decomposition*

Sample	Time stored	Free fatty acid value		Peroxide number	
		Floated mackerel	Mackerel iced in boxes	Floated mackerel	Mackerel iced in boxes
	Days	*Percent*	*Percent*	[1]	[1]
A	0	3.4	3.4	0	0
B	3	2.6	3.3	5.8	1.2
C	7	18.2	2.5	8.0	4.2
D	10	16.8	4.6	0	10.6
E	14	85.2	7.7	15.6	23.0

[1] Millimoles of peroxide per kilograms of oil.

In order to further check the amount of leaching caused by the melting ice, a series of analyses were made for the mineral content of mackerel floated and iced for varying periods. The fish at first contained 1.35 percent ash. After 3 days' storage the iced fish showed no decrease in ash content. After storage for 1 week the iced fish were slightly lower in ash content (1.14 percent) than the floated fish (1.28 percent). It was not until 2 weeks' storage had elapsed that a really pronounced difference occurred. At this time the iced fish contained 0.92 percent ash, as compared with 1.58 percent ash for the floated fish. The increase in this latter sample can be attributed to the decomposed condition of the fish which permitted them to absorb salt from the brine in which they were floated.

Another beneficial result attributed to floating is the prevention of ice marks. Observations were made as to the development of marks on the iced samples and it was soon apparent that if suitable precautions were taken, little or no ice marking of the fish would result. If large pieces of ice were used, and the fish roughly handled, ice marks developed after a very short storage period. On the other hand, if finely crushed ice—such as is used aboard mackerel boats—was employed, and if care was taken to pack the fish in boxes, then no bruising of the fish by ice was encountered. It was believed that possibly the ice marking would be accentuated by actual shipment of the fish, since jostling during transportation might lead to more damage being done by the ice. In order to test this point, two shipments of mackerel were made from Boston, Mass., to Washington, D. C., the fish being packed in boxes of ice. When received in Washington these fish exhibited no signs whatever of ice marks.

An attempt was made to improve the floating of fish. The fish were floated in untreated sea water, sea water treated with perchloron (a germicidal substance), and in a salt-brine solution. The fish floated in the treated sea water kept slightly better than the fish floated in untreated sea water. When a prepared brine was used for floating no improvement in keeping quality of the fish was obtained. These results indicate that floating cannot be used for storing fish successfully, even if the floating water is free of bacteria.

EFFECTS OF METHODS OF DRESSING

COMPARISON OF DRESSING PROCEDURES

A preliminary series of tests was run to compare different methods of dressing. Some of the fish were filleted, some eviscerated, some gibbed, and some were left in the round. Each group was stored separately in boxes of crushed ice. The fillets were wrapped in moistureproof paper and placed in metal fillet boxes to protect them from the melting ice.

Observations made on these fish in storage (see table 10) disclosed the fact that dressed fish kept considerably better than those left in the round; being in better condition after 17 days than the round fish were after 1 week. The fillets kept for 1 week in about the same condition as the round fish and then deteriorated rapidly. The gibbed fish did not keep quite as well as those eviscerated, but very much better than those left in the round.

TABLE 10.—*Effect of methods of dressing on the keeping quality of mackerel packed in ice*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Series	Sample	Time stored	Condition as indicated by organoleptic observation: Eviscerated fish: General appearance	Eviscerated fish: Body cavity	Eviscerated fish: Texture of flesh	Eviscerated fish: Odor	Eviscerated fish: Numerical rating	Gibbed fish: General appearance	Gibbed fish: Body cavity	Gibbed fish: Texture of flesh	Gibbed fish: Odor	Gibbed fish: Numerical rating
		Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
Bc 153	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	3	XXX	XXXX	XXXX	XXXXX	83	XXX	XXXX	XXXX	XXXXX	83
	C	7	XXXX	XXXXX	XXX	XXXXX	90	XXXX	XXXXX	XXX	XXXX	81
	D	11	XXXX	XX	XXXX	XXXX	74	XXX	XX	XXXX	XXX	59
	E	14	XX	XX	XXXX	XXX	53	XX	XX	XXXX	XXX	53
	F	17	XX	XXX	XXXXX	XXX	58	XXX	XX	XXXX	XX	50
Bc 173	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	3	XXXXX	XXX	XXXX	XXXXX	92	XXXXX	XXXXX	XXXX	XXXX	89
	C	7	XXXX	XXXXX	XXXX	XXXX	83	XXXX	XXXXX	XXXX	XXXX	83
	D	10	XXX	XXXXX	XXXX	XXX	68	XXX	XXX	XXXX	XXXX	71
	E	15	XXX	XXXXX	XXXX	XXXX	77	X	X	X	XXX	38

Series	Sample	Time stored	Condition as indicated by organoleptic observation: Whole fish: General appearance	Whole fish: Body cavity	Whole fish: Texture of flesh	Whole fish: Odor	Whole fish: Numerical rating	Fillets: General appearance	Fillets: Body cavity	Fillets: Texture of flesh	Fillets: Odor	Fillets: Numerical rating
		Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
Bc 153	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	3	XXX	XXX	XXXX	XXXXX	80	XXX	(1)	XXXX	XXXX	73
	C	7	XXX	XXX	----	X	36	XX	(1)	X	XX	38
	D	11	XX	X	XX	XX	37	X	(1)	X	X	20
	E	14	X	----	XXX	XX	30	X	(1)	X	----	9
	F	17	XXX	X	X	X	32	----	(1)	----	----	0
Bc 173	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	----	----	----	----	----
	B	3	XXXXX	XXX	XXXX	XXXX	83	----	----	----	----	----
	C	7	XX	XX	XXXX	XXXX	62	----	----	----	----	----
	D	10	XX	X	X	XX	35	----	----	----	----	----
	E	15	----	X	XXX	X	18	----	----	----	----	----

[1] No weight given to this factor, since these were fillets, but a correction was applied to the total rating to compensate for this omission.

The foregoing experiments indicated that mackerel would keep better if eviscerated than if stored whole. However, it was believed advisable to repeat these experiments on a large number of fish at different seasons of the year, so as to take into account any differences caused by varying fat content, presence of red feed in the fish, or other factors. Accordingly, 9 lots of fish were procured at different times, ranging from early summer to late autumn. Fish in each lot were divided into two groups, one of which was left in the round and the other eviscerated. Both dressed and whole fish were then packed in ice and organoleptic and scientific tests were run at intervals. The results of these tests (see table 11) fully confirmed the results of the earlier experiments. In every series the eviscerated fish kept better than the round ones. In some cases the storage life was more than doubled by eviscerating (see figure 6). The biggest improvement was obtained in cases where considerable red feed was present in the fish and the evisceration was carried out immediately after the fish had been caught. On the other hand, evisceration had the least effect in cases where the fish contained much red feed and were not eviscerated until some time had elapsed after catching. The eviscerated fish kept from 41 to 177 percent longer than those left in the round, the average increase in storage life being 119 percent (see table 12).

TABLE 11.—*Effect of evisceration on the keeping quality of mackerel packed in ice*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Series	Sample	Time stored	Condition as indicated by organoleptic observation									
			Eviscerated mackerel					Whole mackerel				
			General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
		Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
Bc 29	A	0	XXXX	XXXXX	XXXXX	XXXXX	94	XXXX	XXXXX	XXXXX	XXXXX	94
	B	7	-----	-----	-----	-----	-----	X	XX	X	XX	32
	C	11	-----	-----	-----	-----	-----	-----	X	-----	X	12
	D	14	X	XXX	X	XX	35	-----	-----	-----	X	9
Bc 30	A	0	XXXX	XXXXX	XXXXX	XXXX	85	XXXX	XXXXX	XXXXX	XXXX	85
	B	3	XXXX	XXXXX	XXXX	XXX	74	XXX	XXX	XXXX	XXX	62
	C	6	XXX	XXXXX	XXXX	XXX	68	XXX	XXX	X	XX	47
	D	10	XXX	XXXX	XX	XXX	61	XX	X	-----	XX	33
	E	13	XXX	XX	X	XXX	53	X	-----	-----	-----	6
	F	19	XXX	XXX	X	XXX	56	XXX	X	-----	X	30
	G	22	X	XXX	X	XX	35	-----	-----	-----	X	9
Bc 48	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	1	XXXXX	XXXXX	XXX	XX	69	XXXXX	XXXX	XXX	XXX	75
	C	4	XXX	XXXX	XXXXX	XXXXX	85	XXX	XX	XXX	XXXXX	75
	D	6	XXXX	XXXXX	XXXXX	XXXXX	94	XX	X	XXXX	XXXX	59
	E	8	XXX	XXXXX	XXX	XXXX	75	XX	XX	XX	XXX	49
	F	11	XXX	XXXX	XXXXX	XXXX	76	XX	X	XXX	XXX	48
	G	14	X	XXX	XX	XXX	46	X	-----	XX	X	19
	H	16	XX	XX	XX	XX	40	X	-----	X	X	17
Bc 56	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	2	XXXX	XXXXX	XXXXX	XXXXX	94	XXXXX	XXXX	XXX	XXX	75
	C	6	XXXX	XXXXX	XXXX	XXXXX	92	XX	XXXX	XX	XXXXX	76
	D	14	X	XX	XXX	XXX	45	-----	X	XX	XX	25
	E	18	-----	XXX	X	X	20	-----	X	X	-----	5
	F	21	-----	XX	X	-----	8	-----	-----	-----	-----	0
Bc 68	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	4	XXXX	XXXXX	XXXX	XXXXX	92	XX	XX	XX	XXXX	58
	C	7	XXXX	XXXX	XXXX	XXXX	80	XX	XXXX	XXXX	XXXXX	77
	D	10	XX	XXX	XX	XX	43	X	-----	-----	XXX	33

TABLE 11.—*Effect of evisceration on the keeping quality of mackerel packed in ice*—Continued

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Series	Sample	Time stored	Condition as indicated by organoleptic observation									
			Eviscerated mackerel					Whole mackerel				
			General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
		Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
Bc 84	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	4	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXX	XXXX	XXXXX	95
	C	7	XXXX	XXXXX	XXXX	XXXX	83	XX	X	XX	XX	37
	D	12	XXX	XXXX	XXXXX	XXX	67	XX	X	XX	X	28
	E	18	XXX	XXXXX	XXXX	XXX	68	XX	XX	XX	XX	40
Bc 131	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	8	X	XXX	XXXX	XXXX	59	X	--------	--------	X	15
	C	11	XX	XXX	XXXX	XXXX	65	--------	--------	--------	XX	18
	D	17	XX	XXX	XXXX	X	38	--------	--------	--------	X	9
	E	23	X	XX	X	X	23	--------	--------	--------	X	9
Bc 141	A	0	XXX	XXX	XXX	XXXXX	78	XXX	XXX	XXX	XXXXX	78
	B	8	XX	XX	XXX	XXXX	60	X	X	X	XX	29
	C	17	XX	X	XX	XX	37	--------	--------	--------	X	9
	D	17	XX	X	XX	XX	37	--------	--------	--------	X	9
Bc 145	A	0	XXX	XXX	XXXX	XXXX	71	XXX	XXX	XXXX	XXXX	71
	B	6	XXX	XX	XXXX	XXXX	68	X	--------	--------	XX	24
	C	15	XX	X	X	XX	35	--------	--------	--------	--------	0
	D	15	XX	X	X	XX	35	--------	--------	--------	--------	0

TABLE 12.—*Increase in storage life of eviscerated mackerel, as compared with whole mackerel, packed in ice*

Series	Increase in storage life due to evisceration			Series	Increase in storage life due to evisceration		
	To reach a freshness index of 70 [1]	To reach a freshness index of 50 [2]	Average		To reach a freshness index of 70 [1]	To reach a freshness index of 50 [2]	Average
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
Bc 30	100	117	108	Bc 131	100	140	120
Bc 48	140	40	90	Bc 153	175	180	177
Bc 56	43	40	41	Bc 173	100	150	125
Bc 84	140	200	170	Average	114	124	119

[1] Fish in good condition although not strictly fresh.
[2] Incipient decomposition; fish barely edible.

The electrometric test was run on all series. As mentioned previously, results by this test are useful only when obtained on fairly oily fish. The electrometric tests confirmed the organoleptic results, showing that eviscerated fish keep much better than the whole ones. Results of one such series are given in table 13. In this series it required about 13 days for the eviscerated fish to reach an index value of 20 (still fairly good, though not fresh), a value reached by the whole fish in 6 days. When applied to mackerel caught in the fall, the test gave erratic results.

TABLE 13.—*Keeping quality of whole and eviscerated mackerel packed in ice, as indicated by the electrometric test*

Sample	Time stored	Freshness					
		Whole mackerel			Eviscerated mackerel		
		A value	B value	B−A+40	A value	B value	B−A+40
	Days						
A	0	35.5	3.0	7.5	35.5	3.0	7.5
B	3	32.2	4.8	12.6	34.9	3.1	8.2
C	6	21.7	1.8	20.1	27.3	4.3	17.0
D	10	22.0	3.5	21.5	25.0	1.7	16.7
E	13	20.4	5.5	25.1	19.8	2.1	22.3
F	19	19.6	4.4	24.8	22.0	3.6	21.6
G	22	19.9	9.4	29.5	18.6	5.4	26.8

BACTERIAL GROWTH [2]

Bacterial counts were made on the fish in five of the test series and in general the eviscerated fish showed higher bacterial counts than the whole fish (see table 14.) This indicates that evisceration stops autolytic rather than bacterial decomposition.

[2] The bacterial counts reported in this section were made by Francis P. Griffiths, formerly junior bacteriologist, U. S. Bureau of Fisheries.

TABLE 14.—*Bacterial count of whole and eviscerated mackerel packed in ice*

Series	Sample	Time stored	Bacterial count per gram of flesh			
			Whole mackerel		Eviscerated mackerel	
		Days	*Number*	*Logarithm of number*	*Number*	*Logarithm of number*
Bc 30	A	0	2, 900	3. 5	2, 900	3. 5
	B	3	9, 000	4. 0	2, 000	3. 3
	C	10	360, 000	5. 6	800, 000	5. 9
	D	13	1, 600, 000	6. 2	23, 000, 000	7. 4
Bc 48	A	0	50, 000	4. 7	50, 000	4. 7
	B	4	100, 000	5. 0	160, 000	5. 2
	C	6	160, 000	5. 2	6, 000, 000	6. 8
	D	8	900, 000	6. 0	3, 500, 000	6. 5
	E	11	4, 900, 000	6. 7	12, 500, 000	7. 1
	F	14	8, 500, 000	6. 9	16, 000, 000	7. 2
	G	16	10, 000, 000	7. 0	2, 000, 000, 000	9. 3
Bc 56	A	0	16, 000	4. 2	16, 000	4. 2
	B	2	150, 000	5. 2	7, 000	3. 8
	C	6	180, 000	5. 3	530, 000	5. 7
	D	14	4, 500, 000	6. 7	4, 400, 000	6. 6
	E	18	46, 000, 000	7. 7	150, 000, 000	8. 2
	F	21	90, 000, 000	8. 0	130, 000, 000	8. 1
Bc 68	A	0	15, 000	4. 2	15, 000	4. 2
	B	4	15, 000	4. 2	44, 000	4. 6
	C	7	330, 000	5. 5	400, 000	5. 6
Bc 84	A	0	3, 800	3. 6	3, 800	3. 6
	B	4	80, 000	4. 9	200, 000	5. 3
	C	7	1, 400, 000	6. 1	4, 000, 000	6. 6
	D	12	14, 000, 000	7. 1	14, 000, 000	7. 1
	D	12	41, 000, 000	7. 6	84, 000, 000	7. 9
	E	18	325, 000, 000	8. 5	180, 000, 000	8. 3
	E	18	116, 000, 000	8. 1	120, 000, 000	8. 1

Since the bacterial counts showed that the eviscerated fish were somewhat more contaminated with bacteria than the whole ones, some experiments were made to see if a treatment of the eviscerated fish with a germicide might reduce such contamination and increase the storage life of the fish. Two types of chemicals were tried, one a hypochlorite (perchloron) and the other an organic compound (chloramine T). Both of these chemicals give off chlorine when dissolved in water. The former was found to be less effective than the latter, since it decomposed very rapidly when in contact with the fish. It was also found that there was an upper limit to the concentration of such compounds which could be used on fish. This maximum limit was a solution containing about 10 parts per million of available chlorine. If stronger solutions were used, the fish were bleached in color and a pronounced chlorine odor was retained by the fish. After being eviscerated the fish were dipped in a solution containing 10 parts per million of available chlorine for 1 minute. While such a treatment definitely reduced the bacterial contamination, it did not increase the storage life of the fish. On the contrary, in some instances the spoilage rate was somewhat increased (see table 15). These results are in agreement with those reported by Stansby and Griffiths (1935) on the chemical treatment of haddock fillets. Apparently even a solution of 10 parts per million of available chlorine reacts with the fish protein, altering it to a form which is more readily attacked by bacteria. Bacterial counts on mackerel treated with such antiseptic solutions showed a decrease immediately after treatment, but upon subsequent storage in ice the counts on the treated fish increased more rapidly than in the case of the untreated mackerel.

TABLE 15.—*Effect of chemical treatment on the keeping quality of eviscerated mackerel packed in ice*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Sample	Time stored	Condition as indicated by organoleptic examination									
		Untreated fish					Treated fish [1]				
		General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
	Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
B	8	X	XXX	XXXX	XXXX	59	XX	XXX	XXX	XX	45
C	11	XX	XXX	XXXX	XXXX	65	XX	XX	X	X	38
D	17	XX	XXX	XXXX	X	38	X	XX	X	XX	32
E	23	X	XX	X	X	23	X	XX	X	X	23

[1] Fish dipped for 1 minute in a solution of chloramine T containing 10 parts per million of available chlorine.

OIL DECOMPOSITION

Tests on the oil in the eviscerated and whole fish (see table 16) indicate a somewhat greater rate of oxidation of the oil and a slightly lower rate of free fatty acid formation in the eviscerated fish. Especially during the first few days of storage, the eviscerated fish have higher peroxide numbers in the oil than the whole fish and the difference is sometimes quite pronounced. For the first few days of storage the whole fish show peroxide numbers of 0 to 1, with the average about 0.6. The corresponding peroxide numbers for eviscerated fish range from 0 to 8, with an average of about 4. Peroxide numbers of 0 to 1 usually correspond to a degree of rancidity so small as to be imperceptible, while values up to 8 usually correspond to a slight degree of rancidity.

In order to further check the difference in rancidity between the eviscerated and whole mackerel, cooking and tasting tests were made. It was found that the average person could not distinguish between the oil from eviscerated and whole mackerel. However, persons with unusually acute sense of taste pronounced the eviscerated fish to have a slight degree of rancid flavor as compared to no rancidity in the whole fish. In fish stored for more than 3 days no difference could be detected by tasting tests, since both the whole and eviscerated fish possess a slight degree of rancidity.

TABLE 16.—*Keeping quality of the oil in whole and eviscerated mackerel packed in ice*

Time stored	Peroxide number [1]						Free fatty acid value [2]					
	Whole mackerel			Eviscerated mackerel			Whole mackerel			Eviscerated mackerel		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Days	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
0	0.6	0	0.1	0.6	0	0.1	3.4	1.5	2.4	3.4	1.4	2.4
1-3	1.2	0	.6	8.2	0	4.1	3.8	3.3	3.6	4.7	1.7	3.2
4-7	4.9	.6	3.2	15.0	.4	6.9	7.9	2.5	4.5	3.4	2.2	2.9
8-11	10.6	2.6	6.4	10.1	1.6	5.9	5.1	2.1	3.9	5.0	1.8	2.9
Over 11	23.0	3.4	7.9	38.5	6.2	11.8	7.8	2.4	4.9	7.9	2.6	4.1

[1] Millimoles peroxide per kilogram of oil.
[2] Percent of free fatty acid.

SHRINKAGE OF EVISCERATED FISH

If fish are eviscerated there will be a reduction in weight due to the loss of the viscera. A number of experiments were run to determine the percent of loss from this source (see table 17). The loss in weight averages 8 percent, with a fairly small deviation from this value from fish to fish. During season the roe could be saved for sale as a byproduct, since it is eaten by many people, and if this was done it should more than offset the cost of evisceration and the accompanying shrinkage.

When fish are packed in ice they either gain or lose weight, depending upon storage conditions. A few experiments were run to determine the nature and extent of such changes in eviscerated and whole mackerel. Preliminary work showed that unless the fish were kept well covered with ice rather large losses in weight occurred, due to evaporation. When sufficient ice was present to cover the fish at all times, the loss from this source was kept at a minimum. Although whole fish usually lost less weight than the eviscerated fish when stored in ice (see table 18), the loss in weight in either case was so small as to be almost negligible. Thus, after 8 days' storage, the loss was 3.3 percent for the eviscerated fish and 1.6 percent for the whole fish. Moreover, after prolonged storage the eviscerated fish lost slightly less weight (6.8 percent) than the whole fish (7.9 percent). The importance of keeping the fish well covered with ice cannot be overemphasized. When an inadequate amount of ice is present, losses in weight are often several times as high as the figures given above.

Table 17.—*Loss in weight of mackerel due to evisceration* [1]

Weight of whole fish	Weight of eviscerated fish	Loss in weight
		Percent
363	338	6.9
412	381	7.5
416	386	7.2
421	386	8.3
449	414	7.8
459	420	8.5
461	421	8.6
498	450	9.6
533	494	7.3
Average		8.0

[1] Weight is given in grams.

Table 18.—*Changes in weight of whole and eviscerated mackerel stored in ice*

Sample	Time stored	Changes in weight	
		Whole fish	Eviscerated fish
	Days	*Percent*	*Percent*
A	2	+1.1	+1.1
B	2	0	−2.3
C	2	−0.7	−1.7
D	2		−.9
Average	2	+0.1	−.9
A	8	+1.5	−3.9
B	8	−5.4	−4.2
C	8	−0.6	−4.1
D	8		.6
Average	8	−1.6	−3.3
A	11	0	−5.2
B	11	−6.4	−4.5
C	11	−1.5	−5.1
D	11		−1.2
Average	11	−2.6	−4.0
A	17	−9.0	−6.5
B	17	−6.9	−8.4
C	17		−4.8
Average	17	−7.9	−4.9

INFLUENCE OF DELAY IN DRESSING

Experiments were conducted to determine whether it is necessary to dress mackerel immediately after they are caught in order to increase their keeping quality. About 100 mackerel were obtained which had been caught 12 hours previously. These were divided into several lots; one lot being eviscerated, another gibbed, and a third left in the round—all three being packed in ice. A fourth lot was floated in the ordinary commercial manner. After 1, 2, and 4 days of storage some of the iced whole fish and some of the floated fish were withdrawn and subdivided into two lots, one of which was gibbed and the other eviscerated. They were labeled to distinguish the different treatments, again packed in ice, and, after a total of 9 days of storage, careful organoleptic tests were made on all samples.

The results of these experiments indicate that mackerel should be dressed as soon as possible after catching in order to insure maximum keeping quality (see table 19). Fish held up to 36 hours in ice (including 12 hours aboard the fishing boat) and then dressed, showed no appreciable decrease in keeping quality over those dressed at the earliest possible time. Fish floated for 1 day, or stored in ice for 2 days, were not greatly benefitted by being dressed, although they did keep slightly better than those stored whole for the entire period. These experiments indicate that fish should be dressed either aboard the fishing boat or immediately after they are landed. If they are shipped in the round and eviscerated when received by the retailer, much of the advantage of evisceration will be lost.

TABLE 19.—*Effect of time and method of handling, prior to dressing, on subsequent keeping quality of mackerel*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Method and time of storage (days)	Condition of dressed fish after a total of 9 days in storage									
	Eviscerated and packed in ice					Gibbed and packed in ice				
	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
Whole fish, floated:	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
0	XXXX	XX	XXXX	XXX	65	XXXX	X	XXXX	XX	53
1	XX	X	XX	XX	37	XX	X	X	XX	35
2	XX	------	X	X	23	XX	------	------	X	21
4	X	X	------	------	9	X	------	------	------	6
9	------	------	------	------	0	------	------	------	------	0
Whole fish, iced:										
0	XXXX	XX	XXXX	XXX	65	XXXX	X	XXXX	XX	53
1	XXXX	X	XXX	XXX	60	XXXX	X	XXX	XX	51
2	XXX	X	XX	XX	43	XXX	X	XX	XX	43
4	XX	X	X	X	26	XX	X	X	X	26
9	XX	------	------	X	21	XX	------	------	X	21

EFFECT OF SIZE OF FISH UPON SPOILAGE RATE

One series of fish was used to determine the effect of the size of the fish upon the spoilage rate. The fish for this test were obtained directly from a fishing boat, and had been caught about 6 to 10 hours previously. These fish were divided into two lots, one lot having an average weight of 0.77 pound and the other an average weight of 1.6 pounds. They were then floated whole in mackerel barrels containing harbor water.

The difference in spoilage rate was quite evident. After 6 days in storage the small fish were badly decomposed, with viscera protruding through the skin, while the large fish were in better condition. Table 20 summarizes the organoleptic tests. One difference in spoilage which was quite marked was the effect of the size of the fish upon the degree of rigor mortis. The small fish never reached the same pronounced degree of stiffness that the large ones did, and the stiffness wore off more rapidly. After 2 days rigor mortis declined in both lots. After 4 days the small fish were only slightly stiff in the tail region, whereas the large fish were fairly stiff throughout. This relative difference persisted to the end of the series. In this connection it is interesting to note the A value of the electrometric test, which is more or less proportional to the degree of rigor present. In this instance it was consistently higher for the larger fish (see table 21).

TABLE 20.—*Effect of size upon the keeping quality of floated mackerel*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Sample	Time stored	Condition as indicated by organoleptic examination									
		Small fish					Large fish				
		General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
	Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
A	0	XXXX	XXXXX	XXXXX	XXXXX	94	XXXXX	XXXXX	X	XXXX	83
B	2	XXX	XXXX	XXXX	XXX	65	XXX	XXXXX	XXXX	XXXX	77
C	4	XX	XXX	X	XX	41	XXX	XXXXX	X	XXXX	71
D	6	X	XX	----------	XX	30	XX	XXX	X	XX	41
E	8	X	X	X	X	20	XXX	X	X	--------	23

TABLE 21.—*Effect of size of fish on rigor mortis*

Storage time	Small fish		Large fish	
	Degree of rigor mortis	A value	Degree of rigor mortis	A value
Days				
0	Fairly stiff	26.2	Very stiff	29.0
2	Rigor beginning to disappear	27.7	Very rigid	31.8
4	Fish still stiff at tail	25.5	Rigor still present though not pronounced	30.5
6	Rigor absent	22.9	Rigor present but beginning to disappear in some fish.	26.0
8	do	20.6	Rigor absent except a slight stiffness in tail region.	24.5

DISCUSSION

GENERAL CONSIDERATIONS

The foregoing section has shown that when mackerel are iced, rather than floated, a considerable increase in storage life takes place, and that the keeping quality can be further increased by eviscerating the fish as soon as possible after they are caught. It has also been shown that when reasonable care is taken in packing the fish in ice they are not unduly bruised or bleached. Indeed, it is hard to reconcile the prevailing belief that shipment of mackerel with ice alone ruins them by causing ice marks and bleaching, especially in view of the fact that mackerel are at present packed in ice on board the fishing vessels for periods up to 3 days and subjected to considerable jostling caused by the motion of the vessel. This treatment is much more drastic than the action of the ice during shipment by express which, under present methods of distribution, rarely requires over 24 hours and is accompanied by much less vibration and jostling than occurs aboard a boat. It is difficult to imagine how the ice storage on board a boat can cause no ill effects, and the subsequent shorter storage during shipment can cause so much damage; as is believed by some to be the case. Moreover, mackerel are shipped in other countries in ice without any complaint of bruising or bleaching, and some dealers in this country now ship in ice with complete satisfaction.

5. Scientific tests can be used to supplement organoleptic tests in evaluating the condition of mackerel. Tests for hydrogen sulfide, and rancidity tests are of special value when used in conjunction with observations as to appearance, odor, and flavor.

6. Mackerel will keep in much better condition if packed in finely crushed ice than if floated in sea water, as is now practiced by the industry. Mackerel stored by the floating method keep in good condition for only about 4 days. When stored in boxes of ice the storage life is increased to a week or more.

7. If care is used in packing mackerel in the special grade of finely crushed ice now available for use by the mackerel boats, bruising of the fish while in transit is practically eliminated and the colors are not bleached materially, except after prolonged storage.

8. A substantial saving on express rates can be made by shipping mackerel in ice.

9. Eviscerated mackerel will keep about twice as long as whole ones, provided the fish are dressed as soon as possible after they are caught.

10. The mackerel industry is confronted with the problem of a widely fluctuating supply of fish and a very limited market. At times when mackerel are found in great abundance the price often falls to levels below production costs. By widening the market, these large fluctuations in price could be considerably diminished, greatly stabilizing the industry. It has been shown that by adopting improved methods of shipment these fish can be transported to Midwestern markets in much better condition than under methods now prevailing, thus increasing the popularity of mackerel and creating an outlet for the surplus which cannot readily be absorbed by the present limited market along the Atlantic seaboard.

RECOMMENDATIONS

I. To producers.—

1. It is recommended that the practice of floating mackerel be discontinued, and that the fish be shipped in boxes of finely crushed ice.

2. If for any reason mackerel must be floated, use sea water that has been chlorinated. Under these circumstances a label should be affixed to each barrel, similar to the one suggested below:

WARNING!

REMOVE THE FISH FROM THIS BARREL IMMEDIATELY UPON RECEIPT AND PACK THEM IN ICE.

This barrel is intended only as a shipping container. Its use for storage purposes will result in rapid deterioration of the fish herein contained.

This practice would add but very little to the cost of production, and would materially assist in the general improvement of present retail handling methods.

3. In no case should mackerel be shipped more than 400 miles by the floating method. For distances of 400 to 1,000 miles icing in the round will usually be sufficient. However, for distances of more than 1,000 miles mackerel must be eviscerated and iced.

II. To retail fish dealers.—

1. In dealing with the wholesaler emphasize a preference for mackerel which have been shipped in ice, similar to the manner in which other species are handled.

2. When mackerel are received in barrels (floated) they should be removed from the water immediately and be repacked in crushed ice.

3. Mackerel which are eviscerated will keep much better than if left in the round. Therefore, it is to your advantage to eviscerate (dress) the mackerel you receive before placing them on sale, thus reducing losses due to spoilage. In adopting this method, you will also provide your customers with mackerel in the best possible condition—a service which should materially increase the demand for fresh mackerel.

4. If the customer indicates that the fish is to be broiled, the method of dressing illustrated in figure 3 (see p. 7) should be followed.

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