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Report of the National Marine Fisheries Service Fishery Products Technology Laboratory, Pascagoula, Fiscal Years 1970 and 1971

TRAVIS D. LOVE, MARY H. THOMPSON,
and MELVIN E. WATERS

SEATTLE, WA.
June 1972

U.S. DEPARTMENT OF COMMERCE
Peter G. Peterson, Secretary
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator
NATIONAL MARINE FISHERIES SERVICE
Philip M. Roedel, Director

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by

TRAVIS D. LOVE, MARY H. THOMPSON,

AND MELVIN E. WATERS[1]

Introduction

In 1969, commercial landings of fish and shellfish in the southeast region amounted to over 1.94 billion pounds, a gain of approximately 17% over the previous year, and accounted for 46% of the total U.S. catch. The value totaled $188 million (an increase of 17% over 1968), representing 36% of the total value landed in the U.S. This increase came in spite of the damage Hurricane Camille inflicted upon the fisheries of Alabama, Mississippi, and Louisiana. Of the states comprising the southeast region, Louisiana accounted for the largest landings and value of catch.

Menhaden led the list of the most important species being landed in this region with shrimp as the second. Shrimp remains the most important in dollar value, accounting for almost $116 million in 1969. Blue crabs and oysters also made important contributions to the catch and value. Oyster landings were down due to the extensive damage to the beds caused by the hurricane.

The year of 1970 produced some increases and decreases in the overall economy in the region. Total catch amounted to 1.97 billion pounds, up only 1.3% over 1969, accounting for 41% (down 5%) of the total U.S. catch. The value of this catch totaled $194 million, an increase of 3% over 1969. The value represents 32% of the total U.S. catch.

The total catch of menhaden, taken principally by South Atlantic and Gulf fishermen, was the largest since 1962. Landings were 17% greater than 1969 and 27% greater than the 1964-1968 average of 1.4 billion pounds.

Shrimp is the first domestic fishery to exceed $125 billion. Landings in the Gulf states approached the 1954 record of over 237 million pounds. Excellent fishing in both inshore and offshore waters of Louisiana and Texas greatly contributed to the near record volume of landings. Fishermen along the South Atlantic coast, however, had a poor year.

Oyster production declined in all Gulf states; production decreased significantly in South Carolina. A factor in the decline of Gulf states was that oyster reefs in Louisiana and Mississippi waters had not fully recovered from the effects of Hurricane Camille in 1969.

The blue crab catch in the Region increased over 1969 but was well below the 1964-1968 average of 152 million pounds.

The catch of calico scallops also showed a significant increase over the previous year.

This report summarizes the results of research carried out the past two years on improving the handling and processing methods for Gulf of Mexico and South Atlantic (Southeast Region) fish and shellfish. Several other important short-term projects initiated to aid the fishing industry are also described.

The Hurricane Camille Disaster

Early in the morning of August 17, 1969, Hurricane Camille dealt the fishing industry of Mississippi and Louisiana a nearly mortal blow. The seafood processing industry in the Biloxi-Gulfport area is located either directly on the Gulf or only a a few miles inland on Biloxi Bay. The 200-mile

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Figure 1. Destruction to the Biloxi seafood processing industry caused by Hurricane Camille.

per hour winds and associated 18- to 21-foot tides leveled or severely damaged all the seafood producing firms. Very little of the warehoused merchandise had been removed from the area prior to the arrival of Camille. When the storm left the area nearly 200,000 cases of canned seafood worth $2 million littered the waterfront intermingled with processing machinery, debris, and mud.

The local industry appealed to the NMFS for aid in recovering as much of their merchandise as possible. In accordance with the Federal policy of extending as much aid as possible to victims of natural disasters, eight technologists and one fishery marketing specialist agreed to cooperate with the American Shrimp Canners Association in helping reclaim as much of the stock as possible. In addition, the technologists provided advice and help in restoring all of the shore facilities to as near pre-Camille conditions as possible.

The American Shrimp Canners Association arranged for a mechanical can cleaner to be provided by the Lansing B. Warner Company. We provided the manpower necessary to assemble the machine in one of the four buildings remaining. After the necessary materials were available (i.e., water, steam, electricity, and chemicals), we remained at the site to aid in checking the reprocessed cans for imperfections.

The reclaiming machine is shown in Figure 2. Although the cleaning apparatus looked rather amateurish, it was surprisingly effective. The cans were introduced at one end where they were cleaned of mud, labels, and debris. Next, the cans entered an electrolytic tank where rust was removed and pin holes exposed. Subsequently the cans were washed and finally sprayed with a thin coat of oil. Plant personnel, under the supervision of the NMFS's technologists, inspected each can and discarded the swelled cans and those containing pin holes. The cans of seafood were separated into codes, packed in cases, and stored for shipment.

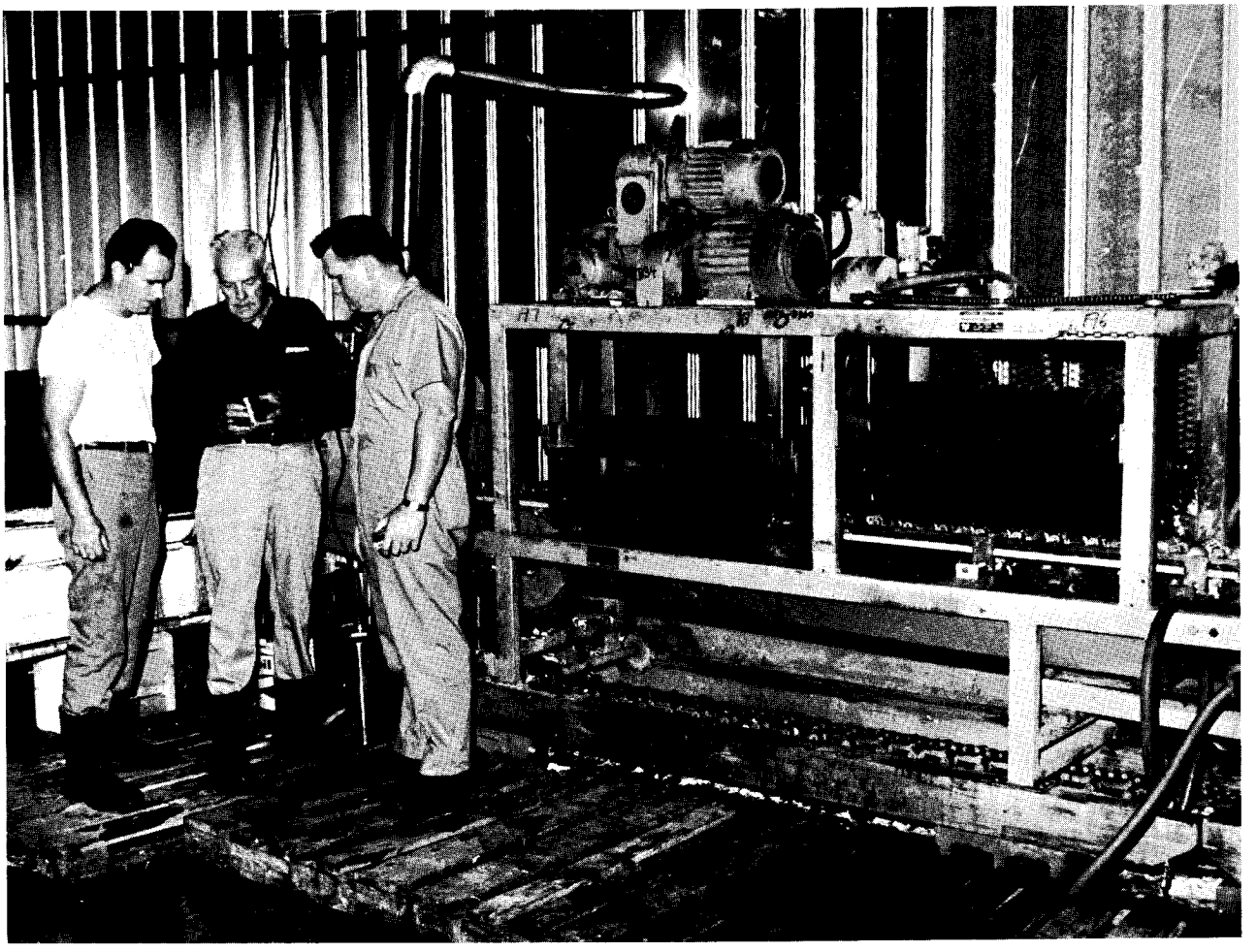

Figure 2. The reclamation of canned seafood products with the aid of the mechanical can cleaner.

During the period of September 15 to November 21, approximately 92,000 cases of canned shrimp, crab, and oysters, with a value of over $1 million, were reclaimed. With this cash income and with stock available to market, most of the canning industry along the coast was able to survive and rebuild.

Numerous requests for technological advice resulted from the hurricane. The staff was invited to sit with the Governor's Council and the Mississippi Research and Development Board in planning the removal of the seafood industry from the hurricane-prone peninsula area to a suitable industrial park on high ground on Back Bay. Meetings were also attended where the Small Business Administration and the Office of Economic Opportunity were attempting to stimulate the formation of a fisherman's co-op for the rebuilding of docks and shore installations.

As a reward for the staff's efforts after Hurricane Camille, all participating personnel were given a written citation and a cash award by the NMFS. At the spring meeting of the American Shrimp Canners Association, the staff was individually cited and a Seth Thomas barometer was awarded jointly to those participating in Operation Clean-Up.

Processing and Preservation of Fishery Products

We continued our work in developing new or improved handling and processing methods for a variety of fish and shellfish. The new techniques are being developed in order that, with increased shelf life, the markets for southern fish and shellfish might be increased.

Figure 3. The seafood industry of the Biloxi area is almost totally rebuilt one year later.

This report describes our research during fiscal years 1970 and 1971 in the following areas: prevention of the browning of the flesh and skin of snappers, *Lutjanus* spp. and *Ocyurus* sp.; prevention of rancidity in frozen spanish mackerel, *Scomberomorus maculatus;* prevention of blue discoloration in canned blue crab. *Callinectes sapidus;* measuring the drip loss of the southern oyster, *Crassostrea virginica;* prevention of black discoloration in the scarlet prawn, *Penaeus edwardsianus,* and determining bacteria of public health significance in fresh water catfish, *Ictalurus punctatus.* We also experimented with producing a fermented fish product from a number of underutilized fish species including thread herring *(Opisthonema oglinum),* whiting *(Menticirrhus americanus, M. littoralis),* white trout *(Cynoscion arenarius, C. nothus),* spot *(Leiostomus xanthurus),* harvest fish *(Peprilus paru),* ribbon fish *Trichiurus lepturus),* blue fish *(Pomatomus saltatrix),* menhaden (*Brevoortia patronus*), croaker (*Micropogon undulatus*), butterfish (*Peprilus burti*), catfish (*Galeichthya felis*), and bumper (*Chloroscombrus chrysurus*).

As interest in the environment continued to mount, we became involved in a collaborative study of chlorinated pesticide residue analysis methodology. The Laboratory also developed a method for the analysis of heavy metal residues. In the latter study, we attempted to determine the amount of copper, zinc, lead, mercury, arsenic, and selenium that would be removed from a variety of fishes by the normal filleting procedures. A concerted effort was made to determine a suitable method for analyzing fishery products for mercury.

The discussion of our work that follows is divided into two parts — (1) species and (2) processing.

Species

The following sections describe the continuation of our work dealing with red snapper, spanish mackerel, blue crab, oysters, fresh water catfish, and scarlet prawns. The research conducted on these species is species-oriented in that the results cannot necessarily be extrapolated to other species. Conversely, the research described in the processing section is applicable to a number of species.

SNAPPER

During FY 69 our research showed that the application of a 0.1% aqueous dip of TDP (3,3'-thiodipropionic acid) for 5 minutes to the surface of snapper fillets and steaks would prevent the appearance of flesh discolorations. When used in conjunction with a package excluding oxygen, snapper fillets or steaks could be preserved for a year or more. The publishing of this new technique in preservation resulted in a large number of inquiries from persons engaged in the industry — from fisherman to broker.

We attempted to determine the basis of the reaction involved in the browning as well as the possible mechanism through which the TDP pre-

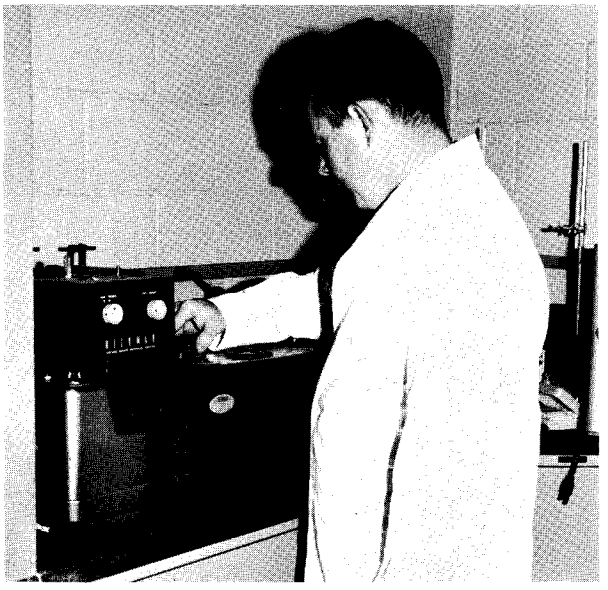

Figure 4. Determining the free and total ribose content of snapper flesh.

vented the browning. We felt that, if this background information was availabe, the use of TDP might be profitably extended to other species.

In general, reactions producing brown discoloration belong to one of two types, enzymatic or non-enzymatic. Enzymatic reactions occur in the presence of oxygen and may be prevented by the use of antioxidants. Non-enzymatic browning involves the reaction between reducing sugars and amino compounds, such as amino acids or proteins. This type of reaction has been called the Maillard reaction and is responsible for the brown color of fried potatoes. The latter is desirable when necessary for the organoleptic qualities of such a product as potato chips but highly undesirable for a product whose eye appeal depends upon whiteness. It may be prevented by the use of a class of compounds which are antioxidants and which also interfere with the production of certain intermediate compounds produced in the Maillard reaction. Thus, the reaction is not allowed to continue to the brown stage.

Previously we had determined that ordinary food grade antioxidants such as BHT (butylated hydroxytoluene), PG (propyl gallate), BHA (butylated hydroxyanisole), and TBHQ (monotertiary-butylhydroquinone) did not prevent the onset of browning. Two compounds — TDP and glutathione — with a history of preventing non-enzymatic browning did, however, prevent the browning of snapper flesh.

Since the measure of decreasing amounts of reducing sugars indicates a Maillard reaction between the sugars and the amino compounds, we decided to measure both total and free ribose in an attempt to determine if the Maillard reaction was indeed taking place.

The data is presented in Table 1 as averages of duplicate analyses. Over a 12-month frozen storage period the free and total ribose content of the TDP and glutathione treated fillets showed a change of 2.30 μg/g in free ribose content from the 1-month to the 12-month draw while the glutathione treated fillets showed a change of only 0.39 μg/g in free ribose content over the same period of storage.

The same trend was observed with the total ribose content of the TDP and glutathione treated fillets. The TDP treated fillets changed in total ribose content by only 3.96 μg/g during their 12-month storage period while the glutathione treated

Table 1.--Free and total ribose content of red snapper meat.

	Averages of duplicate analyses					
	1-month draw	2-month draw	3-month draw	6-month draw	9-month draw	12-month draw
	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g
Free ribose						
Control	13.64	12.93	13.24	11.14	10.43	9.71
Thiodipropionic acid	10.87	10.33	11.01	5.19	4.78	8.57
Glutathione	11.10	10.47	7.61	10.27	10.44	10.71
EDTA + PG	12.15	4.18	7.34	5.07	4.78	7.33
TBHQ	19.27	8.01	16.29	3.11	--	6.88
Total ribose						
Control	31.15	21.51	26.21	21.16	19.88	15.77
Thiodipropionic acid	39.15	18.27	35.82	27.39	21.51	35.19
Glutathione	33.54	19.78	23.84	14.32	28.05	24.91
EDTA + PG	36.88	25.24	28.24	20.01	35.72	23.91
TBHQ	38.04	17.21	28.72	24.43	17.35	25.70

Table 2.--Changes in texture scores of spanish mackerel fillets and free fatty acid content of spanish mackerel oil during storage at -10° F after treatment with EDTA compounds.

Type of pack	Texture score of fillets stored for: 3 months	6 months	9 months	12 months	Free fatty acid content of fillet oil stored for: 3 months	6 months	9 months	12 months
					Percent as oleic			
Control	3.3	3.3	2.6	1.9	2.81	6.35	6.81	6.88
Injected with:								
EDTA								
250 ppm	2.5	2.7	2.6	1.9	--	5.38	4.74	7.69
180 ppm	3.0	2.7	2.2	1.6	--	4.61	4.74	6.10
125 ppm	3.0	2.5	3.0	1.9	--	4.44	5.65	5.17
$(Na)_2CaEDTA$								
250 ppm	3.5	3.5	2.8	1.9	--	4.31	6.26	4.81
180 ppm	3.7	3.3	2.8	1.6	4.61	3.40	5.92	4.31
125 ppm	3.4	3.8	2.8	1.9	5.09	3.66	3.63	5.88
Na_2EDTA								
250 ppm	3.0	3.5	3.0	1.6	2.12	2.44	4.31	4.36
180 ppm	2.5	3.8	2.8	1.6	2.04	4.39	5.84	5.72
125 ppm	2.5	2.8	--	1.9	3.03	3.52	4.89	4.09
Na_4EDTA								
250 ppm	3.7	3.3	3.2	1.9	2.09	3.35	5.54	4.66
180 ppm	3.5	3.5	3.4	2.9	2.68	3.60	5.71	4.03
125 ppm	3.3	3.7	2.8	1.9	2.22	4.80	4.82	--
Ca_2EDTA								
250 ppm	2.8	2.8	3.0	1.9	2.41	4.56	6.27	4.94
180 ppm	3.1	3.7	3.0	2.9	2.22	3.02	4.28	3.71
125 ppm	2.8	3.8	2.6	2.9	2.09	4.45	5.17	5.58
Dipped in:								
EDTA								
250 ppm	3.1	3.2	2.2	1.9	5.89	4.67	6.26	5.85
180 ppm	3.1	2.8	2.6	1.6	3.38	5.01	2.40	5.77
125 ppm	3.1	3.2	2.6	1.6	2.04	3.68	5.93	4.03
$(Na)_2CaEDTA$								
250 ppm	3.3	3.2	3.2	1.6	--	5.29	10.60	6.16
180 ppm	2.9	3.5	2.8	1.6	2.95	2.92	5.85	4.96
125 ppm	2.7	3.0	2.8	1.9	3.32	--	6.03	4.30
Na_2EDTA								
250 ppm	3.4	3.3	2.4	1.9	10.02	4.24	5.61	9.25
180 ppm	3.3	4.0	2.8	1.9	35.90	3.54	5.62	4.96
125 ppm	3.0	3.8	2.2	1.6	2.01	3.25	5.44	3.51
Na_4EDTA								
250 ppm	2.1	3.2	--	1.9	7.23	6.00	5.98	6.77
180 ppm	2.4	4.0	3.4	2.6	1.96	2.87	4.49	4.01
125 ppm	3.1	3.5	2.8	2.9	2.06	6.70	3.99	7.96
Ca_2EDTA								
250 ppm	2.7	4.2	3.0	1.6	3.21	4.48	4.16	6.71
180 ppm	2.7	3.8	2.8	1.9	2.95	4.34	4.74	6.63
125 ppm	2.8	3.7	2.4	2.9	2.54	--	8.12	4.01

fillets changed by only 8.63 $\mu g/g$ during the same period of storage. The control fillets and all of the fillets treated with EDTA + PG and TBHQ showed significantly greater changes in free and total ribose content over the 12-month storage period than did the TDP and glutathione treated fillets. This ribose data correlates well with organoleptic scores and visual color observations of the browning of the snapper flesh. Thus the chemical data supports our original hypothesis showing involvement of the Maillard reaction in snapper flesh discoloration.

SPANISH MACKEREL

One of the problems associated with the minimized market distribution of Spanish mackerel has been the pronounced tendency of this species to develop rancid-like odors and flavors in a relatively short period of frozen storage. During the previous fiscal year we found that the injection of or a dip in a solution of 250 ppm Na_2EDTA (disodium ethyldiaminetetraacetate) would prevent the appearance of the off-flavor and odor for at least 12 months when stored at -10° F. We did find, however, that there was a tendency for Na_2EDTA treated mackerel to become slightly tough in texture.

There are a number of salts of EDTA as well as the acid form which, having a similar action in chelating metal ions, might perform as well in preventing rancidity without causing the side effect of tough texture. Therefore, late in FY 69 we packed a second lot of Spanish mackerel. In this experiment mackerel fillets were either injected with or dipped into water solutions of varying strengths (125 ppm, 180 ppm, and 250 ppm) of the following compounds: EDTA (ethylenediaminetetraacetic acid), $(Na)_2CaEDTA$ (calcium disodium ethylenediaminetetraacetate), Na_2EDTA, Na_4EDTA (tetrasodium ethylenediaminetetraacetatic) and Ca_2EDTA (dicalcium ethylenediaminetetraacetate). We then packed the fillets into Cryovac[1] vacuum bags, froze them, and stored them at -10°F. A sublot packed in a similar manner, but without additives, served as a control.

As before, we evaluated the pack at 3, 6, 9, and 12 months of frozen storage. Organoleptic ratings were based on a scale of 5 (excellent) to 0 (inedible). The free fatty acid content and the peroxide content of the oil were also followed throughout storage.

At the end of the 12-month storage period, the organoleptic scores for texture showed that treatment with either 180 ppm Na_4EDTA or 180 and 250 ppm Ca_2EDTA resulted in the best product. Scores indicate a slightly tough texture in samples treated with EDTA, $(Na)_2CaEDTA$, and Na_2EDTA (Table 2). Rancidity was not detected by the taste panel in any treated sample, even after 12 months of frozen storage.

No significant change in the free fatty acid content was observed in the treated samples. The free fatty acid content in the oil of the control did double during the storage period, however, it did not increase to a level significantly beyond that of the treated samples. Peroxide values were erratic but did not appear sufficient to signify advanced deterioration of the oil.

The development of rancidity in frozen Spanish mackerel fillets has been arrested for a minimum of 12 months. Spanish mackerel fillets can be dipped or injected with 180 ppm Na_4EDTA or Ca_2EDTA and vacuum packed to produce an excellent product stable over extended storage time. Flavor, appearance, and texture will remain excellent. The cost of this processing technique is small after an initial investment for vacuum packaging equipment.

BLUE CRAB

In the early summer of 1969 several processors were troubled with the appearance of blue discoloration in canned crab meat. The blue discoloration is not a new problem but its occurrence is of a sporadic nature. The problem may be a severe one in a certain area one year, another area the next year, or it may die out completely and not occur for 7 or 8 years. A group of those processors affected asked us to devise a series of experiments to determine the cause(s) and method of prevention.

After several experiments we found a number of things which were not involved in influencing the blue discoloration. These were as follows: (1) the use of expired crabs, (2) the use of a parchment liner, (3) the method used for obtaining a vacuum in the can, (4) the plant water supply, and (5) the presence of copper, ammonia, and sulfur ions.

While we were experimenting with the effect of various metal ions on the development of the blue color, we found that it could always be produced by adding iron ions to the crab meat before processing. The final experiment involved adding dilute solutions of the following compounds to crab meat prior to processing: ferrous ammonium sulfate $[Fe(NH_4)_2(SO_4)_2]$, ferric chloride $[FeCl_3.6H_2O]$, ammonium citrate $[(NH_4)_2HC_6H_5O_7]$, ammonium chloride $[(NH_4CL)]$, ammonium sulfate $[(NH_4)_2SO_4]$, cuprous chloride $[(CuCl)]$, cupric sulfate $[Cu_2SO_4]$, ammonium nitrate $[NH_4NO_3]$ and ammonium oxalate $[NH_4)_2C_2O_4.H_2O]$. Distilled water served as a control. After processing and 3 days of storage, the cans of each variable were examined. The results are shown in Table 3.

The copper compounds were included in the experiment since several investigators had found

Figure 5. A can of normal blue crab meat is shown together with a can of severely discolored crab meat.

copper to be incriminated in the formation of blue compounds. The other compounds were added to determine whether the remaining ions in the two iron compounds used could also be partially responsible for the blueing. This experiment was repeated several times using crab meat obtained from different areas. In every case, cans containing either form of iron were heavily discolored while those not containing iron were not appreciably affected. Apparently, at some time during the processing procedure iron is introduced in sufficient quantity to cause blue discoloration.

Now that we found that we could produce the blue color by adding iron we could test a number of compounds for their effectiveness in retarding its formation. Various organic acids have been used to prevent such discolorations. Table 4 shows the results of the experiment in which various levels of citric, ascorbic, lactic, and tartaric acids in water were added to cans in the presence of added iron. Only the 3 and 5% solutions of citric acid were effective in preventing blueing. These levels of citric acid, however, produced a bitter taste in the crab meat.

In an effort to reduce the level of citric acid needed, we experimented with various EDTA compounds. We felt that the EDTA compounds might chelate the iron, thus, by removing one of the participants, keeping the reaction to a minimum.

Table 3.--Results of adding chemicals containing $SO_4^{=}$, NH_4^{+}, Cu, and Fe^{++} and Fe^{+++} ions to canned crab meat.

Additive	Concentration	Visual rating[1/]
Cu_2SO_4	0.1M	++
CuCl	0.1M	++
$(NH_4)_2C_2O_4 \cdot H_2O$	0.1M	0
$Fe(NH_4)_2(SO_4)_2$	0.005M	++++
$FeCl_3 \cdot 6H_2O$	0.1M	++++
	0.05M	++++
	0.01M	++++
$(NH_4)_2HC_2H_5O_7$	0.1M	+
NH_4NO_3	0.1M	+
	0.01M	+
NH_4Cl	0.1M	+
	0.01M	+
$(NH_4)_2SO_4$	0.1M	+
	0.01M	0

1/ 0 = no visible blueing
+ = very slight blueing
++ = slight blueing
+++ = moderate blueing
++++ = heavy blueing

Table 4.--Results of adding organic acids to canned crab meat to prevent blueing.

Additive	Concentration	Visual rating[1/]
	Percent	
Citric acid	2	++
	3	0
	5	0
Ascorbic acid	1	++++
	3	++++
Lactic acid	1	++++
	3	+++
Tartaric acid	1	++
	2	++
Ferrous ammonium sulfate	0.005M	++++

1/ 0 = no visible blueing
+ = very slight blueing
++ = slight blueing
+++ = moderate blueing
++++ = heavy blueing

Although we added Na_2EDTA, $(Na)_2CaEDTA$, and Na_4EDTA at a 250 ppm level, none of these compounds had any appreciable deterent effect.

A combination of citric acid and a food grade phosphate compound has proven most effective in controlling the formation of the blue color. This

combination does not completely inhibit blueing but does reduce its intensity. Further work is necessary to find an inhibitory chemical which operates at all pH ranges.

OYSTERS

In cooperation with the Shellfish Institute of North America, a study was conducted to determine what the limits should be for drip loss of freshly shucked Gulf of Mexico oysters. There are many factors to be considered if one standard is to apply to all shucked oysters. Variables influencing drip loss are: (1) season of the year, (2) geographical location of the beds, (3) temperature of the waters from whence the raw stock was taken, (4) method of processing, i.e., blowing vs. non-blowing, (5) method for determining drained weight, and (6) distance in transportation to market.

Producers of southern oysters have felt for some time that more uniformity in drained weights was needed. In discussing our plan of study with industry, they agreed the study should be done immediately and pledged their support. Consequently, we obtained freshly shucked oysters from shell stock harvested from four areas of the Gulf off the coasts of Florida, Alabama, Mississippi, and Louisiana. Oysters packed in both pint and gallon containers were obtained monthly for a year, the drained weights determined immediately and again after 14 days of storage.

Such samples were representative of actual production practices and were analyzed for drip loss, pH, salt, and moisture content. Oyster beds in Florida, Alabama, and Mississippi are closed in May for the summer months. We were able, however, to obtain oysters from Louisiana year round.

Differences in the drip loss of freshly shucked oysters packed in pints were more inconsistent than that of those packed in gallons from month to month. The Florida and Mississippi samples showed the greatest variability from one sampling period to another. The inconsistent results obtained to date might be due to changes in the salinity of the water in these areas.

The data obtained from month to month from all four areas showed that the drip loss from pints, analyzed after packing, ranged from 0 to 20%, with an average of 9%. Drip loss from these same samples stored 14 days ranged from 5 to 29% (34% in one case), averaging 18%. Loss from the gallons ranged from 4 to 23%, averaging 8% on the initial

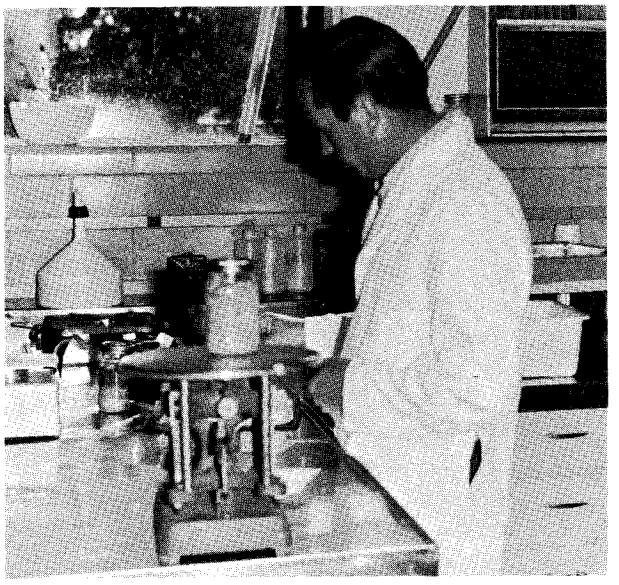

Figure 6. Determining the drip loss of southern eastern oysters.

examination. Drip loss of gallons stored 14 days ranged 10 to 38%, averaging 20%.

Strange as it may seem, oysters from Alabama produced less drip loss at the initial examination but were among those with the highest percentage loss after 14 days of storage. They were the only samples that were subjected to the blowing process.

The results were erratic, producing little correlation between areas where the samples were taken and time of year when samples were taken. The factors that seemed to influence the drip loss most were (1) amount of rainfall, (2) shucking method and holding procedures prior to packing, (3) area where taken, and (4) condition of the oyster at the time of shucking.

Salt and moisure analyses were conducted concurrently with drip loss and there was an inverse relationship between the constituents as was expected. When the moisture levels were high, the salt content was low indicating dilution with or contact with fresh water either before or after shucking or both. The drip loss correlated well with the moisture analysis.

A limited study was conducted to determine the effect of blowing on shucked oysters. Results showed that oysters increase in weight by 6.7%. This gain could vary, however, depending on handling of the oysters prior to the blowing process.

It was of interest to us to determine the pH of the oysters at the time of shucking. We found that

the pH ranged from 6.0 to 6.4, averaging 6.13 on a year-round basis. We have learned that at least one processor refrigerates his shell stock to maintain a high pH and it is not uncommon for him to produce oysters with a pH of 6.6 to 6.8.

SHRIMP

In processing a catch of scarlet prawns we noted that glazing frozen prawns with tap water produced an extremely unsightly black discoloration of the carapace and surrounding glaze. An experiment was devised to be carried out aboard RV *Oregon II* to determine if the appearance of the black color could be prevented. The whole prawns were blast-frozen in 5-pound boxes and then glazed with each of several solutions and returned to 0° F storage. A control was packed without glaze. The solutions used were as follows: tap water, 3% NaCl, 10% NaCl, 20% NaCl, 5% polyphosphate, 10% Freez-Gard, 0.1% Na_2EDTA, and 0.02% TDP.

After two months of storage, visual examination indicated varying degrees of blackening had occurred in each of the several packs with the exception of the prawns glazed in the heavy brine. The 20% brine appears to have the necessary characteristics to inhibit the formation of the black material. In the salt series (tap water through heavy brine), a definite gradation from heavy blackening through no visible signs of blackening was observed, depending upon the increasing degree of salt concentration.

FRESH WATER CATFISH

The fresh water catfish processing industry is a new industry and for the most part inexperienced in handling and processing methods. Technologists were assigned to visit all catfish processing plants to help management (1) increase efficiency, (2) upgrade sanitation, (3) suggest new and improved equipment, and (4) develop standards and specifications for their product. After visits to each plant and a discussion of the operation, management was furnished with a list of discrepancies and suggestions on how to improve his operation. Samples of the finished product were graded at each plant and the data used to develop Standards.

A second objective was to analyze the finished product for bacteria of public health significance and for bacteria used as an indicator of the level of sanitation. Ten plants were selected at random and 10 samples of each type of finished product were obtained from each plant and analyzed to establish baselines for future Standards. The baselines can also be used to make future decisions as to overall bacterial quality of processed catfish products and to evaluate sanitary practices during processing. AOAC methods were used to determine the bacterial population.

Processing

There are a number of un- and underutilized fish species in the South Atlantic and Gulf of Mexico. Estimates are that for every pound of shrimp taken in these areas, 6 pounds of industrial fish are culled from the catch and thrown overboard. At present there are also estimates of as much as 16 billion pounds of unutilized pelagic fish that could be taken from these southern waters each year. We decided to attempt to develop a process that would be both simple and economical in order that use could be made of this now-wasted protein.

Since most of these species are not used as food fish for one reason or another, we decided to produce an industrial product. The average low yield of oil and the general availability of knowledge in the manufacture of fish meal prompted us to attempt to produce a liquid fish product which could be produced aboard a vessel, manufactured and stored at room temperature and which could be the starting material for a variety of products. Starting with a liquid fish product, numerous manufactured materials — from fertilizers through high-grade animal feeds — could be produced.

Sometimes the term "fermented fish" is used interchangeably with the term "liquid fish," which is not an altogether correct practice. Liquid fish may be produced by any of several processes, i.e., enzymatic digest, autolytic breakdown, fermentation, or various combinations. Fermentation, by definition, takes place under anaerobic conditions with the production of alcohol or acids along with evolution of carbon dioxide, therefore, the term "fermented fish" or ensiled fish implies the addition of a carbohydrate to the raw product and concomitant reduction of the pH of the raw material as fermentation proceeds.

The enzymes Taka-diastase and papain were used singly or in combination along with lactic acid with the ratio of raw material to enzyme being at least 1000:1. Incubation was carried out at 37°C under anaerobic conditions for 8 to 12 hours. At the termination of incubation, the enzymes were de-

activated for 5 minutes at 80°C. No odors indicating putrefaction were detected; however, there was a slightly disagreeable odor of fish oil which ranged from very noticeable to only slightly noticeable. The combination of Taka-diastase/papain produced the most liquid sample with papain alone producing a very liquid sample. Lactic acid alone and Taka-diastase alone produced little change from the control. The oil present rose to the top and appeared to be unaffected by the digestion.

Insufficient liquefaction and more costly aspects of the utilization of commercial enzyme preparations caused us to turn to the use of micro-organisms as fermenters.

Three different organisms were used to produce fermented fish. The respective organisms were *Aspergillus oryzae* (a fungus used in the production of soy sauce), *Streptococcus lactis* (a bacterium used in the production of buttermilk and cheese), and *Lactobacillus plantarum* (a homofermentative organism used in the production of sauerkraut). Of these, *Lactobacillus plantarum* produced the most acceptable product.

After several trials we found that the most effective recipe to be 10% by weight of ground fish of commercial molasses as the carbohydrate and 30% by weight of either tap water or sea water. This mixture is set aside at room temperature or above. Within 24 hours the material is completely liquid and has a pH of 4.5 or less.

The minimum number of *Lactobacillus* cells necessary to ferment fish was determined. Sixty to 100 cells per gram of fish produced a response similar to that of the control (6,000-12,000/gr). Furthermore, we found that fermentation occurred even when 3-month old cells were used. The minimum number of cells per gram of sample needed to elicit a pH depression was 6 to 12 cells; however, the depression occurred only after prolonged incubation at optimum temperatures (36 hours at 37.5° C).

Figure 7. The variety of species from which liquid fish has been produced.

Fourteen speices of fish were liquefied collectively and singly. The species included king and silver whiting, white and sand trout, thread herring, spot, harvest fish, ribbon fish, bluefish, menhaden, croaker, butterfish, catfish, and bumper. During the course of these experiments the pH was determined at 2-hour intervals. Lag periods were observed at two incubation temperatures (22.5 and 37.5° C) which lasted about 6 hours. Then a rapid pH depression phase lasted about 10 hours with a gradual flattening at 18 hours. Interestingly enough, liquifaction continued even after the pH ceased to drop. All of the species produced an acceptable product.

Miscellaneous Activities

During the fiscal year the Laboratory staff undertook a number of projects not directly associated with the ongoing handling and processing of fish and shellfish program. These activities will be described briefly in the following paragraphs.

PESTICIDE RESIDUES

The Laboratory participated in an inter-laboratory collaborative study on chlorinated pesticide residue methodology. An additional five samples were analyzed at the request of industry.

STANDARDS

At various times the Laboratory is asked to participate in drafting Codex Alimentarius standards and codes of hygienic practice. During the year we assisted with the preparation of the (8th and 9th) draft of the Codex Alimentarius Standard for Canned Shrimp and Prawns plus the third draft of the Standard for the Raw Frozen Shrimp.

A draft Code of Hygienic Practices for the Production of Fish Oil for Human Consumption was written at the request of industry. It is now in editorial channels and will be published next year.

TECHNICAL ASSISTANCE

Twelve plants were aided in developing and maintaining better sanitation practices. Several were assisted to overcome difficulties associated

with the efficiency of their production lines and/or product quality. After Hurricane Camille, we analyzed samples of fish meal which had been reprocessed to eliminate contamination.

TRAINING COURSE FOR SEAFOOD INSPECTORS

The State of Florida initiated enforcement of its seafood code as of July 1, 1970. The Pascagoula Technological Laboratory was asked to conduct a 2-week training course to teach and train 12 seafood inspector-enforcement officers in quality control. Two weeks were spent by the Laboratory staff teaching courses pertaining to their work. Courses taught included detergents, records and documents, causes of spoilage, transportation, vessel and plant construction, inspection of vessel and plants, and sanitation procedures. Each day the students were asked to examine shrimp, crab meat, oysters, and two types of fish (high and low oil content fish) during various stages of spoilage. Spoilage characteristics were pointed out as each student was urged to ask questions when in doubt of the quality.

Professional Staff

Fiscal Year 1970

Robert N. Farragut, Chemist
George J. Haines, Jr., Microbiologist
Richard W. Hamilton, Microbiologist
Travis D. Love, Laboratory Director
Harold C. Thompson, Jr., Chemist
Mary H. Thompson, Assistant Laboratory Director
Melvin E. Waters, Research Food Technologist
Bobby J. Wood, Chemist

Fiscal Year 1971

Robert N. Farragut, Chemist, transferred to Tropical Atlantic Biological Laboratory, Miami, Fla., 6/18/71
George J. Haines, Microbiologist
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Travis D. Love, Laboratory Director, transferred to Extension Service, 1/9/71
Harold C. Thompson, Jr., Chemist, transferred to Tropical Atlantic Biological Laboratory, Miami, Fla., 6/18/71
Mary H. Thompson, Assistant Laboratory Director, transferred to Tropical Atlantic Biological Laboratory, Miami, Fla., 6/18/71
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