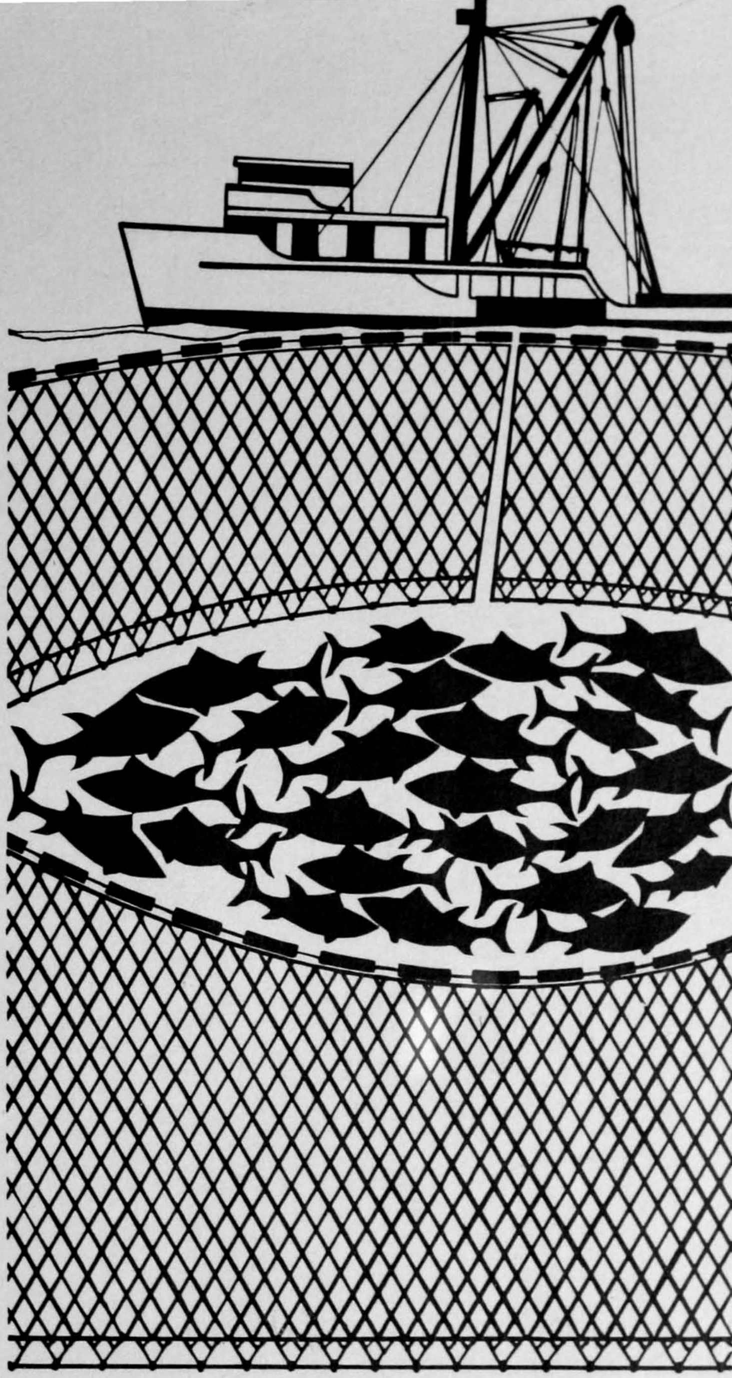

FISHERY INDUSTRIAL RESEARCH

VOLUME 2 NO. 2

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

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ECONOMIC FACTORS RELATED TO LAKE TROUT QUOTAS ON LAKE SUPERIOR

by

Keith D. Brouillard

ABSTRACT

In some fisheries, a quota on catch as a method of management has proved successful insofar as physical yield is concerned. This method, however, has been based primarily on biological concepts, with little concern for the economic aspects.

The philosophy of management should include a consideration of economic rent. This rent can be obtained by limiting costs--that is, effort--as well as by limiting production. The combination of a quota on catch and a limitation on amount of gear will produce both biological and economic benefits.

The lake trout fishery on Lake Superior presents an opportunity to apply economic as well as biological principles to the management of an entire body of water. If both of these factors are considered in the regulation of the fishery, the industry will be stronger in its long-term operations.

INTRODUCTION

The catch of lake trout in Lake Superior and elsewhere on the Great Lakes has declined because of a reduction in their population caused by the sea lamprey. Control of the sea lamprey now appears to be feasible through the use of selective poisons and should end their predation as a major factor in the abundance of lake trout.

In order that the population of lake trout can be reestablished quickly, the catch will be rigidly controlled, which raises a question as to the basic principles involved in the management of a fishery. This problem was explored in a conference held in Ottawa, Canada, in June 1961. In the meeting, it was recognized that a fishery is important mainly because of its contribution to the economic well being of the community and that in any program of control, economic principles must be considered as well as biological ones.

The purpose of this report is to outline the ideas presented at the conference insofar as they apply to the regulation of the lake trout fishery of Lake Superior. Most of the following discussion will be devoted to economic factors, but since biological factors are inseparably involved, they will be discussed also, though briefly.

ECONOMIC FACTORS

In our discussion of economic factors, three situations will be considered: (1) What happens in an unregulated fishery, (2) what happens in one in which quotas are put on

Author Note.--Keith D. Brouillard, *Commodity Industry Economist*, Bureau of Commercial Fisheries Economics Office, U.S. Fish and Wildlife Service, Ann Arbor, Michigan.

catch only, and (3) what happens when quotas are put on both catch and effort.

Unregulated Fishery

Gordon (1954, 1955) presented a hypothesis that relates the yield in a fishery to effort. His hypothesis states that costs (effort) in an unregulated fishery tend to equal monetary returns. (In this paper, the term "cost" refers to the cost of operating the entire fleet, not to that of operating an individual vessel.) As is indicated by figure 1, costs C increase as landings increase, but at a different rate. When costs have increased to point Y, any further effort will result in an operating loss to the fishermen as a group.

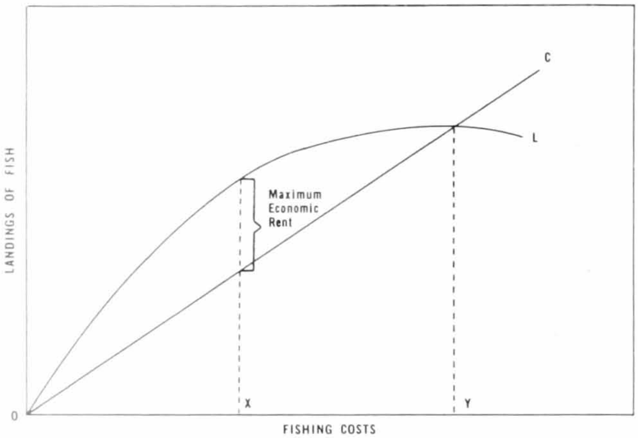

Figure 1.--Result of unregulated fishery.

In the past, excessive costs have developed in various fisheries. The basic difficulty is that the investment in fishing vessels and gear, and the many fishermen attracted into a fishery during good times, results in an oversupply of capital and labor. The general slowness of capital and labor in leaving the industry then causes a prolonged period of economic loss.

To obtain the maximum economic rent--that is, to obtain the maximum monetary return from the resource over and above the amount needed to keep it going--operations obviously should be conducted at the point where the difference between returns and costs is greatest. On the graph, this point is represented by X. It can be seen that the economic optimum is reached while both the costs and the returns are less than maximal. At point Y, for example, the total income to the fishery is greater than at point X, but at point Y, costs have caught up with income, so there is no economic rent.

Quota on Catch but Not on Effort

The theoretical point of maximum economic return has been defined in figure 1. If, at this point, an attempt is made to regulate the fisheries to obtain this maximum through limiting the catch by a quota, q, but without limiting the fishing effort, the conditions shown in figure 2 will develop. Here costs do not stabilize at the point where the line X intersected the cost curve originally, but instead, rise to where C_2 intersects L. The line C_1 represents the original cost curve. The higher costs, C_2, under the quota, result from efforts of all prospective fishermen and boat owners to share in the quota with more fishermen and gear occupied in the fishery than are necessary to attain the most economic production.

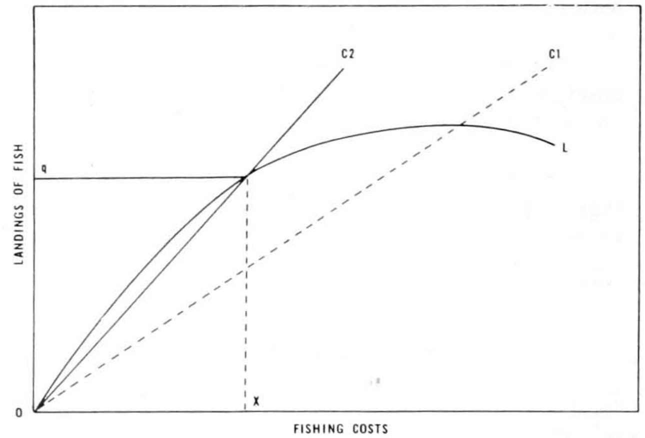

Figure 2.--Results of quota.

There is a resemblance between this theoretical situation and the actual developments in the Pacific coast halibut fishery (Crutchfield, 1959; Sinclair, 1960; Crutchfield and Zellner, 1962). Quotas were set in that fishery to increase the size of the stock and the availability of halibut to the fishermen. The actual achievement of this purpose deserves recognition. It must be said, however, that this fishery is not greatly profitable. As production has increased, the investment in vessels and gear has increased. At present, the halibut fishery is overcapitalized, so returns from many of the vessels are below what could easily be obtained from other investments. In such a situation, a fleet does not operate at maximum efficiency. Both labor and capital are wasted, and problems are encountered in marketing as well, owing to the shortness of the season.

A condition of this kind can develop in the fisheries on Lake Superior. Assume that a quota is placed on the production of lake trout. If the rehabilitation program is successful, the abundance of fish will result in an increase in the amount of gear fished, since each fisherman will wish to catch the greatest share possible of the quota. It will then be necessary to close the season because the quota, in all probability, will be filled in a short time. The industry now will be faced with the problem of finding employment for fishermen, gear, and vessels during the off season. The unused gear and vessels represent wasted capital and, hence, a loss to the national economy.

In addition to the economic losses in the producing segment of the industry, the American consumer suffers. The production of a quota during a short period of time necessitates the freezing and storage of the fish. The consumer pays for these added costs through higher prices. Another consideration is the unavailability of prime quality fresh fish, which are aesthetically appealing to consumers.

Quota on Both Catch and Effort

The cost curve shown in figure 3 is the same as the cost curve of figure 1. For simplicity, the assumption has been made that the fishing effort is frozen at the level represented by X. Now a quota is placed on this fishery at the point designated by q. (Actually, the quota would be in terms of pounds of fish, but pounds can be converted to dollars by means of price.) This point would be the optimum when the quota could be filled with a minimum of the most efficient gear, vessels, and labor. The rent from this fishery would be the maximum that could be obtained.

In the above analysis, the future trout fishery of Lake Superior is of primary concern. Presently, fishing effort for lake trout is low; hence, it is doubtful whether any further reduction from present levels would be necessary to rebuild the stock, presuming that the control of lamprey will be successful. It will be necessary, therefore, to wait until the stock of lake trout

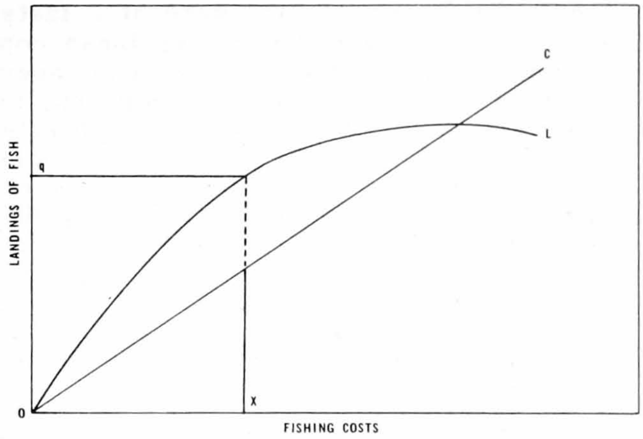

Figure 3.--Quota and gear limitations.

has been rebuilt to determine the proper fishing level. Limiting gear to its present level would aid in preventing uneconomic expansion of effort.

The point of maximum net economic return probably will not be reached simply by holding gear at its present level. If this is the correct level, it would be the result of pure chance. Adjustments in effort therefore will be necessary. If an upward adjustment becomes advisable, as seems likely, some problems would be encountered. For example, who should get licenses or who should fish additional gear? If a decrease in effort were advisable, the reverse problems would be presented--that is, who should leave the fishery or who should reduce the amount of gear? A discussion of these problems is beyond the scope of the present article, but they are treated in detail by Crutchfield and Zellner (1962) and are also discussed in a report on the Japanese trawl fishery (Fisheries Research Institute of Japan, 1961).

BIOLOGICAL FACTORS

As is indicated in figure 1, the economic optimum appears to fall below the maximum sustainable physical yield. Possibly, from a physical yield standpoint, biologists will discover that it is desirable to harvest the trout population at a level above the most economic point. Should this problem arise, it would be necessary to make a judgment as to which yield is more desirable.

In the future, the situation may develop where the need for protein foods causes

SAMPLES

Five hundred pounds of round whiting, caught less than 24 hours previously, was placed in a refrigerated sea-water tank (Cohen and Peters, 1963), and sea water (previously chilled to 30° F.) was added to give a density of about 45 pounds of fish per cubic foot. The temperature throughout the 14-day storage period was 30° ± 1° F.

In addition, 300 pounds of round whiting, from the same lot as those above, were carefully iced in a large wooden box with 300 pounds of fresh-water flake-ice. The box was kept in a cold room at 40° F. The fish were maintained at a temperature of 32° F. and were re-iced when necessary during the test.

CHEMICAL ANALYSES

Procedure

After 0, 7, and 13 days of storage, six fish were removed both from the refrigerated sea water and from the ice. The fish were filleted, ground in an electric blender, and analyzed in triplicate the same day.

Proximate and mineral analyses.--The analytical methods used for proximate determinations (protein, oil, ash, and moisture) are described by Sohn, Carver, and Mangan (1961). Sodium and potassium determinations were made on acidified solutions of the ash from the proximate analysis. The determinations were carried out in a Baird-Atomic direct-reading flame spectrophotometer. The chloride determination was carried out according to the Volhard method described in the Association of Official Agricultural Chemists' "Official Methods of Analysis" (1960).

Amino acid analysis.--A 0.2-gram sample of wet homogenized fish flesh (weighed to the nearest 0.1 milligram) was hydrolyzed for 20 hours under reflux with 6N (glass distilled) hydrochloric acid. The hydrochloric acid was then removed by evaporation under vacuum, and the residue was taken up with pH 2.2 buffer and analyzed according to the method of Sparkman, Stein, and Moore (1958), using a Phoenix Amino Acid Analyzer (fig. 1). Tryptophan and cystine, which are destroyed during acid hydrolysis, were determined separately, using the method of Graham, Smith, Hier, and Klein (1947) for tryptophan and the method of Schram, Moore, and Bigwood (1954) for cystine.

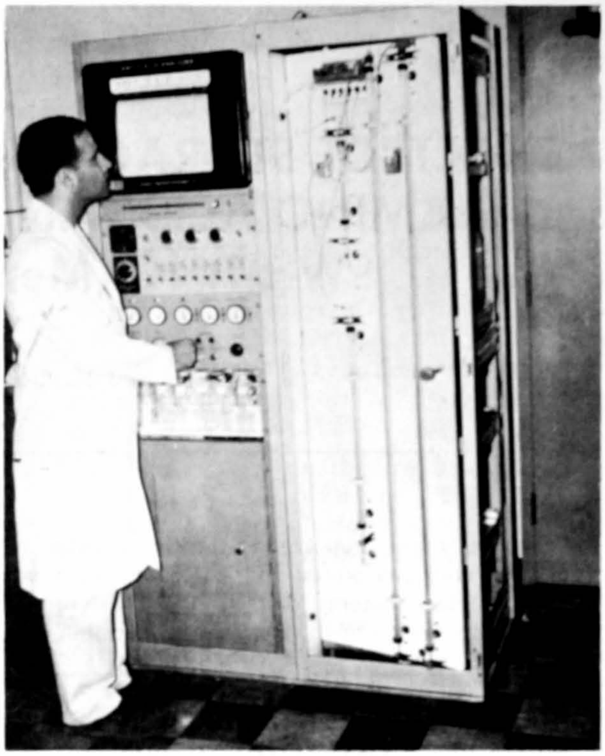

Figure 1.--Amino acid analyzer.

Results

Proximate composition and mineral contents.--The proximate composition and the sodium, potassium, and chloride contents of the fillets are shown in table 1. During storage in refrigerated sea water, the fish flesh increased in ash, sodium, and chloride, and decreased in potassium. No change occurred in protein and moisture. During iced storage, the fish flesh decreased in protein, ash, potassium, and chloride, and increased in moisture. No change was noted in sodium. The fish stored in refrigerated sea water, however, increased in sodium content and therefore were not suitable for use in low-sodium diets. The decrease in oil content with storage time shown in table 1 probably was fortuitous.

Amino acid analyses.--The results of the amino acid analyses of the zero-day fish flesh samples are shown in table 2. No significant change occurred in the

TABLE 1.--Proximate composition, sodium, potassium, and chloride content of whiting

Storage time	Storage medium	Protein	Moisture	Oil	Ash	Total of proximate components	Sodium	Potassium	Chloride
Days		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Mg/100g.*	*Mg./100g.*	*Mg./100g.*
0		16.68±.28	80.73±.13	1.35±.04	1.07±.05	99.8	80±4	347±26	0.149±.013
7	Refrigerated sea water	16.48±.04	80.31±.11	0.475±.03	1,47±.06	98.7	324±16	280	0.484±.008
	Ice	15.36±.14	83.30±.04	0.400±.08	0.844±.061	99.9	89±2	215±12	0.108±.022
13	Refrigerated sea water	16.51±.01	81.17±.21	0.13±.08	1.59±.02	99.4	347±12	229±9	0.539±.030
	Ice	15.17±.07	83.51±.09	0.08±.04	0.82±.02	99.6	72±2	216±1	0.094±.016

TABLE 2.--The amino acid composition of whiting (*Merluccius bilinearis*) at the start of the storage period

Amino acid	Relative amount
	Percent of protein
Lysine..........	9.11
Histidine........	1.73
Arginine.........	5.67
Tryptophan.......	1.05
Aspartic acid....	11.08
Threonine........	4.63
Serine...........	4.06
Glutamic acid....	16.29
Proline..........	3.61
Glycine..........	4.67
Alanine..........	6.36
Cystine..........	2.12
Valine...........	5.43
Methionine.......	[1] 3.31
Isoleucine.......	5.03
Leucine..........	8.50
Tyrosine.........	3.49
Phenylalanine....	4.27
Total	100.44

[1] After storage of the fish in refrigerated sea water or in ice for 13 days the methionine content was found to be 1.62 percent and the methionine sulfoxide content was found to be 3.00 percent (see below in reference to methionine sulfoxide).

majority of the amino acids during the 13 days that the samples were stored in either ice or refrigerated sea water.

It is noted, however, that although a small amount of methionine sulfoxide was in the chromatograms of fish stored for 0 and 7 days in both media, a very sharp increase appeared at the 13th day of storage (fig. 2) with a corresponding decrease in the methionine content. This increase is believed to be due to an oxidative process during storage. Methionine sulfoxide has been shown by Bennett (1941) to possess biological activity in the growth of rats and by McRorie, Glazener, Skinner, and Shrive (1954) to possess biological value in the growth of *Escherichia coli* and other organisms.

Taurine, of which trace amounts appear in the chromatograms of the fish stored for 7 days in both media, had increased significantly in both samples by the 13th day. This finding may be accounted for by a very small and not statistically significant breakdown of cystine.

ORGANOLEPTIC TESTS

Procedure

After 0, 7, 10, 12, and 14 days of storage, six fish were removed both from the refrigerated sea water and from the ice for organoleptic tests. The fish were graded for appearance, odor, and texture by two or three people experienced in the examination of raw fish and were then headed and gutted, packed in 1-pound cartons, over-wrapped, plate-frozen, and stored at -10° F. For taste-panel evaluation, the headed and gutted fish were removed from storage, cut into pieces, steamed in covered containers, and served to a panel composed of 10 to 12 members of the laboratory staff. The panel evaluated the fish for appearance, odor, flavor, and texture. At each test, four samples were served to the panel. Two of these were control samples of very high quality; one was identified as such and served as a standard of comparison, and the other was unidentified and served as a check on the accuracy of the panel. Of the remaining samples, one was from refrigerated sea water and the other was from iced storage.

Results

The results of the organoleptic evaluation of the raw and cooked fish are shown in table 3. The quality ratings of the raw fish were nearly identical in both the ice-stored and refrigerated-sea-water-stored fish.

The ratings for the cooked flesh of fish stored in ice show a change in quality at the 7th day, at which time the score dropped from "very good" to "good." After the 12th day of storage on ice, the score dropped from "good" to "poor." By the 14th day, the score was "very poor." These findings show close agreement with previous tests. It will be noted that quality losses were more readily detected in the cooked flesh than in the raw fish.

The ratings for the cooked fish held in refrigerated sea water show a change in

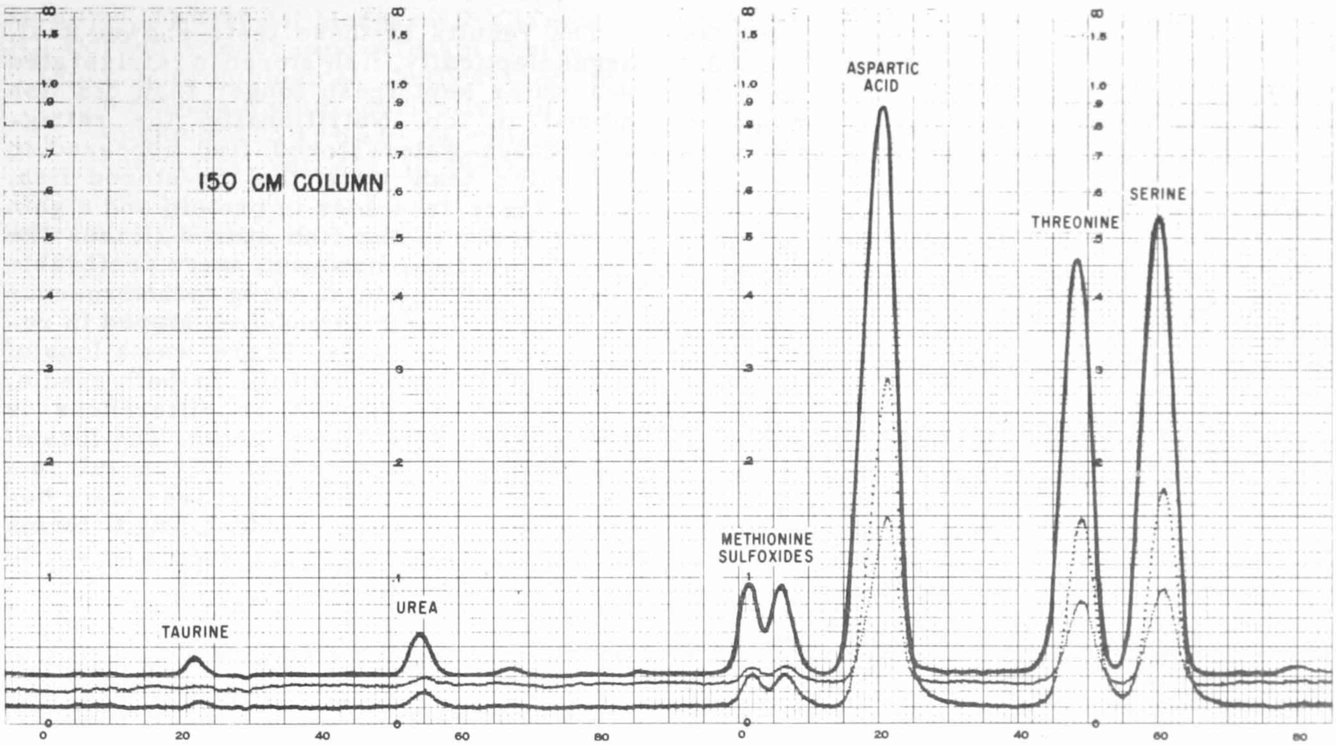

Figure 2.--A section of the chromatogram of the amino acid analysis of the edible flesh of whiting stored in refrigerated sea water for 13 days, showing the presence of methionine sulfoxide.

TABLE 3.--Results of examination of whiting stored in refrigerated sea water and in ice

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

[1] Six fish from each storage medium were rated on a scale of very good, good, fair, poor, and very poor.
[2] These results represent an average rating based on appearance, odor, flavor, and texture of the steamed samples.
[3] The test was discontinued at this point, since the cooked fish were considered to be unfit for consumption.

quality at the 10th day, at which time the score dropped from "very good" to "good." After the 12th day of storage in refrigerated sea water, the score dropped from "good" to "fair." By the 14th day, the score was "poor." These findings also show close agreement with previous tests and demonstrate that a higher quality level is maintained in whiting stored in refrigerated sea water than in whiting stored in ice.

CONCLUSIONS

1. Chemical analyses made initially and at periodic intervals during storage of whiting in ice and refrigerated sea water indicated that when whiting was stored in refrigerated sea water, there was no loss of protein compared with a slight loss from the fish stored in ice.

2. A very significant increase in the sodium content of the whiting stored in refrigerated sea water would make these fish unsuitable for use in low-sodium diets.

3. At or near the end of their edible storage life, whiting from both storage mediums showed a small amount of methionine sulfoxide formed from methionine, but no significant changes were found in the other amino acids.

4. The edible-quality life of whiting stored in refrigerated sea water was about 3 days longer than that of whiting stored in ice.

SUMMARY

Since storage of fish in refrigerated sea water has shown promise in reducing loss of quality resulting from improper icing procedures, investigations were made to compare the effect of storage of whiting in refrigerated sea water and in ice on quality loss, on proximate composition, and on the amino acid, sodium, potassium, and chloride contents of the edible flesh.

Five-hundred pounds of whiting was stored in refrigerated sea water at 30° F.; and 300 pounds, in ice at 32° F. Periodically, organoleptic tests were conducted on raw and cooked fish. Samples of the flesh were homogenized and analyzed for their proximate composition and their amino acid, sodium, potassium, and chloride contents.

The results of these tests showed that, organoleptically, fish stored in refrigerated sea water kept fresh longer than did fish stored in ice. Nutritionally, the refrigerated-sea-water-stored fish appeared to be better than were the ice-stored fish, since there is a loss in protein and a gain in moisture in the fish stored in ice. The ice-stored fish, however, were preferable for low-sodium diets, owing to the presence of additional salt in the fish stored in refrigerated sea water. There was a loss of methionine during storage in both media, but no other changes or differences in amino acid content were noted. The loss of methionine did not necessarily result in a corresponding loss of nutritive value because the oxidation product which forms methionine sulfoxide has been shown to possess biological activity.

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DRIP FORMATION IN FISH. 1.--A REVIEW OF FACTORS AFFECTING DRIP.

by

David T. Miyauchi

ABSTRACT

This paper is a review of the current literature on the formation of drip in fishery products. Included among the many factors that may influence drip formation are species of fish, post mortem age of fish, rate of freezing, time and temperature of frozen storage, and rate of thawing.

INTRODUCTION

Drip consists of fluid that is released from the tissue of fish and is not reabsorbed. It is the free liquid that separates. Drip may become evident during above-freezing refrigerated storage, during and after thawing of previously frozen products, or during cooking. It contains dissolved protein, other nitrogenous substances, vitamins, and minerals. The term drip is also sometimes used in a broader sense to include water that is acquired during handling and processing or that is added to the frozen product as a protective glaze.

The various types of drip mentioned in this paper may be defined as follows:

1. "Drip" or "free drip" means liquid or muscle juice that exudes by natural flow from the fish tissue without the application of force.

2. "Expressible drip," "press drip," or "centrifuge drip" is the liquid obtained when external force is applied to the tissue of the fish.

3. "Thaw drip" is the liquid that exudes when frozen fish tissue thaws.

4. "Cook drip" is the liquid released when the fish tissue is heated or cooked.

Excessive formation of drip constitutes a serious loss to producers, processors, retailers, and consumers. Economically, drip represents shrinkage or loss in net weight. From the standpoint of quality, drip affects the appearance, the texture, and the flavor of the product, and if the drip is discarded, water-soluble nutrients are lost. Drip losses therefore should be minimized at all stages of handling.

If methods for controlling drip are to be developed, it is necessary to understand what factors contribute to its formation. Empey and Howard (1954) listed the following factors as influencing the formation of drip in fish tissue:

1. Time and temperature of holding the muscle before freezing.

2. Rate of freezing, especially through the "critical temperature zone" (30° to 23° F.).

3. Time and temperature in the frozen state.

Author Note.--David T. Miyauchi, *Chemist*, Bureau of Commercial Fisheries Technological Laboratory, U.S. Fish and Wildlife Service, Seattle, Washington.

4. Rate of thawing.

5. Storage after thawing.

6. pH of the fish muscle.

7. Osmotic pressure.

8. Species--drip may be greater from coarse-textured species than from fine-textured ones.

Numerous studies have been made during the past 30 years on the various aspects of drip formation in fish. The objective of this paper is to review some of these studies and to discuss the status of our present knowledge. These studies are cited conveniently under three main headings: (1) Effect of raw material variables, (2) effect of brining, and (3) effect of other factors involved during and after freezing.

EFFECT OF RAW MATERIAL VARIABLES

The formation of drip is related to many factors that are involved before the freezing process, such as the species of fish, the size of fish, and the ratio of the cut surface to the total volume.

Effect of Species

Fish with unusually high moisture content or low protein content are apt to produce a large amount of drip.

The quantity of drip formed varies widely from species to species and from fish to fish, both in the chilled product and in the frozen one.

Chilled product.--The most striking example of loss of fluid in unfrozen products is the "bleeding" of shucked oysters. Fingerman, Fairbanks, and Plauche (1957) reported that as high as 69 percent by weight of the eastern oyster may be lost as fluid in the first 60 minutes after it is shucked. With fish fillets, the loss in drip is much lower, but the loss varies with the species. Tarr and Sunderland (1940b), for example, reported that the loss during storage at 32° to 35° F. was considerably more for Pacific flounder than for pink salmon. In 1 day, the flounder lost 4 percent of their weight and the salmon, 0.7 percent; in 8 days, the flounder lost 14 percent and the salmon, 1.7 percent.

Frozen product.--Young (1941b) reported that losses of thaw drip from steaks for red king salmon varied from 2 to 3.5 percent, which was about the same as for silver and chum salmon but was much less than for Pacific halibut. Stansby and Harrison (1944) found that petrale sole fillets formed considerably more drip than did fillets of pink, silver, or chum salmon.

Effect of Size of Fish

No definite correlation has been established between the size of fish and the amount of drip formed. Young (1941b) found that in general, steaks from larger halibut were more subject to drip than were steaks from smaller halibut. The variation among fish was great, however, with losses during 12 days of storage at 34° F. ranging from 2.5 percent for a 9-pound halibut to 13.8 percent for an 81-pound halibut. With red king salmon steaks, the variation in drip did not appear to depend on size.

Banks (1955) reported that the amount of expressible fluid from iced cod did not appear to be related to the size of the fillet. He pointed out, however, that his results may have been influenced by the fact that he sampled only a few large fish and that some of these were in poor condition.

Effect of Increasing Cut Surface Area

The amount of drip formed is related directly to the ratio of cut surface area to total volume, or weight, of fish flesh. Sanford[1] found that the amount of drip from defrosted rockfish fillets increased as each fillet was cut into increasingly larger numbers of pieces. Whole fillets averaged 3.6 percent drip; fillets cut into 3 pieces, 4.0 percent; and fillets cut into about 18 pieces, 7.2 percent.

Effect of Sampling from Different Parts of a Fish

Young (1941a, 1941b) found that the quantity of drip varied greatly according to the location of part of the fish from which the sample was taken, particularly in reference to the spinal column. With halibut over 40 pounds in weight, for example, the amount of drip increased from head to tail, but

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

with smaller halibut, the variation in drip was less and did not always increase in this manner.

Effect of Post-Mortem Age of Fish

Chilled fish.--Tarr and Sunderland (1940b) reported that fillets of four species of Pacific flounder that were wrapped in cellophane and stored at 32° to 35° F. had drip losses of 4 percent in 1 day and 14 percent in 8 days. They concluded that because such a large amount of drip was formed in unfrozen fish, factors such as autolysis by muscle enzymes and bacterial action may contribute to drip formation.

Banks (1955) found that as iced whole cod passed out of rigor and became less resistant to pressure during 18 to 68 hours of storage, the amount of expressible fluid obtained from the fillets started at a low value and increased rapidly to 7 percent. The amount then increased slowly and, after 168 hours in ice, had reached about 8 percent, possibly as a result of further slight softening of the flesh. Thereafter, the amount increased rapidly again, possibly as a result of further softening of the flesh together with slight denaturation of the intercellular proteins. Results of experiments in Sweden (Anonymous, 1959) showed that the fluid-binding capacity of cod fillets, as determined by centrifugation, was greatest in unfrozen fish before rigor set in and decreased with time of storage in ice; the centrufuge fluid was about 10 percent in freshly caught fish and nearly 20 percent in the fish after 10 days of storage in ice. Thus, in summary, both expressible drip and centrifuge drip increase with time of storage of iced cod.

Frozen fish.--The quantity of free thaw drip from previously frozen fish varies considerably and does not appear to be a reliable index of the post-mortem age of the fish.

Prerigor fish that are frozen pass through rigor and exude varying amounts of drip when thawed. Dyer and Fraser (1961) report that the excessive moisture in some frozen fish blocks that are processed from prerigor fish result from high temperature and rough handling of the fish during processing and not from the fact that the fish had not passed through rigor before being frozen. No drip appeared below 60° F., but about 5 percent was formed at 70° to 75° F., and up to 12 percent at 75°.

Young (1941b) determined the effect of storage time (up to 14 days) at 34° F. on drip formation in halibut steaks (a) before freezing and (b) after freezing and thawing. He found losses before freezing increased with increasing storage time at 34° F. but that, inversely, losses after freezing and thawing decreased; however, the total loss was greater in samples that had been stored for a longer time before freezing. Good (1954) found the quantity of thaw drip from English sole fillets, in general, increased with the time that the round fish were stored in ice but that the variation in quantity of drip was considerable.

A Swedish study (Anonymous, 1959) indicated that the thaw-centrifuge drip may reflect the post-mortem age of the fish prior to freezing. Freshly caught and frozen fish, which were thawed 3 days later, lost 24 percent centrifuge drip, whereas fish iced for 10 days prior to being frozen lost 27 percent; after the fish were stored for 3 months at -20° C., the corresponding values were 34 to 38 percent. Expressible drip, however, does not appear to reflect this difference. The Report of the Food Investigation Board (Anonymous, 1952) summarizes studies made at the Torry Research Station as follows:

1. In fresh cod fillets, expressible fluid increases with time of storage in ice.

2. Freezing causes an immediate increase in expressible fluid, which is greater in the fresher fish.

3. The sum of the two effects is fairly constant, and there is little difference in the amount of expressible fluid derived when newly frozen fish of differing initial freshness are thawed.

4. With increasing time of frozen storage, stale fish, when thawed, tends to lose more fluid than does fresh fish.

Effect of pH

Tarr (1942) found that on either side of an approximate "isoelectric zone" of about pH 4.5 to 6.0 the addition of hydrochloric acid or sodium hydroxide caused fish muscle to swell markedly and to withhold liquid against hydraulic pressure; however, above and below about pH 10.0 and pH 2.0 respectively, peptization of the protein occurred. Between about pH 4.5 and pH 7.0, incorporation of 1 to 3 percent salt increased the swelling and liquid-binding power of fish muscle, but below pH 4.5 the addition of salt had an opposite effect. From pH 7.0 to 8.5 the addition of salt did not further increase swelling; above pH 8.5, progressive increase in pH caused an apparent decrease in swelling.

EFFECT OF BRINING

Pottinger (1956) stated that aside from keeping the storage temperature low and the storage time short, there is no good way of markedly reducing the quantity of drip that forms when frozen fish is thawed. Brining does appear to reduce the quantity of drip, but it also appears to accelerate changes in the odor and the flavor of stored fish, especially in species with a high content of oil.

Effect of Brining during Above-Freezing Storage

Tarr and Sunderland (1940a) demonstrated that losses from drip could be prevented by dipping fresh fillets in brine. Fresh halibut fillets that were dipped in brine until the flesh absorbed about 1 percent by weight of salt, gained weight initially. This weight was gradually lost during subsequent storage at 32^{o} to 35^{o} F. Other brine-dipped fillets with a higher content of salt retained their gained weight throughout their storage life. In comparison, the untreated fillets formed drip at the rate of over 1 percent per day; fillets immersed in distilled water had a temporary increase in weight, which was rapidly lost during the first day or two in storage, after which a further considerable loss occurred.

Tarr (1941a) controlled formation of drip in defrosted fish by brining the fish flesh either while frozen or after being defrosted. The brining of frozen salmon and halibut flesh caused an increase in weight and prevented drip. The brining of defrosted flounder fillets caused a considerable increase in weight, most of which was retained during 11 days of storage at 34^{o} to 36^{o} F.; in contrast, untreated fillets lost 10 to 11 percent of their weight during this period.

Effect of Brining on Thaw Drip

Tarr (1942) demonstrated that in whole and in comminuted muscle at its natural pH, free thaw drip could be almost completely inhibited and expressible thaw drip could be greatly reduced by incorporation of about 1 percent salt, which caused the protein to swell and thus tended to bind the liquid firmly. Ford[2] also found that incorporation of about 1 percent of salt in fresh fillets drastically reduced drip when these fillets were subsequently frozen and thawed (drip of 10 to 17 percent reduced to 0 to 7 percent). With Dover sole, 0.9 percent of salt, on the average, appeared to be the optimum for palatability. Concentrations of salt lower than 0.75 percent in fish fillets appeared to have little or no practical effect in reducing drip. Holston and Pottinger (1955) reported that free drip from unbrined frozen haddock fillets, after 3.5 hours of thawing at room temperature, varied between 4 and 6 percent, whereas incorporation of 0.8 to 1.2 percent of salt reduced free drip to a maximum of about 2.3 percent. Stansby and Harrison (1944) reported (1) that preliminary brine treatment of petrale sole fillets was very effective in minimizing drip, (2) that it enhanced the appearance of the fillets, but (3) that it also accelerated the development of rancid and salt-fish odors and flavors.

Effect of Brining on Cook Drip

Tarr (1941b) found that brining either fresh or defrosted fillets did not significantly affect the amount of free liquid lost during heating. For fillets treated in an otherwise identical manner, samples heated at 248^{o} F. had greater cook drip than did those heated at 212^{o}.

EFFECT OF FACTORS DURING AND AFTER FREEZING

Effect of Rate Freezing

Young (1941b) subjected steaks of king, silver, and chum salmon and halibut to the following freezing rates: quick frozen--7 minutes in passing through critical zone of temperature 32^{o} to 23^{o} F., and slow

[2] Lorne Ford (formerly with Canadian Fishing Company, Ltd., Vancouver 4, B.C.): Paper presented at the Pacific Fisheries Technologists Meeting held at Victoria, B.C., Canada, March 1958.

frozen--16 to 21 hours in passing through the critical zone. Pieces of fish from the various samples were placed in plastic bags, and the loss of drip was determined during storage at 34° F. at intervals up to 11 days. Young concluded that the rate of freezing influences the amount of drip considerably and that rapid freezing results in the least drip. Reay (1934) found that as the rate of freezing from 0° to -5° C. of minced haddock muscle was decreased, the amount of drip increased; as the freezing rate decreased from the most rapid rate, the rate of increase of drip formation, which was large at first, decreased until it became quite small. Tarr and Sunderland (1940b) reported that for Pacific flounder fillets, the losses of drip for quick-frozen fillets were about 10 percent and for slow-frozen fillets, about 15 percent, but that for pink salmon, the rate of freezing had no effect on the amount of drip formed. Stansby and Harrison (1944) found that quick-frozen fillets had less drip and better texture immediately after freezing than did the slow-frozen fillets but that upon subsequent storage, the differences became less apparent.

Effect of Time and Temperature of Frozen Storage

The Torry Research Station (Anonymous, 1952) reported the effect of storage temperature on the amount of expressible fluid from defrosted cod fillets as follows:

1. At -10° C., the amount of expressible fluid increased rapidly during the first 3 months and then increased by a smaller amount during the next 6 months; staler fish lost more fluid than did fresher fish (table 1).
2. At -30° C., the increase in expressible fluid during storage was slight, even with initially staler fish; but staler fish tended to lose more fluid than did fresher fish with increased time of frozen storage.
3. At -20° C., the amount of expressible fluid was intermediate to that obtained at -10° and -30° C., and here again, the increase was greatest during the first 3 months.

Stansby and Harrison (1944) compared the effect of storing sole and salmon fillets at 10° and -5° F. and found that the fillets stored at -5° lost less drip during the test than did those stored at 10°. At both temperatures, the amount of drip generally showed an increase with increasing time of storage. Good (1954) reported that the quantity of drip from English sole fillets increased with time in frozen storage. Osterhaug and Nelson (1957) reported that although the drip values between individual samples of frozen Pacific oysters varied considerably, the average values of five or six samples showed an increase with storage time.

Effect of Rate, Time, and Temperature of Thawing

Young (1941b) found that the rate of thawing was of minor practical importance except when fish were held for more than 3 days after being thawed, in which case rapid thawing induced the least free drip. Reay (1934) reported that as the rate of thawing from -5° to 0° C. decreased, the amount of drip increased. Odan (1952) found that differences in the rate of thawing cod fillets in air and in water of the same

Table 1.--Percent by weight of expressible fluid from cod fillets as a function of time on ice before freezing and time in storage at -10° C. after freezing

Time on ice	Expressible fluid			
	Fresh	Immediately after freezing	After 3 months	After 9 months
Days	*Percent*	*Percent*	*Percent*	*Percent*
0.75	5.0	9.6	20.0	24.0
11	8.8	10.4	27.5	32.1

temperature caused no significant difference in the quantity of drip but that the temperature at which the fillets were thawed was of importance. Thus, fillets that were thawed in air at 34° and 80° F. had drip quantities of 4.9 percent and 10.1 percent, respectively. Armstrong, Park, and McLaren (1960) found that with frozen Atlantic cod fillets, the amount of thaw drip increased with increasing length of time and with higher temperature used in various defrosting methods. Sanford,[3] in thawing quick-frozen and slow-frozen Pacific oysters, found that more drip was formed at high thawing temperatures than at low. At 50° F., the quick-frozen and slow-frozen oysters had 9.9 percent and 10.6 percent drip, respectively; whereas at 75° F., the quick-frozen and slow-frozen oysters had 27.6 percent and 29.3 percent drip, respectively.

DISCUSSION

In general, excessive amounts of drip reflect degradation in the quality of fishery products. If the drip is discarded, water-soluble nutrients and flavor are lost. Fish that exude a large amount of drip are usually dry and woody or tough in texture afterwards. A large amount of drip adversely affects the appearance of the product and represents a shrinkage or loss of net weight. Accordingly, the amount of drip is often measured and used as one of the criteria for judging quality of fishery products.

Many factors influence the formation of drip, and numerous studies have been made to correlate the amount of drip formed with other factors that affect the quality of fishery products. The various studies show that losses of drip vary (1) from species to species, (2) from fish to fish within a species, (3) from one part of a fish to another, (4) possibly according to the size of the fish, (5) according to the area of the cut surface, (6) with the treatment--such as brining--given the fillets before they are frozen, (7) with rate of freezing and time and temperature of frozen storage, and (8) with the rate, time, and temperature of thawing.

Drip lost from iced fish increased with increasing time of storage in ice. Since a large amount of drip is formed in the unfrozen fish, factors such as autolysis by muscle enzymes and bacterial action probably contribute to the formation of drip. Centrifuge drip and expressible drip of flesh taken from iced fish may possibly be used to indicate the post-mortem age of the iced fish.

In frozen fishery products, the quantity of free thaw drip varies considerably and does not appear to be a reliable index of the post-mortem age of the fish. In some instances, the losses of thaw drip were smaller for the samples that were held in ice for a longer period than for those held in ice for a shorter period prior to freezing. The amount of expressible fluid derived from cod fillets immediately after freezing varied but little with differing initial freshness of the fish, but with increasing time of cold storage, the amount of expressible fluid was greater in the staler fish than in the fresher fish. Centrifuge drip in one study appeared to correlate with the post-mortem age of fish prior to freezing.

In general, rapid freezing induced less drip than did slow freezing, but this relation between freezing rate and formation of drip does not appear to be simple. Also, there are indications that any differences due to rate of freezing are nullified by subsequent storage conditions.

It has been generally accepted that the amount of drip increases with increasing time and temperature of frozen storage. Even though investigators have found that the large variation in free drip from sample to sample has made it impossible to correlate free drip with these variables, expressible drip or centrifuge drip does appear to have some correlation with time and temperature of storage.

The rate of thawing appears to be of less importance than does the temperature to which the product is allowed to rise. Considerably more drip is formed when frozen fishery products are thawed to room temperature than to refrigerator temperatures (32° to 40° F.).

Since many factors influence the formation of drip, it would be difficult to correlate the amount of drip obtained from a fishery product with any particular raw material, processing, storage, or handling

[3] See footnote 1, p. 14.

practice. If measurements of drip are to be a meaningful index of quality, the relation between thaw drip and cook drip needs to be established and correlated with other quality factors such as texture, juiciness, and flavor.

Before further work on the formation of drip in fishery products is carried out, suitable methods of measuring drip should be developed and adapted because the amount of drip obtained from any particular sample varies widely with the thawing procedure and with the method of separating the drip from the solid portion. Studies made by the author on the effects of some variables in the thawing procedures and methods of measuring drip and on the comparison of the chemical composition between free drip and centrifuge drip from defrosted cod fillets now are being prepared for publication.

SUMMARY

This paper reviews references in the literature on the formation of drip in fish. Among the factors that affect drip formation are:

1. Species of fish - fish that have a high water content or a low protein content tend to form excessive amounts of drip.

2. Size of fish - no direct correlation has been established between size of fish and amount of drip.

3. Relative amount of cut surface area - within limits, the amount of drip tends to increase as fillets are cut into progressively smaller pieces.

4. Sampling from different parts of fish - quantity of drip varies with location on body of fish from which sample is taken.

5. Post-mortem age of fish - autolysis by muscle enzymes and bacterial action apparently contributes to drip.

6. pH - changes in pH can either increase or decrease the formation of drip.

7. Brining - brining fish flesh appears to reduce the amount of drip formed, but it accelerates undesirable changes in the odor and the flavor of stored fish, especially of those species with high oil content.

8. Rate of freezing - fish frozen slowly tend to form more drip than do those frozen quickly.

9. Time and temperature of frozen storage - drip increases with increased storage time and is greater at higher storage temperatures.

10. Rate, time, and temperature of thawing - high thawing temperatures and increasing time of thawing give more drip.

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STORAGE OF FISH IN REFRIGERATED SEA WATER.
2.--QUALITY CHANGES IN WHITING AS DETERMINDED BY ORGANOLEPTIC AND CHEMICAL ANALYSES

by

Edward H. Cohen and John A. Peters

ABSTRACT

Whole whiting stored in ice or refrigerated sea water at 30° F. were subjected to organoleptic and objective tests. The findings showed that the objective tests will need further study before they can be used practically. The sensory evaluations of the raw and the cooked fish, however, indicated a preference for the whiting stored in the refrigerated sea water.

INTRODUCTION

Need for Research

A report by Mendelsohn and Peters (1962) discussed (1) the commercial importance of whiting *(Merluccius bilinearis)* to the New England fishing industry, (2) the need for further work on the effect of prefreezing storage conditions on the quality of whiting, and (3) the need for further investigation of objective tests as a means for indicating quality changes.

Part 1 of the present series of papers reported the potential importance of refrigerated sea water for extending the chilled storage life of ocean perch (Cohen and Peters, 1962).

Because of the positive results obtained with ocean perch, there was need to determine the applicability of this technique of storage to whiting. To determine the value of refrigerated sea water for prolonging the fresh storage life of whiting, it would be necessary to run sensory tests; also, it seemed desirable to test further the physical and chemical tests of quality employed in the earlier studies.

Objectives

The objectives of this report thus were (1) to determine, by organoleptic analysis, if holding whiting in 30° F. refrigerated sea water results in an increase in their storage life as compared to holding them in ice and (2) to determine if tests for refractive index of the eye fluid, volatile base nitrogen, trimethylamine, and volatile acid number could be used for objectively measuring the changes in quality during storage.

CONDITIONS OF STORAGE

In each test series, one lot of whiting was stored in refrigerated sea water at 30° F.; and concurrently, another lot of the same catch was stored in fresh-water flake ice.

Two series of storage tests were conducted: the first in September 1959 and the

Authors' Note.--Edward H. Cohen and John A. Peters, *Chemists*, Bureau of Commercial Fisheries Technological Laboratory, Gloucester, Mass.

second in August 1960. In this report the first series will be called "whiting 1959"; the second, "whiting 1960."

Refrigerated Sea-Water Tank

The tank used in these tests was described in part 1 of this refrigerated sea-water study. The jacketed type of construction, combined with high velocity circulation of the sea water, permits maintenance of 30° ± 0.5° F. and prevents the fish from freezing to the walls of the tank.

Iced Storage

The wooden box with removal penboards described in part 1 was used in the storage of the fish in ice.

General

Five hundred and fifty pounds of round whiting caught less than 24 hours previously were placed in the tank with sufficient refrigerated sea water to give a density of 45 pounds of fish per cubic foot. For iced storage, 300 pounds of whiting from the same lot used for the refrigerated sea-water test were iced with 300 pounds of fresh-water flake ice.

The whiting 1959 samples were fresh when received at the laboratory. The whiting 1960 samples, when received, were fresh but contained fish that had been feeding heavily; and the viscera of some had perforated the belly wall. During storage of the 1960 samples in refrigerated sea water, the circulating pump failed for 5 hours on the 11th day; and the temperature rose to 47° F.

ORGANOLEPTIC TESTS

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

Examination

In these subjective tests on raw whiting, quality was evaluated at periodic intervals by two or three qualified laboratory observers. A minimum of six fish were removed from storage in refrigerated sea water and in ice and examined for appearance, odor, and texture.

After being examined, the fish were headed and gutted, packaged in 1-pound cartons, overwrapped, plate frozen, and stored at -20° F. until prepared for taste panel tests. The fish were removed from the storage at -20° F., thawed for 1 hour at 68° F., cut into $1\frac{1}{2}$-inch pieces, steamed in covered containers for 30 minutes, then served to a panel composed of 8 to 12 members of the laboratory staff, who rated the fish for appearance, odor, flavor, and texture.

When the fish were first received at the laboratory, samples were freshly frozen and held at -20° F. for use as controls in the taste tests. At each test, four portions of cooked fish were served to each panel member (fig. 1). Two of these portions were unidentified samples from fish stored in refrigerated sea water or in ice. The remaining two samples were controls, one of which was identified as the "known control"; and the other, not identified, was referred to as the "blind control" and was used to check the sensitivity of the panel to quality differences.

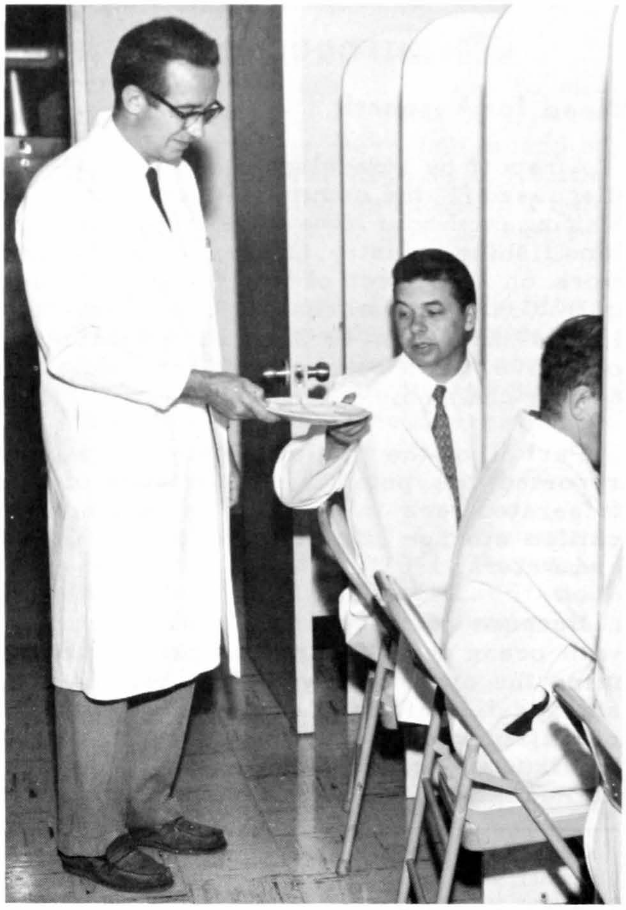

Figure 1.--The taste panel testing cooked fish for quality changes.

Results

Results of the organoleptic tests of raw and cooked whiting are shown in tables 1 and 2.

Raw fish.--Whiting 1959 samples were found to be of very good quality for the first 7 days in both storage media. The fish stored in ice were of good quality through the 9th day, fair through the 16th day, poor on the 18th day, and very poor on the 21st day. The fish stored in refrigerated sea water were of good quality through the 16th day, fair on the 18th day, and poor on the 21st day.

Whiting 1960 samples were found to be of very good quality in both storage media for the first 7 days, of good quality through the 11th day, and fair quality by the 14th day. The iced fish were of poor quality on the 16th day; however, the fish stored in refrigerated sea water were still of fair quality on the 16th day, despite the temporary malfunctioning of the pump on the 11th day.

Cooked fish.--The results of the taste panel evaluation of the cooked whiting samples represent the averages of the ratings given for appearance, odor, flavor, and texture. Samples rated poor are considered unmarketable.

The whiting 1959 samples stored in refrigerated sea water were of very good quality through the 7th day, good quality through the 14th day, poor quality on the 16th day, and very poor quality on the 18th day. The fish stored in ice were of very good quality only on the initial day, of good quality through the 7th day, of fair quality through the 11th day, and of very poor quality on the 14th day.

The whiting 1960 samples kept in refrigerated sea water or ice were of very good quality through the 7th day of storage. The ice-stored samples were of good quality through the 11th day but very poor on the 14th day. The samples stored in refrigerated sea water were slightly better than the iced fish, being of very good quality through the 11th day, until the pump failed, and of poor quality on the 14th day.

OBJECTIVE TESTS

Physical and chemical tests were conducted to determine (1) weight changes, (2) refractive index of the eye fluid, (3) salt content, (4) volatile base nitrogen, (5) trimethylamine, and (6) volatile acid number.

Weight Changes

Ten fish were tagged and then weighed before and after storage in refrigerated sea water or in ice.

The whiting 1959 samples held in refrigerated sea water for 21 days showed an average increase in weight of 4.8 percent; the ice-stored samples showed a decrease in weight of 0.8 percent. The whiting 1960 samples stored in refrigerated sea water for 16 days showed a weight gain of 1.4 percent; the ice-stored samples showed a weight loss of 0.8 percent. The weight increase in the 1959 refrigerated sea-water samples is within the range found for other species of fish (Roach, Harrison, and Tarr, 1961), but we cannot account for the much smaller increase in the 1960 samples stored in refrigerated sea water.

Refractive Index

Refractive index (Proctor, Nickerson, Fazzina, Ronsivalli, Smith, and Stern, 1959) of the eye fluid was determined with an Abbé refractometer kept at constant temperature of 25° C.

The results obtained are shown in table 3. The refractive index of whiting 1959 samples, stored in refrigerated sea water, showed no correlation with taste panel scores; the refractive index of the ice-stored samples showed a correlation with taste panel scores at the 5-percent level of significance. The refractive index of whiting 1960 samples stored in refrigerated sea water showed a correlation with taste panel scores significant at the 1-percent level, but showed no correlation for the ice-stored samples.

Salt Content

The modified Volhard method (Association of Official Agricultural Chemists, 1960, p. 235) was used to determine the salt content of the whiting stored in refrigerated sea water and in ice. Ferric ammonium citrate was used as the indicator.

The uptake of salt in the samples stored in refrigerated sea water and the leaching effect of salt in the samples stored in ice

Table 1.--Results of examination of whiting 1959 stored in refrigerated sea water and in ice

Storage time	Quality rating of raw fish[1]		Quality rating of cooked fish[2]	
	Refrigerated sea-water samples	Iced samples	Refrigerated sea-water samples	Iced samples
Days				
0	Very good	Very good	Very good	Very good
2	Very good	Very good	Very good	Good
4	Very good	Very good	Very good	Good
7	Very good	Very good	Very good	Good
9	Good	Good	Good	Fair
11	Good	Fair	Good	Fair
14	Good	Fair	Very good	Very poor*
16	Good	Fair	Poor*	([3])
18	Fair	Poor*	Very poor	---
21	Poor*	Very poor	([3])	---

[1] Six fish from each storage medium were rated on a scale of very good, good, fair, poor, and very poor.
[2] These results represent an average rating based on appearance, odor, flavor, and texture of the steamed samples.
[3] The scoring of the cooked fish was discontinued because the fish were inedible.
* Samples rated poor were considered unmarketable.

Table 2.--Results of examination of whiting 1960 stored in refrigerated sea water and in ice

Storage time	Quality rating of raw fish[1]		Quality rating of cooked fish[2]	
	Refrigerated sea-water samples	Iced samples	Refrigerated sea-water samples	Iced samples
Days				
0	Very good	Very good	Very good	Very good
2	Very good	Very good	Very good	Very good
4	Very good	Very good	Very good	Very good
7	Very good	Very good	Very good	Very good
9	Good	Good	Very good	Good
[3] 11	Good	Good	Very good	Good
14	Fair	Fair	Poor*	Very poor*
16	Fair	Poor*	([4])	([4])

[1] Six fish from each storage medium were rated on a scale of very good, good, fair, poor, and very poor.
[2] These results represent an average rating based on appearance, odor, flavor, and texture of the steamed samples.
[3] The pump failed for 5 hours on the 11th day in the refrigerated sea-water tank, and the temperature rose to 47° F.
[4] The scoring of the cooked fish was discontinued because the fish were inedible.
* Samples rated poor were considered unmarketable.

Table 3.--Correlation of objective tests with taste panel scores

Sample	Storage medium	Significance of correlation[1]			
		Refractive index	Total volatile base	Trimethylamine	Volatile acid number
Whiting September 1959	Refrigerated sea water	Not significant[2]	Highly significant[3]	Not significant	---
	Ice	Significant[4]	Highly significant	Highly significant	---
Whiting August 1960	Refrigerated sea water	Highly significant	Highly significant	Highly significant	Highly significant
	Ice	Not significant	Not significant	Highly significant	Significant

[1] The coefficient of correlation was determined according to the simplified method described by Arkin and Colton (1959a). The level of significance was taken from Arkin and Colton's (1959b) statistical tables.

[2] Not significant--probably no correlation between the objective test and sensory test.

[3] Highly significant--1 percent probability that there is correlation between the objective test and sensory test.

[4] Significant--5 percent probability that there is correlation between the objective test and sensory test.

are shown in figures 2 and 3. The whiting 1959 samples increased their salt content significantly during the first 4 days of storage in refrigerated sea water, whereas the ice-stored samples showed a substantial loss of salt during the same period.

The whiting 1960 samples stored in refrigerated sea water, showed a rapid increase in salt during the first 2 days, reaching their peak at about the 7th day. The samples stored in ice decreased in salt content very slowly until the 9th day and decreased more rapidly thereafter.

Volatile Base Nitrogen

Volatile base nitrogen was determined by the alcoholic extraction method (Stansby, Harrison, Dassow, and Sater, 1944). The distillation was carried out with a 12-place electric macro-Kjeldahl unit. Methyl red-methylene blue indicator was substituted for the methyl red indicator used in the original procedure.

The volatile base nitrogen determinations (table 3) showed highly significant correlation with taste panel scores for both the refrigerated-sea-water-stored samples of whiting 1959 and 1960 and the ice-stored samples of whiting 1959; however, there was no significant correlation for the 1960 samples stored in ice.

Trimethylamine

Trimethylamine nitrogen determinations were carried out on whiting 1959 samples using the method of Dyer (1959). A modification of Dyer's method was used on whiting 1960 samples.[1]

Trimethylamine determinations (table 3) correlated with taste panel scores at the 1-percent level of significance for whiting 1959 and 1960 ice-stored samples and whiting 1960 refrigerated-sea-water-stored samples. The whiting 1959 refrigerated-sea-water-stored samples showed no significant correlation with taste panel scores.

Volatile Acid Number

Volatile acid number (Association of Official Agricultural Chemists, 1960, p. 236-237) was determined only on whiting 1960 samples.

[1] Personal communication from G. A. Reay and J. M. Shewan, Torry Research Station, Aberdeen, Scotland.

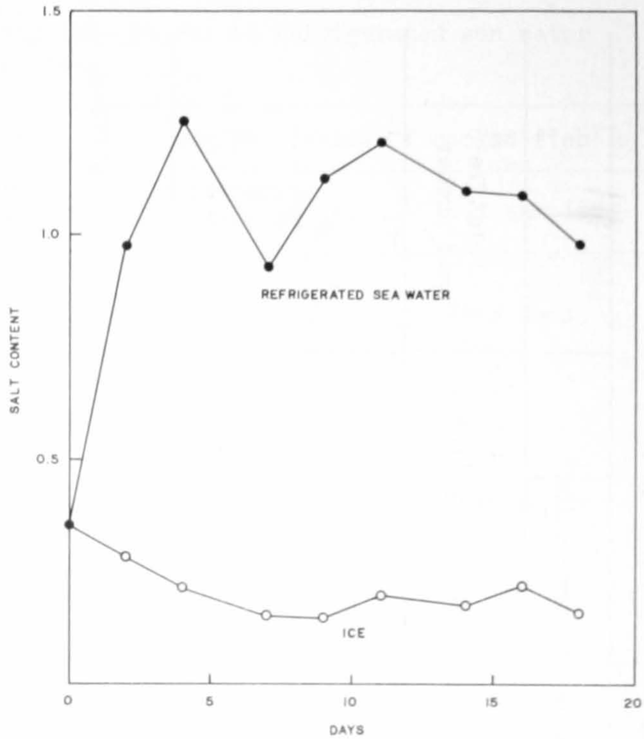

Figure 2.--Salt content of whiting 1959 (in percent) during storage in refrigerated sea water and in ice.

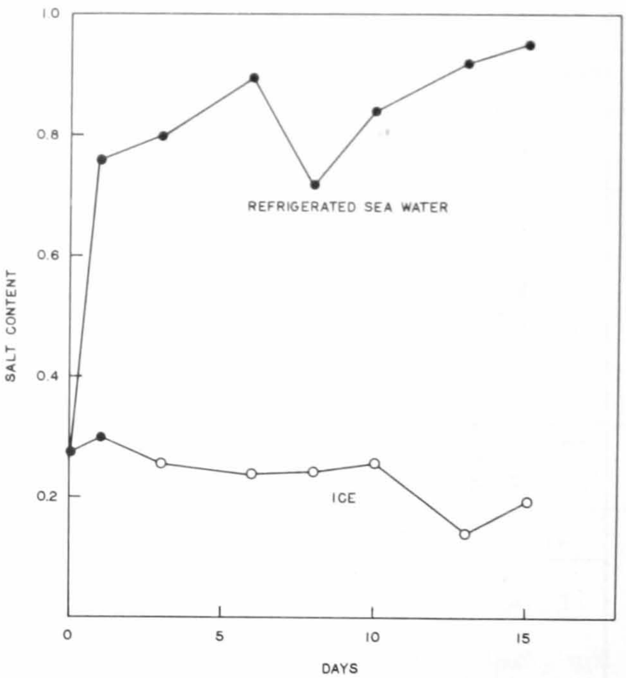

Figure 3.--Salt content of whiting 1960 (in percent) during storage in refrigerated sea water and in ice.

The volatile acid number of the whiting 1960 samples stored in refrigerated sea water correlated with the taste panel scores at the 1-percent level of significance; the ice-stored samples correlated with the taste panel scores at the 5-percent level of significance.

CONCLUSIONS

On the basis of the results of the organoleptic examination of both the raw and cooked whiting, refrigerated sea water maintained at a constant temperature of 30° F. will extend the chilled storage life of whiting for 2 to 3 days longer than will ice.

Although volatile base nitrogen, trimethylamine, and volatile acid number determinations showed some correlation with taste tests, at present there is no one test or combination of objective tests that can replace the subjective organoleptic test.

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TECHNOLOGICAL INVESTIGATIONS OF POND-REARED FISH
PART 1.--PRODUCT DEVELOPMENT FROM BUFFALOFISH

by

Leo J. Sullivan and Harry L. Seagran

ABSTRACT

Methods of developing smoked, frozen, and new types of reconstituted products from buffalofish were studied. Procedures were developed to produce a highly acceptable smoked product from the rib section and a reconstituted product from the remaining dorsal loin section. This method of processing eliminated a bone problem that limited the marketing of products from buffalo. Finely grinding the bony loin section and extruding the resulting material into casings yielded a variety of products having potential appeal for the consumer. Storage life tests indicate that products from buffalo are particularly prone to fat oxidation; off-flavors may develop after only moderate periods of refrigerated storage.

INTRODUCTION

Several forms of fish-farming exist in the United States. This paper, the first in a series concerning technological investigations of pond-reared commercial fish, discusses operations of ricefield areas adjacent to the lower Mississippi River. Historical and management aspects of this industry have been reviewed by Riggs (1957), Johnson (1959), and Olden (1960). Technological developments in harvesting and in utilizing products of the fishery have been limited, however, and related literature is lacking. Though catfish, bass, and crappie are (raised for food in these areas), the predominant fish is the bigmouth buffalo [*Ictiobus cyprinellus* (Valenciennes)].

This paper reports on preliminary development studies conducted cooperatively with industry on conventional smoked and frozen buffalo products. It also describes laboratory studies on new types of products in which attempts are being made to alleviate a problem in the efficient utilization of the buffalo created by the presence of branched or "floating" bones found deep in the tissue of members of the sucker family (Catostomidae).

THE RICEFIELD FISHERY

In the preparation of new land for rice cultivation, wooded areas are often flooded with surface water to kill the timber. Many "wild" species of fish are incidentally introduced with the surface water. Previously, when these areas were drained, the fish were collected and used by the landowner for his own purposes or, if the crop of fish was large, were sold on local markets. This newly cleared land was highly productive, but after several successive crops of rice, soil fertility was reduced and rice production fell off. Weeds also became an increasingly serious problem with each successive rice crop. In order to restore these lands to high productivity, rice

Authors' Note.--Leo J. Sullivan, *Food Products Technologist*, and Harry L. Seagran, *Chief*, Bureau of Commercial Fisheries Technological Station, U.S. Fish and Wildlife Service, Ann Arbor, Mich.

fields were either rotated with nitrogen-fixing crops (for example, soybeans) planted in forage crops, or left fallow. When left fallow, fields were often flooded with surface water to control weed growth. This flooding resulted in unplanned fish crops. It soon became apparent that with proper management, the rearing of fish as a commercial crop could become profitable.

It has been estimated that 100,000 acres were capable of food-fish production in Arkansas in 1961 of which 20,000 acres were utilized (Walters, 1961). This figure represents a substantial decrease from the 70,000 acres in fish production in 1958 as cited by Johnson (1959). Factors contributing to the decrease in production are discussed later in this paper. It is difficult to assess the true potential of the extensive bottom-land areas of the lower Mississippi, but it has been estimated[1] conservatively that in excess of 2 million acres of such land could be utilized to produce fish.

The bigmouth buffalo, a member of the sucker family, has an elliptical rather than the circular cross-section that is the shape typical of suckers (fig. 1). It closely resembles the carp (family Cyprinidae), but lacks barbels and has a terminal mouth. The buffalo is dark olive to black and has large prominent scales. Like other bottom feeders, buffalo eat weeds, seeds, algae, insects, and other benthic organisms that are often detrimental to rice production. Since buffalo thrive well on the natural food available in flooded rice fields and impoundments, they do not require supplemental feeding. Buffalo return nitrogenous wastes to the soil, resulting in increased rice yields. If fish are allowed to remain in ponds for periods in excess of 2 years, however, overfertilization causes the rice to be lodged from luxuriant growth, and difficulties in the harvest of rice result. Fish farmers thus prefer to drain their ponds and harvest the fish at the end of a 2-year growing season. Buffalo harvested at the end of 2 years weigh approximately 3 pounds. Production estimates of over 600 pounds of buffalo per acre per year have been cited, with an average of 121 pounds per acre from eight different impoundments (Green and Mullins, 1959).

[1] Proceedings, Fish Farming Seminar, March 29, 1962. U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Ann Arbor, Mich., 37 p. [Unpublished.]

Harvesting of impounded fish is seasonal; major fish-harvesting periods are in early spring and late fall. Little or no mechanized equipment is employed (fig. 2) and, even at prevailing low labor costs, the expense often equals the price received for the fish. Although buffalo weighing over 6 pounds always have been in good market demand (Albano, 1961), the 3-pound buffalo harvested from agricultural impoundments generally net only about one-half that received for the larger fish. The principal reason for a significantly lesser price for small buffalo than for larger fish is the presence of numerous small floating bones in the small fish. These branched bones, which are connected to the major skeletal system, remain deep in the loin area when the side is cut from the backbone. They are impossible to remove by conventional processing. Bones in fish weighing over 6 pounds are generally large enough to be removed easily during eating, whereas those found in the 3-pound class make the cooked fish difficult to eat. Although the buffalofish market traditionally has been of the fresh-fish type, the marketing of processed products could offer a possible solution to this problem.

The difficulties that beset all aspects of the fish-farming industry--arising largely from lack of management and technical knowledge--resulted in a request for Federal aid[2] to provide various forms of technical assistance. The technological studies that were initiated gave priority to immediate aid to improve handling and processing and, particularly, to determine methods whereby the small, pond-reared buffalo could be utilized more effectively.

PRELIMINARY FIELD STUDIES

A technologist of the Bureau of Commercial Fisheries was assigned to an area of concentrated fish-farming activity to give immediate advice on handling and processing of fish and to evaluate better the most critical areas in which technological research could improve the market position of pond-reared fish. Since small buffalo would not sell competitively as dressed whole fish, it was imperative that products of higher consumer appeal be developed. Cooperative product development studies were therefore undertaken.

[2] Resulting in passage of Public Law 85-342 in 1958.

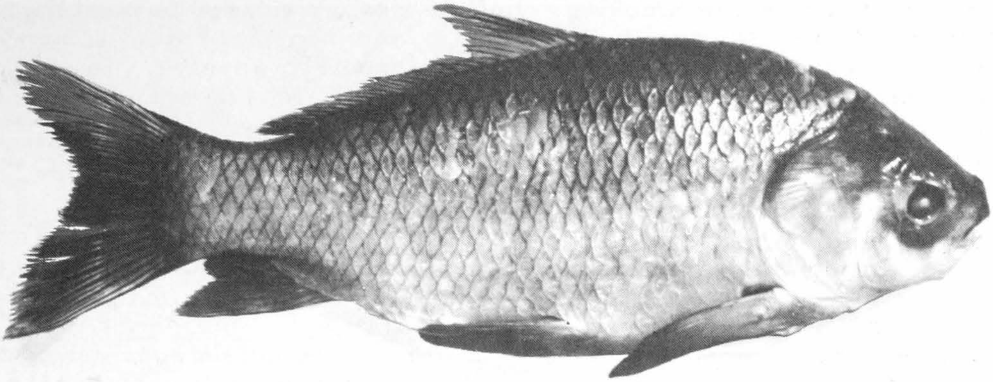

Figure 1.--Bigmouth buffalo.

Figure 2.--Harvesting buffalo from a ricefield impoundment.

The first product developed was a smoked item, since information on the smoking of fish was readily available and materials needed by industry for the preparation of the product were relatively inexpensive. Smoked products from whole split sides of dressed buffalo were first prepared in a small portable smokehouse.[3] Although the

[3] Lynne G. McKee. 1961. An inexpensive small smokehouse from an old refrigerator cabinet. U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries Technological Laboratory, Seattle, Wash. Manuscript Report No. 46, 6 p. [Unpublished.]

equipment employed initially for smoking was somewhat crude, the resulting products were generally regarded as flavorful. The smoked product from the whole split sides was not entirely acceptable, however, owing to the many small bones in the loin area. Attempts to cut the bones into very small pieces by manual "scoring" (closely spaced knife-cuts through the flesh perpendicular to the bones but not through the tough outer skin) did not result in an acceptable product. Pieces of bone were still evident, and scoring caused considerable drying of the smoked product. The fattier flesh of the rib cage, which contains only the heavy rib bones, remained desirably moist during smoking. Since the floating bones are confined to the loin or dorsal area, the entire loin was therefore cut away from the rib section (fig. 3), and the resulting parts processed separately.

The rib sections were smoked by a kippering which utilized a high temperature and a short smoking time. Although the batches of finished product lacked uniformity, a smoked rib product from small buffalo was considered to meet the requirements for a consumer item of high quality. Portion control appeared to be feasible, because a 3- to 4-ounce product suitable to modern packaging and merchandising methods could be produced. Acceptance, based on organoleptic examination, proved excellent.

Attempts to utilize the entire edible part of the fish resulted in extensive development work on the bony loin of the buffalo. The loin was manually scored to determine if this procedure would prove effective after the rib section was removed. The results were not entirely satisfactory; furthermore, manual scoring was not practical for high-volume production. A mechanical scoring device, identical in principle to the cube steak machine illustrated in figure 4, performed the operation more satisfactorily. After the product was breaded and fried, however, the small pieces of bone remaining were often objectionable. Conventional fish portions, sawed from frozen blocks of the mechanically scored loins, suffered as well from this problem of residual bones.

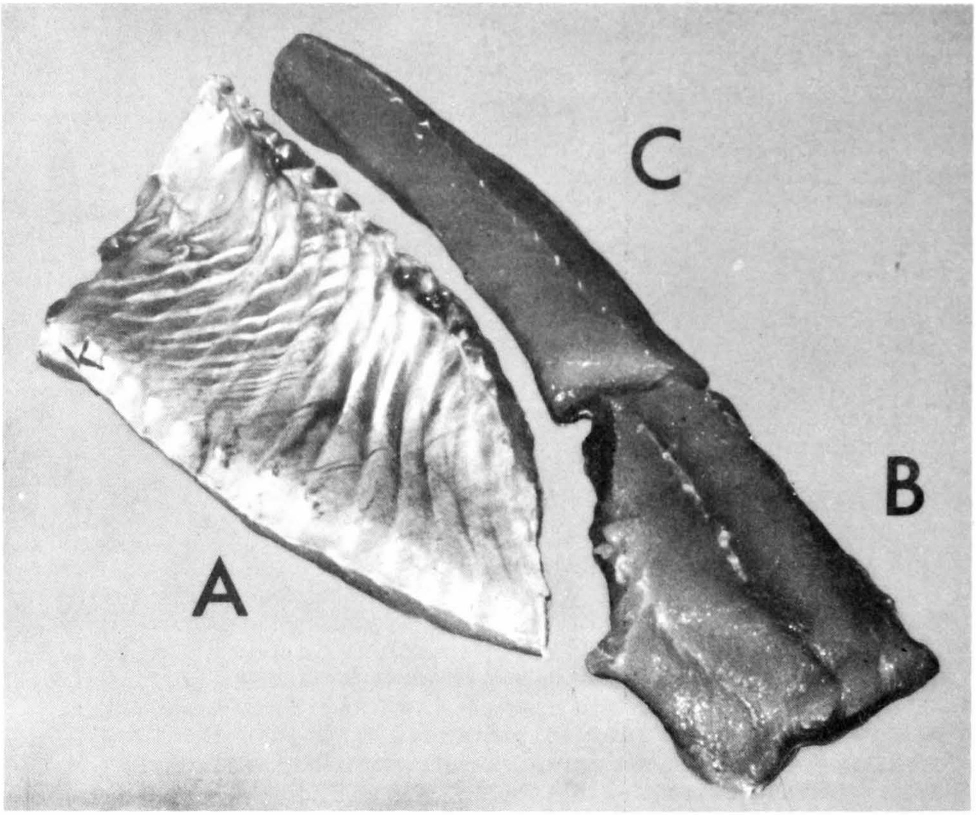

Figure 3.--Buffalo side cut into 3 pieces: A - rib section; B - posterior loin section; C - anterior loin section.

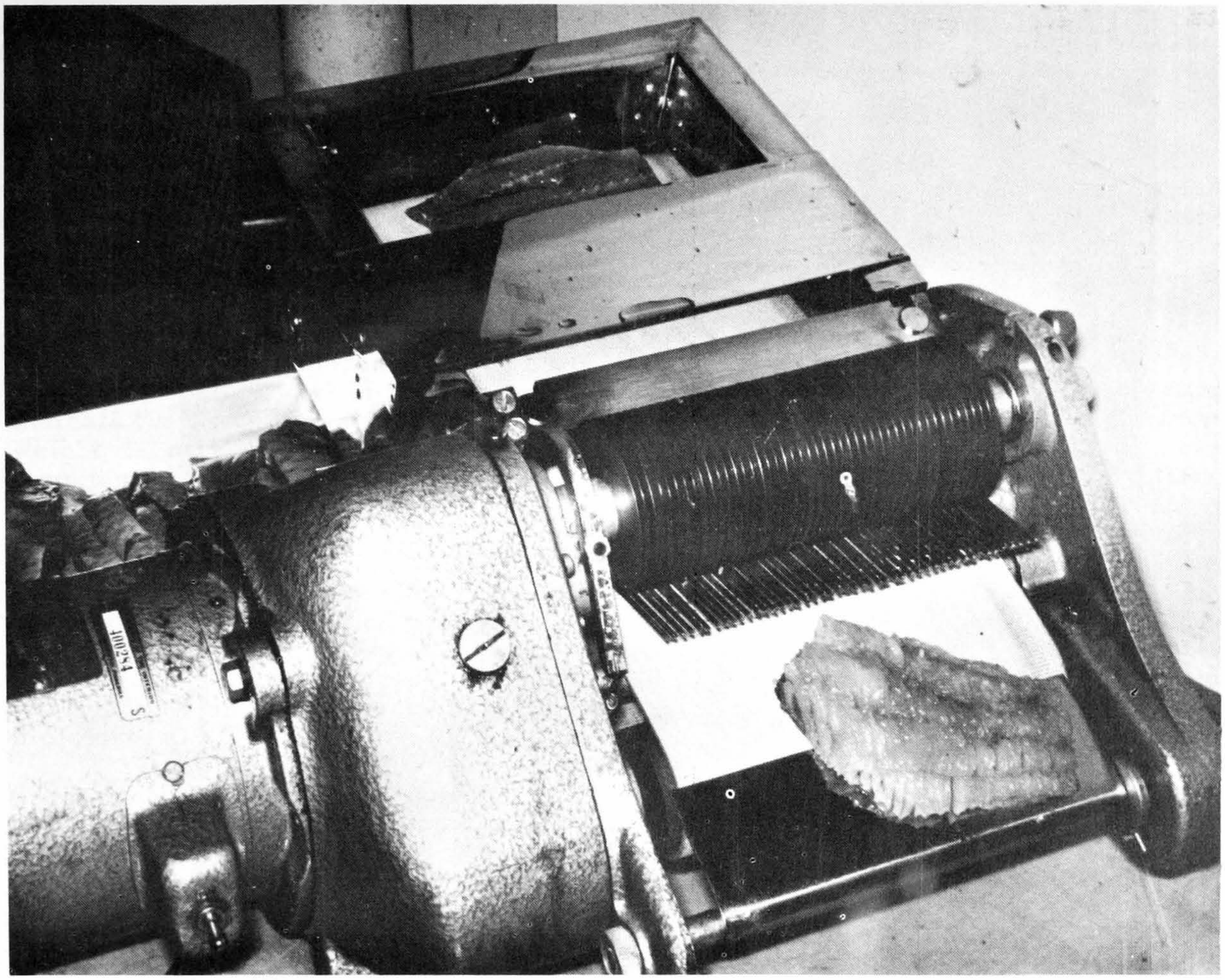

Figure 4.--Machine used in "scoring" floating bones of buffalo.

At the conclusion of the preliminary field studies, it was evident that, although a satisfactory smoked product could be obtained from the rib section of the buffalo, further work would be required to eliminate the bones of the loin portion. The results of subsequent laboratory investigations, reported in the following section, appear to offer one solution to this problem.

LABORATORY STUDIES

Development studies concerned: (1) the refinement of the previously discussed smoked and frozen products and an estimation of their storage life; (2) the study of reconstituted products, in which attempts to eliminate the problem of floating bones proved to be successful; and (3) the development of barbecued and canned products of potential commercial value.

Smoked and Frozen Products

Smoked buffalo ribs and frozen breaded products from buffalo loins were developed.

To produce consistent products, a thermostatically controlled electric smokehouse with an independently controlled smoke generator was employed (fig. 5). The most satisfactory results were obtained through use of a long drying and smoking period at relatively low temperature, followed by a short period at moderately high temperature to cook the product. The product thus retained significantly more moisture and, correspondingly, possessed a more smoky flavor. A typical procedure for preparing the smoked-rib product was as follows:

1. Scale, dress, and split the fish and remove the backbone.

Figure 5.--Smoking buffalo ribs using an electric smokehouse with independent smoke-producing unit.

2. Cut the rib section from the loin section, retaining as much flesh as possible on the rib.

3. Brine the ribs in 80° salinometer salt brine (2.23 pounds of salt per gallon of water) at room temperature for 1-1½ hours, depending upon the size of the ribs.

4. Remove the ribs from the brine, sponge off excess moisture, and place them skin-side down on smokehouse racks that have been brushed with a release agent (such as vegetable oil) to prevent sticking.

5. Place the racks in prewarmed smokehouse (100° F.) for 1 hour without addition of smoke. (During this time a glossy film or pellicle develops on the exposed surface of the flesh which aids in the retention of moisture and improves the appearance of the product.)

6. Increase the smokehouse temperature to 120° F., introduce smoke, and process for 4-6 hours, depending upon

the thickness of the ribs. During the last half hour of smoking, increase the smokehouse temperature to 160° F. to cook the product.

7. Remove the ribs from the smokehouse and allow them to cool slightly. Package the product promptly with as little handling as possible and refrigerate.

A 3-pound buffalo in the round gives approximately equal yields of raw rib and loin (20.5 and 21.2 percent, respectively). Yield data (table 1) on smoked-rib products indicate that approximately 20 percent of the weight is lost through dehydration during smoking.

Brining as previously described resulted in about 2 percent salt (table 2) in the smoked product, a level that appeared to be satisfactory on organoleptic evaluation. The edible portion of a typical smoked-rib product from 3-pound fish was about 19 percent protein, 24 percent oil, 54 percent moisture, and 3 percent ash (table 2).

Shelf life of the smoked-rib product (without added preservatives and at 0° and 36° F.; table 3) was also estimated. Immediately after being processed, several smoked ribs were packaged in perforated plastic pouches and placed in storage. Subsequent organoleptic examinations indicated a satisfactory shelf life of 3 weeks at 36° F. and at least 2 months at 0° F. Longer storage resulted in the development of rancid flavors in the dark tissue of the medial-lateral area. In addition, surface mold was frequently noted after 4 week's storage at 36° F.; growth of the mold could be retarded readily by a slight increase in the salt content of the product.

Since the preliminary experiments with mechanical scoring of the loin gave inconclusive results, it was felt desirable to evaluate the technique further in the preparation of conventional frozen, breaded products. The distribution of floating bones throughout the loin had not been previously determined. The loin was divided, therefore, into two approximately equal parts: a posterior part cut to resemble a small fish fillet and the remaining anterior part (fig. 3). A commercial cube-steak machine (fig. 4) with circular knives spaced 1/8-inch apart and clearing the rubber conveyor belt by only the thickness of the scaleless buffalo skin was used to score the two loin sections. The scored posterior pieces were breaded with a commercial breading, packaged in 1-pound wax cartons, overwrapped with a moisture- and vapor-proof film, and frozen to 0° F. on a double-contact plate freezer at a plate temperature of -30° F. The anterior pieces were frozen into blocks (fig. 6) and subsequently sawed into "portions" and breaded. Samples were stored at 0° F. and periodically evaluated organoleptically, following cooking in deep fat at 375° F. for 3 minutes.

Although products were not extensively examined, the anticipated shelf life at 0° F. (without added preservatives) appears not to exceed 3 months (table 3). The dark meat of the buffalo developed noticeably rancid flavors on further storage. Further, it was generally concluded that the scoring principle was not completely effective in eliminating the bone problem. The frequent appearance of uncut or large pieces of branched bone in both products indicated the need for more efficient "bone removal" if quality products for human consumption from the loin were to be produced.

Reconstituted Products

Since the bony loin section of small buffalo proved difficult to adapt to conventional products, either directly or through scoring, subsequent study was directed towards the development of reconstituted products. Cooperative studies with industry were started in which the bony flesh of small buffalo was ground, emulsified, mixed with other ingredients, stuffed into cellulose casings, and molded and cut into various forms. These products included links, patties, and portions of different sizes and shapes (fig. 7), including a fish-shaped portion sawed from a stuffed roll frozen and shaped in a wire cage-mold (fig. 8).

The grinding and emulsifying process used was essentially identical for all products and consisted of mechanically grinding the loins through a ½-inch plate, then a 1/8-inch plate, and finally through the superfine plate of a sausage emulsifier. In a typical formulation, 10 pounds of emulsified buffalo loins were blended with the following ingredients: 3 ounces of salt, 2 ounces of monosodium glutamate, 10 egg whites, 1/8 ounce of onion powder, and 3 ounces of nonfat milk powder. The resulting mixture was stuffed into various types

Table 1.--Product yields from 3-pound pond-reared bigmouth buffalo

Product	Product description	Product yield
		Percent
Eviscerated	Headed and gutted	55.6
Fillets	Whole sides with rib-bones and skin removed	31.3
Ribs	Skin-on rib sections cut from whole side	20.5
Loins	Skin-on loin sections cut from whole side	21.2
Waste	All inedible parts resulting from cutting sides	58.3
Smoked ribs	Rib sections smoked	16.4

Note: These are average data resulting from several lots of fish.

Table 2.--Proximate and salt[1] composition of bigmouth buffalo products

Product[2]	Protein	Oil	Moisture	Ash	Salt
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Fillets[3]	15.3	16.6	68.6	1.49	----
Waste[4]	15.6	23.1	55.5	4.38	----
Rib prior[5] to brining	----	----	----	----	0.135
Rib after brining but prior to smoking[5]	----	----	----	----	1.88
Rib after smoking[5]	19.0	24.1	54.2	2.82	2.09

[1] Association of Official Agricultural Chemists, 1960.
[2] As described in table 1.
[3] Represents an average of two determinations, using six fillets per determination.
[4] Represents an average of two determinations, using waste from two fish.
[5] Represents an average of two determinations, using six boneless ribs per determination.

Table 3.--Cold-storage life of bigmouth buffalo products[1]

Product	Packaging material	Rating following storage at 36° F. for:						Estimated shelf life
		0 week	1 week	2 weeks	3 weeks	4 weeks		
								Weeks
Smoked rib	Perforated polyethelene pouch	Excellent	Excellent	Good	Dark fatty layer slightly off-flavor	Dark fatty layer slightly rancid. First notice of mold		3
		Rating following storage at 0° F. for:						
		0 month	1 month	2 months	3 months	4 months	5 months	
		Excellent	Excellent	Good	----	----	Dark fatty layer definitely rancid	8
Scored and breaded loin	Waxed carton with cellophane overwrap	Excellent	Good	Good	Dark fatty layer slightly off-flavor	Dark fatty layer slightly rancid	Dark fatty layer definitely rancid	12

[1] Based on organoleptic evaluation.

Figure 6.--Freezing blocks of "scored" buffalo loins on a double-contact plate freezer.

of cellulose casings, then further processed into specific products, descriptions of which follow.

Breaded Buffalo Links.--The mixture was stuffed into frankfurter-type casings, linked, and processed in water at 165° F. for approximately 10 minutes to an internal temperature of 152° F. The product was chilled with ice water to an internal temperature of 80° F. The casings were removed, and the links breaded and tray-packed with an overwrap of plastic film and placed in a freezer-chest held at 0° F.

Smoked Buffalo-Furters.--The mixture was stuffed into frankfurter-type casings and linked. The linked strands were processed in a smokehouse starting at 140° F. The temperature was increased 10 degrees every 15 minutes until it reached 170° F. Processing was continued at this temperature until an internal temperature of 150° F. was attained. Total smoking time was approximately 1 hour. The links were then sprayed with cold water for about 10 minutes to an internal temperature of 85° F. and held overnight in a 40° F. cooler. The casings were removed, and the links

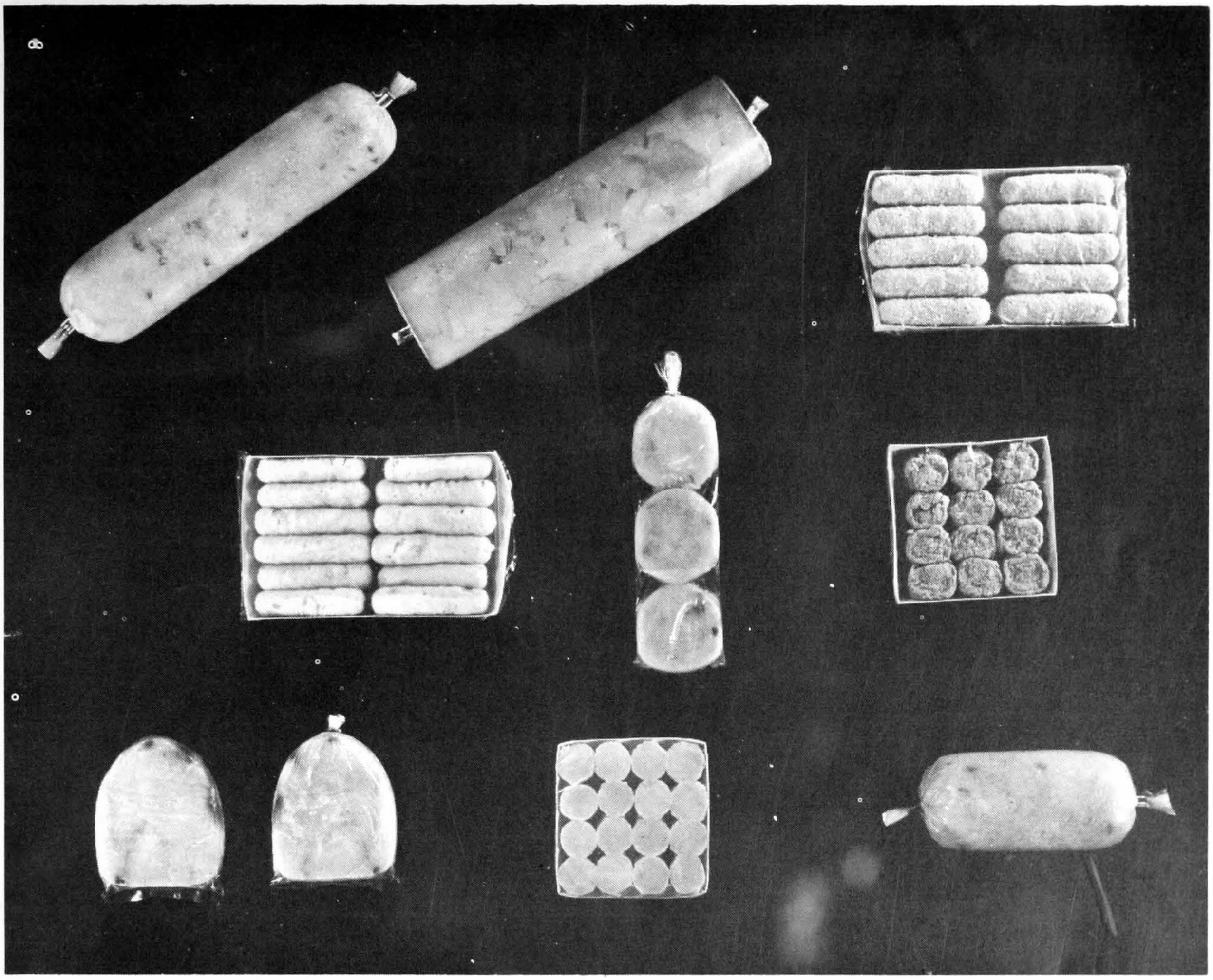

Figure 7.--Various reconstituted buffalo products processed in cellulose castings. Left to right; *bottom row:* fish roll, "scallops," fish steaks; *middle row:* breaded bits o'fish, patties cut from roll, fish links; *top row:* breaded fish links, fish portions in roll form, olive and pimento roll.

tray-packed with a plastic film overwrap and frozen.

Buffalo-Patties.--The mixture was stuffed into $2\frac{1}{2}$-inch diameter casings and cooked in water at 165° F. for approximately 1 hour to an internal temperature of 155° F. The product was then cooled with ice water to an internal temperature of 84° F. and frozen. The frozen rolls were sliced into $\frac{1}{2}$-inch thick patties and packaged on backboards with a plastic film overwrap. The patties may or may not be breaded before cooking.

Fish-Shaped Buffalo Portions.--The mixture was loosely stuffed into a 4-inch diameter casing and the stuffed casing inserted into an opened fish-shaped wire cage-mold (fig. 8). When the cage was closed, the stuffed casing conformed to the shape of the cage. The product in the cage was then frozen. Portions $\frac{1}{2}$-inch thick were sawed from the frozen roll, breaded, and packaged in a conventional overwrapped wax carton.

Buffalo Olive-Pimento Roll.--In addition to the ingredients mixed with the emulsion for the previous reconstituted products, the following ingredients were added to 10 pounds of emulsion: $1\frac{1}{2}$ ounces of monosodium glutamate, $4\frac{1}{2}$ ounces of cider vinegar, $4\frac{1}{2}$ ounces of diced green olives, $4\frac{1}{2}$ ounces of diced pimentos, $4\frac{1}{2}$ ounces of diced carrots, and $4\frac{1}{2}$ grams of powdered celery. The mixture was stuffed into $2\frac{1}{2}$-inch diameter casings and cooked in water for approximately 1 hour at 165° F. to an internal temperature of 152° F. The product

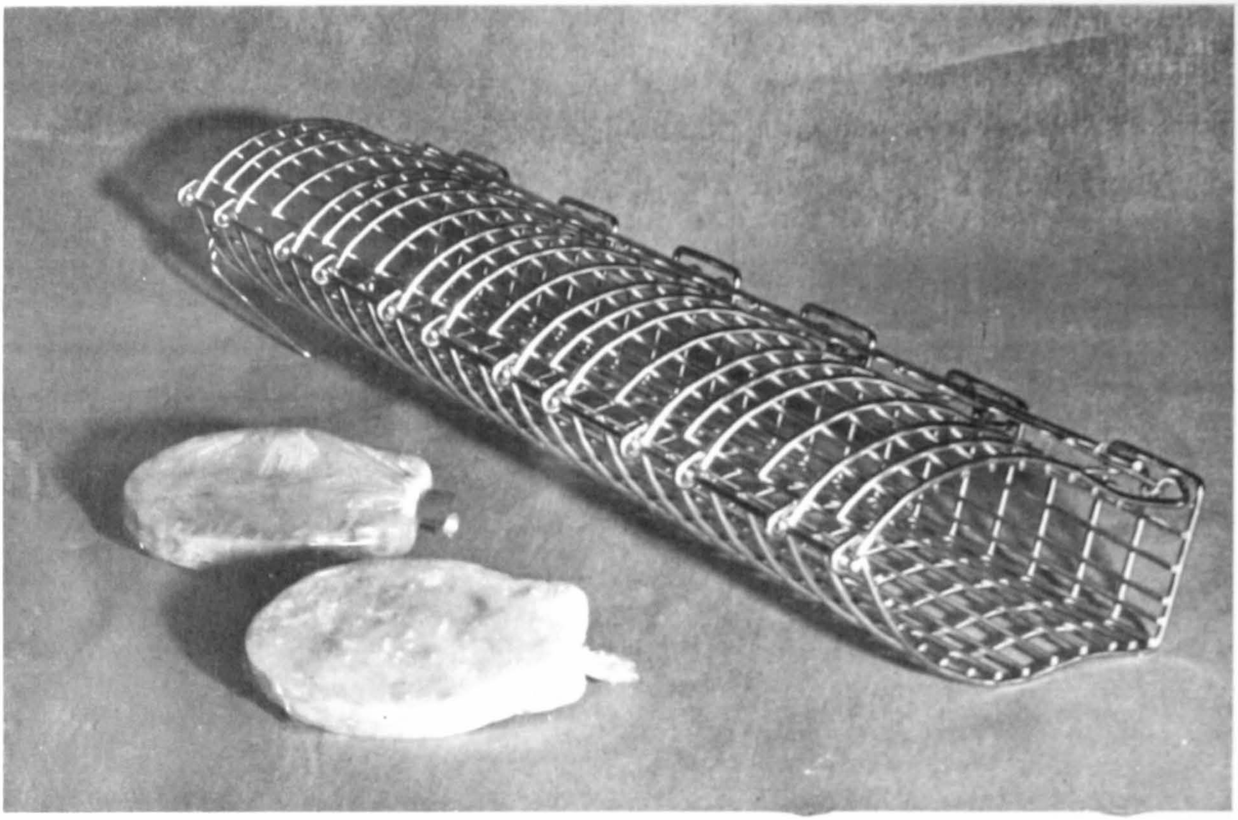

Figure 8.--Wire cage-mold used in shaping reconstituted fish-shaped buffalo portions.

was then chilled with ice water to an internal temperature of 80° F. and frozen. The roll was thawed, sliced, and served cold as a buffet item.

Each of the reconstituted products has been tested by various industry, technical, and consumer groups for acceptance. Results of these examinations have been most encouraging in that no evidence of residual bone was noted. Shelf life data for the products have not been obtained.

Canned and Barbecued Products

In addition to the products previously described, canned and barbequed products from buffalo were prepared. Typical procedures were as follows:

Barbequed Buffalo Ribs.--The rib section was hand rubbed with $\frac{1}{2}$ ounce of barbeque seasoning powder, tray-packed with a plastic film overwrap and frozen. For serving, the rib was removed from the wrapper, rewrapped in aluminum foil, and baked at 400° F. for 15 minutes. It is likely that this product would be ideally suited for packaging and cooking in "boilable-type" plastic pouches. This barbequed product, which is simple and inexpensive to prepare, rated highly in acceptance tests.

Canned Buffalo Flakes.--Canned buffalo products initially prepared consisted of chunk-style packs similar to canned salmon. This style proved highly unsatisfactory, as the heavy bones did not soften sufficiently. Furthermore, the flavor was strong, the texture mushy, and the cans (with conventional enamel) were severely discolored. Subsequent packs, similar to canned flake tuna, proved more satisfactory. Dressed buffalo were precooked in steam at 240° F. for 5 minutes. The flesh was chilled, boned and flaked, and packed in $\frac{1}{2}$-pound aluminum cans. To 5 ounces of precooked flakes in each can were added $\frac{1}{2}$ teaspoon of salt, 2 teaspoons of a dilute vegetable broth, and $\frac{1}{2}$ ounce of vegetable oil. The cans were vacuum-seamed and processed at 240° F. for 75 minutes. When only white meat was used, the flavor proved satisfactory, but when dark meat was included, an objectionable flavor resulted. Precooking greatly improved the texture of the product by removing considerable moisture. Manual boning and flaking or use of aluminum cans may not prove economically feasible. Use of the aluminum container, however, eliminated the discoloration of cans.

DISCUSSION

A smoked rib product highly acceptable to consumers can be produced from the bigmouth buffalo. This item should prove economical to produce and could bring a market price comparable to other smoked fishery products. Because the relatively short shelf life of the product could hamper its development, further work is needed to preserve its initial high quality. The barbequed rib product also appears to have possibilities and could have a variety of applications.

Technical problems still exist in the development of products for human consumption from the remainder of the edible portion of the buffalo. The objection of consumers to bones in frozen convenience-type products would suggest that the loin will be difficult to use unless it is ground. Grinding and reconstituting, however, does appear promising. The great flexibility of this method, and particularly the use of casing materials in the manufacture of extruded products, should permit use of a variety of processing procedures and development of convenience-type products.

Of no small concern is the relative instability of the oil in the dark muscle of the buffalo, which causes oxidative rancidity after only moderate periods of frozen storage. Although no data on storage have as yet been obtained for the reconstituted products, this problem could be made more acute because of the emulsification. On the other hand, inclusion of antioxidants would be facilitated by this processing method. A more uniform and intimate distribution of the additives would be possible. This problem is the object of current technological investigations; the results of these studies will be reported in a subsequent paper.

Although the primary objective of the present study has been to develop products for human consumption, use of buffalo and other pond-reared fish in the manufacture of industrial products should not be overlooked. If the potential value of this inland resource is to be fully realized, wastes from conventional processing operations, as well as the whole fish of species not suited for human consumption, should be utilized for the production of animal foods (Jones, 1960). Species such as gizzard shad, which are harvested incidentally with buffalo in some ponds, currently have little commercial value and are discarded. These and other rapidly growing species, if raised in quantity, possibly could be exploited for industrial purposes.

Two million acres of potential fish-pond areas lie in the lower Mississippi valley. If the conservative estimate of 300 to 500 pounds[4] of fish per acre is accepted, it becomes apparent that this country possesses within its boundaries a vast potential source of protein. For this potential to be realized, however, there must be a cooperative effort in all phases of the fish-farming industry to produce modern and competitive products from a technically advanced fishery.

SUMMARY

This study was conducted to develop marketable products from bigmouth buffalo, the predominant species produced by the fish-farming industry of the lower Mississippi River valley (ricefield areas). Although buffalo weighing 6 pounds and over are sold readily on the fresh-fish market, smaller fish, such as the 3-pound buffalo harvested from ricefield impoundments, are difficult to sell because of small objectionable bones in the flesh.

Preliminary attempts to produce acceptable products by smoking whole split sides were not successful, owing to this bone problem. Since the objectionable bones of the buffalo are confined to the dorsal loin area, this part was cut away, and the remaining rib section yielded a smoked product of excellent acceptance. The remaining loin part was "scored" in an effort to reduce the size of the bones to an unobjectionable level. The scored loin was used in the preparation of conventional fillets and portions, but adverse reaction to the size of the remaining bone fragments made the product unacceptable.

Since the bony loin did not lend itself to a conventional product, it was ground, emulsified, mixed with other ingredients, stuffed into casings, and processed into a variety

[4] See footnote 1, p. 30.

of frozen and cured products. These reconstituted products were judged to be completely free from detectable bone particles and of excellent acceptability.

Shelf life of smoked and frozen buffalo products (without added preservatives) proved relatively short. Objectionable rancid flavors in the smoked product were detected after 3 weeks of storage at 36° F. and after 2 months at 0° F. The frozen breaded products developed similar off-flavors after 3 months of storage at 0° F.

Limited data are given on yield and proximate analysis for certain buffalo products. Detailed formulations for a number of products are listed.

ACKNOWLEDGMENT

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LIST OF PUBLICATIONS--DIVISION OF INDUSTRIAL RESEARCH

By Branch, Year, and Author 1955-61 inclusive

by

Virginia Whorley

ABSTRACT

This report lists, for the years 1955-61, the publications of the various branches of the Division of Industrial Research of the Bureau of Commercial Fisheries (namely, Branch of Economics, Branch of Exploratory Fishing, Branch of Foreign Fisheries and Trade, Branch of Marketing, and Branch of Technology). Since the publications by the various branches differ markedly in subject matter, the publications are listed first by branch. They are then listed by whether the publication was in a Bureau medium or in an outside medium, by year, and by author.

INTRODUCTION

The major responsibility of the Division of Industrial Research is to aid in maintaining the welfare of the commercial fisheries of the United States by performing research and studies in such disciplines as fishery economics, exploratory fishing, gear development, foreign fisheries and trade, marketing, technology, and product inspection services. Because the programs are so diversified, the results may be published in technical periodicals, trade magazines, or any one of several Bureau series, each peculiar to its area of research and each reaching a different group of readers. Publication of this list provides a reference to reports on all the disciplines of the Division.

The Branch of Economics plans and organizes investigations, and performs studies of the economic position of the fishing industry in the national economy. Studies the economics of production, distribution, and consumption of fishery products; the economic effect of technological and biological developments in the fishing industry; labor conditions; price levels and marketing of fishery and competitive products; transportation rates and services; tariff and trade problems; and other fishery economics subjects. Prepares commodity situation reviews and other types of reports resulting from these investigations. Obtains information on activities of fishery cooperatives to assure their compliance with provisions of the Fishery Cooperative Marketing Act (Public Law 464, 73d Congress) approved June 25, 1934. Renders educational, research, and other services concerning fishery cooperatives.

The Branch of Exploratory Fishing uses specially equipped vessels to conduct exploratory fishing programs to locate and determine the extent of new fishing grounds and the size and character of the resource. Designs, tests, and develops new types of fishing gear and equipment. Determines the effectiveness of new and conventional types of fishing gear and fishing craft and demonstrates the most efficient and safest means and methods of operations.

Author Note.--Virginia Whorley, *Program Assistant*, Division of Industrial Research, Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service, Washington, D.C.

The Branch of Foreign Fisheries and Trade prepares and coordinates reports on (1) foreign and domestic fishery situations; (2) production and flow to market of foreign produced fishery products that affect domestic fisheries; and (3) competitive position of domestic and foreign produced fishery products. Conducts studies and provides services on foreign trade and tariff problems, prepares materials for trade agreement negotiations, and prepares analyses of import and export trends. Services the foreign reporting program for fisheries, coordinates and prepares requests for information from foreign posts, appraises and evaluates foreign reporting, and services the fishery attache program.

The Branch of Marketing develops markets for domestic fishery products through (1) increasing the use of fishery products in school lunch, institutional, and consumer menus; (2) encouraging greater distribution of fish through frozen food centers; (3) sponsoring special market promotion programs; (4) forecasting future marketing conditions; (5) developing and expanding foreign markets; and (6) finding new uses for underutilized species. Conducts an educational service to promote the free flow of fishery products of domestic origin by (1) developing visual and other educational materials, including recipe development and the production and distribution of fishery motion pictures in cooperation with the industry; (2) informing the industry and consumers of new and more efficient methods of production, distribution, and preparation by means of field demonstrations and a consulting service; (3) conducting test kitchen activities and fish cookery demonstrations; and (4) encouraging commercial fishery courses in educational institutions.

The Branch of Technology conducts chemical, bacteriological, nutritional and engineering research, and development studies to improve methods of handling, processing, preserving, and distributing fish and shellfish, as well as studies on the utilization of industrial fish and marine plant products. Performs research on processing techniques and on the effects that processing methods and equipment have on the quality and shelf life of fish and fishery products. As a means of maintaining product quality develops improved packaging and refrigeration procedures for shipping and storage. Develops methods of improving shelf life through improved sanitation techniques develops methods of quality identification and measurement applicable to requirements for voluntary U.S. standards of grade and condition of fishery products. Conducts voluntary plant sanitation, product inspection, and certification services on a continuous basis and in cooperation with other Federal product inspection services.

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Household consumer preferences for breaded fish shrimp and breaded fish sticks. Part 1, National and regional summary. Fishery Leaflet 424, 61 p.

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Stolting, W. H., M. J. Garfield, and D. R. Alexander.
Fish and shellfish preferences of household consumers. Research Report 41, 115 p.

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BRANCH OF EXPLORATORY FISHING

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