PROCEEDINGS

of the

FIRST ANNUAL TROPICAL AND SUBTROPICAL FISHERIES TECHNOLOGICAL CONFERENCE

Volume II

Compiled by

Bryant F. Cobb III and Alexandra B. Stockton

October 1976

TAMU-SG-77-105

Partially supported through Institutional Grant 04-6-158-44012
to Texas A&M University by the National Oceanic and Atmospheric
Administration's Office of Sea Grants, Department of Commerce

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TROPICAL AND SUBTROPICAL FISHERIES TECHNOLOGICAL CONFERENCE

March 8-10, 1976

Corpus Christi, Texas

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TRANSFER OF LIPIDS THROUGH MARINE FOOD CHAINS

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Lipids constitute a significant source of energy for marine organisms since the content of digestible carbohydrate of the diet of most of these organisms is rather low (Love, 1970). In addition, lipids are structural part of cell membranes and, as such, they are intimately associated with crucial cell functions such as permeability, oxidation of foodstuffs, respiration, photosynthesis, etc. A third important role of lipids in marine ecological systems is to be the "carriers" of some trace elements such as mercury (Guirguis et al, 1972 and Friberg and Vostal, 1972) and arsenic (Lunde 1972, 1973, 1975; Woolson 1975)

Marine lipids are characteristically different from those of land animals and birds in having a higher content of long-chain highly unsaturated fatty acids. Studies performed in this laboratory (Bottino, 1972, 1974, 1975, 1976) suggest that these marine highly unsaturated fatty acids originate in phytoplankton and that they are transferred from phytoplankton to the upper trophic or nutritional levels of the marine ecosystem. During this transfer from phytoplankton to zooplankton to fish and whales, the highly unsaturated fatty acids undergo "biological magnification" and they can be found in large concentrations in the phospholipids of the organisms of the upper nutritional levels (Bottino, 1976). The organisms located in nutritional levels above phytoplankton may modify slightly the fatty acids they obtain from the diet, but they seem to contribute very little with endogenous fatty acids synthesized _de novo_. In this respect, evidence from my laboratory indicates that the liver of marine catfish (_Arius felis_) has, under various dietary situations, a lipogenic activity as low as that of a starved rat. This low activity of the fish liver enzymes responsible for the production of fatty acids, namely, Acetyl coenzyme A carboxylase and Fatty acid synthetase, cannot be enhanced by feeding a fat-free carbohydrate-rich diet either alone or accompanied by insulin administration (Warman, 1975). Equally diminished lipogenic activity is found in omnivorous and herbivorous fish and in freshwater fish as well (Bottino, unpublished results).

Thus, there are good reasons to believe that the fatty acid synthesizing activity of most marine organisms, except perhaps phytoplankton, remains always low. If this assumption is true, one could follow the transfer of lipids and fatty acids through the nutritional levels of the marine ecosystem just by studying the fatty acid composition of the members of the various nutritional levels. I have attempted to do that and have met various degrees of success. For that reason, I shall give two extreme examples of work done in my laboratory.

The first example is a study (Bottino, 1974) on the lipids and fatty acids of two species of Antarctic krill, _Euphausia superba_, and _E. crystallorophias_, and of the phytoplankton collected in the corresponding stations in the Ross Sea. Both euphausiids are believed to be herbivorous. Once the fatty acid profiles of all the samples were obtained, the "distance" or D value between the phytoplankton fatty acids and those of the krill of the corresponding stations was calculated by the formula of McIntire et al (1969). The results were compared with the known feeding habits. The conclusions were as follows: The distance between the fatty acids of E. superba and phytoplankton was rather small (D=10-15) thus corroborating the herbivorous nature of the crustacean. On the other hand, the distance between the fatty acids of E. crystallorophias and those of phytoplankton from the same area was rather large (D = 30-40). Further studies (Bottino, 1975) uncovered the fact that E. crystallorophias had among their lipids relatively large amounts (about 40%) of waxes with a unilateral fatty acid composition (about 83% oleic acid). When the wax fatty acids were calculated out from the total lipid fatty acids of E. crystallorophias, acceptable correlation with phytoplankton was obtained (D = 10-32).

A second, less successful example was the comparison of the fatty acids of the stomach contents of an Antarctic Sei Whale with those of whale body tissues such as liver, blubber, and muscle (Bottino, 1976). In this case, the distance D between the stomach contents and the body tissues was consistently high (Table 1), indicating that the diet lipid composition had very little effect on the whale body lipid composition.

Of the two examples given above, the phytoplankton-krill lipid interrelation is positive, probably due to the small degree of organ lipid differentiation that is found in krill (Rottino, 1974). In the whale, on the other hand, the results in Table 1 show a very definite degree of differentiation among tissue lipids.

Experimental

Methods for lipid extraction, thin-layer chromatographic separation of lipid classes and gas-liquid chromatography of fatty acids were as described previously (Bottino, 1974, 1975).

Acknowledgements

This work was supported by the Texas Agricultural Experiment Station, College Station, Texas, and by National Science Foundation Grants GV-30413 and GV-41541.

REFERENCES

Bottino N. R. 1972. Fatty acid exchange among trophic levels of the Ross Sea: phytoplankton, copepods, and euphausiids. Antarctic J., U. S. 7: 178.

Bottino N. R., 1974. The fatty acids of Antarctic phytoplankton and euphausiids. Fatty acid exchange among trophic levels of the Ross Sea. Mar. Biol. 27: 197.

Bottino N. R., 1975. Lipid composition of two species of Antarctic krill: *Euphausia superba* and *Euphausia crystallorophias*. Comp. Biochem. Physiol. 50 B: 479.

Bottino N. R., 1976. The lipids of the Antarctic Sei Whale, *Balaenoptera borealis*. In preparation.

Friberg L. and Vostal J., 1972. Mercury in the environment. CRC Press Cleveland, Ohio. pp 39 and 60.

Guirguis H. A., Steward W. K., and Taylor W., 1972. In: Hartung R. and Dinman B. D., eds. Environmental Mercury contamination. Ann Arbor. Sci. Publ., Ann Arbor, Mich., pp 239-246.

Love R. M. 1970. The Chemical Biology of Fishes. Academic Press, London, p. 202.

Lunde G., 1972. The analysis of arsenic in the lipid phase from marine and limnetic algae. Acta Chem. Scand. 26: 2642.

Lunde G., 1973. The synthesis of fat and water soluble arseno-organic compounds in marine and limnetic algae. Acta Chem. Scand. 27: 1586-1594.

Lunde G., 1975. Isolation of an organoarsenic compound present in cod liver. J. Sci. Food Agr. 26: 1247.

McIntire C. D., Tinsley I. J. and Lowry R. R. 1969. Fatty acids in lotic periphyton: another measure of community structure. J. Phycol. 5: 26.

Warman A. W., 1975. Properties of fish liver Acetyl coenzyme A carboxylase and Fatty acid synthetase. Lack of response to dietary changes. Thesis Texas A&M University.

Woolson E. A., ed. 1975. Arsenical Pesticides. Am. Chem. Soc. Press, Washington, DC, pp. 97-107.

Table 1

Fatty acid	Stomach content	Blubber	Muscle	Liver
	weight %			
14:0	4	9	15	11
16:0	13	8	20	10
18:0	1	2	7	2
16:1(n-7)	6	5	4	4
18:1(n-9)	12	13	13	11
20:1(n-9)	10	29	3	25
22:1(n-9)	1	11	11	5
20:5(n-3)	24	3	5	3
22:5(n-3)	7	2	3	2
22:6(n-3)	10	7	12	9
Distance from stomach content	--	31	29	26

Legend for Table 1:

Table 1: Fatty acid composition of Antarctic Sei Whale food and tissues. Only major fatty acids are included. Distance values were calculated according to McIntire _et al_. (1969).

ABSTRACT

The transfer of lipids and fatty acids through the nutritional' levels of marine ecosystems has been investigated. The studies are possible if one assumes that fatty acids are synthesized only to a minor extent by carnivorous members of the food chains. Experimental data from this laboratory support, both directly and indirectly, the above assumption. Thus, with practically no contribution from endogenous fatty acids, the transfer of fatty acids through nutritional levels can be followed simply by studying the fatty acid composition of the feeder and that of the food. Examples of studies of this type done in the Antarctic are phyto-plankton-krill relationships and krill-whale relationships.

LIPID METABOLISM IN CHANNEL CATFISH

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Abstract

The optimum quantity of lipid for best growth and tissue quality in channel catfish (Ictalurus punctatus) has not been precisely determined; however, diets containing approximately ten percent lipid appear to spare some protein and do not lead to high levels of depot fat. Studies have shown that catfish fingerlings grow more rapidly on triglycerides and free fatty acids than on ethyl esters of lipids. More rapid growth has been achieved in a range of environmental temperatures using beef tallow (high in oleic acid) and menhaden oil (high in $\omega 3$ fatty acids) than on safflower oil (high in linoleic acid). Best food conversion and most rapid growth on all diets occurs at about 30 C. While catfish do not appear to require $\omega 6$ fatty acids and grow most rapidly on $\omega 3$ and $\omega 9$ fatty acids, flavor problems could be encountered when $\omega 6$'s are excluded or limited in the diet. A finishing ration containing $\omega 6$ fatty acids could result in improved flavor by allowing a change in body lipid quality after the fish have reached near market size on a diet which produced optimum growth but contained low levels of $\omega 6$ fatty acids.

LIPID METABOLISM IN CHANNEL CATFISH

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Introduction

Lipids, defined as that portion of an organism which may be extracted with nonpolar solvents such as benzene, chloroform, diethyl ether and petroleum ether, may be present in tissue in various forms. Free fatty acids, triglycerides, phospholipids, terpenes, steroids, lipoproteins and lipopolysaccharides are examples of compounds included in the general category of lipids (White, Handler and Smith, 1968). Most dietary lipids occur in the form of triglycerides; molecules containing three fatty acids associated with glycerol. Once triglycerides are consumed, hydrolysis by lipases converts them to free fatty acids and glycerol. Following absorption, storage of lipids in the body is primarily in the form of tryglycerides.

The degree of unsaturation of fatty acids is dependent upon the number of double bonds in the molecule. Saturated fatty acids have no double bonds, mono-unsaturated fatty acids have one double bond and polyunsaturated fatty acids (PUFA) have two or more double bonds. Fish characteristically have high levels of PUFA largely in the form of long chain 18 and 20 carbon unit fatty acids, whereas terrestrial animals have depot fats consisting of shorter chain length fatty acids. The levels of saturated fatty acids are much higher in terrestrial than aquatic organisms (Carroll, 1965). Unsaturated fatty acids occur in three major families: the oleic ($\omega 9$), linoleic ($\omega 6$) and linolenic ($\omega 3$) acid series. Fatty acids of longer carbon chain length are derived from these basic groups. For example, linoleic acid (18:2ω6) gives rise to such other $\omega 6$ family fatty acids at 20:2ω6, 20:3ω6, 22:3ω6, 22:4ω6, 22:5ω6 and others as reviewed by Sinnhuber (1969). In the case of linoleic acid, there are 18 carbon atoms in the chain with two double bonds, the first of which occurs between the sixth and seventh carbon atom from the methyl end of the molecule (the $\omega 6$ position).

Holman (1958) defined essential fatty acids as, "...those substances which are active both for growth and for maintenance of dermal integrity...." Holman limits the fatty acids which fit the definition in warm blooded animals to linoleic acid (18:2ω6) and arachidonic acid (20:4ω6) and to other fatty acids which may be derived from them through metabolic pathways. Therefore, $\omega 6$ family fatty acids are of primary importance to homoiothermous animals, including man.

Fishes contain high levels of 18 and 20 carbon unit PUFA (Carroll, 1965), primarily in the form of $\omega 3$ and $\omega 9$ family fatty acids, with only low levels of $\omega 6$ family acids present in body depot fat as compared with terrestrial animals. Monounsaturated as well as polyunsaturated fatty acids have been found in high concentrations in a variety of fishes (Gruger, et al., 1964; Ackman and Ke, 1968; Culkin and Morris, 1970).

Nicolaides and Woodall (1962) determined that linoleic acid

(18:2ω6) induced recovery from depigmentation brought on by feeding chinook salmon (Oncorhynchus tshawytscha) a fat free diet, and that both linoleic acid and linolenic acid (18:3ω3) stimulated growth. A group of more recent papers have demonstrated that rainbow trout (Salmo gairdneri) require ω3 fatty acids (Lee, et al.1967; Castell, et al.1972a, 1972b, 1972c; Yu and Sinnhuber, 1975). A recommendation has been made that rainbow trout receive no more than two percent ω6 family fatty acids in their diet (National Academy of Sciences, 1973). This report also suggests that the same level may be appropriate for salmon and catfish.

Channel Catfish Lipid Requirements

Information on the quantitative and qualitative lipid requirements of channel catfish (Ictalurus punctatus) is presently incomplete. Most commercially available diets contain lipids as a consequence of adding materials such as fish meal and plant protein meal from which most of the oil has been removed. Feed manufacturers are generally reluctant to add oils back into their formulations because of technical difficulties which the addition will cause in the pelleting process. The utilization of expanded pellets appears to allow more freedom in feed formulation by the milling companies.

Dupree (1968) fed channel catfish diets of varying lipid quality and quantity. An increase in lipid concentration in the diet from four to eight percent resulted in some protein sparing action as indicated by increased protein deposition. A further increase from eight to sixteen percent dietary lipid failed to produce a concomitant increase in protein deposition. No lipid levels between eight and 16 percent lipid were tested, so the absolute value at which an increased level of lipid would fail to result in additional protein sparing action was not determined. Stickney and Andrews (1971, 1972) fed 10 percent lipid to channel catfish at four percent of body weight per day and achieved rapid growth and good food conversion with several different lipid supplements.

The feeding level, digestibility of the lipid and its quality will all affect growth in fish, so these factors must be considered when defining the optimum level of lipid quantity in catfish rations. The sparing action of lipid on protein is important since lipid contains over twice the energy per gram contained in protein. Replacement of some dietary protein by lipid can result in a diet containing more energy and one which allows more of the dietary protein to be laid down as fish tissue and less to be metabolized for energy. Too much lipid in the diet, on the other hand, can result in the storage of lipids in the body and the deposition of fats in the visceral cavity. These deposits can be detrimental to flavor as well as adding to the percentage of waste incurred during processing. A certain amount of depot lipid is desirable, however, to enhance texture and flavor of the product.

Dupree (1968) compared the growth of channel catfish fingerlings fed for four weeks on semi-purified diets supplemented with liquid or solid (hydrogenated) corn oil or beef tallow at four, eight and 16 percent of the diet. In general, the fish which received the solid corn oil grew more rapidly than those offered diets containing the other lipids.

Somewhat different results were obtained by Stickney and Andrews (1971) who reared channel catfish fingerlings over a 70 day experimental period at five temperatures and on three lipid supplements: beef tallow, liquid safflower oil and menhaden oil. The most rapidly growing fish increased 500 percent during the experimental period. Table 1 presents the dietary formulation utilized in this experiment. The fatty acid composition for each lipid supplement is presented in Table 2. Beef tallow, solid at room temperature, is composed of saturated fatty acids and oleic acid (18:1ω9). Safflower oil, very similar in fatty acid composition to corn oil, contains high levels of linoleic acid (18:2ω6), while menhaden oil is characterized by long chain ω3 family fatty acids.

Results of the experiment expressed as final average weight of the fish on each diet and at each temperature are presented in Figure 1. With the exception of 24 C, fish fed the safflower oil diet grew more slowly at all temperatures than did fish on the menhaden oil supplemented diet. At 26, 30 and 33 C faster growth was achieved on menhaden oil than on either of the other lipids, and at all temperatures the fish grew more rapidly on the beef tallow than on the safflower oil diet.

Various studies with channel catfish have demonstrated that the optimum temperature for growth occurs in the vicinity of 30 C (West, 1966; Asadi, 1967; Shrable, et al. 1969; Kilambi, et al. 1970; Andrews and Stickney, 1972). The best growth by catfish on each of the three lipids tested occurred at 30 C (Figure 1).

Similarly, the best food conversions occurred in relation to beef tallow and menhaden oil, with similar values being recorded at 26 and 30 C (Figure 2). At lower and higher temperatures food conversions in excess of 1.5 were obtained on all three diets.

This experiment appears to support the previously mentioned studies which indicated that certain fishes do not require ω6 family fatty acids. The excellent growth obtained with the beef tallow supplemented diet, even at cold temperatures,indicates that the fish were able to metabolize this lipid source which is solid at room temperature. More concrete evidence that beef tallow was effectively metabolized is presented in Table 3 which shows the levels of selected fatty acids in the carcasses of fish on each diet and at each temperature.

Comparison of Table 2 with Table 3 demonstrates that channel catfish reflect to a large extent the dietary lipid composition provided sufficient time is allowed for mobilization and replacement of fatty acids within the tissue. Similar results were obtained from liver analyses run in conjunction with the experiment (Stickney and Andrews, 1971). The rate of growth of channel catfish on beef tallow, an inexpensive lipid source, was similar to that of catfish on menhaden oil (Figure 1), and food conversions were 1.2 for both lipid supplements at 30 C (Figure 2).

Menhaden oil is somewhat more expensive than beef tallow, and both can be expected to affect the flavor of the final product in different ways. Rearing catfish on feeds supplemented with corn oil, safflower oil or other lipids which are high in ω6 fatty acids may provide a more desirable flavor than either beef tallow or menhaden oil, and would provide a less saturated product than that which would occur with fish reared on beef tallow. Research is currently underway at Texas A&M University to determine if the lipid composition of catfish reared on beef tallow or menhaden oil can be rapidly altered near the end of the growing period by altering the diet to one containing higher levels of $\omega 6$ fatty acids. The use of a finishing ration could provide a good tasting, highly unsaturated product without sacrificing growth rate.

In a second experiment, Andrews and Stickney (1972) investigated the growth rate of channel catfish on 27 diets which varied both in lipid composition and in the form in which the lipid was offered: triglycerides, free fatty acids and ethyl esters. Triglycerides and free fatty acids led to more rapid growth than did ethyl esters. Since chemical alteration of commercially available lipid supplements is required to change them from the triglyceride form to either free fatty acids or ethyl esters and no advantage is gained in doing so, feeding lipids in their readily available triglyceride form is advised.

Stickney and Andrews (1972) fed the same basic diet presented in Table 1 at 26 C until the most rapidly growing group of fish achieved a 500 percent increase in weight over their weight at stocking. Figure 3 presents the growth of fish on selected triglyceride diets. The relationships between growth and lipid quality for beef tallow, safflower oil and menhaden oil outlined by Stickney and Andrews (1971) and presented in Figure 1, were confirmed in the second study (Stickney and Andrews, 1972). Growth of catfish on the olive oil diet was slightly less than that on beef tallow although these diets were similar with respect to 18:1ω9 (54.8 percent in olive oil and 57.5 percent in beef tallow). A major difference between these two diets was in the ω6 fatty acids, specifically 18:2ω6. Beef tallow contained 2.1 percent linoleic acid, whereas olive oil contained a level of 22.5 percent, intermediate between beef tallow and safflower oil.

Cocoanut oil, more highly saturated than beef tallow and only containing 14.6 percent 18:1ω9, resulted in a growth pattern similar to that of fish fed a fat free diet (Figure 3) and a diet formulated with medium chain triglycerides (composed of 8:0 and 10:0). A diet containing a mixture of butyric and hexanoic acids (4:0 and 6:0) resulted in the poorest growth obtained during the experiment (Figure 3). It is interesting to note that the diets supplemented with beef tallow and menhaden oil gave rise to more rapid growth in channel catfish than did a practical diet.

Linseed oil, containing 57.6 percent 18:3ω3, might have been expected to lead to rapid growth; however, the results indicated that the fish on that diet grew at a rate similar to and slightly below that of fish reared on safflower oil. Unpurified linseed oil was utilized in the research and may have contained ingredients which contributed to retarded growth. In addition, the absorption and metabolism of linseed oil may have been poor compared to other lipid sources. Table 4 presents the fatty acid composition of fish carcasses from channel catfish reared on linseed oil. Even though the dietary level of 18:3ω3 was very high, and storage of linolenic acid was also high, there is little evidence to indicate that the ingested 18:3ω3 was converted to higher molecular weight ω3 fatty acids.

The fatty acid requirements of channel catfish appear to be satisfied by lipids containing either ω9 or ω3 series fatty acids. Fish on a fat free diet retained a high level of 18:1ω9 (Table 4) although their high molecular weight ω3 fatty acids were depleted. Whether or not catfish could be reared from fingerling to market size on beef tallow without developing symptoms of fatty acid deficiency remains to be determined.

Environmental temperature appears to have a good deal of influence upon the amount of lipid deposited in channel catfish (Andrews and Stickney, 1972) and increasing the level of lipid in the diet also results in increased levels of lipid deposition (Dupree, 1968). In terms of temperature, channel catfish carcasses contained 33.5 percent lipid at 22 and 26 C when fed four percent daily, with higher levels being deposited at higher temperatures and lower levels at lower temperatures (Andrews and Stickney, 1972). In that study a practical diet was utilized to which no lipid supplementation was added above the level present in the dietary ingredients (often about eight percent in practical diets).

In the previously described experiment where semi-purified diets were used to examine the effects of temperature and lipid quality on channel catfish growth (Stickney, 1971), lower levels of carcass lipid were recorded at all temperatures than were obtained with the practical diet (Andrews and Stickney, 1972). The highest levels of depot lipid occurred at 30 C and were less than 20 percent on all three diets (Figure 4). The 10 percent lipid level utilized by Stickney (1971) did not appear to be excessive relative to results with the practical diet. Additional protein sparing action may have been achieved at even higher dietary lipid levels. At 26 and 30 C, more lipid was stored in fish fed the menhaden oil diet than those fed beef tallow, even though fish on both diets were growing rapidly (Figures 1 and 2). This implies that energy from the beef tallow was being utilized for metabolism and that more protein sparing action was occurring with the beef tallow diet than with the menhaden oil diet. Additional clarification of this aspect of lipid metabolism in channel catfish is required.

In summary, the best level of lipid in the diet of channel catfish has not been determined, although it appears to lie within the region of 10 percent of the total diet. Channel catfish, like salmonids, appear to have little or no requirement for $\omega 6$ fatty acids, but the former grow well on $\omega 9$ and $\omega 3$ fatty acids, especially as provided in beef tallow and fish oil, respectively. A great deal of information remains to be gathered on lipid metabolism in channel catfish, but it appears likely that supplementation of the diet with either beef tallow or fish oil could result in more rapid growth than that achieved on presently available commercial diets. The advantage gained through accelerated growth must be weighed against the potential for reduced flavor quality in the product. The feasibility of placing catfish on a finishing ration to offset flavor problems is presently under investigation and may provide a means of producing channel catfish rapidly and with high consumer acceptance.

REFERENCES

Ackman, R. G. and P. J. Ke. 1968. Commercial redfish and flatfish (flounder) oils: comparative features of fatty acid composition. J. Fish. Res. Bd. Can., 25: 1061.

Andrews, J. W. and R. R. Stickney. 1972. Interactions of feeding rates and environmental temperature on growth, food conversion, and body composition of channel catfish. Trans. Am. Fish. Soc. 101: 94.

Asadi, S. 1967. Effect of temperature on the digestive enzymes of channel catfish, Ictalurus punctatus (Rafinesque). M.S. Thesis, Kansas State University, Manhattan, Kansas.

Carroll, K. K. 1965. Dietary fat and the fatty acid composition of tissue lipids. J. Amer. Oil Chem. Soc. 42: 516.

Castell, J. D., D. J. Lee and R. O. Sinnhuber. 1972a. Essential fatty acids in the diet of rainbow trout (Salmo gairdneri): lipid metabolism and fatty acid composition. J. Nutrition, 102: 93.

Castell, J. D., R. O. Sinnhuber, D. J. Lee and J. H. Wales. 1972b. Essential fatty acids in the diet of rainbow trout (Salmo gairdneri): physiological symptoms of ERA deficiency. J. Nutrition, 102: 87.

Castell, J. D., R. O. Sinnhuber, J. H. Wales and D. J. Lee. 1972c. Essential fatty acids in the diet of rainbow trout (Salmo gairdneri): growth, feed conversion and some gross deficiency symptoms. J. Nutrition, 102: 77.

Culkin, F. and R. J. Morris. 1970. The fatty acids of some marine teleosts. J. Fish. Biol. 2: 107.

Dupree, H. K. 1968. Influence of corn oil and beef tallow on the growth of fingerling channel catfish. USDI, BSFW, Tech. Paper No. 27, 12 p.

Gruger, E. H., Jr. R. W. Nelson and M. E. Stansby. 1964. Fatty acid composition of oils from 21 species of marine fish, fresh-water fish and shellfish. J. Amer. Oil Chem. Soc. 41: 662.

Holman, R. T. 1958. Essential fatty acids. Nutrition Reviews, 16: 33.

Kilambi, R. V., J. Noble and C. E. Hoffman. 1970. Influence of temperature and photoperiod on growth, food consumption and food conversion efficiency of channel catfish. Proc. S.E. Assoc. Game and Fish Comm. 24: 519.

Lee, D. J., J. N. Roehm, T. C. Yu and R. O. Sinnhuber. 1967. Effect of ω3 fatty acids on the growth rate of rainbow trout, Salmo gairdnerii. J. Nutrition, 92: 93.

National Academy of Sciences. 1973. Nutrient requirements of trout, salmon and catfish. NAS, Washington, D. C. 57 p.

Nicolaides, N. and A. N. Woodall. 1962. Impaired pigmentation in chinook salmon fed diets deficient in essential fatty acids. J. Nutrition, 78: 431.

Shrable, J. B., O. W. Tiemeier and C. W. Deyoe. 1969. Effects of temperature on rate of digestion by channel catfish. Prog. Fish-Cult. 31: 131.

Sinnhuber, R. O. 1969. The role of fats. In: O. W. Neuhaus and J. E. Halver (eds.). Fish in Research. Academic Press, New York. p. 245.

Stickney, R. R. 1971. Effects of dietary lipids and lipid-temperature interactions on growth, food conversion, percentage lipid and fatty acid composition of channel catfish. Ph.D. Dissertation, Florida State University, Tallahassee, Florida.

Stickney, R. R. and J. W. Andrews. 1971. Combined effects of dietary lipids and environmental temperature on growth, metabolism and body composition of channel catfish (Ictalurus punctatus). J. Nutrition, 101: 1703.

Stickney, R. R. and J. W. Andrews. 1972. Effects of dietary lipids on growth, food conversion, lipid and fatty acid composition of channel catfish. J. Nutrition, 102: 249.

West, B. W. 1966. Growth, food conversion, food consumption, and survival at various temperatures of the channel catfish, Ictalurus punctatus (Rafinesque). M. S. Thesis, University of Arkansas, Fayetteville, Arkansas.

White, A., P. Handler, and E. L. Smith. 1968. Principles of biochemistry, fourth edition. McGraw-Hill, New York. 1187 p.

Yu, T. C. and R. O. Sinnhuber. 1975. Effect of dietary linolenic and linoleic acids upon growth and lipid metabolism of rainbow trout (Salmo gairdneri). Lipids, 10: 63.

Table 1--Diet formulation for semi-purified diets utilized to determine the effects of various lipid supplements on the growth of channel catfish {adapted from Stickney (1971)}.

Ingredient	Percentage in diet
Casein	32.0
Corn starch	40.0
Lipid supplement	10.0
Vitamin diet fortification mix	2.5
Agar (powdered)	1.0
Mineral mix	2.5
Alphacellulose	7.9
Terramycin (TM-10)	0.1
Calcium phosphate dibasic	2.5
L Arginine HCl	2.0
L Cystine	0.5
Antioxidant	0.0125

Table 2--Fatty acid composition of lipid supplements used to evaluate the effect of temperature and fat source on lipid metabolism in channel catfish {adapted from Stickney (1971)}.

Lipid	Fatty acid	Percentage
Beef tallow	14:0	2.9
	16:0	18.8
	16:1ω7	5.1
	18:0	10.9
	18:1ω9	57.5
	18:2ω6	2.1
	Others	2.5
Safflower Oil	16:0	5.7
	16:1ω7	1.9
	18:0	1.9
	18:1ω9	12.4
	18:2ω6	72.5
	18:3ω3	2.9
	Others	2.7
Menhaden Oil	14:0	5.1
	16:0	17.0
	16:1ω7	9.4
	18:0	3.2
	18:1ω9	16.8
	18:2ω6	2.5
	18:3ω3	3.1

Table 2--Continued.

Lipid	Fatty acid	Percentage
	20:3ω9	0.2
	20:3ω6	0.8
	20:4ω3	2.0
	20:5ω3	17.2
	22:5ω3	2.9
	22:6ω3	13.2

Table 3--Selected fatty acid composition (expressed as percentage of total fatty acids) in carcasses of fish fed diets containing three different lipid supplements at five environmental temperatures. {Adapted from Stickney and Andrews (1971)}.

Fatty Acid	Temperature	Beef Tallow	Safflower Oil	Menhaden Oil
14:0	20	1.3	0.7	2.4
16:0	20	14.8	13.7	15.1
18:0	20	3.9	4.0	2.9
18:1ω9	20	49.1	34.4	37.2
18:2ω6	20	9.9	33.2	8.4
18:3ω3	20	2.0	1.1	2.1
20:3ω9	20	0.6	1.6	0.5
20:3ω6	20	1.0	2.5	0.5
20:4ω6	20	2.0	1.8	0.7
20:5ω3	20	1.3	0.5	7.2
22:6ω3	20	2.4	0.9	9.8
Total PUFA	20	23.3	42.9	34.1
Total ω3	20	8.8	2.7	23.6
Total ω6	20	13.9	38.6	10.0
14:0	24	1.3	0.8	2.9
16:0	24	16.5	11.9	16.7
18:0	24	3.3	3.9	4.1
18:1ω9	24	57.7	35.2	37.1
18:2ω6	24	6.1	34.1	7.7
18:3ω3	24	1.8	0.8	1.7
20:3ω9	24	1.0	1.3	0.4

Table 3--Continued

Fatty Acid	Temperature	Beef Tallow	Safflower Oil	Menhaden Oil
20:3ω6	24	0.5	1.7	0.3
20:4ω6	24	0.5	1.8	0.5
20:5ω3	24	0.7	0.6	5.9
22:6ω3	24	1.0	1.1	8.8
Total PUFA	24	12.9	44.1	29.7
Total ω3	24	4.5	2.7	20.5
Total ω6	24	7.4	39.1	8.8
14:0	26	2.0	0.6	2.6
16:0	26	17.7	11.6	16.4
18:0	26	3.5	3.4	3.3
18:1ω9	26	54.6	33.2	37.2
18:2ω6	26	6.5	37.2	3.4
18:3ω3	26	1.6	1.3	2.2
20:3ω9	26	0.9	1.6	0.3
20:3ω6	26	0.4	3.1	0.4
20:4ω6	26	0.4	1.5	1.2
20:5ω3	26	1.0	0.5	7.6
22:6ω3	26	2.4	0.8	10.1
Total PUFA	26	15.5	47.9	31.0
Total ω3	26	6.9	2.8	25.0
Total ω6	26	7.7	42.8	5.7
14:0	30	1.8	0.7	3.0

Table 3--Continued

Fatty Acid	Temperature	Beef Tallow	Safflower Oil	Menhaden Oil
16:0	30	17.6	13.2	15.2
18:0	30	3.3	2.9	2.8
18:1ω9	30	59.2	35.8	36.7
18:2ω6	30	4.1	35.3	3.5
18:3ω3	30	2.1	1.0	2.2
20:3ω9	30	0.7	1.6	0.2
20:3ω6	30	0.3	2.3	0.3
20:4ω6	30	0.4	1.0	0.5
20:5ω3	30	0.7	0.5	7.8
22:6ω3	30	0.5	0.6	10.9
Total PUFA	30	10.3	43.5	31.1
Total ω3	30	4.6	2.2	26.2
Total ω6	30	5.0	39.3	4.7
14:0	33	1.3	0.9	2.2
16:0	33	18.0	11.4	15.8
18:0	33	2.9	2.6	2.0
18:1ω9	33	56.1	33.0	34.0
18:2ω6	33	5.9	37.7	4.8
18:3ω3	33	2.2	1.0	2.4
20:3ω9	33	0.7	2.0	0.4
20:3ω6	33	0.5	1.6	0.2
20:4ω6	33	0.5	1.2	0.6
20:5ω3	33	1.0	0.6	8.8

Table 3--Continued

Fatty Acid	Temperature	Beef Tallow	Safflower Oil	Menhaden Oil
22:6ω3	33	1.1	1.1	11.0
Total PUFA	33	13.9	48.1	33.9
Total ω3	33	6.1	3.0	27.5
Total ω6	33	7.1	41.3	6.0

Table 4--Selected fatty acid composition (expressed as percentage of total fatty acids) in carcasses of channel catfish fed a fat free diet and one containing 10 percent linseed oil {adapted from Stickney and Andrews (1972)}.

Fatty Acid	Fat Free	Linseed Oil
14:0	1.4	2.9
16:0	17.7	10.3
18:0	2.8	2.3
18:1ω9	51.9	31.2
18:2ω6	4.9	9.9
18:3ω3	2.4	28.3
20:3ω9	2.7	1.3
20:3ω3	0.7	0.6
20:4ω6	1.4	1.8
22:5ω6	1.3	4.2
22:6ω3	2.2	4.5
Total PUFA	18.2	50.0
Total ω6	8.6	12.3
Total ω3	6.9	36.4

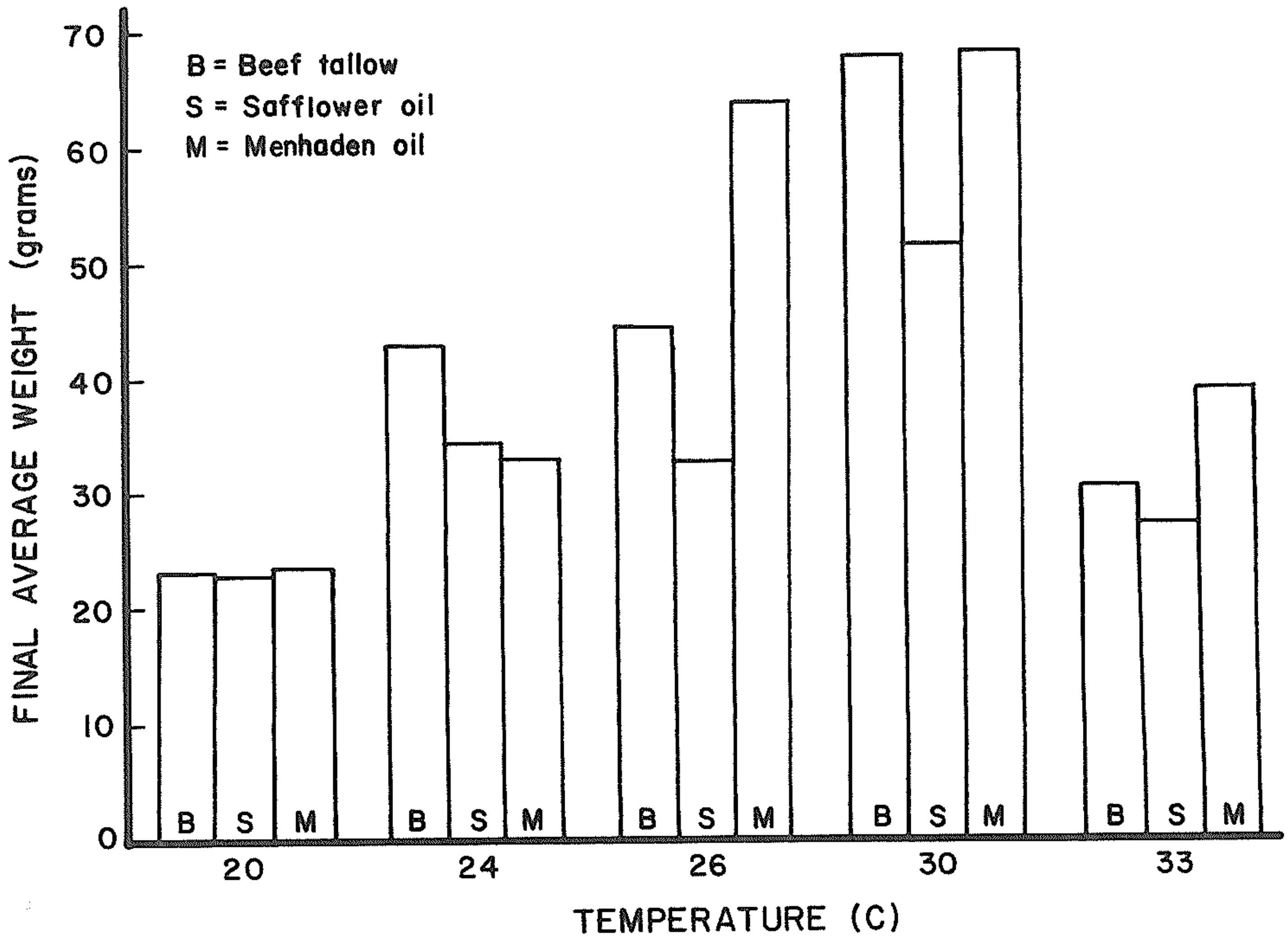


Fig. 1--Average final weights of channel catfish fingerlings fed three lipid supplements at five environmental temperatures. [Adapted from Stickney (1971).]

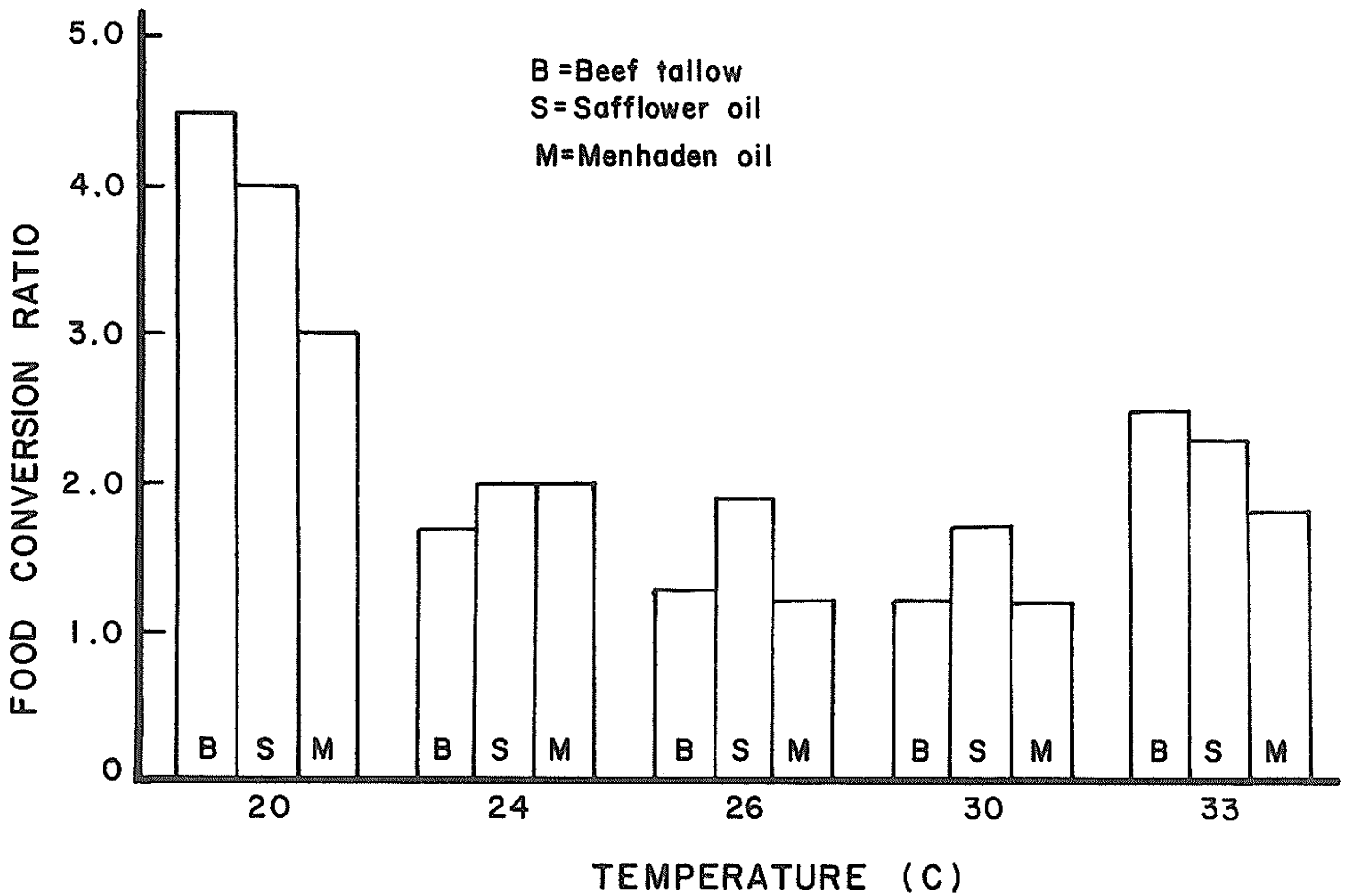


Fig. 2--Food conversion ratios (g fed/g gain) for channel catfish fingerlings fed three lipid supplements at five environmental temperatures. {Adapted from Stickney (1971).}

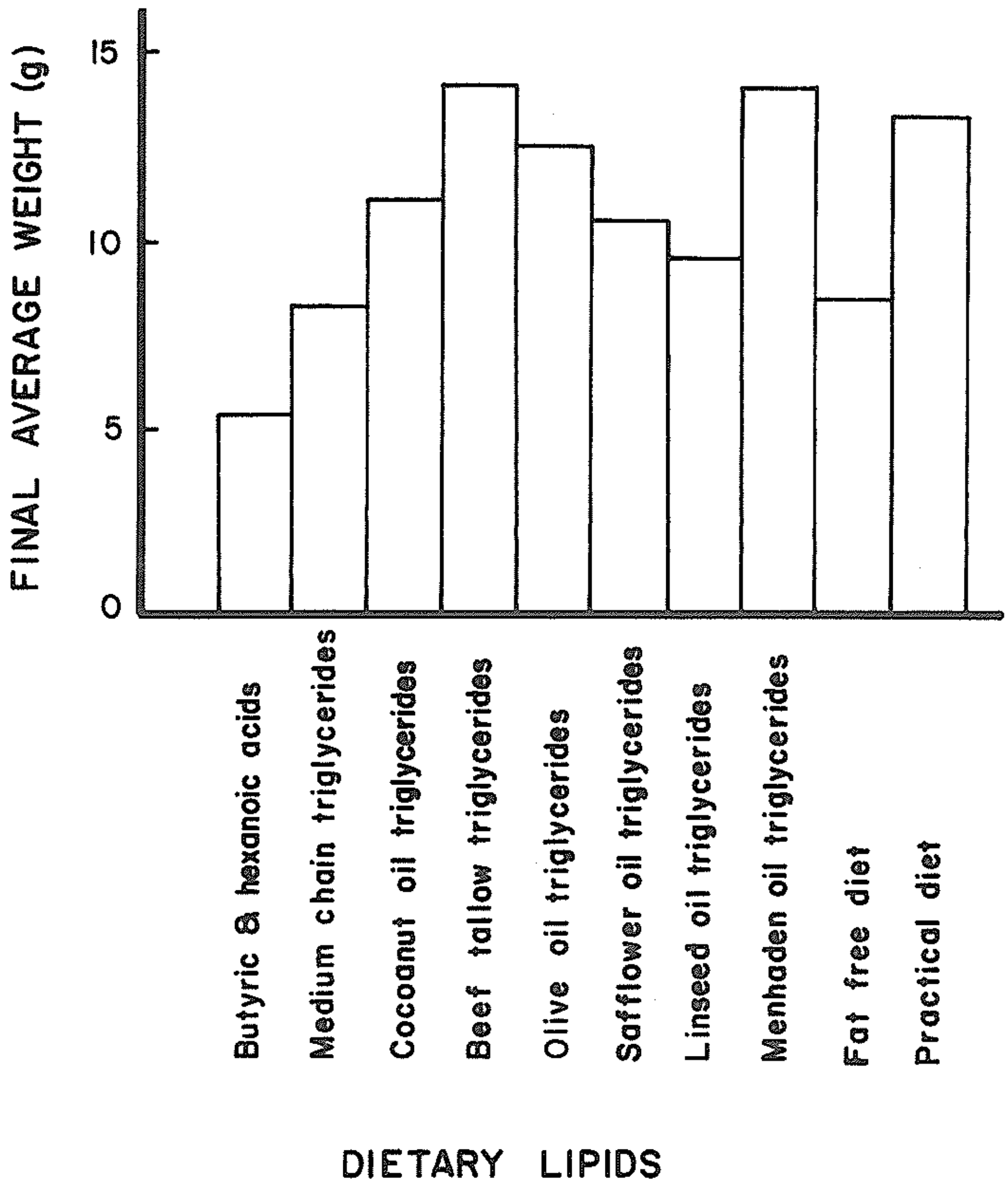


Fig. 3--Growth of channel catfish fingerlings fed diets supplemented with various lipids in the form of triglycerides. {Adapted from Stickney (1971).}

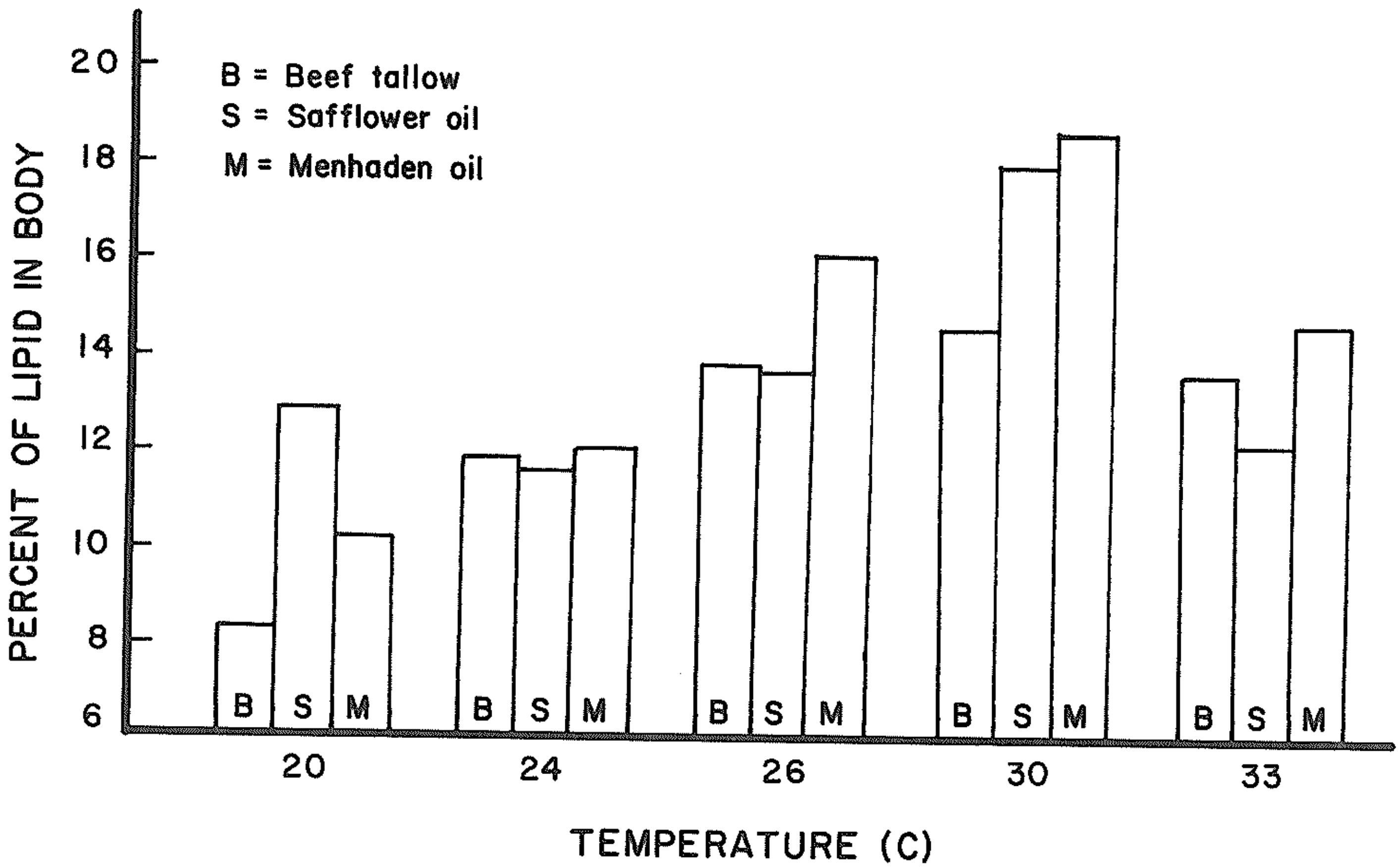
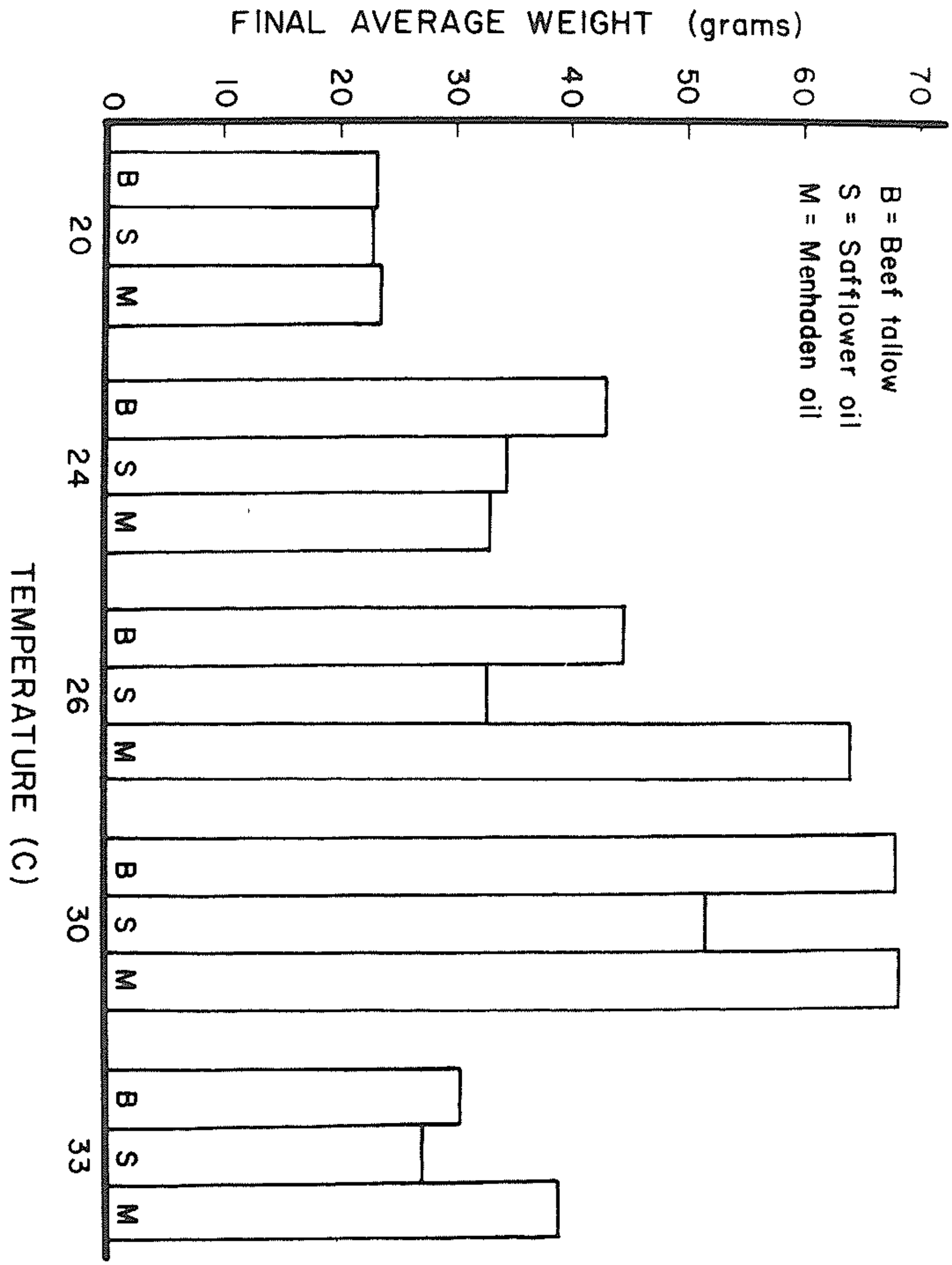
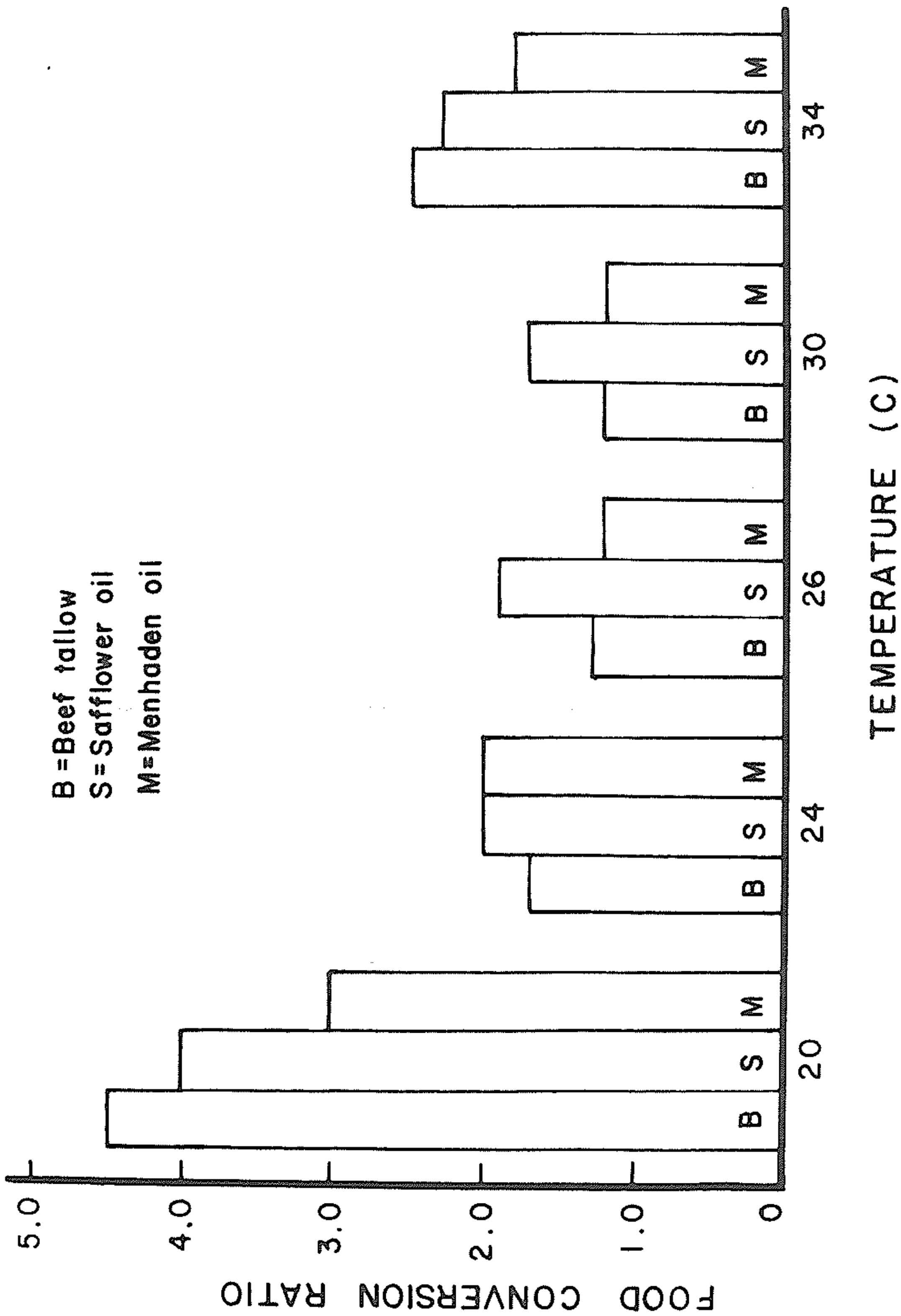
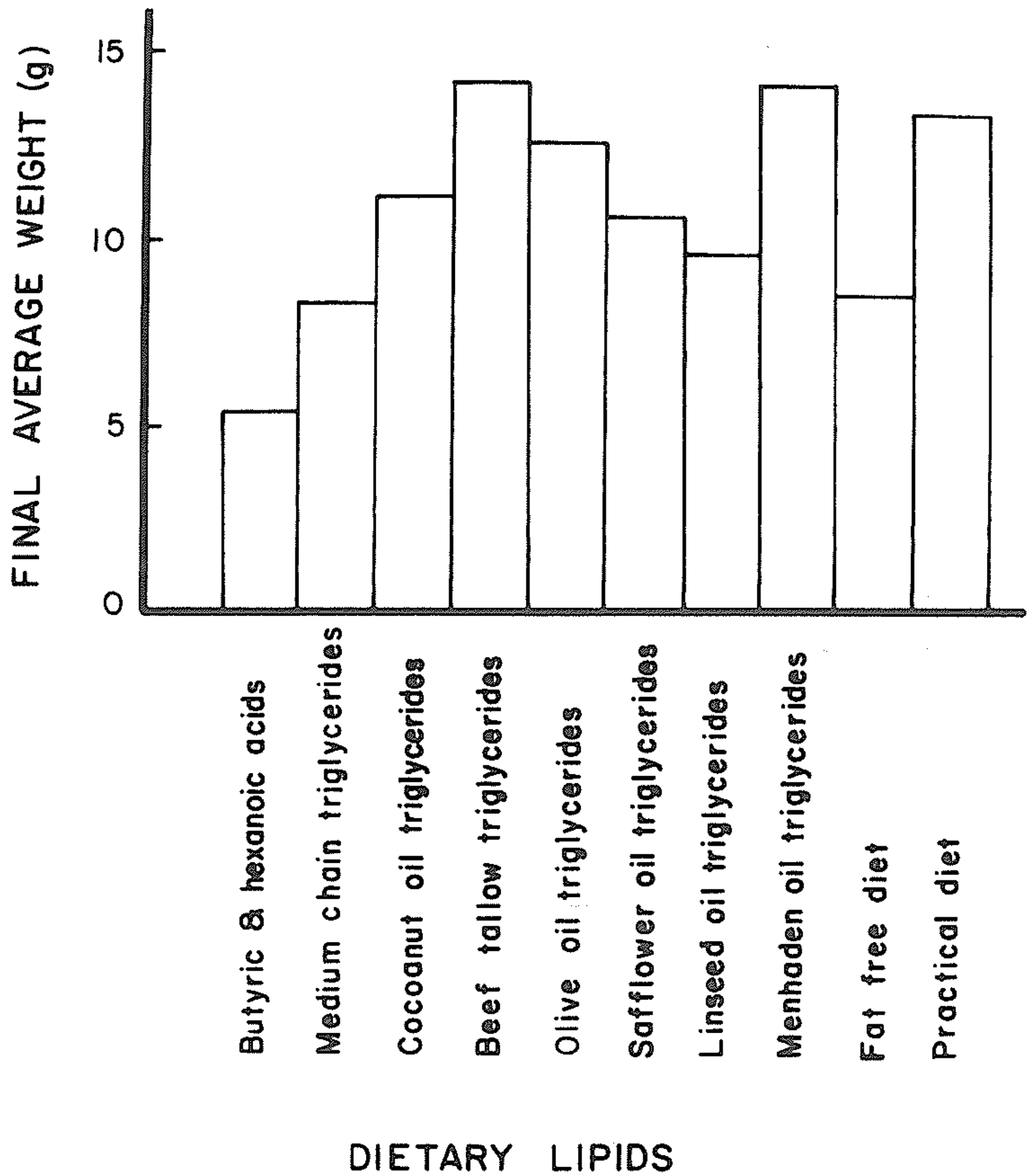


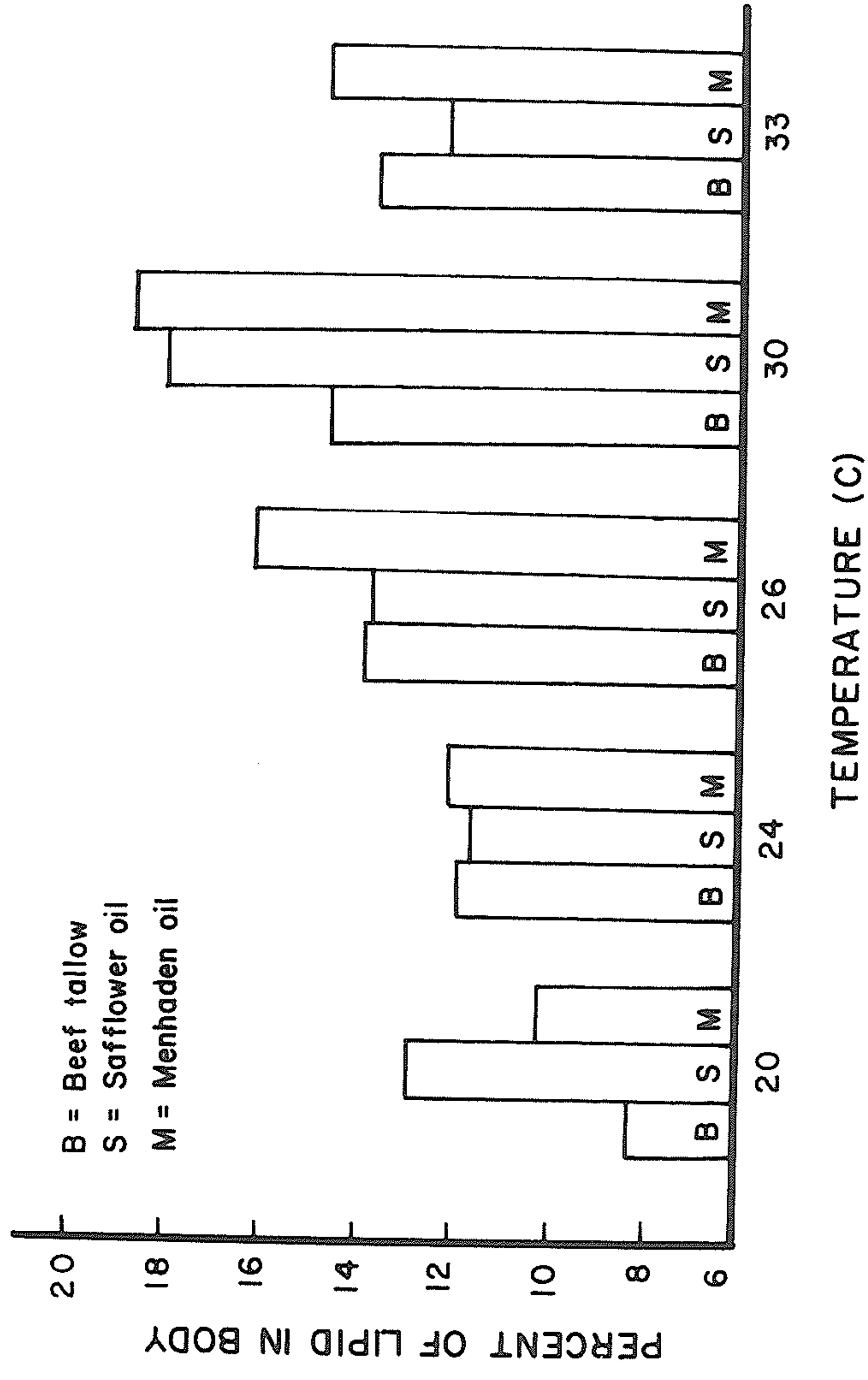
Fig. 4--Percentage of channel catfish carcass lipid in fingerlings reared on three different triglyceride lipid supplements at five environmental temperatures. {Adapted from Stickney (1971).}



FINAL AVERAGE WEIGHT (grams)
0
10
20
30
40
50
60
70
B = Beef tallow
S = Saffflower oil
M = Menhaden oil
B
S
M
20
24
26
30
33
TEMPERATURE (C)


B = Beef tallow
S = Safflower oil
M = Menhaden oil
FOOD CONVERSION RATIO
0
1.0
2.0
3.0
4.0
5.0
B S M
20
24
26
30
34
TEMPERATURE (C)


FINAL AVERAGE WEIGHT (g)
15
10
5
0
Butyric & hexanoic acids
Medium chain triglycerides
Cocoanut oil triglycerides
Beef tallow triglycerides
Olive oil triglycerides
Safflower oil triglycerides
Linseed oil triglycerides
Menhaden oil triglycerides
Fat free diet
Practical diet
DIETARY LIPIDS


B = Beef tallow
S = Safflower oil
M = Menhaden oil
PERCENT OF LIPID IN BODY
6
8
10
12
14
16
18
20
TEMPERATURE (C)
20
24
26
30
33
B
S
M

ABSTRACT

FLAVOR PROBLEMS IN FISH CULTURE

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Environment related off-flavors, usually an earthy-musty type, are a chronic problem in intensive fish culture. A pond survey revealed odor-producing algae and actinomycetes in ponds with off-flavor channel catfish. Incidence of off-flavor was independent of season, location, or density of algal bloom. Aquarium studies with cultures of geosmin-producing algae indicated that catfish can absorb off-flavor compounds exclusive of the digestive tract. Geosmin was absorbed at sensory detectable levels within 24 hours. Off-flavor can be purged from catfish relatively quickly by holding in clean water for 4 to 14 days, depending on flavor intensity and temperature. High temperature enhances rate of flavor removal but also increases rate of weight loss by the fish.

FLAVOR PROBLEMS IN FISH CULTURE

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Introduction

A serious and frequent problem in intensive fish culture is the absorption of objectionable flavor compounds by fish from the culture environment. The fact that fish readily absorb organic and inorganic compounds through their gills and skin, as well as from digestive tract makes it understandable that some of the compounds synthesized by organisms that thrive in the highly enriched culture environment can have an adverse effect upon the flavor of fish flesh. The off-flavor that occurs most frequently, often rendering fish unmarketable, is one described as "earthy-musty" ("musty" or "muddy").

Although environment-related off-flavor was observed in pond-raised fish centuries ago in China (Lovell et al., 1975) and is a universal phenomenon in farm-grown fish, aquacultural researchers have generally found other areas more stimulating than ascertaining causes and controls for "mustiness" in fish. Since removal of off-flavor from affected fish prior to marketing (in most societies) is necessary but inconvient, management procedures that will minimize the incidence of environment-related off-flavor would be extremely valuable to fish culturists.

History

Thayson (1936) first described "musty" flavor in fish in studies of trout taken from rivers in Scotland. He associated the cause of the off-flavor to *Actinomyces* which grew in mud that was high in organic matter along the river bank. He demonstrated that trout could absorb compounds from water which were elicited by an oderiferous *Actinomyces*. Aschner *et al*. (1969) reported that a blue-green alga, *Oscellatoria tenuis*, was responsible for a disagreeable "earthy" flavor in carp which made the fish unacceptable in Israel. They recommended holding the off-flavored fish in clean, flowing water for several days prior to marketing to improve the flavor.

Lovell (1971) reported that a characteristic, objectionalbe "earthy-musty" flavor is frequently found in intensively-cultured catfish in the southcentral and southeastern U.S.A. A survey of the catfish processing industry (Lovell, 1972) showed that in the autumn of 1971 several large-scale processors reported that over 50 percent of the ponds tested before being drained contained fish with such intense off-flavor that harvesting was postponed until the flavor improved. Heavy concentrations of odour-producing actinomycetes or bluegreen algae have been identified from ponds with earthy-musty flavored catfish, and are suspected of being the organisms responsible for the off-flavor (Lovell, 1972). Conversely, on many occasions off-flavored fish have been found in ponds which contained actinomycetes and algae not unlike the aquatic flora in ponds where fish had normal flavor. Off-flavor-producing algae and actinomycetes have been found to produce noxious odours or flavors under one set of conditions but not under conditions (Leventer and Eren, 1969; Lovell, 1971). This contributes to the complexity of defining the etiology of the off-flavor problem in fish.

Iredale and Shaykewich (1973) reported that commercial rearing of rainbow trout in prairie lakes in central Canada has been impeeded by the occurrance of "muddy" flavor in fish from some lakes. They found that certain smoking and canning processes can effectively reduce the intensity of "muddiness" in the fish. Off-flavor has been a common problem in carp ponds in China, Japan, and Europe for many years (Lovell, 1975) and the traditional solution has been to hold the fish in clean, water for a period until the flavor becomes acceptable.

The compound(s) responsible for the "earthy-musty" flavor in fish apparently is geosmin, a highly odorous colorless neutral oil with a molecular formula of $C_{12}H_{22}O$ (Gerber and Lechevalier, 1966), or chemically related metabolites synthesized by aquatic microorganisms. Gerber and Lechevalier (1965), Medsker _et al_. (1968) and Rosen _et al_. (1970) isolated the "earthy-musty" smelling metabolite, geosmin, from several actinomycetes. Safferman _et al_. (1967) discovered the blue-green alga _Symploca muscorum_ produced geosmin and Medsker _et al_. (1968) showed that another alga, _Oscillatoria tinuis_, also produced this compound. Other odorous compounds isolated from actinomycete cultures or natural waters, which differ slightly from geosmin, are mucidone (Dougherty _et al_., 1966) and

2-methylisoborneol (Rosen et al., 1970). Recently, Yurkowski and Tabachek (1974) isolated geosmin from rainbow trout and identified it as the principal compound responsible for the muddy flavor in farmed fish from lakes in Canada. At Auburn we identified goesmin in flesh of musty flavored channel catfish from commercial and experimental sources.

Personal observations indicate that off-flavor is a chronic problem in recirculating raceway systems. Although causitive organisms have not been identified, actinomycetes growing on organic sludge below the biofilter are a probable source.

Etiology

Pond Observations

Research on off-flavor in pond-grown channel catfish has been in progress at Auburn University since 1971. During a 2-year period a pond survey was made to identify conditions and organisms associated with the "earthy-musty" flavor problem that often occurred in fish from intensively fed ponds.

The first year, fish were collected from commercial ponds where farmers or processors reported off-flavor fish, and sensorily evaluated for intensity of off-flavor. An evaluation scale was established and judges were conditioned and selected on the basis of their ability to perceive the geosmin-type odor in prepared solutions and in fish. In the survey, and in all subsequent sensory evaluations of fish for "earthy-musty" flavor, the fish were dressed, wrapped in aluminum, and cooked without seasoning for 15 minutes at 250°C. Initially, the evaluators compared the suspect off-flavor fish against control fish with no off-flavor in triangle difference tests prior to assigning a numerical rating to fish with established off-flavor. As the evaluators gained experience, it was found that the initial difference test was not necessary. The evaluators assigned each sample a score of 1 to 10 according to the following scoring system: 10 = no off-flavor; 8 = slight; 6 = distinct, 4 = intense; and 2 = extreme. In addition to sensory evaluators, other information obtained included date, location of pond, water temperature and total hardness (as $CaCO_3$), condition of plankton bloodm, predominate algae, and presence of odorous actinomycetes. Samples of water, mud and residue from the fish's stomachs were cultured on actinomycete-specific agar plates and colonies grown on the plates were tested sensorily for odorous volatiles.

Forty-two alleged off-flavor ponds were surveyed. Most contained fish with slight to extreme off-flavor that was highly characteristic of the geosmin type ordor. The survey revelaed very little conclusive information regarding season, geographic location, pond condition or types of organisms associated with off-flavor in the fish. The following generalizations were made regarding incidence of "earthy-musty" flavor in pond-cultured channel catfish:

1) Off-flavor was found during all parts of the growing season.
2) Off-flavor was found in ponds in hilly areas with low-productive, sandy soils and low water hardness and in ponds in fertile loam and clay soils with high water

hardness.

3) Off-flavor was not related to intensity of plankton bloom or occurrance of a plankton die-off.

4) Off-flavor was not consistently related to a specific alga or to an odor-producing actinomycete. Generally, algae in the off-flavor ponds were similar to those found in ponds where fish did not have off-flavor. Odor-producing actinomycetes were found frequently in off-flavor ponds but were found as often in ponds with fish having no off-flavor.

5) Off-flavor in ponds in hilly, acid soils with soft water usually occurred early or late during the growing season when the water temperature was around 20°C or slightly lower; whereas, ponds in the more fertile clay and loam soils with higher water hardness had off-flavor fish during all parts of the growing season.

In 1973, channel catfish from 40 ponds on the Auburn University Fishery Research Station were removed at various times during the year and evaluated for off-flavor. In the early spring, fish in three ponds had a distinct earthy-musty flavor. Each of these ponds had heavy blooms which were almost exclusively the blue-green alga *Anabaena circinalis*. Fish from a pond without off-flavor were placed in a floating cage in one of the ponds with the *A. circinalis* bloom and allowed to stay for 1, 2, 4, 7 and 14 days. After 1 day the fish had a distinct flavor as determined by a panel of four experienced evaluators, and at 7 days the off-flavor was intense. No off-flavor was detected in fish from any ponds during the. summer or early fall. In late fall off-flavor fish were found in one pond with a heavy bloom of *A. circinalis* and in two ponds with intense growths of *Volvox aureus*.

No odorous actinomycetes were found in the off-flavor ponds. Of the forty ponds evaluated, most had algae blooms; however, only two algae, *A. circinalis* and *V. aureus*, both found in cool weather (20°C), could be associated with the earthy-musty flavor in catfish.

Controlled Studies

Although blue-green algae have frequently been suggested as causes of earthy-musty flavor in pond-cultured fish, such an association has not been established under controlled conditions. A study was conducted at Auburn University (Lovell, 1972) to determine the capability of geosmin-producing blue-green algae to impart the earthy-musty flavor in the flesh of channel catfish. Cultures of geosmin-producing blue-green algae *S. muscorum* and *O. tunuis* were obtained from the Federal Water Quality Control Laboratory in Cincinnati, Ohio. Fifty-gram channel catfish were held in 150-liter stainless-still tanks containing dense masses of luxuriantly growing *S. muscorum* or *O. tenuis* to determine the capability of these algae to impart the geosmin flavor in the fish. To measure the rate of off-flavor development in the tanks, four fish were collected from each of two tanks of *S. muscorum* and four from each of the two tanks of *O. tenuis* at 1, 2, 4, 6, 10 and 14 days after stocking. After each collection the fish were quick-frozen and stored in hermtically-sealed pouches at -23°C for subsequent sensory analysis. To determine time required to purge the fish of any flavor acquired from the algae, catfish were held in two tanks of *S. muscorum* for 14 days, then removed and placed in charcoal-filtered, flowing water. The fish were removed from the flowing water after 0, 3, 6, 10 and 15 days and quick-frozen for subsequent analysis.

To determine the ability of fish to absorb the flavor compounds from the water without having an opportunity to ingest the algae, two "algae-free" tanks were stocked with fish. Water passed from two *S. muscorum* culture tanks into the two cell-free tanks by gravity through a glass wool filter, and was exchanged between the tanks twice daily. The algae tanks and the algae-free tanks both were enriched with nutrient solution; consequently, exchange of water between the two tanks did not dilute the nutrient concentration in the algae tanks. Fish were removed from the algae-free tanks according to the same schedule as was followed with the fish taken from the algae tanks.

After all samples had been collected, the frozen fish were thawed, dressed, and cooked for sensory evaluation for earthy-musty or algae-related flavor by a taste panel composed of four trained, experienced evaluators.

Within one day, the fish from the *S. muscorum* tanks had developed a distinct earthy-musty flavor, similar to the odor of the alga, which became stronger at two days and reached maximum intensity at ten days (Table 1). Algae-related flavor was only slight, but significant (P 0.05), in fish from the *O. tenuis* tanks at 2 days and reached a maximum at 14 days, but never equalled the intensity of that in the fish from the *S. muscorum* tanks.

Stomach contents of the fish revealed that moderate amounts of both algae were eaten during the first day they were in the culture tanks.

The fish which were exposed to the algae-free filtrate from algae culture tanks developed a flavor qualitatively similar to that of the fish held in direct contact with the algae. This indicated that the fish were able to absorb the dissolved geosmin-like compounds from the water, primarily across the gill membrane, into the blood. Absorption of the off-flavor compounds was appreciably slower by fish held in the algae-free filtrate than by those held in the algae culture tanks (Table I). Evidently acquisition of algae-related off-flavor by channel catfish is greatly facilitated when the fish ingest the algae.

This study presents evidence that channel catfish absorbed compounds synthesized by two species of geosmin-producing blue-gree algae which imparted an earthy-musty type of flavor in the fish. This supports the contention that some blue-gree algae are likely important causes of off-flavor in commercially cultured catfish. Catfish apparently can absorb and subsequently deposit in their flesh sensorily detectable quantities of the flavorous compounds within 24 hours after being exposed to a significant amount of the algae growth, particularly if the algae cells are in dense masses so the fish can feed on them.

Control of Off-Flavor

Removal of Off-Flavor from Pond-Cultured Fish

Three collections of off-flavor channel catfish from commercial ponds were delivered to the Auburn University Fisheries Research Laboratory and held in flowing, charcoal-filtered water at 16, 22, or 26°C. The fish were weighed, and evaluated for flavor by six experienced judges, using the evaluation scale discussed previously, at 0, 3, 6, 10, and 15 days. Changes in flavor and weight of the fish are shown in Table II. The data show that at 16°C between 10 and 15 days was necessary to render the fish free of off-flavor, but weight loss was less than 9%. At 22°C the fish had lost most of the off-flavor between 6 and 10 days but weight loss was 9.5 to 12.2%. At 26°C flavor change was about the same as at 22°C but weight loss was 15 to 17% by the time the flavor was reduced to a tolerable level.

These results indicate that pond-absorbed "earthy-musty" flavor can be purged from the fish in perhaps 5 to 15 days, depending upon water temperature and, certainly, intensity of off-flavor in the fish. However, concomitant with off-flavor removal will be a weight loss ranging from 9 to 17%.

Removal of Geosmin from Aquarium-Cultured Fish

The channel catfish held in the tank containing the geosmin-producing alga *S. muscorum* for 14 days, as discussed previously, subsequently were transferred to a tank containing flowing, charcoal-filtered water at 25°C. After 3, 6, 10 and 15 days the fish were removed and evaluated for flavor by four experienced judges. As shown in Table III, after 3 days in clean water the flavor had improved significantly (P .05). After 10 days, the flavor was not significantly (P .05) different from that of control fish. These results indicate that fish with intense "earthy-musty" flavor caused by geosmin can be "cleaned" within a 10-day period at 26°C by separating the fish from the source of the compound. Apparently, and fortunately for fish culturists, this lipid-soluble, odorous compound is rapidly mobilized from its storage sites in the fish's body.

Practical Controls for Off-Flavor in Fish

Control of environment-related off-flavor in cultured fish concerns three areas: control off-flavor in the culture system; remove off-flavor from the fish after they have developed it; and, utilize off-flavor fish in a process that will mask the flavor.

Control of off-flavor in the culture system is a difficult task inasmuch as a highly enriched aqueous medium favors the grwoth of microorganisms which synthesize the "earthy-musty" compounds. Suggested practices are the following:

1) Minimize feed waste by using good feeds and feeding practices. Growth of geosmin-producing microorganisms is stimulated by unconsumed and unabsorbed organic (actinomycetes) and inorganic (algae) nutrients.
2) Exchange of water through the culture system will remove unused nutrients and minimize the growth potential for off-flavor causing microorganisms. It will also reduce the concentration of microorganisms and off-flavor compounds in the water.
3) Chemical control of blue-green algae in catfish ponds is geingpracticed by some farmers in the United States, although there are no established guidelines. Periodic application of 0.34 kg/ha of copper sulfate crystals

controlled the growth of *Microcystis* in fish ponds at Auburn, Alabama (Crance, 1963); however, this rate was not effective in catfish culture ponds in Mississippi where the water hardness was greater. (Recently a commercial herbicide, simizine, has been legally approved for use in food fish ponds, although most agricultural herbicides are not.) Variations in water chemistry, density and species of algae, and management practices make general recommendations for chemical controls difficult. Permanent elimination of phytoplankton blooms in pond culture is undesirable. Ideally, restriction of noxuous blue-greens and allow harmless green species to grow would be helpful. However, keeping the bloom thinned may reduce the incidence of off-flavor, or, killing off the algae a few days prior to harvest when off-flavor is present may be helpful. Until safe recommendations are established, chemical control of algae should only be practiced where compensatory measures can be taken in the event of an oxygen depletion resulting from an overkill of phytoplankton.

4) Increasing turbidity or muddiness of pond water through mechanical agitation or with bottom-feeding fish wil suppress phytoplankton growth. Also, thereis evidence that the suspended clay particles act as adsorbants for the off-flavor compounds.

Removal of off-flavor from fish:

(1) Off-flavor in ponds is usually, but not always, short-

lived, but will in time disappear. For lack of a better practice, catfish farmers in the United States usually leave off-flavor fish in the ponds until the flavor improves. When this is done the fish should be fed to prevent them from feeding on detritis and other materials that may augment the problem. When possible water should be exchanged as much as possible in the pond.

2) Remove fish from the off-flavor pond and place them in a clean pond or a holding tank with flowing water. Usually the flavor will be acceptable after 5 to 14 days depending upon intensity of the off-flavor and temperature. If possible the fish should be moved where they can be fed to avoid a 9 to 17% weight loss.

3) Meade (1975)[1] found that adding salt to water in a closed system raceway, to achieve a salinity of 10 parts per 1,000, several days before harvesting the fish solved the off-flavor problem that is usually associated with this culture method. The salinity destroyed the microorganisms, probably actinomycetes, growing in the sludge below the filter.

Processing off-flavor fish:

1) Iredale and Shaykewich (1973) with rainbow trout and Lovell (1972) with channel catfish found that smoking for 5 to 6.5 hrs. with simultaneous cooking partially masked the earthy-musty flavor so that the fish would

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[1]Mead, T. L. 1975. Fish culture in closed-system raceways. Reported at the Midwest Fish Disease Workshop, June 12-13, 1975, Carbondale, IL.

probably be acceptable to consumers.

2) Iredale and Shaykewich (1973) reported that steam precooking of filet strips of rainbow trout and subsequently adding vegetable oil before canning eliminated the earthy-musty flavor.

References

Aschner, M., C. Laventer and I. Chorin-Kirsch. 1969. Off-flavor in carp from fish ponds in the coastal plain and the Gelid. Bamidgeh, 19(1): 23-25.

Crance, J. H. 1963. The effects of copper sulfate on Mycrocystis and zooplankton in ponds. Progr. Fish. Cult. 25: 198-202.

Dougherty, J. D., R. D. Campbell and R. L. Morris. 1966. Actinomycetes: isolation and identification of agent responsible for musty odours. Science, 152: 1372.

Gerber, N. N. and H. A. Lechevalier. 1965. Geosmin, an earthy-smelling substance isolated from actinomycetes. App. Microbiol., 13: 935.

Iredale, D. G. and K. J. Shaykewich. 1973. Making muddy flavor in rainbow trout (Salmo gairdneri) by smoking and canning process. J. Fish. Res. Board Can. 30: 1235-1239.

Leventer, H. and J. Eren. 1969. Taste and odour in the reservoirs of the Israel National Water System. In Developments in water quality research. Proc. Jerusalem International Conf. on Water Quality. p. 19-37.

Lovell, R. T. 1971. The earthy-musty flavour in intensively-cultured catfish. Proc. Ass. South. Agr. Workers 67th Annual Meeting. p. 102.

Lovell, R. T. 1972. Absorption of earthy-musty flavour by channel catfish held in monospecies cultures of geosmin-producing blue-green algae. Trans. Am. Fish. Soc., 103: 775-777.

Lovell, R. T., R. O. Smitherman and E. W. Shell. 1975. Progress and prospects in fish farming. In New protein foods. Academic Press, New York and London. (In print).

Maloney, T. E. 1966. Research on algae odour. J. Amer. Water Works Ass., 55(4): 481-486.

Medsker, L. L., D. Jenkins and J. F. Thomas. 1968. Odorous compounds in natural waters: An earth-smelling compound associated with blue-green algae and actinomycetes. Environ. Sci. Tech., 2: 461-464.

Rosen, A. A., C. I. Mashni and R. S. Safferman. 1970. Recent developments in the chemistry of odour in water: the cause of earthy-musty odour. Water Treatment and Examination, 19: 106-119.

Safferman, R. S., A. A. Rosen, C. I. Mashni and M. E. Morris. 1967.

Earthy-smelling substance from a blue-green algae. Environ. Sci. Tech., 1: 429-430.

Thaysen, A. C. 1936. The origin of an earthy or muddy taint in fish. Ann. Appl. Biol. 23: 99-109.

Yurkowski, M. and J. L. Tobochek. 1975. Geosmin in muddy-flavored rainbow trout. J. Fish. Res. Board Can. (In print).

ORGANOLEPTIC AND BIOCHEMICAL COMPARISONS OF CAGE RAISED AND WILD STRIPED MULLET (*Mugil cephalus*)

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Presented at the First Tropical and Subtropical Fisheries Technological Conference, at Corpus Christi, Texas on 7-10 March 1976 for publication in Proceedings of the First Tropical and Subtropical Fisheries Technological Conference.

ORGANOLEPTIC AND BIOCHEMICAL COMPARISONS OF CAGE RAISED AND WILD STRIPED MULLET (Mugil cephalus)

Abstract

Native wild and cultured striped mullet (Mugil cephalus) and wild spotted seatrout (Cynoscion nebulosus) were compared simultaneously by a taste panel for appearance, flavor, texture, and overall satisfaction. Cultured mullet included those grown for approximately 2 years, 1 year (both fed and nonfed), and 42 days. Specific objectives, utilizing six treatments, were to determine if: (1) mullet cultured in cages differed organoleptically and biochemically from wild mullet; (2) wild mullet confined in a cage for a short time would purge their flesh of off-flavors and odors; (3) flesh quality of caged, fed mullet differed organoleptically and biochemically from that of caged, nonfed mullet; and (4) acceptability of mullet differed from spotted seatrout. Results of proximate chemical analyses on fish tissue of each treatment were related to taste results.

The majority of taste panel members rated all fish samples in all evaluation categories acceptable. Cultured-two-year mullet were rated more desirable to wild mullet in appearance and flavor but inferior in texture and overall satisfaction. Wild mullet did not have any discernible off-flavors or odors, possibly due to very low fat reserves in their flesh, and were not rated significantly inferior in any category. Wild mullet were rated more acceptable in every category than mullet which had been fed for 42 days.

Appearance of spotted seatrout taste samples received the highest rating of any treatment, but when appearance of whole baked fillets was judged, they were rated relatively lower due to presence of excessive oil on their tissue. Trout were rated lower than mullet in flavor and overall satisfaction.

Due to their smaller size, cultured-1-year mullet, both fed and nonfed, were rated lower than other fish in appearance and subsequently in flavor. Fed, cultured-1-year mullet were rated better in flavor and overall satisfaction than unfed, cultured-1-year mullet but were viewed inferior in appearance and texture. Texture of the three fish treatments which received supplemental food was judged inferior, possibly because of a higher water content in their flesh, to texture of the three nonfed treatments.

In another experiment flavor of smoked, cultured mullet was compared to that of smoked, wild mullet captured in Florida. Cultured mullet was preferred by judges to mullet captured in Florida.

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Introduction

Of all estuarine fish species, probably none is as widely distributed as striped mullet (*Mugil cephalus*). It is among the principal products of brackish water fish culture in regions as widely separated as Taiwan and Italy (Bardach et al., 1972). Mullet possess many of the desirable characteristics necessary for successful culture including high quality flesh, wide salinity and temperature tolerances and as compared to carnivorous species a lower position on the food chain.

From a fish culture standpoint, it is desirable to select an organism such as striped mullet which feeds on plankton, benthic algae or decaying higher plants (Cobb, 1976); however, feeding habits may be responsible for off-flavors and odors, dependent upon the environment from which the fish is taken. Mullet are not considered edible in some areas of the world while they are relished as a food fish in others. Striped mullet captured along the Gulf Coast of Florida, which is characterized by sandy bottoms and clear waters, are considered by local residents to be of excellent quality. However, striped mullet taken from the Gulf Coast of Texas, which has muddy bottoms and turbid water, are reported to have oily, muddy or petroleum flavors or odors in their flesh (Cobb, 1976).

This study compared organoleptic acceptability of striped mullet grown in cages with that of native or wild striped mullet. Specific objectives were: (1) to determine if mullet cultured in cages, thereby prevented from ingesting bottom sediments, differed organoleptically and biochemically from wild mullet captured from a nearby bay; (2) to determine if wild mullet confined in a cage and fed a commercially prepared diet for a short time would purge their flesh of off-flavors and odors; (3) to determine if flesh quality of caged, fed mullet differed from that of caged, nonfed mullet which received their nutrition from grazing upon materials and organisms attached to the cage mesh; and (4) to compare organoleptic acceptability of mullet and the commercially desirable spotted seatrout (Cynoscion nebulosus). In a separate experiment, flavor of smoked cage-cultured mullet was compared with that of smoked wild mullet captured in Florida.

Description of the Study Area

Cedar Bayou Electric Power Station, owned by Houston Lighting & Power Company, is located near Baytown in Chambers County, Texas, on a peninsula which separates upper Galveston and Trinity Bays (Fig. 1). The plant intakes cooling water from Galveston Bay through Cedar Bayou and discharges into Trinity Bay through a 9.8-km canal. Prior to entering Trinity Bay, discharge water passes through a 1,053-ha cooling lake. Fish captured in 1973 were cultured in the cooling lake at station 2 while all other fish were cultured at station 1 (Fig. 1). Hydrological parameters at the two stations were similar (Holt and Strawn, 1976).

Materials and Methods

In July, 1973, striped mullet were seined from two 0.1-ha study ponds, located adjacent to the power plant's discharge canal and utilized by Texas A&M personnel for maricultural research, stocked in cages at station 2, fed commercial food for over 2 years and harvested 29 September 1975. This lot was designated C2YF (cultured 2-years and fed). Other striped mullet were captured on 18 August 1975 by cast net from Trinity Bay at the location of the cooling lake outflow, stocked in cages in the cooling lake, and offered supplemental food until 29 September 1975; therefore, these fish, cultured 42 days and fed, were designated C42DF.

Striped mullet seined from Galveston Bay and cultured in cages at station 1 from June, 1974, until 29 September 1975 were partitioned into 2 treatments--(1) those which received supplemental food (cultured 1 year and fed--C1YF) and (2) those offered no supplemental food (C1YNF). Supplementally fed mullet were offered Purina Catfish Chow, floating ration (fr) approximately 6 days per week at a daily feeding rate equivalent to 5% of their body weight. Daily feeding rates were calculated at 2% during November through February. Feeding amounts were adjusted after monthly sampling. Feeding was halted 3 days prior to harvest.

At harvest all fish were placed immediately in crushed ice, transported to the laboratory, weighed, deheaded and eviscerated but not scaled. They were then placed in containers filled with tap water, frozen and stored for 5 days.

Simultaneous to harvest of cultured fish, wild striped mullet were captured from the Trinity Bay outfall (wild nonfed--WNF) and spotted seatrout were taken by gill net from the cooling lake (seatrout nonfed--SNF). They were processed in the same manner as cultured mullet.

Taste panel experiments were performed on fish from each of the 6 treatments with the test being replicated once. Fish were thawed under cool, running tap water, scaled and filleted. Fillets of cultured-1-year mullet averaged approximately 23 g while fillets of other fish samples averaged approximately 42 g. Fillets from each treatment were placed in individual uncovered aluminum foil trays and baked, without condiment, at 120 C for approximately 40 minutes.

Baked samples were number coded and submitted simultaneously to a taste panel of 15 judges at individual stations in a quiet room. The panel was composed primarily of untrained members. Judges were informed of the general nature of the experiment. A glass of water was provided and judges were asked to drink a small amount of water before tasting each sample. Samples were evaluated for appearance, flavor, mouthfeel or texture, and overall satisfaction. After completion of taste sampling, panel members were asked to judge appearance of whole baked fillets of fish in each treatment. A questionnaire employed by Marcello and Strawn (1973) which utilized a hedonic scale of 1 to 8 showing extreme dislike to extreme like, respectively, was used to score each category (Fig. 2).

Proximate chemical analyses of tissue for each treatment included protein, moisture, and fat composition. Total nitrogen (TN) was determined according to the method employed by Cobb and Hyder (1972). Non-protein nitrogen (NPN) was determined on trichloroacetic acid (TCA) extracts and protein nitrogen (PN) was calculated by the relationship:

$$PN = TN - NPN \times 6.25$$

Moisture and/or volatile substances were determined by heating to a constant weight in a drying oven at 125 C (AOAC, 1975). Fat content was determined by the Rapid Modified Babcock Method (AOAC, 1975).

In a separate experiment, hot-smoked, cultured mullet were compared to hot-smoked, wild mullet taken from the Gulf of Mexico at Suwannee, Florida. Florida mullet were deheaded, eviscerated and split longitudinally along the ventral midline before being placed in plastic bags, covered with ice and transported to Texas A&M University. Care was taken to remove black pigment from the coelomic cavity before smoking. Cage-cultured mullet were treated in like manner. Both groups of fish remained on ice approximately 2 days prior to freezing. They were frozen at -20 C prior to and again after smoking.

The smoking procedure utilized was developed by Nickelson (1975). Fish were thawed at room temperature and then placed in a 74^0 salometer brine solution for 5 minutes. Brine ingredients included: 4 gal water, 8.0 lb NaCl, 1 lb sugar, 1 1/2 cps reconstituted lemon juice, 2 tbs onion powder, 1 tbs garlic powder, and 1 bag of crab, shrimp and/or crayfish boil. Hickory chips were used for smoking.

Fish were smoked in a Freeland Smoker* (manufactured by Freeland Smokehouses, Waelder, Texas) at 121 C oven temperature and 60% humidity. A temperature probe was inserted in the muscle of a fish to monitor internal temperature. Light smoking was begun when an internal temperature of 40-50 C was reached (approximately 45 minutes). Fish were maintained at 83 C for 30 minutes to meet FDA regulations for smoked fish. Total smoking time was approximately 1 1/2 hours. Fish were left on trays in a cold room (5 C) overnight before being refrozen.

A 10 member taste panel, composed primarily of untrained judges, employed a triangle test (ASTM, 1968) to compare smoked samples of the 2 treatments. Three samples, two from one treatment and the third from the other treatment, were placed simultaneously on a plate and judges were asked to identify the odd sample. The test was completed three times with selection of the odd sample and its position on the plate chosen at random.

Results

The majority of judges rated fish samples acceptable (5 or higher on the 8 point scale) in all categories with mean taste panel scores ranging from 53.3% acceptable for flavor of spotted seatrout to 92.2% acceptable for overall satisfaction of wild mullet (Table 1). Statistical analysis of variance revealed signif-

*mention of trade name does not imply endorsement by Texas Agricultural Experiment Station.

icant differences (P>0.01) among mean scores within both appearance and flavor categories. Subsequent Duncan's New Multiple Range Test (Steel and Torrie, 1960) determinations revealed that appearance of seatrout (SNF) and cultured-2-year mullet (C2YNF) were statistically superior to cultured-1-year mullet, both fed (C1YF) and nonfed (C1YNF). Flavor scores of cultured-2-year and wild mullet were significantly higher than those for trout and cultured-1-year, nonfed mullet. Although definite trends and divisions were evident, the tendency for panel members to rate samples from 3 through 6 on the 8 point hedonic scale and to avoid extreme values (1,2 and 7,8) reduced statistical significance.

Appearance of trout and cultured-2-year mullet taste samples were rated first and second, respectively (Fig. 4). Although tissue of trout was white (without dark muscle) and flakey, appearance of whole, baked fillets due to presence of an oily substance on their muscle was rated relatively lower than mullet (Fig. 4). Mullet captured for 1 year, both fed and nonfed, received the lowest appearance evaluations with fed fish considered slightly less desirable.

Spotted seatrout had the least desirable flavor while cultured-2-year mullet had the best flavor of all treatments (Fig. 5). Flavor of cultured-1-year mullet was rated only slightly higher than that of trout.

Although scores for texture of all six treatments were not significantly different (Fig. 5), the three fish treatments which received supplemental food (C1YF, C42DF), and C2YF) were rated slightly lower than the treatments which did not receive supplemental food (SNF, WNF, and ClNF). Wild mullet were rated best in overall satisfaction and spotted seatrout were considered the least acceptable (Fig. 5). Again significant differences were absent.

Cultured mullet were rated superior to wild mullet in appearance and flavor but wild mullet were rated better in texture and overall satisfaction. Wild mullet were rated superior to the cultured-42-day mullet in every category. Uncooked flesh of wild mullet had a much darker reddish color, possibly due to higher myoglobin content, than other treatments. Fed, cultured-1-year fish were rated better in flavor and overall satisfaction than unfed, cultured-1-year mullet but were viewed inferior in appearance and texture.

Proximate chemical analyses for each group of fish are presented in Table 2. Protein content ranged from 18.82% for cultured-42-day mullet to 22.24% for wild mullet. Fat content was very low in all fish tissue with spotted seatrout having slightly higher levels. Water content ranged from 72.89% to 75.77% for wild and cultured-42-day mullet, respectively.

The 10 member taste panel statistically ($P>0.01$) distinguished flavor differences between smoked cultured and smoked Florida mullet (Table 3). Of 30 responses, 17 correctly identified the odd sample. Fourteen of 17 correct responses (82.4%) were scored as preferring cultured mullet.

Discussion

Spotted seatrout was expected to be rated superior to mullet especially in terms of flavor. However, flavor of trout was rated least desirable of all treatments and significantly less than wild mullet and cultured-2-year mullet.

The amount of lipid in fish flesh greatly affects quality of fish (Hanson and Oiley, 1965). Cobb (1976) reviewed environmental effects on mullet flesh quality and reported that mullet have been shown to concentrate fish odors and taste producing substances in fat reserves. Fish used in this study had very low fat levels (0.4%) compared to an average of 5.5% reported for striped mullet by Sidwell et al. (1974). Flesh and coelomic cavities of all fish appeared to be devoid of fat deposits. Muscle of wild mullet did not have any discernible off-flavors or odors, possibly due to their low fat content, and subsequently were not rated inferior to other treatments. Cobb and Hyder (1972) found low fat levels (0.4%) in another estuarine species, Atlantic croaker (Micropogon undulatus). Low fat levels in croaker were attributed to post spawning depletion, but the reason for low levels in this study was not clear. Caged fish did not spawn but may have been underfed. Wild mullet captured in Trinity Bay may have been undernourished since they were part of a very large population concentrated about a lake outfall. However, spotted seatrout were captured from a cooling lake where, presumably, food was not limiting.

Although an attempt was made to standardize taste samples, samples of the smaller cultured-1-year mullet contained proportionally more dark muscle and were less desirable in appearance. Their appearance may have contributed to poor flavor ratings, but dark muscle has been shown to concentrate off-flavors (Vale et al., 1970).

Texture of fish in the three treatments which were fed were rated inferior to texture of the three nonfed treatments. Proximate chemical determinations revealed that fish in the three fed treatments had a higher water content than those which were not fed. Inferior texture ratings may have been a result of excessive water content in flesh of fed fish.

Toledo (1973) reported that taste panel members could statistically discern flavor differences among unseasoned fillets of wild Florida and wild Texas mullet, but preference results were not decisive. Flavor of smoked, cultured mullet in this study was preferred over that of wild Florida mullet. The majority of judges felt flavor of wild Florida mullet was stronger, with a more pronounced fishy taste than that of cultured fish. Although chemical analysis was not made, Florida mullet appeared to contain more fat in their flesh which could have resulted in the stronger taste.

References

AOAC. 1975. "Official Methods of Analysis". Association of Official Agricultural Chemists, Washington, D. C.

ASTM. 1968. "Manual of Sensory Testing Methods". Spec. Tec. Pub. (STP) 434. ASTM, Phil., Pa.

Bardach, J. E., Rhyther, J. H. and McLarney, W. 1972. "Aquaculture, The Farming and Husbandry of Freshwater and Marine Organisms". Wiley-Interscience, New York.

Cobb, B. F. III. 1976. Effects of environment on mullet - A review. Univ. of Florida Sea Grant Press (In press).

Cobb, B. F. III and Hyder, K. 1972. Development of a process for preparing a fish protein concentrate with rehydration and emulsifying capacities. J. Food Sci. 37: 743.

Hanson, S. W. F. and Olley, J. 1965. Observations on the relationship between lipids and protein deterioration. In "The Technology of Fish Utilization". Kreuzer, R. ed. p. 57. Fishing News (Books) Ltd., London.

Holt, R. S. and Strawn, R. K. 1976. The culture of black drum, Pogonias cromis, in cages receiving effluent from a power plant. Proceedings of 8th Annual Workshop, World Mariculture Society. (In press).

Marcello, R. A. and Strawn, R. K. 1972. Cage culture of some marine fishes in the intake and discharge canals of a steam electric generating station, Galveston Bay, Texas. Proceedings of 4th Annual Workshop, World Mariculture Society 4: 97.

Nickelson, Ranzell. 1975. Smoking catfish. Proceedings Fish Farming Conference and Annual Convention Catfish Farmers of Texas. Texas A&M University. 82.

Sidwell, V. C., Foncannon, P. R., Moore, N. S. and Bonnet, J. C. 1974. Composition of the edible portion of raw (fresh or frozen) crustaceans, finfish, and mollusks. I. protein, fat, moisture, ash, carbohydrate, energy value, and cholesterol. Marine Fisheries Review 36(3): 21.

Steel, R. G. D. and Torrie, J. H. 1960. "Principles and Procedures of Statistics". McGraw-Hill Book Co., Inc. New York.

Toledo, R. T. 1973. Smoking of mackerel and mullet. Paper presented at Fish Expo., New Orleans, La.

Vale, G. L., Sidhu, G. S., Montgomery, W. A. and Johnson, A. R. 1970. Studies on a kerosene-like taint in mullet (Mugil cephalus). I. General nature of the taint. J. Sci. Fd. Agric. 21: 429.

This research was funded by Houston Lighting & Power Company through Texas Agricultural Experiment Station Project 1869. Thanks are expressed to Mr. M. C. Morris, Cedar Bayou Electric Power Station plant superintendent. Gratitude is extended to Dr. Frank Schlicht and personnel of Houston Lighting & Power Company's Environmental Protection Department for their cooperation and to project graduate students without whose help this study could not have been completed. Appreciation is extended to Mr. Joe Raines, commercial fisherman, for donating the Suwannee, Florida mullet; to Larry Wyatt, graduate student, for smoking the fish; and to Dr. Ranzell Nickelson, Texas Agricultural Extension Service, Texas A&M University, for giving much needed advice and providing use of equipment and materials.

Table 1--Frequency of scores expressing acceptability of the fish*

Treatment	Percent Acceptability**			
	Appearance	Flavor	Texture	Overall Satisfaction
Spotted seatrout (SNF)	83.3	53.3	76.7	60.7
Cultured-2-Year Mullet (C2YF)	76.7	86.7	70.0	82.1
Wild Mullet (WNF)	70.0	80.0	83.3	92.9
Cultured-42-Day Mullet (C42DF)	73.3	63.3	66.7	71.4
Cultured-1-Year, Fed Mullet (C1YF)	56.7	70.0	76.7	71.4
Cultured-1-Year, Nonfed Mullet (C1YNF)	56.7	63.3	80.0	71.4

* Acceptable score was 5 and above in an 8 pt scale

** Total number of judges on taste panel was 15, however one judge did not rate products for overall satisfaction

Table 2.--Proximate chemical analysis of spotted seatrout (SNF) and cultured-2-year (C2YF), wild (WNF), cultured-42-day (C42DF), cultured-1-year, nonfed (C1YNF) and cultured-1-year, fed (C1YF) striped mullet

	Flesh Composition (%)		
Treatment	Moisture	Crude Fat	Protein
SNF	73.36	0.5	19.44
C2YF	74.38	0.4	20.40
WNF	72.89	0.4	22.24
C42DF	75.77	0.4	18.82
C1YNF	73.81	0.4	21.05
C1YF	74.79	0.4	19.79

Table 3.--Taste panel results for triangle test comparisons of smoked, wild Florida mullet and smoked, cage-cultured Texas mullet

PANELIST	1	2	3	4	5	6	7	8	9	10	TOTAL	PERCENT
Number of judgments with positive identification	3	1	0	2	3	1	2	2	2	1	17	
Total number of judgments	3	3	3	3	3	3	3	3	3	3	30	
Number of correct judgments for significant differences ($P>0.01$)											17	
Number preferring cultured mullet	2	1		2	2	1	2	2	1	1	14	82.4
Number preferring Florida wild mullet	1				1				1		3	17.6

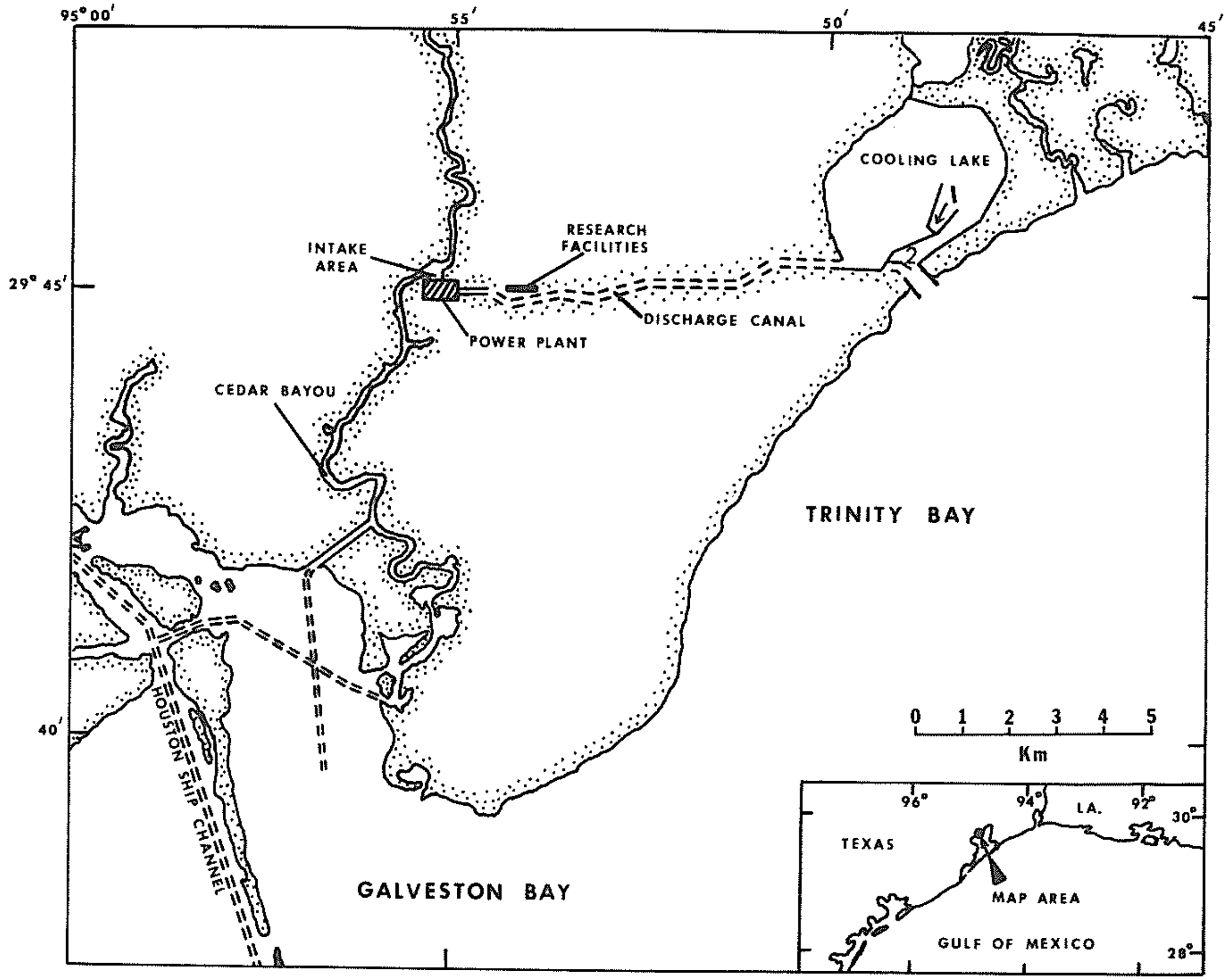


Fig. 1-- Map of Cedar Bayou area. Numbers on the cooling lake indicate station locations.

NAME____________________

QUESTIONNAIRE____________

Texas A&M Fish Palatability Study

Please score the sample of fish for the various characteristics according to the following scoring system:

Score	Description
8	Like extremely
7	Like very much
6	Like moderately
5	Like slightly
4	Dislike sligthly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

I. a) Palatability Score (eating the fish):

Sample						
Appearance						
Flavor						
Texture (Mouthfeel)						
Overall satisfaction						

b) Any other comment (write in) ____________________

____

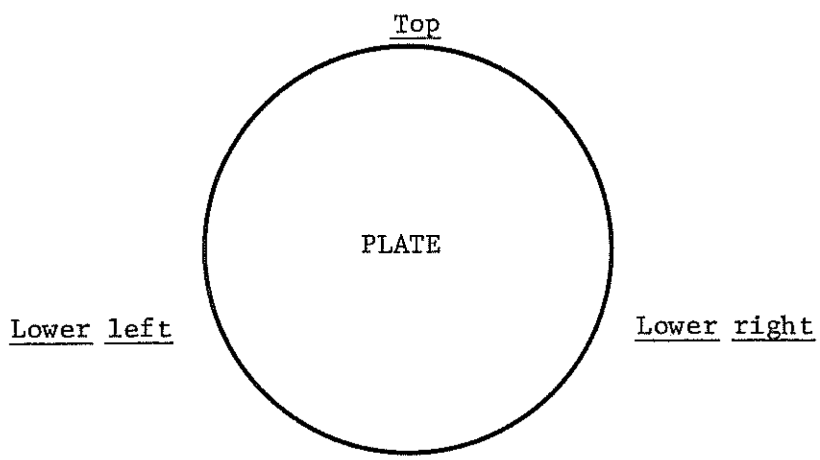
II. How often do you eat fish (write the frequency per month)

Fig. 2--Questionnaire for organoleptic evaluation by a taste panel utilizing an 8-point hedonic scale.

Name ____________________

Replicate ______________

Texas A&M Fish Palatability Study



1. Which of the 3 samples differ from the other two (denote unlike sample by top, lower left or lower right position).

2. Do you prefer this sample to the other two? Why or why not?

3. Have you eaten smoked fish before this test? How many times?

4. Have you eaten smoked mullet before this test? How many times?

Fig. 3--Questionnaire for organoleptic evaluation by a taste panel utilizing a triangle test.

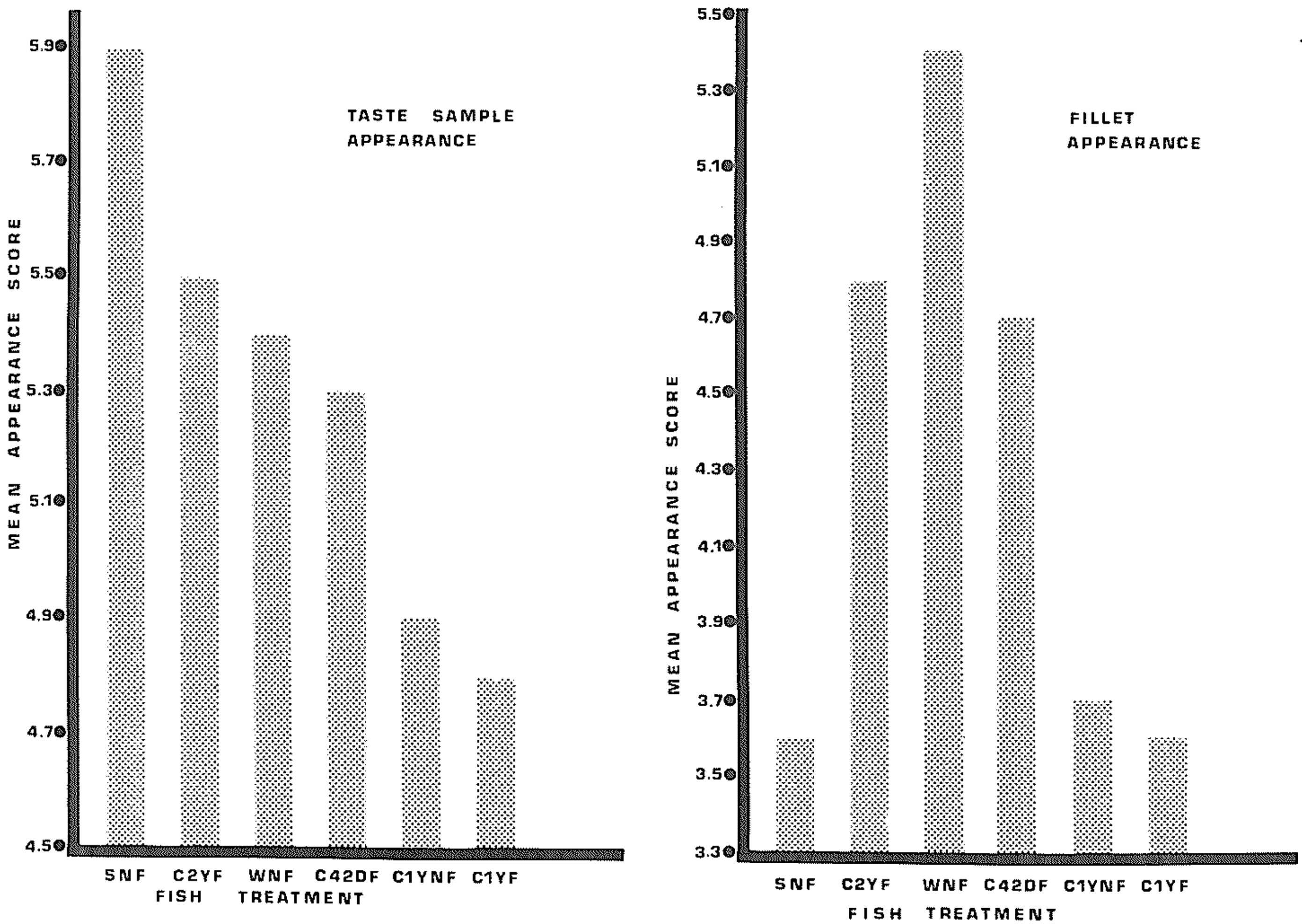


Fig. 4. Taste panel comparisons for appearance of taste samples and fillets of spotted seatrout (SNF), and cultured-2-year (C2YF), wild (WNF), cultured-42-day (C42DF), cultured-1-year, nonfed (C1YNF) and cultured-1-year, fed (C1YF) striped mullet.

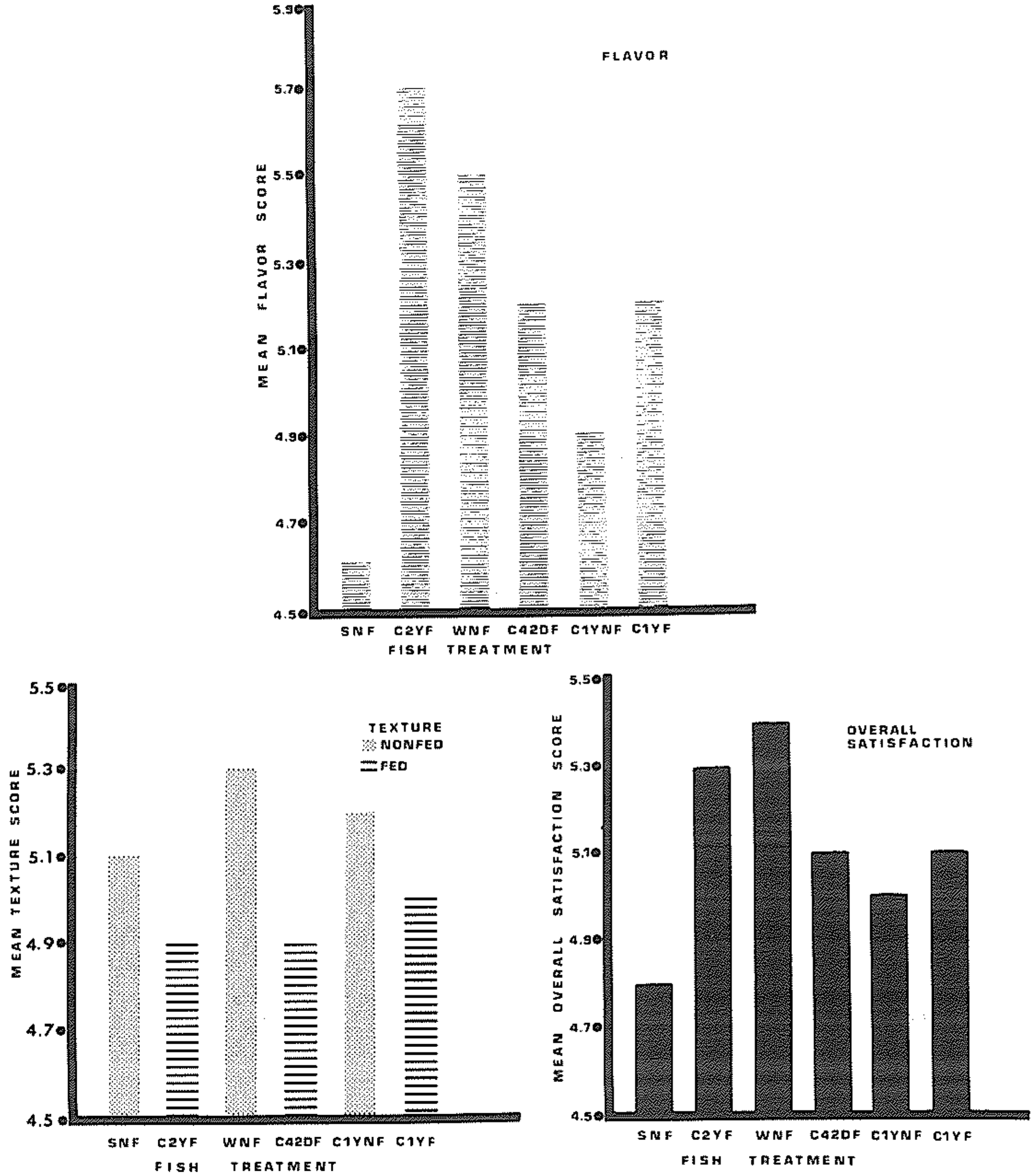


Fig. 5. Taste panel comparisons for flavor, texture, and overall satisfaction of spotted seatrout (SNF), and cultured-2-year (C2YF), wild (WNF), cultured-42-day (C42DF), cultured-1-year, nonfed (C1YNF) and cultured-1-year, fed (C1YF) striped mullet.

UTILIZATION OF INSECTS AS COMPLEMENTARY DIET

IN CHANNEL CATFISH FEEDING

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Introduction

The objective of this research was to study the possibility of utilizing the natural fauna of insects as complementary diet in channel catfish feeding in artificial ponds.

The required methodology consisted in trapping different species of insect by means of black light traps; weighing and classifying the trapped species, investigating at the same time its protein content.

In using the daily catch of insects as food complement for fish in a pond we tried to determine the profitability of the project, always keeping in mind the conversion of feed to fish meat as well as the cost of energy consumed by the trap.

Insects as source of feeding

In utilizing insects as a source of complementary feding one has to take into account certain characteristics of the insects, such as the attraction that light exerts upon certain species and the high protein content of the same. It is necessary, however, to mention some important points concerning this subject, such as the high content of free amino acids in the insect's blood, as well as the presence of lipid bodies in the hemocele. These last bodies constitute an important glucose storing center; also the insect's cuticle is mainly proteins and quitine of a high proteic value.

Materials

Ponds

Two ponds were included in the catfish project, both of them located at the Experimental Station, School of Agriculture of the Monterrey Institute of Technology in Apodaca Nuevo León. The ponds' dimensions are 50 x 23 meters, with a mean depth of 1.40 meters, and a capacity of 1,280 cubic meters.

Black-light traps

Two traps of diminished ultraviolet light, with a wave length equal to 3,600 Å (black light), General Electric, F C 12T 10 BL rapid-start black light were used.

Experimental units

One thousand and two hundred fingerlings of channel catfish (*Ictalurus punctatus*) were used.

Balanced feed.

Imported feed to cultivate the channel catfish made up of 32% protein, 2% fat and 10% crude fiber.

The feeding rations were completed for pond No. 1 at a rate of 3.6 kg which corresponds to the 3% of the biomass of fish, and one half of that which was used for pond No. 2 (Experimental pond.

Methods

Both ponds (No. 1 and 2) of the channel catfish project were utilized, having pond number one as control and pond number two as experimental.

In pond number one we placed 600 channel catfish with the following mean measures:

$\overline{X}$ weight = 0.174 kg

$\overline{X}$ total length = 24.7 cm

$\overline{X}$ standard length = 21 cm

In pond number 2 we also placed 600 units with the following mean measures:

$\overline{X}$ weight = 0.140 kg

$\overline{X}$ total length = 24.1 cm

$\overline{X}$ standard length = 20.3 cm

The biomass of both ponds was a total of 104 kg in pond number one and 64 kg in pond number two. Daily samples of insects were collected from trap 'B' up to May 11th, 1974. Two simultaneous samplings were made during the whole period in traps 'A' and 'B', with the purpose of checking the efficiency of the control trap in reference to trap 'A'.

The collected samples were weighted in an analytical scale and were also classified in order to determine the average weight, in grams, of insects that were fed daily to pond number two, and the type of insects that were more predominant in the daily catch.

Protein analysis were made of the general samples, of a lepidopter sample and of a coleopter sample, in order to determine the percentage of crude protein in each sample.

Samplings

Ponds 1 and 2 were sampled on the following dates: March 30, April 24 and May 11, 1974. The sampling was practiced collecting in both ponds after the water level was decreased, with two persons drawing the net along the pond.

Conversion appraisal

Pond (1):

Beginning weight -- 113.44 kg

Final weight -- 226.42 kg

Net kg of fish obtained -- 102.972 kg

Amount of food fed during 62 days:

Balanced feed 225.45 kg

Pond (2):

Beginning weight -- 64.82 kg

Final weight -- 127.045 kg

Net kg of fish obtained -- 62.225 kg

Amount of food fed during 62 days:

Balanced feed	--	112.727 kg
Insects	--	3.257 kg
Total	--	115.984 kg

The conversion in two ponds in % :

Pond (1):

$$\text{Conversion in \%} = \frac{102.972}{225.45} \times 100 = 45.6\%$$

Pond (2):

$$\text{Conversion in \%} = \frac{62.225}{115.984} \times 100 = 53.649\%$$

Conclusions

From this study we can come to the following conclusions:

1. Fish fed with insects as food complement reach a higher conversion level than those fed with balanced feed only; this leads us to believe that a fish diet, complemented with insects, has a greater protein content than its equivalent weight of balanced feed only.

2. Due to the fact that the amount of insects caught during the year in the traps varied, we feel reasonably safe in inferring that the disposable amount of insect-based food for catfish is also variable, this produces variations in the rate of growth of this species.

3. We can say that the mass production of insects could be a source of protein of a good quality in the food chain of human beings, refraining from offering insects as such as food for humans, due to its low acceptance.

4. Utilization of insects in a different presentation could also be a good way of using them. They could serve as basis for the production of balance feed for other type of animal production. The cost for this would be very low, considering its high rate of reproduction and the fact that its protein content competes with and it can even exceed that of some components of balanced feed, such as soy beans and fish meal.

Table 1. Analysis of percentage of humidity in sample of insects collected. Apodaca, Nuevo León 1974.

Type of Sample	Weight in Grams
Humid coleopter	2.4
Dried coleopter	1.7
% of humidity = 28.4%	
Humid lepidopter	2.4
Dried lepidopter	1.2
% of humidity = 47.68%	
Humid general of insects	2.9
Dried general of insects	2.1
% of humidity = 27.7%	

Table 2. Analysis of percentage of crude protein of samples collected. Apodaca Nuevo León 1974.

Group	% of protein
Humid coleopter	42.0
Dried coleopter	40.0
Humid lepidopter	36.2
Dried lepidopter	38.1
Humid of insects (general)	34.8
Dried of insects (general)	36.7

Table 3. Report of weights registered by samples of insects collected. Apodaca, N. L. 1974.

March	
11	9.4
16	40.2
21	42.1
26	28.5
30	23.2
April	
6	24.9
15	20.6
20	26.6
25	19.7
26	18.4
27	24.6
28	31.6
29	33.5
30	45.2
May	
1	22.8
2	12.7
3	24.6
4	21.8
5	22.4
6	26.8
7	24.7
8	28.1
9	34.6
10	70.2
11	62.5
12	84.4

$\overline{X}$ in 23 samples approximately = 30.7 g

Note: In the mean weight it was added the sum of the weights of samples collected from May 13 - 17, 1974.

Table 4. This table presents the amounts of insects belonging to the same order, as collected in each sample (total catch in one day).

Date	Hime.	Col-eop.	Lepi-dop.	Dip.	Hemip.	Der-map.	Orthop.	Neu-rop.
March								
6	6	6	26	13	2	5	-	-
16	4	16	137	21	7	4	6	1
21	2	11	168	17	6	4	-	-
26	6	17	45	16	12	-	1	3
30	8	624	322	20	16	8	-	-
April								
6	87	726	848	24	14	76	-	-
15	92	203	811	28	29	42	2	2
20	34	512	634	22	36	22	-	-
25	27	615	421	17	28	30	4	2
26	48	821	699	32	-	37	-	-
27	69	742	847	28	7	38	13	1
28	57	762	863	35	71	45	15	1
29	23	873	924	39	18	24	-	2
30	102	1142	1211	56	62	27	11	-
May								
1	93	564	629	22	21	64	-	3
2	7	52	96	17	9	11	1	6
3	7	657	818	31	26	62	-	5
4	13	903	943	37	16	48	11	-
5	27	874	972	42	-	56	-	2
6	24	909	1052	40	22	53	-	-
7	34	932	1126	27	18	62	26	-
8	39	945	1046	32	24	64	13	-
9	40	1116	1214	39	30	71	7	9
10	57	1324	1447	56	34	69	-	-
11	62	1418	1422	45	29	42	4	4
12	46	1420	1366	52	40	63	2	3

Table 5. Identification of samples of insects collected.

Coleopter Order	
Family of Elateridae	
Genera	Conoderus
	Aeolus
	Ischiodontus
	Megaphentes
	Neotrichophorus
	Gliphonyx
	Melanotus
	Horistonotus
	Esthesopus
Lepidopter Order	
Family of Noctuidae	
	Helicoverpa (Heliothis) zea Boddie
	Heliothis virescens (Fab)
	Trichoplusia ni (Hubner)
Family Saturniidae	
	Alabama argillacea (Hubner)
	Automeris io (Fab)
Family Sphingidae	
Family Yponemeutidae	
Orthoptera Order	
	Several genera of unidentified leaf cutters

Table 6. Standard weight and length and total averages of *Ictalurus*, placed in pond no. 1 with a complete diet, and in pond no. 2 with an incomplete diet complemented with insects.

Pond	Average Weight (kg)	Std. Length (cm)	Total Length (cm)
	First Sampling		
1	0.174	21.0	24.7
2	0.140	20.4	24.1
	Second Sampling		
1	0.227	22.1	25.7
2	0.180	22.3	25.0
	Third Sampling		
1	0.268	24.5	28.4
2	0.232	23.8	27.9
	Fifth Sampling		
1	0.331	26.6	30.9
2	0.274	25.6	30.5

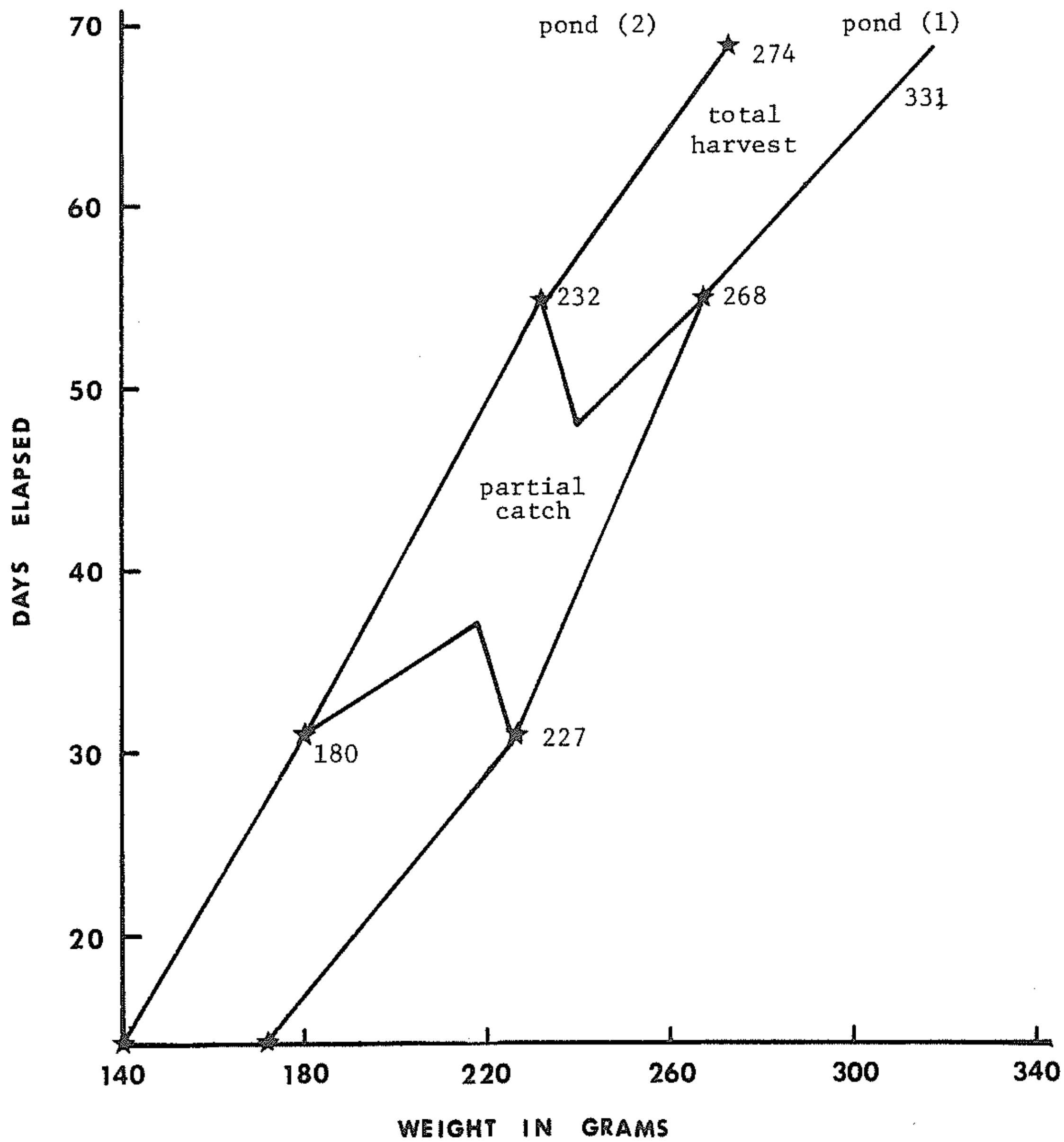

Fig. 1--Comparison of growth of fish samples from ponds No. 1 and 2, expressed in unit weights. Pond No. 1 is the control pond, while pond No. 2 is the pond where insects were fed as food complement.

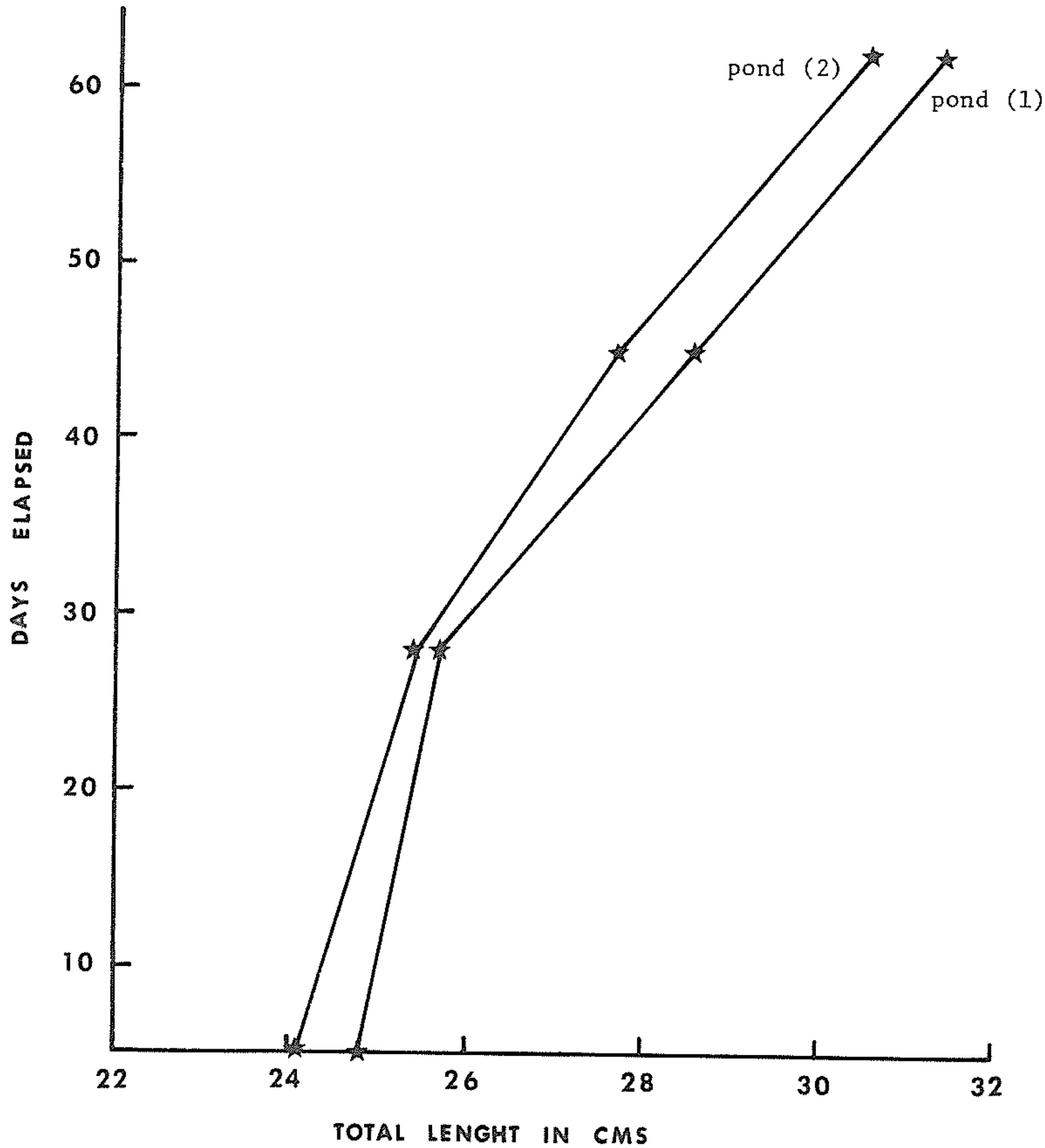

Fig. 2--Growth of fish, expressed in cm., sampled from ponds 1 and 2. (Total length).

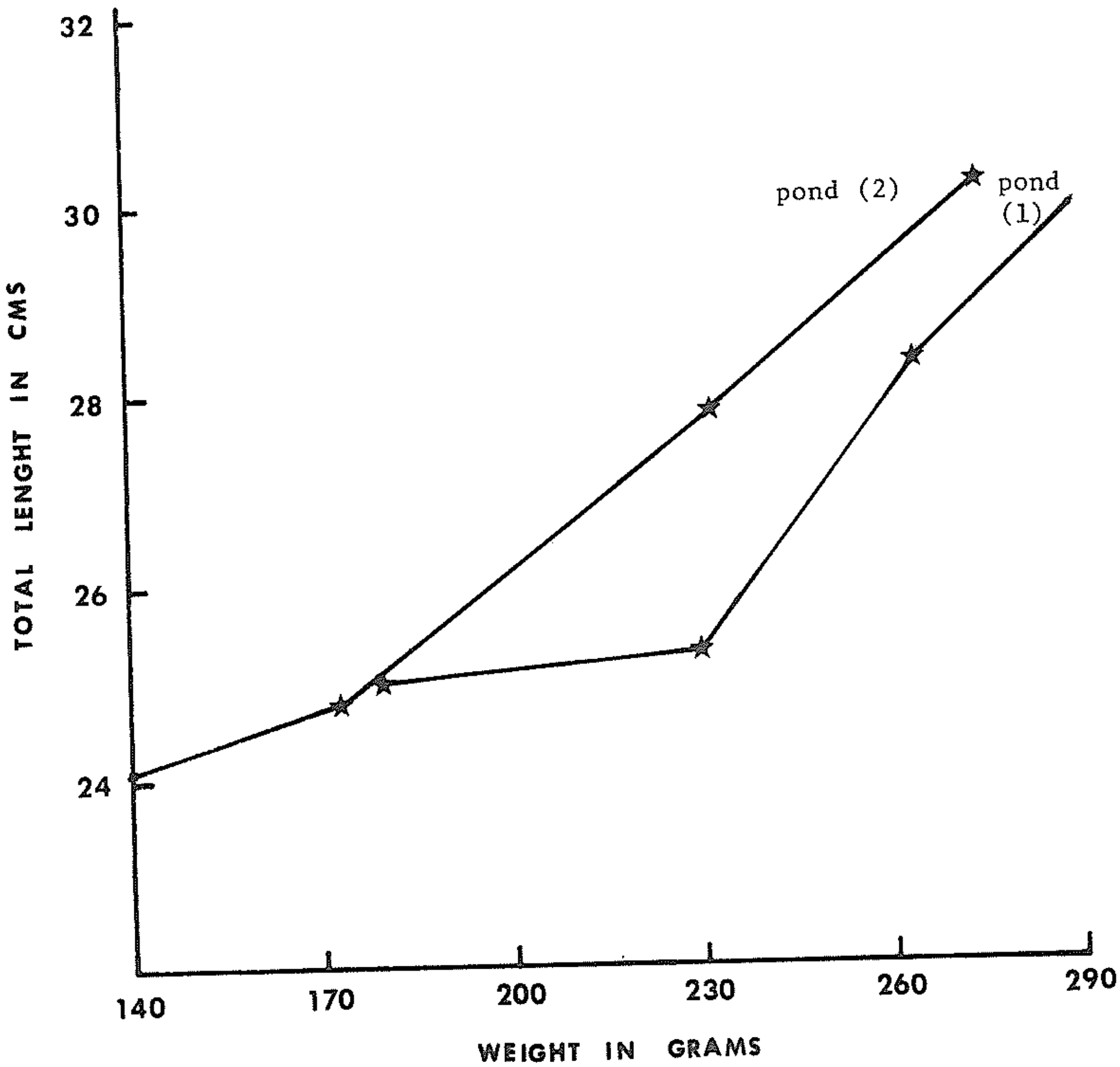

Fig. 3--Relationship between total length - weight from ponds
1 and 2.

REFERENCES

Deyoe, C. W., P. W. Tiemeir and C. Suppes. 1968. Effects of protein, amino acid level and feeding methods on growth of fingerlings channel catfish. Prog. Fish Cult. 30 (4): 187-188.

Fryed Man, L. and S. I. Shibko. 1972. Nutrient Component of the diet. Fish Nutrition, Academic Press.

Hasting, W. H. 1968. Warm water fish nutrition. Ann. Fishes Mag. May-June.

Hasting, W. H. and H. K. Dupree. 1969. Formula feed for channel catfish. The Progressive Fish Culturist. 31(4): 188.

Hasting, W. H. and L. M. Dickie. 1972. Feed formulation and evaluation. Fish Nutrition, Academic Press, 327-370.

Lovell, R. T. 1969. Nutrition in commercial catfish culture. Agric. Exp. Sta. Auburn Univ. 99th Meeting Fisheries Suc. New Orleans, La. pp. 2-38.

Mertz, E. T. 1972. The protein and amino acid need. Fish Nutrition, Academic Press. 106-143.

Phillips, A. M. Jr. 1972. Calorie and energy requirement. Fish Nutrition, Academic Press, 2-27.

Prather, E. E. 1960. A note on the results of feeding fire ants to Bluegills and Reader Sunfish. Auburn Univ. Agric. Exp. Sta., Auburn, Alabama.

Rojas, C. M. E. 1970. Dinámica de las poblaciones de Elateridae presentes en Apodaca, N.L. Durante el ciclo 1969-1970. Tesis inédita Inst. Tec. de Monterrey, México.

Shell, W. E. 1968. Feed and feeding of warm-water fish in North America. FAO Fishery Rep. 44(3:III/R-3):312-315.

Swingle, H. S. 1961. Raising crickets for bait. Agric. Exp. Sta. of the Alabama Polytechnic. Inst. Auburn, Alabama.

UTILIZATION OF SMALL MULLET BY A COLD SMOKING PROCESS

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Introduction

Florida harvests some 35 million pounds of mullet a year, with most of the harvest occurring during certain peak seasons of the year. One of the major harvests is associated with the period of spawning, and varies as to location along both coasts of Florida. In addition, a relatively large harvest of small mullet (less than a pound) takes place during spring and early summer. The quality of these mullet is quite good, however, they are not desirable for retail trade because of low filleting yield. If a product could be developed that effectively utilized these small mullet, it would benefit both the fisherman and consumer. This report represents a preliminary study on the development of a cold smoked product made from these small mullet which might find use as an entree in Florida restaurants.

Materials and Methods

Mullet were obtained from Cedar Key, Florida, in the Spring of 1975 and the Winter of 1976. They averaged 11 oz. in weight. Three

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Florida Agricultural Experiment Stations Journal Series No. 9016.

experiments were conducted using fresh fish, usually less than 24 hours from harvest. Three additional experiments were conducted with mullet harvested on the same dates but frozen at -5°F for at least 30 days prior to processing.

The mullet were butterflied, rinsed and iced the day prior to smoking. They were then brined in a 20% salt solution for 20 minutes at a ratio of 1:1, rinsed and allowed to dry on the smoke racks for 30 minutes prior to smoking. A Koch "Grandprize" Smokehouse with a separate smoke generator employing hickory sawdust as the source of smoke was used in all experiments.

The fish were placed in the smokehouse with the smokehouse vents open, the heaters set at 120°F and the smoke generator on. After the first thirty minutes, the smokehouse vents were closed and the fish smoked for an additional 4.5 hours. After smoking, they were cooled to ambient temperature, packed in aluminum foil and stored at either 40°F for seven days or -5°F for up to 40 days. Three trials were conducted on freshly harvested fish and three on frozen stocks.

The fish were prepared for sensory evaluation either by baking in foil for 20 minutes at 425°F or by being cut into pieces approximately 2-3 square inches and deep-fat fried for 2.5 minutes at 350°F. The sensory panel was composed of between 14 and 16 members for each trial.

Microbial analyses were by standard procedures (Food and Drug Adm. 1969). TBA values were determined by the method of Yu and Sinnhuber (1957).

Results and Discussion

Cold smoking has been traditionally carried out at temperatures less than 85°F. However, Lantz and Iredale (1969) reported that temperatures between 90 and 120°F could be used for the preparation of "Winnipeg Goldeye", a cold smoked product prepared in Canada. The choice of the higher temperature in this study was based on the desire to produce a slightly drier product than is produced at the lower temperatures and the fact that it would be extremely difficult in Florida to maintain commercial smokehouse temperatures much below 120°F (Koburger and Mendenhall, 1973).

Table 1 shows the TBA values for the smoked mullet stored both at 40 and -5°F. The fish stored at 40°F held up well at this temperature for seven days, which is considered to be the maximum storage time for this product under these conditions. Those samples stored for 40 days at -5°F had a TBA value of 6.35. While this value is high, Thompson (1962) demonstrated that a TBA value of approximately 8 is necessary before smoked mullet is judged rancid. Yield data (Table 2) is given for both hot (held 165°F for 30 min) and cold smoked mullet of the same size. It was observed that the weight loss from cold smoked mullet is considerably less than that for the hot smoked mullet, as would be expected.

Our results do not show the destructive effect on microorganisms of cold smoking (Table 3) that has been reported by others (Cutting, 1965). The reason for this is not clear at this time; however, studies are being conducted to determine the surviving species and their growth potential in this product. The data does indicate that with cold smoked mullet, 7 days is probably the maximum period of storage for this product at 40°F.

The sensory panels for evaluation of this product were performed in the following manner (Table 4). In the morning session, a single sample of baked mullet was presented to the panelists for evaluation. Then in the afternoon, samples were prepared by both baking and frying for evaluation and comparison. The data indicated that the panelists rated the cold smoked mullet high, indicating that the product is quite acceptable. The fried smoked mullet was as equally well liked as the baked product, indicating that this novel means of preparation has promise. The data also indicated that frozen storage of the mullet prior to smoking had no effect on acceptance by the panelists.

Although these data are preliminary, they demonstrate that cold smoking of mullet may be an effective way of utilizing these small fish.

ABSTRACT

During certain times of the year, predominantly small mullet are available to Florida fishermen. These fish generally weigh less than a pound and are not desirable for retail sale due to their poor yield upon cleaning. In order to find alternative uses for these fish, a cold smoked process was developed in which the mullet were cold smoked before storage and baked in foil at 425°F for 20 minutes immediately before consumption.

Fresh mullet (approx. 11 oz.) were cleaned, butterflied and brined. Smoking was at 120°F for five hours using hickory chips as the source of smoke. Samples were stored at either 40°F for seven days or -5°F for up to 40 days. Organoleptic changes, rancidity development and microbial growth were monitored throughout storage.

The smoked mullet exhibited good storage stability toward both rancidity and microbial spoilage. Sensory evaluations of the cooked fish were excellent, indicating a potential for this product as an entree in restaurants.

REFERENCES

Cutting, C. L. 1965. Smoking in Fish as Food, Vol. III, Academic Press, New York, New York, pp. 55-105.

Food and Drug Administration. 1969. Bacteriological Analytical Manual. 2nd ed. U. S. Public Health Service, Washington, D. C.

Koburger, J. A. and Mendenhall, V. T. 1973. Smoked mullet quality: an assessment. J. Milk Food Technol. 36:194.

Lantz, A. W. and Iredale, D. G. 1969. Techniques in smoking goldeye (Hiodon Alosoides). Can. Inst. Food Technol. J. 2:157.

Thompson, M. H. 1962. Effect of butylated hydroxy toluene and potassium sorbate on development of rancidity in smoke mullet. Comm. Fish. Rev. 24:5.

Yu, T. C. and Sinnhuber, R. O. 1957. 2-Thiobarbituric acid method for the measurement of rancidity in fishery products. Food Technol. 11:104.

Table 1. TBA values for stored cold smoked mullet

Sample	Storage Conditions 40°F	-5°F
Fresh fish	1.73	1.34
One day	3.40	3.98
7 days	3.74	--
20 days	--[1]	5.60
40 days	--	6.35

[1]Not done

Table 2. Yield data for both hot and cold smoked mullet

	Hot (165°F)	Cold (120°F)
	%	
Whole fish	100	100
Butterflied	59	62
Brined	60	62
Smoked	37	50

Table 3. Microbial changes of cold smoked mullet during storage

	APC	Coliforms
	org/g	
Fresh fish	24,500	43
Brined fish	28,000	43
1 day/40°F	26,000	23
7 days/40°F	276,000	220

Table 4. Sensory evaluation of cold smoked mullet[1]

Product Storage	Odor	Color	Texture	Flavor	General Acceptance
7 days @ 40°F					
Baked	8.1[2]	8.1	7.4	7.6	7.6
Baked	8.0	7.7	7.7	7.6	7.8
Fried	8.0	7.4	7.6	7.4	7.4
40 days @ -5°F					
Baked	7.6	7.8	7.7	7.8	7.8

[1]Each value, the mean of three replicated experiments.

[2]Scale = 9 - point hedonic with 1 = dislike extremely to 9 = like extremely.

POTENTIAL DEMERSAL-FISH FISHERIES IN THE NORTHWEST GULF OF MEXICO

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Introduction

The Gulf of Mexico (Gulf) supports large demersal fish (bottom fish) stocks that have great biological potential to support fisheries.

This paper presents basic biological data that identifies the more abundant fishes in the northwestern Gulf on an overall and seasonal basis and estimates the magnitude of the fish resource currently being discarded by commercial shrimpers in the Gulf off Texas. Finally, this paper describes the general nature of the population dynamics of the most abundant demersal species to suggest the probable effects that harvesting would have on these resources. Although the emphasis in this paper is on the northwestern Gulf, many of our findings have broader application in the Gulf.

The biological information presented herein indicates potential fisheries. Whether or not the potentials become actual fisheries obviously depends, in part, on other considerations such as economic ones.

Materials and Methods

The data that this paper is based on were collected aboard working shrimp trawlers off east and central Texas. We made four cruises in depths of 2-42 fathoms during the periods late September-early October 1973 (September), mid-January 1974, late March 1974, and late June 1974. We trawled for 83 hr in 21 tows on what we define as the white shrimp grounds (an inshore community at about 2-12 fathoms), and we trawled 240 hr in making 39 tows on the brown shrimp grounds (an offshore community at about 12-50 fathoms).

We obtained a 40 lb sample from each tow by shoveling small amounts of fish from various areas of the deck into a 5-gallon container. All fishes in these samples were identified, counted and measured. Finally, we shoveled the entire catch into 80 lb fish baskets to measure the catch.

The scientific names of the fishes mentioned herein are listed in Appendix 1.

Magnitudes of the Discard Catch

Discard catches were much higher on the brown shrimp grounds than on the white shrimp grounds, and they were much greater in summer than during winter (Table 1). The term discard, as used herein, refers to everything but shrimp. It is about 90% fish. Discard/tow on the brown shrimp grounds was twice that on the white shrimp grounds during September. It was five times that on the white shrimp grounds during January. Catches declined greatly by winter and were especially small on the white shrimp grounds during winter.

The ratio of the mean discard and shrimp catches was 11.35

volumes of discard to one of headed shrimp with the 95% confidence limits of the ratio being 9.7 and 13.0. The mean annual shrimp catch (headed shrimp) of Texas-based trawlers in the Gulf during the ten-year period 1962-1971 was 48.3 million lb. based on published landing statistics of the National Marine Fisheries Service. Therefore, by applying the discard-shrimp ratio of 11.35:1 to that figure, we can estimate that the mean annual discard was 548 million pounds from 1962-1971. The 95% confidence limits for the mean annual discard were about 470 to 630 million pounds. The overall fish-shrimp ratio was about 10 volumes of fish to one of shrimp, so that shrimpers discarded about 483 million lb of fish annually. According to our observations, essentially the entire catch is discarded. These discarded fish are either dead or dying.

Overall Compositions of the Fish Fauna

The fish communities of the white and brown shrimp grounds were distinctly different. However, a single species dominated the community on each grounds and a few other species each comprised 2-15% of the catch (Fig. 1). Most species were not abundant.

Four families comprised 88% of the fishes on the white shrimp grounds (Table 2). These were the drums (64%), cutlassfishes (14%), threadfins (5%), and sea catfishes (5%). Five other families each comprised 1-4%. These families were the butterfishes, herrings, jacks, grunts and lefteye flounders. The nine families cited comprised 98% of the fishes on the white shrimp grounds.

Six families comprised 82% of the fishes on the brown shrimp grounds (Table 2). These were the porgies (40%), searobins (17%), drums (8%), goatfishes (6%), lefteye flounders (6%), and sea basses (5%). Nine other families each comprised 1-4%. These families were the batfishes, lizardfishes, snappers, toadfishes, cusk-eels, jacks, butterfishes, scorpionfishes, and puffers. These 15 families comprised 99% of the fishes on the brown shrimp grounds.

Seven species were very important on the white shrimp grounds. These were the dominant Atlantic croaker (30%), the Atlantic cutlassfish (14%), silver seatrout (13%), star drum (10%), sand seatrout (8%), Atlantic threadfin (5%), and sea catfish (5%).

Four species were very important on the brown shrimp grounds. These were the dominant longspined porgy (39%), the Mexican searobin (8%), horned searobin (6%), and dwarf goatfish (6%).

Most species that were important on one shrimp grounds were absent on the other or virtually absent. The white shrimp grounds fish community is closely associated with estuaries whereas the brown shrimp grounds fish community is independent of estuaries. Therefore, the brown shrimp grounds fish community is probably less affected by development of coastal areas than the white shrimp grounds community is. The brown shrimp grounds may have larger fishery potential than the white shrimp grounds; because about 2/3 of the continental shelf in the northern Gulf lies within the bathymetric range of the brown shrimp grounds, and relative biomass appear larger on the brown shrimp grounds.

Seasonal Compositions of the Fish Fauna

The most abundant species on the white shrimp grounds during the warmer months included the Atlantic croaker and Atlantic cutlassfish in that order. The star drum, sand seatrout, sea catfish, and Atlantic threadfin were also important. During winter the most important species by far was the silver seatrout. The Gulf butterfish, Atlantic cutlassfish, and Atlantic croaker were also important during winter.

On the brown shrimp grounds, the longspined porgy was always most abundant. The Atlantic croaker, shoal flounder and blackear seabass were also abundant during late summer, and the Mexican searobin and horned searobin were also important in winter.

Population Dynamics and Harvest Potentials

The bottom fishes on both the white and brown shrimp grounds appear very similar in certain aspects of their life histories. They are small: nearly all the fishes captured on both grounds were less than 200 mm in length with the exception of the Atlantic cutlassfish. The life spans of nearly all the fishes appear to be only one or two years, in general, so that they must mature rapidly. Their theoretical total annual mortality rates are about 90% or more.

The Atlantic croaker and longspined porgy, the dominant species on the white and brown shrimp grounds, respectively, illustrate these points.

Nearly all the croaker captured were 100-210 mm in length (Fig. 2). Except for a few large fish, our length frequencies indicate that only one year class occurred at a given time. Spawning of this species occurs primarily in the fall. The year class that we observed in September was apparently approaching age I, because the sizes of the fish we captured agree with the sizes at age I that have been reported in the literature. Therefore, the typical life span of this species is apparently about one or two years.

Nearly all the longspined porgies captured were 85-145 mm fork length (Fig. 3). The largest specimen that we captured was 156 mm, and a 221 mm fish is the largest recorded. Spawning occurs in the spring, and 25-35 mm long fish have been reported in early May and June. These young apparently grow to 80-110 mm by late September, because only one year class appears in our length frequency then. Only one, or at most two, year classes were present in winter. Most fish apparently approached age I in January. Therefore, the typical life span of this species is apparently about one or two years.

Because of the high mortality rates of the fishes, there must be a rapid turnover of biomass on each shrimp grounds and large seasonal changes in the numbers of each species. Fishes with this type of life cycle tend to withstand very high fishing mortalities without danger of over-harvesting. Therefore, the Gulf demersal fishes apparently represent an enormous potential protein resource as our estimate for the discard off Texas suggests. The population dynamics of Gulf demersal fishes contrast with the larger sizes, longer life spans, apparently lower mortality rates etc. of fishes in northern waters. This apparent geographical difference in population dynamics may mean that the Gulf demersal fishes are not very susceptible to overfishing and that they may have a higher harvest potential than northern fishes do.

The shrimp fishery is the major fishery now affecting the demersal fishes. The Gulf shrimp fishery at present, however, does not appear to be overharvesting the dominant demersal fishes, because the species and size compositions that we found are very similar to those reported early in the history of the white and brown shrimp fisheries.

ACKNOWLEDGEMENTS

We thank A.M. Landry, W.H. Neill and R.R. Stickney of Texas A&M University for reviewing the manuscript.

Table 1. Relative discard catches on the white and brown shrimp grounds expressed as the number of 80 lb baskets/tow

PERIOD	CATCH/TOW ON THE: WHITE SHRIMP GROUNDS	BROWN SHRIMP GROUNDS
September	14.8	26
January	3.9	21
March	-	10
June	9.1	-
Overall	9.8	17

Table 2. The most important families of fishes captured on the white and brown shrimp grounds. Numbers represent percentages of the total catch on a given grounds.

FAMILY	WHITE SHRIMP GROUNDS	BROWN SHRIMP GROUNDS
Sea catfishes	5	Absent
Seabasses	0	5
Porgies	0	40
Drums	64	8
Goatfishes	0	6
Threadfins	5	0
Cutlassfishes	14	0
Searobins	0	17
Lefteye flounders	1	6
TOTALS	89	82

Appendix 1. Scientific names of fishes mentioned in the text

Scientific Name	Common Name
Clupeidae	herrings
Synodontidae	lizardfishes
Ariidae	sea catfishes
Arius felis	sea catfish
Batrachoididae	toadfishes
Ogcocephalidae	batfishes
Ophidiidae	cusk-eels
Serranidae	seabasses
Serranus atrobranchus	blackear seabass
Carangidae	jacks
Lutjanidae	snappers
Pomadasyidae	grunts
Sparidae	porgies
Stenotomus caprinus	longspined porgy
Sciaenidae	drums
Cynoscion arenarius	sand seatrout
Cynoscion nothus	silver seatrout
Micropogon undulatus	Atlantic croaker
Stellifer lanceolatus	star drum
Mullidae	goatfishes
Upeneus parvus	dwarf goatfish
Polynemidae	threadfins
Polydactylus octonemus	Atlantic threadfin

Appendix 1. continued

Scientific Name	Common Name
Trichiuridae	cutlassfishes
Trichiurus lepturus	Atlantic cutlassfish
Stromateidae	butterfishes
Peprilus burti	Gulf butterfish
Scorpaenidae	scorpionfishes
Triglidae	searobins
Bellator militaris	horned searobin
Prionotus paralatus	Mexican searobin
Bothidae	lefteye flounders
Syacium gunteri	shoal flounder

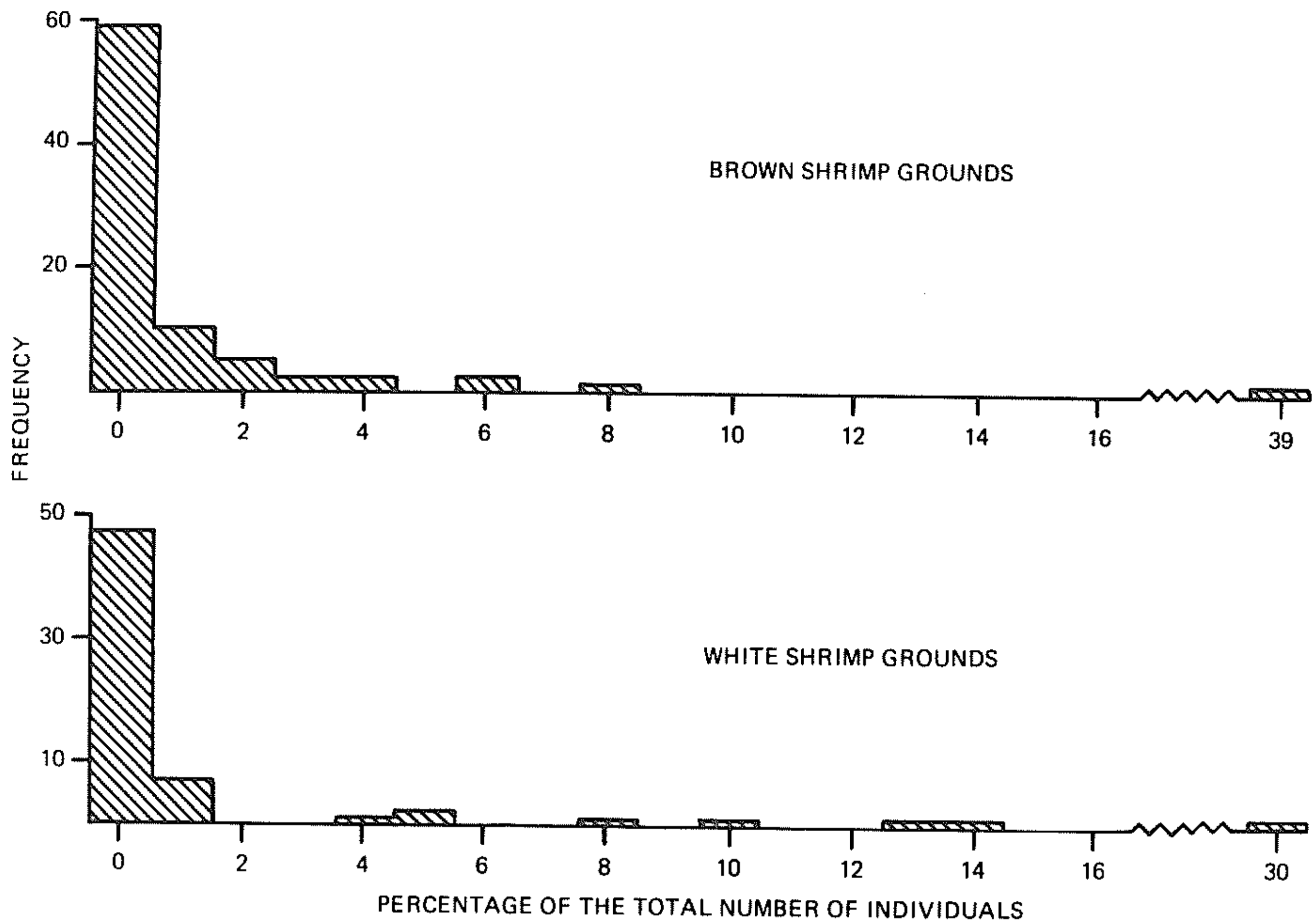

Figure 1. Community structures on the white and brown shrimp grounds.

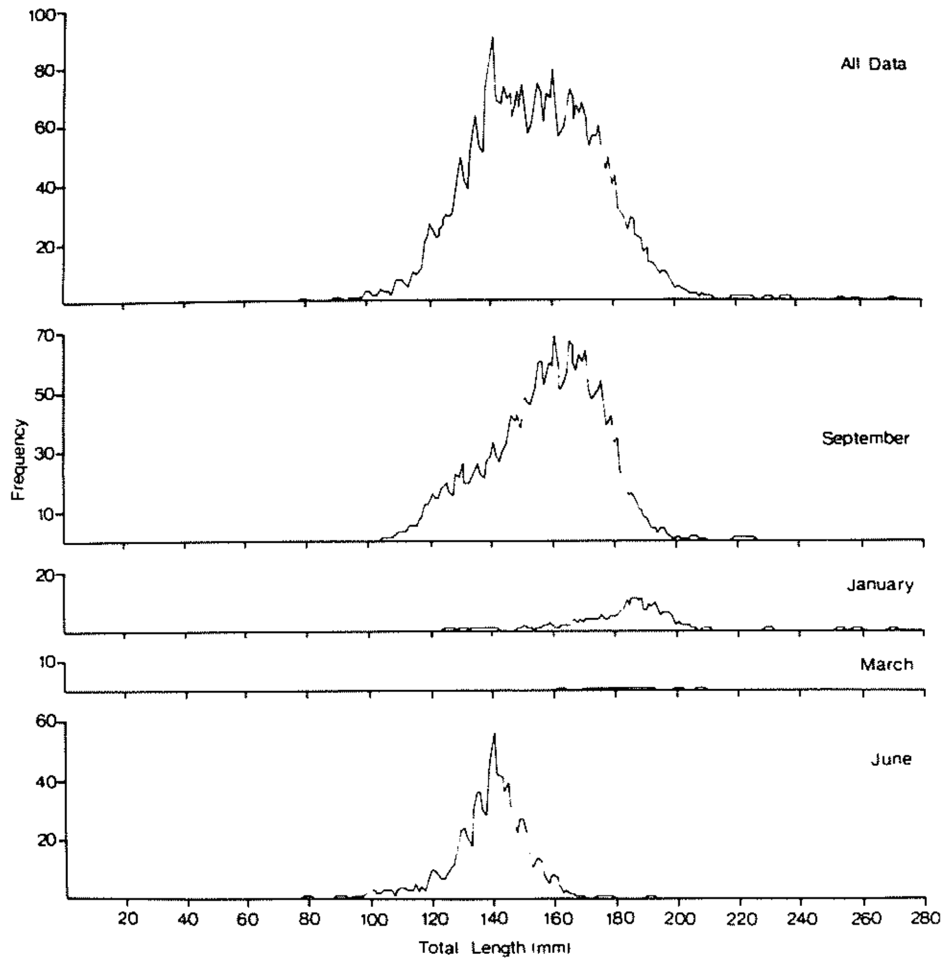

Figure 2. Length compositions of the Atlantic croaker.

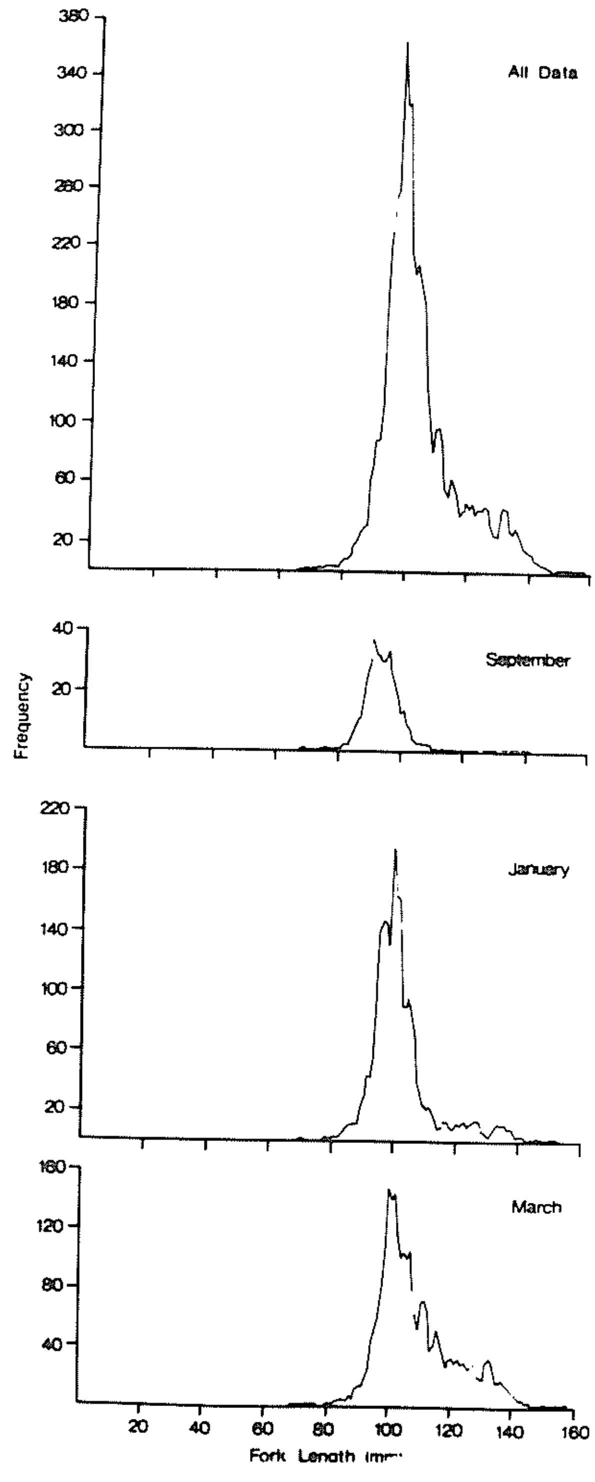

Figure 3. **Length compositions** of the longspined porgy.

NOTES ON THE UNDERUTILIZED FISHERY RESOURCES OF THE GULF OF MEXICO

ABSTRACT

The Gulf of Mexico is considered extremely productive, especially the north central area around the Mississippi Delta. The area approximately 10,000 square miles extending on either side of the Delta produces from 2/3 to 4/5 of the total Gulf production. Information about the latent and underutilized fishery resources of the Gulf is summarized for this First Annual Tropical and Subtropical Fisheries Technological Conference. Although data are provided on both pelagic and demersal fish resources, the latter is emphasized. Latent resources include several tunas and coastal pelagic species such as herring, sardine, and anchovy. Underutilized species include many species taken by the shrimp fleet incidental to the shrimp catch. The volume of fish discarded by this fleet may reach 3 billion pounds per year. Because of the rapid turnover of the fish stock and consequent rapid growth, a high continued yield can be expected. However, there is a need for developing short-range prediction about the status of the stocks.

NOTES ON THE UNDERUTILIZED FISHERY RESOURCES OF THE GULF OF MEXICO

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Pascagoula Laboratory

Introduction

In agreement with the objectives of this Conference which relate, in part, to the possibility of utilizing latent and/or underutilized fishery resources, this paper provides general information about the Gulf of Mexico fisheries. Although special interest is focused on demersal fish, owing to their relevance to the objective of the Conference, other groups are also included.

The area under discussion extends from Brownsville, Texas to the Dry Tortugas off Florida. Here the area of the Continental Shelf is roughly 100,000 square miles; about 90,000 square miles lie inside the 50-fathom curve and about 24,000 lie inside 10 fathoms. Most of the fish production comes from inside the 50-fathom curve. The average distance from shore of the 10-fathom depth in this area is 12-15 miles; the 50-fathom depth 75 miles; and the 100-fathom curve lies 85 miles from shore.

The most productive region, and the area where most of the fishery is concentrated, is around the

Mississippi Delta with approximately 2/3 to 4/5 of the total Gulf production taken within a 10,000 square mile area extending east and west of the Delta. The total U. S. landings for 1974 were 4.9 billion pounds valued at a record $898.5 million at the ex-vessel level (Wheeland, 1975). The latest production figures (1970-75) show the Gulf of Mexico landings have grown to 40% of the U. S. total by volume and 30% by value. This is compared to the figures of 1930 when the Gulf production was a mere 5% and 4% in volume and value respectively. (Figure 1). With respect to the fish landings and relative value in the Gulf states, Figures 2 and 3 in the appendix are self-explanatory.

As a corollary on a world-wide basis the productivity of the Gulf, specifically the northern area, is considered second only to that of the Peruvian coast. However, much of this productivity in the Gulf is not being effectively used.

On the producing and processing side, records show that until 1900 the entire Gulf fishing fleet had less than 400 vessels larger than 5 net tons and 5,000-6,000 smaller boats. By 1967 the fleet contained nearly 4,000 vessels and over 10,000 motor boats manned by more than 20,000 fishermen. Fish wholesaling and processing facilities now number over 800 and support more than 13,000 employees (Thompson and Arnold, 1971).

The 1974 landings (millions of pounds) of the eight leading species are:

1. Shrimp, 186.0
2. Menhaden, 1,300.0
3. Red Snapper and Grouper, 15.0
4. Oyster, 12.0
5. Mullet, 35.2
6. Industrial Bottomfish, 103.2
7. Spanish and King Mackerel, 15.0
8. Blue Crab, 28.0

In addition to these landings, large amounts of fish are taken as by-catch to shrimp and foodfish trawling and discarded. This by-catch issue has received some attention in the past but in fragmented surveys and research efforts. At present the National Marine Fisheries Service, Southeast Fisheries Center's (SEFC) Laboratory, Pascagoula, Mississippi is expanding its work on this to cover the entire Gulf shrimp fishery through contractual arrangements with Texas, Louisiana, and Florida. Preliminary data on the by-catch issue indicate that at least 2 billion and possibly up to 3 billion pounds of fish are discarded annually by the Gulf shrimp fleet. Obviously, this by-catch is considered to have development potential.

Underutilized and Latent Resources

Numerous oceanic surveys and exploratory fishing activities in the Gulf area have shown that this region supports vast fishery resources which are not being fully utilized. These resources include demersal or groundfish and pelagic species. A summary of general knowledge about the more important species groups comprising these resources follows, including estimates on biomass of each. Bear in mind, however, that the estimates are rough and need to be refined through further resource assessment surveys.

Large Pelagics

Coastal Pelagics

Demersal Fish

Large Pelagic Fishes

(Billfish, Dolphin, Mackerel, Shark)

The Gulf supports a sizable billfish population about which little is known. Work currently underway on life histories indicates adults may migrate to spawn in the southern Gulf and Caribbean areas during winter. Though they now have limited commercial value, they do have a high value to sport fishermen, both on the east coast and in the Gulf. High mercury levels found in swordfish and in some of the marlins tend to discourage U. S. commercial exploitation but do not apparently affect the recreational catch. At this time, there is no estimate of the sustainable yield.

Mackerel

Two important mackerels are found in the area: the king, *Scomberomorus cavalla*, and the Spanish, *S. maculatus*. Both are migratory and, at present, commercial and recreational fisheries exist for both species. The bulk of the commercial catches occurs within 12-15 miles from shore but the migratory behavior of these animals could increase their harvest considerably. Estimates of the mackerel population in the Gulf are from 100 to 140 million pounds with large portions of these stocks assumed to be found in the northwestern Gulf during summer and fall.

Sharks

Several species of sharks (i.e., blacktip, silky, dusky, whitetip, tiger, hammerhead) inhabit the Gulf area in seemingly high abundance. The Mississippi River Delta and other commercial fishing areas are particularly productive due, in part, to the shrimp fisheries scrap discards in that area. The standing stock of sharks in the Gulf has been estimated by Bullis and Carpenter, 1968; and Bullis, Carpenter, and Roithmayr, 1971, at 300 million pounds, a large portion of this in the northern Gulf.

Blackfin, Skipjack, and Little Tuna

These species abound in the subject area. Little tuna prefers inshore areas in the mixing zone of clear and murky water while the blackfin and skipjack prefer clear waters over the edge of the Continental Shelf. Commercial harvest of little tuna is 600 tons per year and practically non-existent for blackfin and skipjack. The biomass or standing stock is estimated to be over

160 million pounds.

Coastal Pelagic Fishes

This group refers to small, surface, and midwater schooling fishes of the herring, sardine, and anchovy groups. Included are some jacks, butterfish, and bumpers. The principal coastal pelagic species taken commercially in the Gulf is menhaden and 1.3 billion pounds were landed in 1974.

Other coastal pelagic species occurring in the Gulf are thread herring, Spanish sardine, scad, round herring, cigarfish, and anchovy, which are exploited only on a very limited basis. Most occur inside of 10 fathoms but seasonal shifts in abundance indicate the stocks range seaward to 50-60 fathoms. The most abundant may be thread herring for which a temporary commercial fishery existed in Florida waters in the late 1960's. Estimates of the latent potential for thread herring in the Gulf of Mexico are 2 billion pounds with the greatest abundance off Florida. The biomass is estimated to be over 8 billion pounds.

NOTE: Some of these coastal pelagic species such as menhaden and thread herring are readily taken by purse seine gear but others such as Spanish sardine, round herring, and anchovy are difficult to catch. New and innovative harvesting systems would be required to successfully harvest the bulk of the coastal pelagic resources in the Gulf.

Demersal Fish (Groundfish)

This group of finfishes, comprising some 175 species, constitutes perhaps the second largest resource, by volume, of the Gulf. The dominant group within the resource are the drums (Sciaenidae)--croaker, spot, seatrout; however, other species such as sparids and sea catfish are major constituents (Roithmayr, 1965). Groundfish occur on the Continental Shelf, on mud or sand bottoms, generally found inshore of 30 fathoms but often reaching sizable densities outside this depth. Most are estuarine-dependent during part of their life cycle.

In the early 1960's, approximately two-thirds of the resource was harvested inside the 10-fathom line; however, recent data indicate that only 55 percent of the catch came from inside this depth, demonstrating a trend to larger vessels having a greater operating range. A large volume of industrial groundfish is taken during shrimping operations in the south Atlantic and Gulf and discarded overboard. Estimates of this loss range from 4 pounds to 20 pounds of discards per pound of shrimp caught. If these ratios are referenced with total shrimp landings in the Gulf, the annual volume of discarded groundfish could be 2 to 3 billion pounds.

Directly related to the demersal resources of the subject area, the SEFC initiated a Groundfish Program in 1973. Program objectives are to evaluate the industrial and foodfish groundfish fishery in the northern Gulf and provide information on availability, abundance, and status of the resource. The specific work area extends from Apalachicola, Florida to Galveston, Texas in the depth range from 10 to 50 fathoms (Juhl, et al., 1973).

Recent analyses of the trawl survey have included studies on occurrence of the major families by season and depth. A study was also made on occurrence of sciaenids by weight and by season. Results of these are shown in Table 1 and Figure 5. Figure 4 describes the survey area depicted in Figure 5.

Efforts by the Pascagoula Groundfish Program in the area west and south of Galveston have been limited in recent years; however, current information will be reported here by others (Chittenden and McEachran, 1976).

Additional latent resources of the Gulf and estimated standing stock, considered important but for which limited information is available, includes:

Resource	Estimated Standing Stock (million lbs.)
Mullet	600-800
Ten-pounder (Ladyfish)	15-20
Bluefish	40-50
Flyingfish	400-500
Squid	700-800
Flatfish	50-60

It should be noted that these standing stock figures are rough estimates and need to be substantiated. Nonetheless, they are included to provide examples of the resource potential in the Gulf.

In closing, it should be noted that many important stocks now being harvested are reaching their maximum yield. Fishery development programs and continued growth of the extant industry will have to depend on the aforementioned underutilized and latent resources. The ever present increasing pressure on the shrimp stocks, owing to greater competition by more and larger vessels, will undoubtedly aggravate the fish by-catch situation; also because more fishing will be done in marginal shrimp production areas where the ratio of shrimp to fish may be higher than normal. This makes the urgency of implementing plans for use of the discards more apparent.

It is also obvious that additional knowledge and continued monitoring of the Gulf resources are needed. Contrary to the fishes of northern waters, many of the Gulf species are relatively short-lived and have a high rate of turnover. It is believed that the mortality rate is 90% by their second year. As a consequence, the conventional method of determining population estimates, such as following a strong year class, is not valid. Therefore, there is a need for developing short-range prediction capabilities. On the optimistic side, because of the dynamic character of the stocks and the exceptional productivity of the Gulf, we can depend on a continued high yield from the existing resources. Such an assurance is a must in considering fisheries development which required costly fish processing and high volume production plants as indicated by the theme of this Conference.

REFERENCES

Bullis, Jr., H. R. and J. S. Carpenter. (1968). Latent fishery resources of the Central West Atlantic region. The Future of the Fishing Industry in the United States, University of Washington Publications in Fisheries, New Series, Volume IV, pp. 61-64.

Bullis, Jr., H. R., J. S. Carpenter, and C. M. Roithmayr. (1971). Untapped West-Central Atlantic Fisheries. In Our Changing Fisheries. U. S. Department of Commerce, NOAA, NMFS, Washington, D. C., pp. 374-391.

Chittenden, Jr., M. and J. D. McEachran. (1976). Potential demersal fish fisheries in the Northwest Gulf of Mexico. Texas A&M Sea Grant Program.

Dime, S. (1976). Distribution and abundance of selected families of fish in the northern Gulf of Mexico (manuscript)

Juhl, R., E. J. Gutherz, C. M. Roithmayr, and G. M. Russell. (1973). Southeast groundfish program status report.

Roithmayr, C. M. (1965). Industrial bottomfish fishery of the northern Gulf of Mexico, 1959-63. U. S. Fish Wildl. Serv., Spec. Sci. Rep.--Fish No. 518, 23 pp.

Taylor, J. L., D. L. Feigenbaum, and M. L. Stursa. (1973). Utilization of marine and coastal resources. In A summary of knowledge of the eastern Gulf of Mexico 1973. State University System of Florida Institute of Oceanography, St. Petersburg, Florida, pp. IV1-IV63.

Thompson, S. H. and E. L. Arnold, Jr. (1971). Gulf of Mexico fisheries. In Our Changing Fisheries, U. S. Department of Commerce, NOAA, NMFS. Washington, D. C., pp. 201-217.

Wheeland, H. A. (1975). U. S. Department of Commerce, NOAA, NMFS, Current Fishery Statistics No. 6700, 97 pp.

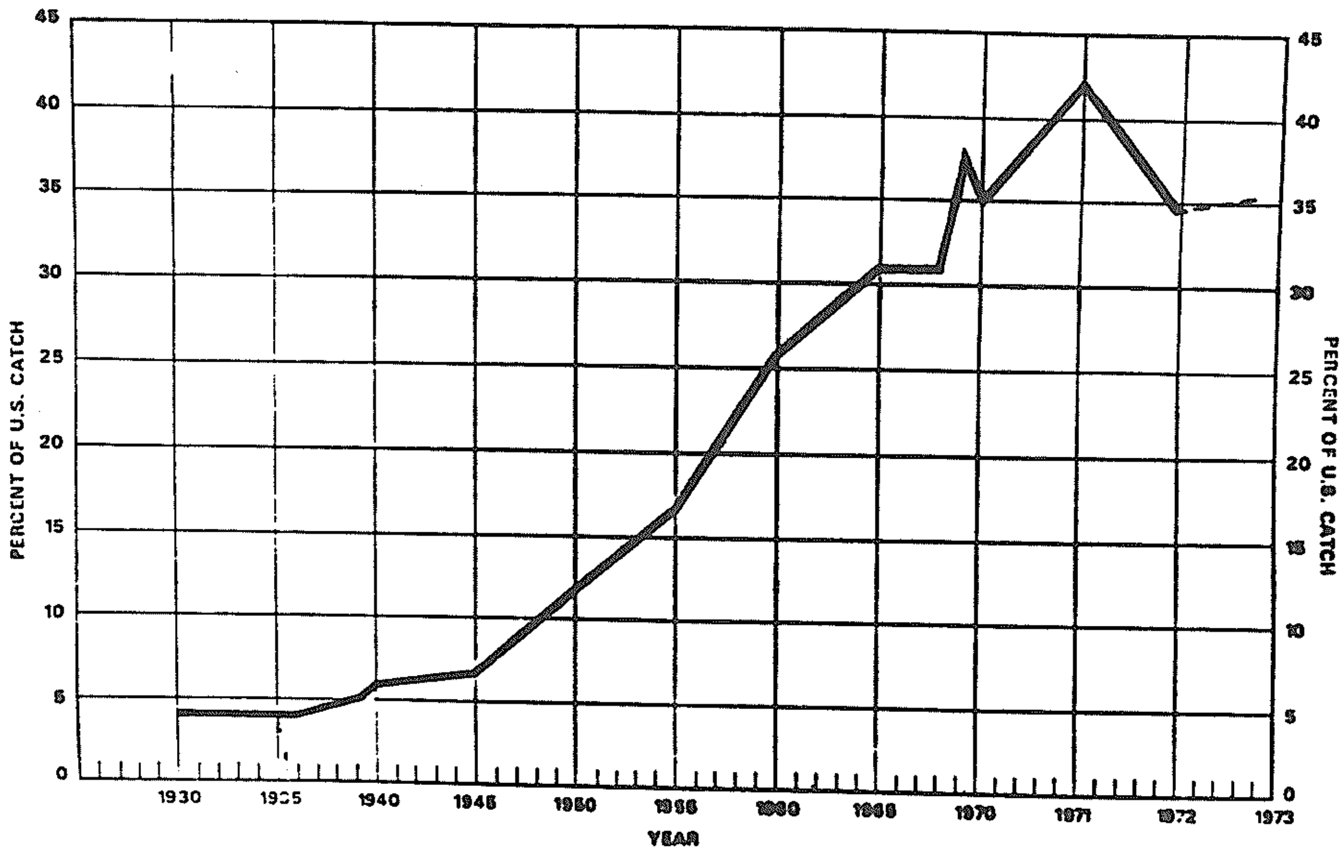

Fig. 1--Gulf state fisheries in percent of total U. S. catch.
Various years, 1930-1971.

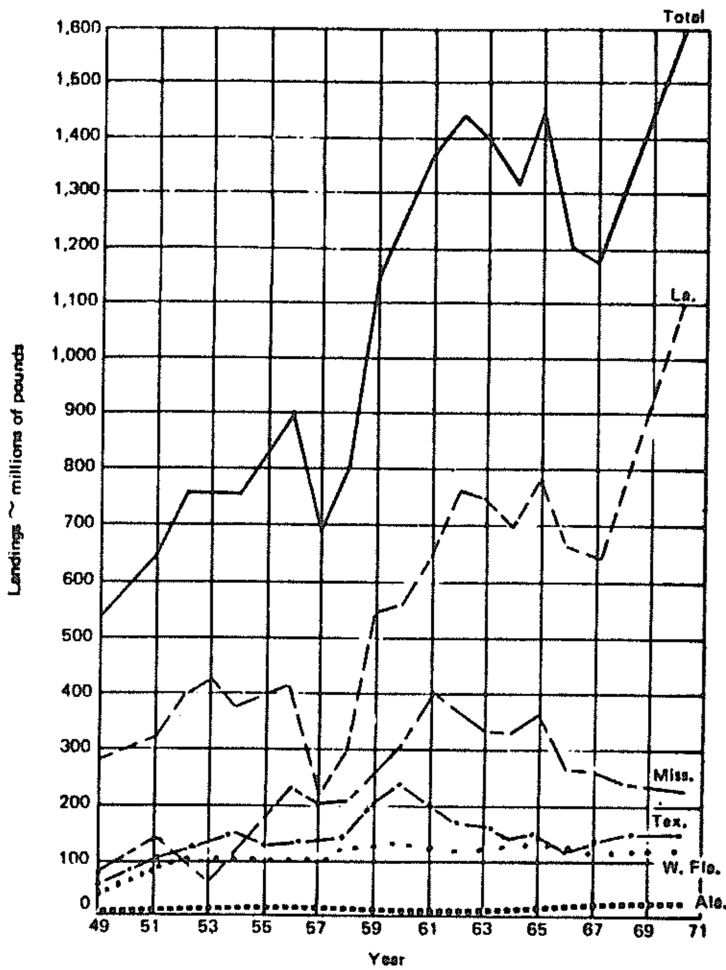

Fig. 2--Gulf landings, all species (1948-1970). Taken from Taylor et al., 1973.

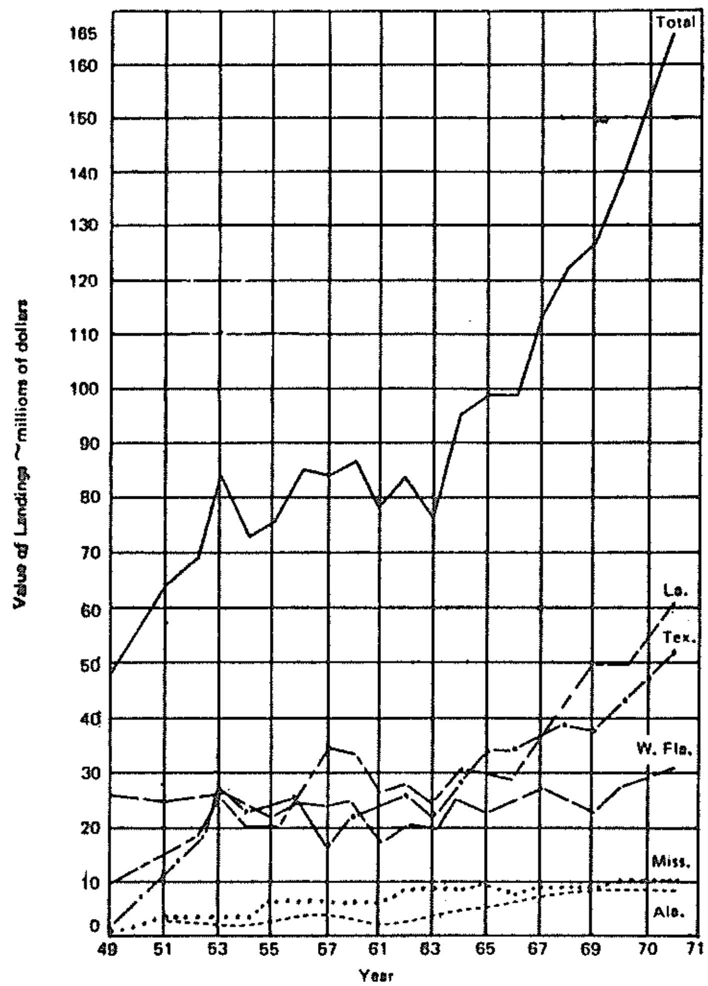

Fig. 3--Value of Gulf landings (1948-1970). Taken from Taylor et al., 1973.

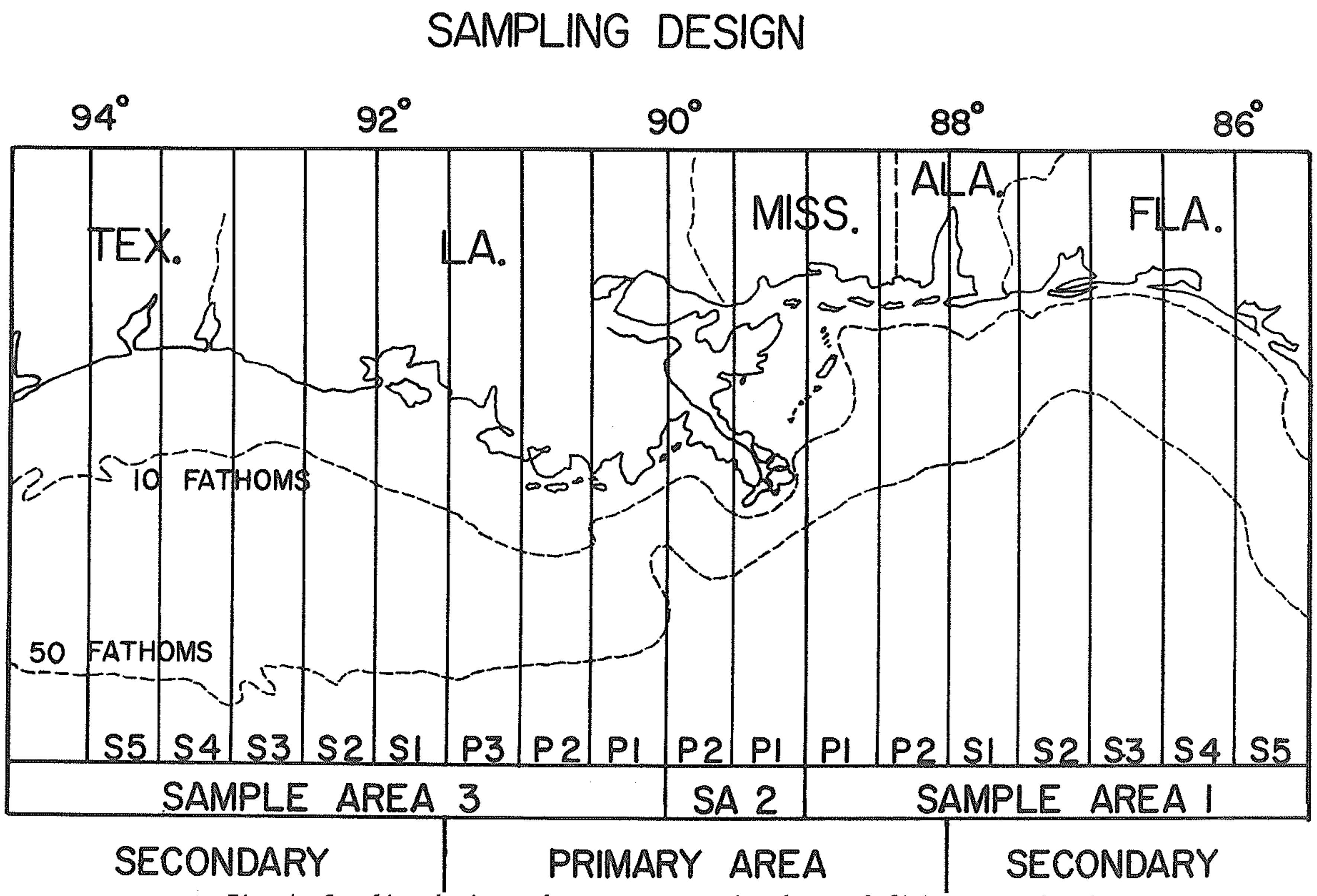

Fig. 4—Sampling design and area encompassing demersal fish surveys by the NMFS, SEFC, Groundfish Program, Pascagoula, MS.

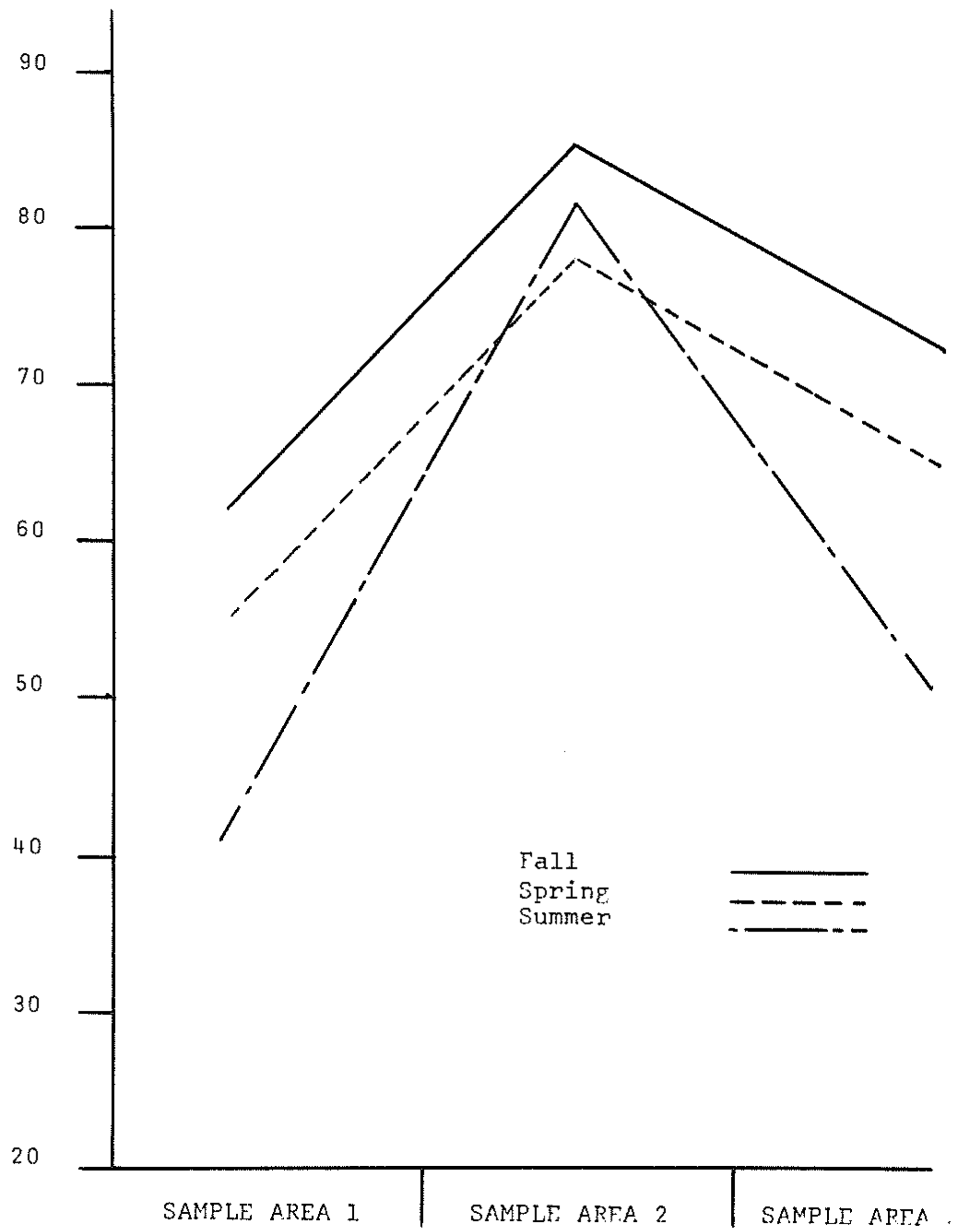

Fig. 5--Percent weight by sample area and season for total sciaenids

Table 1.--Percent occurrence of each family within the sampling area by season and depth

Family	0-19 Fathoms			20-49 Fathoms		
	Spring	Summer	Fall	Spring	Summer	Fall
Ariidae	76.6	52.1	53.0	1.8	0.8	2.9
Trichiuridae	52.8	25.6	32.0	45.1	61.2	32.4
Stromateidae	30.8	20.4	16.7	34.5	34.9	39.3
Sparidae	0.4	39.8	16.7	63.0	59.1	64.8
Sciaenidae	97.7	53.5	80.5	87.3	71.9	87.2
Croaker*	76.0	42.8	77.1	84.1	65.4	84.0
Trout*	83.3	39.8	62.1	70.5	43.2	62.8
Spot*	49.9	13.3	42.0	36.4	14.2	58.8
Bothidae	64.6	47.2	55.8	71.3	71.1	65.5
Triglidae	65.7	48.1	53.4	84.5	67.5	74.9
Synodontidae	27.4	34.1	37.9	67.7	61.5	62.4
Clupeidae	34.1	24.1	31.2	9.2	10.2	8.7
Engraulidae	55.0	15.0	29.4	7.1	7.7	2.1
Carangidae	26.3	64.5	55.5	49.5	65.5	44.8
Sharks	7.3	8.4	10.3	9.7	4.2	16.0
Lutjanidae	0.1	14.6	18.0	35.0	33.5	49.4

* Species of Sciaenidae

SALT-MINCED COD: MICROBIAL CONSIDERATIONS

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Introduction

With the development of meat-bone separators, a method for the increased recovery of flesh from fish wastes and underutilized species has become available (DeValle and Gonzalez-Inigo, 1968). During the processing of fish, such as cod, the fish is filleted, which only removes about 50% of the edible flesh, leaving behind material which is channeled into products not directly used as human food. If it were possible to recover the additional flesh and formulate acceptable products which were inexpensive and stable to storage at ambient temperatures, much more relatively inexpensive protein would become available with benefits for both fishermen and consumer.

Of all the methods available for preserving fishery products, the combination of salting and drying is one of the most inexpensive and simple procedures. The technical feasibility of quick salting minced fish had been earlier established (Anderson and Mendelsohn, 1972; DeValle and Gonzalez-Inigo, 1968), however, little information is available describing the microbial parameters of this product. The

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Florida Agricultural Experiment Stations Journal Series No. _______.

present study was undertaken to determine some of the quantitative aspects of the microbiology of the product. This was believed necessary in that the most logical starting material would be fish frames; i.e., the filleted, beheaded and gutted fish, which by virtue of previous handling would be of unpredictable microbial quality.

Materials and Methods

Beheaded and gutted cod and cod frames (filleted, beheaded and gutted) were obtained from a fish processing plant in the Halifax, Nova Scotia area. Minced flesh was prepared by passing the raw material through a Bibun meat-bone separator with 5 mm drum holes. The minced flesh was then mixed with 35% by weight of fine grain salt in a Hobart mixer for 1.5 to 2.0 hours. Following the mixing period the excess brine was removed by passing the wet salted product through a Bibun meat strainer with 1.6 mm holes which separated the brine and salted fish cake. Samples were removed for microbiological analyses during preparation as well as after 7 and 28 days of storage at 35 C. Samples for storage studies were held in Whirlpak(R) bags.

For microbiological analyses duplicate 50 gram samples were weighed directly into blender jars and brought up to 500 grams using either sterile phosphate buffer or 20% sodium chloride solution. The samples were then mixed at 8000 rpm for 1.5 minutes. The first dilution was made by weighing the mixture directly into a dilution bottle because of the large amount of foam which formed during blending. Subsequent dilutions were by volume.

For determination of total count, the samples were plated in duplicate from the phosphate buffer dilutions using Plate Count Agar

(Difco) with 0.5% salt added and incubated at 20 C for 5 days. Halophilic counts were made from 20% salt dilution blanks by plating 0.2 ml aliquots in duplicate directly upon previously prepared plates of Plate Count Agar with 15% salt added and onto plates of the Milk-Salt Agar of Dussault and Lachance (1952). Incubation for the halophilic counts was at 35 C for 10 days.

Results and Discussion

Table 1 gives the composition of the minced flesh and the salted mince cake. The mince composition is typical for a product of this type. However, with the salt mince, much of the water loss that occurs during processing is replaced by the added salt and it is this addition which is desired for microbial stability. The data from Table 2 clearly indicates that cod frames are heavily contaminated as compared to cod which are merely beheaded and gutted. The counts for the three experiments using the frames average much higher than those using the whole cod and could reflect the effects of long periods of iced storage and added contamination during processing.

Regardless of the initial count, once the salt is added and a period of equilibration takes place, there is a marked reduction in microorganisms. The brine surrounding the mince is saturated and destroys many of the organisms present as well as injuring a portion of the remaining ones. That the salt mince environment is not hospitable can be seen in the rapid loss of viable organisms that takes place during storage for even a week. The numbers of halophilic organisms (about 1000/g) followed a similar pattern and were never observed to increase during storage by either of the two methods of enumeration. In addition, there was no indication that the red halophilic bacteria were present in any of the samples analyzed. This was not unexpected in that the chief source of these organisms is known to be the solar salt used in the manufacture of salted fish (Klaveren and Legendre, 1965) as well as plant contamination during manufacture. The salt used in this study was a fine grade of mined salt to ensure rapid dissolution and equilibration with the flesh.

The data in Table 3 outlining the material balance show that the yield of salt mince from cod frames was about 30%. Estimating that there are 450 million pounds of cod harvested each year in Atlantic Canada, it would be possible to produce 34 million pounds of salt mince a year from the frames. There is a relatively stable demand for salt fish (Mendelsohn, 1975), and the mince procedure would appear to be a good means of recovering additional protein to help meet the world's food needs.

The production of salt mince is quite rapid. While an equilibration period of two hours was used in this study, it is expected that a shorter time could be possible because of the small size of flesh particles. This is in sharp contrast to the production of traditional salt fish, which requires about 30 days for manufacture (Klaveren and Legendre, 1965).

The data presented here defines some of the microbial parameters of immediate concern. The problem of spoilage by red halophilic bacteria (Dussault and Lachance, 1952) during extended storage and the effect of available technology to control this spoilage need to be investigated to assure the potential of salt mince fish.

ABSTRACT

Salt-minced cod was prepared from flesh obtained by mechanically deboning beheaded and gutted cod as well as cod frames (beheaded, gutted and filleted). The minced flesh was mixed with 35% salt, blended for two hours and then passed through a strainer to obtain a moist cake.

Total counts of the salted product were a reflection of the microbial load of the fresh mince. Regardless of the initial microbial count, there was approximately a ten-fold reduction in viable organisms following the period of salting and equilibration. During storage of the salt cake at 35 C, the number of viable microorganisms further decreased until they were no longer recovered, usually within 30 days. Additionally, studies of the salt tolerant organisms in the product showed that they were similarly reduced during storage.

REFERENCES

Anderson, M. L. and Mendelsohn, J. M. 1972. A rapid salt-curing technique. J. Food Sci. 37:627.

De Valle, F. R. and Gonzalez-Inigo, J. L. 1968. A quick-salting process for fish. 2. Behavior of different species of fish with respect to the process. Food Technol. 22:85.

Dussault, H. P. and Lachance, R. A. 1952. Improved medium for red halophilic bacteria from salt fish. J. Fish Res. Board Can. 9:157.

Klaveren, F. W. and Legendre, R. 1965. Salted Cod in Fish as Food III. G. Borgstrom, ed. pp. 133-160. Academic Press, New York, N. Y.

Mendelsohn, J. M. 1975. Rapid techniques for salt-curing fish: A Review. J. Food Sci. 39:125.

Table 1. Composition of Cod Mince and Salted Mince Prepared from Cod Frames.

	Mince	Salt Mince
	%	%
Moisture	83.0	48.0
Solids	17.0	52.0
Ash	0.9	27.0
Protein	16.1	25.0
Fat	0.8	0.6
Bone	0.5	0.4

Table 2. Microbial Profile of Salt-Mince Production.

(average of three studies)

Sample	Beheaded Cod	Cod Frames
	org/g	
Mince	1,300,000	3,900,000
Salted mince	160,000	820,000
Wet cake	170,000	800,000
Brine	110,000	600,000
Wet cake		
1 week	500	460
1 month	< 10	< 10

Table 3. Material Balance for Production of Salt-Mince from Cod Frames.

	Pounds
Frames	100
Mince	68
Mince and salt	92
Brine	61
Salt-mince cake	31

ABSTRACT

YIELD AND QUALITY OF MECHANICALLY SEPARATED FLESH FROM SEVERAL SPECIES OF CULTURED FRESHWATER FISH

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Buffalo fish (*Ictiobus cyprinellus*), *Tilapia aurea*, and channel catfish (*Ictalurus punctatus*) grown in fish culture ponds were mechanically deboned on a Bibun Model HM-15 separator. All fish were headed, gutted, washed and dark pigments were removed from the skin of catfish and from the abdominal wall of tilapia before deboning. A 7-mm diameter hole size in the extrusion drum provided for satisfactory separation of skin, scales and bone and yielded relatively coarse textured flesh. Yields of separated flesh, as percentages of whole fish, were 50.5 for buffalo fish, 39.7 for tilapia, and 43.7 for catfish.

Percentages of calcium in the minced flesh for all species were below 0.1%. Bone and scale contents were 0.16% for tilapia, 0.09% for catfish, and .07% for buffalo fish. Whiteness values measured by a color difference meter (Hunter-Lab values for white = 100, dark - 0) were 52 for ocean perch (control), 49 for catfish, 46 for tilapia, and 42 for buffalo fish.

Total aerobic mesophilic bacteria counts per g of deboned flesh from fresh fish ranged from 10^3 to 10^4. Neither scaling nor washing in 50 ppm chlorine before deboning significantly improved bacterial quality of flesh from fish processed immediately after harvesting. However, prior scaling and the chlorine rinse significantly reduced bacteria counts in flesh from fish ice-stored for 11-13 days prior to processing.

YIELD AND QUALITY OF MECHANICALLY SEPARATED FLESH FROM SEVERAL SPECIES OF CULTURED FRESHWATER FISH

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Introduction

Channel catfish (*Ictalurus punctatus*) is the only farmed warm-water food fish in the United States that has extensive market value. However, several other species of fish can be grown in ponds with channel catfish without affecting catfish yield, or in fact, possibly increasing catfish yield. This culture method, where two or more species of fish with different feeding habits are grown simultaneously to more efficiently utilize all of the nutrients available in the pond, is known as polyculture and has been practiced in many parts of the world for years.

Marketability of the secondary species from catfish culture in the United States is poor, primarily because of their boniness or the unfavorable opinion that consumers have of them as food fish. By separating the flesh from the bones and utilizing the minced flesh in consumer-type fish products, the marketability of these secondary species may possibly be improved. Also, boneless catfish flesh may have applications for creating new markets for this species.

Several commercial types of machines that efficiently separate edible flesh from skin and bones have allowed formerly unused sources of fish muscle to be utilized in various types of fabricated fish products (Patashnik et al., 1974).

Polyculture research studies at Auburn University have demonstrated that such species as tilapia, buffalofish, and some of the Chinese carps can be grown in catfish ponds without a substantial sacrifice in catfish yield but with increases in total fish production of up to 50 per cent. Two species of fish that are presently grown commercially in combination with channel catfish are tilapia and buffalofish.

The present study was initiated to evaluate the yield and quality of fish separated from hybrid buffalofish (*Ictiobus cyprinellus* x *Ictiobus niger*), tilapia (*Tilapia aurea*), and channel catfish (*Ictalurus punctatus*) with a Bibun bone separator, using various pre-process treatments. Also, various consumer-type products were developed and evaluated from the minced flesh from these species.

Materials and Methods

Sources of Fish

Buffalofish averaging 4.4 lbs. were obtained from intensively-fed catfish ponds at draining in October, 1975, and held in cages suspended in water for 5 days until slaughtered.

The tilapia averaged 0.5 to 0.75 lbs. and were taken from intensively-fed catfish ponds. Some were processed on the bone separator immediately and some were packed in ice without removal of heads, scales or viscera, for 13 days storage.

The channel catfish averaged approximately 1.0 lb. and were taken from intensively-fed culture ponds upon draining. They were held in cages until slaughtered.

Pre-Processing Treatments

Buffalofish were processed on the separator, either fresh or after 11 days storage in ice. In each group, one-half of the fish were headed, gutted, and scaled and one-half of them were only headed and gutted.

Prior to deboning, one-half of the scaled fish was washed with municipal tap water and one-half was washed first in tap water, then in 50 ppm chlorine solution, and again in tap water. The unscaled fish were also divided into two lots and given the same two pre-process wash treatments. The fish were washed in flowing tap water, dipped in 50 ppm chlorine solution for 1 minute, and rinsed with flowing tap water.

Tilapia were processed on the Bibun separator, either fresh or after 13 days storage in ice. The two pre-processing wash treatments described for the buffalofish were applied to both scaled and unscaled tilapia prior to deboning. The peritoneal cavities of the tilapia were brushed to remove the dark peritoneal lining before the fish were washed.

Before deboning, the dark pigment on the skin of channel catfish was removed to prevent discoloration of the processed flesh. Several treatments, involving heated NaOH solutions (140, 150, 155, and 160^{o}F) for various times (0.5 to 5 minutes), were evaluated for removing the pigment from the skin of catfish. The most suitable treatment was a solution of 5% NaOH at 155^{o}F for 0.5 minutes. After heading and eviscerating, the fish were dipped into the solution, then scrubbed with a brush. Fresh channel catfish weighing approximately 1.0 lb. were headed and eviscerated, and after the pigment was removed, the fish were washed in tap water and processed on the bone separator.

Mechanical Separation of Flesh from Bones and Scales

Flesh was separated from skin, bones, and scales as the fish were passed between a flexible belt and a rotating perforated drum. The flesh was pressed through the preforations in the cylinder by the pressure of the belt. The scales, skin, and bones did not pass through the perforations. The flesh was recovered from inside the perforated cylinder while the bones were carried away by the moving belt.

The extrusion cylinder which was used in the deboning machine had 7-mm diameter holes. The 7-mm diameter holes allowed the fish muscle to be separated into larger pieces which preserves the flaky texture of fish muscle better than smaller diameter holes. King (1973) found that although drums with 3-mm or 5-mm holes can be used, drums with 7-mm holes increased the yield of recovered flesh and minimized fragmentation of bones in the separator.

To measure yield of deboned flesh from buffalofish, eleven whole fish were processed and the yield of minced flesh was based on round weight of the fish. Twenty-five pounds of deboned buffalofish flesh was packaged and frozen for future analyses.

One hundred-sixty whole tilapia were processed and yield of minced flesh was taken based on round weight of the fish. Twenty-six pounds of deboned tilapia flesh were packaged and frozen for subsequent analyses.

Twenty whole channel catfish were deboned, and the yield of minced flesh was calculated from round weight of the fish. Twenty-seven pounds of separated catfish were frozen for subsequent use.

Quality Evaluation of Mechanically Deboned Fish Flesh

The minced flesh of all species of fish was analyzed for pieces of scale and bone by determining calcium content (A.O.A.C., 1966) and also, by isolating bone and scale fragments by a method described by Yamamoto and Wong (1974). This method involved solubilizing proteins on the flesh with urea. Calcium content of minced flesh is a relatively good index of the scale and bone content (personal communication, M. Yamamoto, Fisheries and Marine Science, Vancouver, Canada, 1975).

Lightness of the deboned flesh from buffalofish, tilapia, and channel catfish were compared with that of ocean perch using a Hunterlab Color Difference Meter (Model D 25D2M) using a white plate (Standard No. C2-3310) on thawed samples.

Total aerobic, mesophilic bacteria counts were made on the minced flesh from each of the pre-process treatments for tilapia and buffalofish, using the Standard Plate Count Method of the American Public Health Association (1966).

Results and Discussion

Yield of Deboned Flesh

Yields of separated flesh, expressed as percentages of the whole fish, are presented for the three species in Table 1. Yield of flesh from buffalofish was the highest (50.5%), which was anticipated because these were the largest fish, followed by channel catfish (43.7%), then tilapia (39.7%).

Miyauchi and Steinberg (1970) have shown that the total yield of minced flesh from various species of marine and fresh-water fish, such as rainbow trout, Atlantic croaker, Northern anchovy, spiny dogfish, English sole, Pacific hake, Pacific herring, lingcod, silvergray rockfish, starry flounder, and Pacific cod ranged from 37-60%. Yields of flesh from the three species of farm-raised fish used in this experiment were comparable to those obtained in other studies.

Yields of commercially dressed catfish (removal of head, skin, fins, and viscera) is 60% of the whole fish. A yield of 43.7% when catfish are processed by the deboning method represents 27% less recovery of marketable product from the whole fish. Also, the market value of minced catfish flesh would probably be less than that of conventionally dressed catfish. Since dressed channel catfish is a widely accepted consumer product, it is not feasible at the present time to mechanically debone this fish.

Appearance of Deboned Flesh

The raw, minced flesh from all three species was relatively light in color with coarse texture. The flesh from the depigmented catfish had the lightest color and was relatively free of dark spots. The buffalofish had a small amount of dark muscle pigment which, when minced with the white muscle, gave the homogenate a pink appearance, slightly darker than that of the tilapia and channel catfish. The color of the minced tilapia flesh appeared to be between that of channel catfish and buffalofish, but with some dark flecks caused by bits of skin.

King (1973) found that washing and straining the minced flesh after deboning improved the appearance. The color was described as off-white rather than snow-white. Clotted blood was removed by the washing treatment, but the strainer broke up these clots and diffused their color into the rest of the flesh. Some variation in color results from the choice of species of raw material from which the minced flesh was obtained. A slight pink color (the color of very dilute normal blood) in a minced block has been synonymous with good odor, flavor, and low total plate counts (King, 1973). In contrast, minced blocks which have a brownish tint (the color of dilute oxidized blood) were considered inferior in quality.

Comparisons of whiteness, measured by the Hunterlab Digital Color Difference Meter, of deboned flesh from buffalofish, tilapia, and channel catfish and muscle from ocean perch are shown in Table 2. Effects of pre-process scaling of buffalofish and tilapia on the whiteness of the deboned flesh were negligible for both of these species. Deboned channel catfish had the highest (whitest) Hunterlab color score of the three freshwater species, but was slightly darker than the ocean perch which had very light flesh.

Bacterial Quality

Total bacteria plate counts of deboned flesh from buffalofish and tilapia are shown in Tables 3 and 4. In the freshly processed fish flesh, the only significant difference in bacteria counts among the pre-process treatments was the higher concentration of bacteria in the flesh from the non-scaled fish washed only in tap water. Scaling fresh buffalofish did not reduce bacteria counts when the fish were washed in 50 ppm chlorine solution before deboning. Buffalofish stored in ice for 11 days and scaled prior to pre-processing treatments, had about the same concentration of bacteria as buffalofish processed fresh. Non-scaled fish were slightly higher in bacteria counts that scaled fish when stored in ice of several days.

Washing fresh tilapia in 50 ppm chlorine solution did not appreciably improve bacterial quality (Table 4). However, removing scales prior to pre-processing did reduce bacteria count of processed scaled fish. Fish that were held iced for 13 days prior to deboning followed by washing the non-scaled fish in 50 ppm chlorine solution improved the quality of the processed flesh. There was no benefit of washing scaled fish with chlorine solution.

Deboned tilapia had slightly higher bacteria counts when compared to freshly deboned buffalofish. However, when tilapia were held in ice for several days and not scaled prior to processing without washing in tap water, not rinsing in 50 ppm chlorine solution increased the bacteria count.

Quality of deboned flesh from the fresh fish would be considered satisfactory, based upon the findings of Blackwood (1973) who reported bacteria counts up to 1.5×10^6 for minced flesh from marine species, although he pointed out that many of his samples came from fish of poor quality.

Bacteria counts for flesh from fresh fish appear favorable when compared with data reported by King (1973), wherein the lowest total aerobic plate counts in minced fish blocks were in the order of 10^3 to 10^4 per gram. His counts were highly dependent on freshness of raw material and speed with which the material was processed, but were influenced only slightly by washing the minced flesh before freezing.

Flesh from tilapia stored on ice for 11 days prior to deboning had appreciably higher bacteria counts than that from fresh fish. Flesh from the 11-day iced, non-scaled fish had counts about 1 x 10^6 per gram; counts at this level are generally associated with food of inferior quality.

Bones and Scales in Deboned Flesh

Even when buffalofish and tilapia were deboned without prior scaling, there was remarkably little scale or bone in the separated product.

Calcium levels less than 0.5% are considered to be indicative of low and acceptable levels of bone in mechanically deboned meat (United States Department of Agriculture, 1975). As shown in Table 5, calcium levels in the minced flesh for all species were well below 0.1%. Quality standards with regard to acceptable levels of bone or calcium in mechanically separated fish flesh have not been established but are being developed by National Marine Service, Vancouver, Canada, 1975). The relatively large diameter (7-mm) holes in the extrusion cylinder of the deboner are apparently quite satisfactory for separating bones and scales from flesh in the three species.

Calcium content of deboned fish flesh appears to be a good measure of bone content, as indicated by the close agreement between these two measurements among all the samples of fish flesh (Table 5). Calcium determination is a more convenient assay procedure than total bone measurement, and should be selected as the standard assay procedure for bone content in minced fish flesh.

Tilapia flesh contained the highest content of bone and/or scale (0.158%), followed by channel catfish (0.091%), and buffalofish (0.071%). Tilapia was expected to have the highest percent bone. Since tilapia were relatively small fish, they had small bones and scales. Buffalofish contain a large number of tiny intermuscular bones; however, none were found in the separated flesh.

Summary and Conclusions

Buffalofish (4.4 lbs.) and tilapia (0.5 lb.), which were grown in combination with channel catfish in intensively-fed polyculture ponds, were mechanically deboned along with channel catfish (1.5 lbs.) on a Bibun bone separating machine. The fish were headed, gutted, scaled or not scaled, and washed in tap water or 50 ppm chlorine solution prior to deboning. Dark pigments were removed from the skin of catfish and from the abdominal wall of tilapia before processing.

A relatively large hole diameter of 7 mm in the extrusion drum of the machine was satisfactory for separating flesh from skin, scales, and bone, and yielded minced flesh of relatively coarse texture in all three fish species. Only very small amounts of bone or scales were found in the flesh even when scales were not removed prior to deboning the fish.

Yields, expressed as percentages of whole fish were 50.5 for buffalofish, 39.7 for tilapia, and 43.7 for channel catfish.

Calcium level agreed closely with bone and scale content of the mechanically separated flesh and analyses for calcium in flesh from all species were less than 0.1%.

Bacterial contents of deboned flesh from fresh fish were relatively low, with counts in the range of 10^3 cells per gram. Scaling prior to deboning did not improve bacterial quality except when fish had been ice-stored for 11 to 13 days. Rinsing fish in 50 ppm chlorine solution before processing improved bacterial quality only slightly in fresh fish but appreciably in unscaled fish stored for 11 to 13 days on ice.

Catfish flesh had a slightly lighter appearance followed by tilapia and buffalofish in that order. Deboned catfish flesh had the fewest specks of dark pigment.

Texture, appearance (and flavor) are similar for the three freshwater species, indicating that the fish may be substituted for one another in minced flesh food products, assuming they are in good condition and do not have environment-related off-flavors. Subsequent studies will evaluate various consumer type products, such as shrimp and crab products and fish cakes, with the minced flesh from these cultured species.

Since channel catfish presently have relatively high market value as dressed, intact fish, it is probably not feasible to mechanically debone this fish at the present time.

This research indicates that yields of 40 to 50% of minced flesh may be obtained from freshwater fish that can be intensively cultured in ponds, provided proper quality control measures are practiced and dark pigments are removed prior to processing. This flesh is slightly darker than that in most ocean fish, but has a mild flavor quality that will blend well in combination with other products such as shrimp or crab.

References

American Public Health Association. 1966. Recommended methods for the microbiological examination of foods. 2nd Ed. Amer. Pub. Health Assn. Inc., New York, N.Y.

Blackwood, C. M. 1973. Utilization of mechanically separated fish flesh-Canadian experience. Technical Conference on Fishery Products. U.S. Food Agr. Org. 6 pp.

King, F. J. 1973. Improving the supply of minced blocks for the fish stick trade. Mar. Fish. Rev. 35(8): 26-32.

Miyauchi, D. and M. Steinberg. 1970. Machine separation of edible flesh from fish. Fishery Ind. Res. 6(4): 165-171.

Patashnik, M., G. Kudo and D. Miyauchi. 1973. Smooth, white spread from separated fish flesh forms a base for flavored dips, snack items. Food Prod. Dev. 4 pp.

U.S. Department of Agriculture. 1975. Preparation of mechanically deboned meat and meat fatty tissue. Meat and Poultry Inspection Bulletin 865, Animal and Plant Health Inspection Service, U.S.D.A. Washington, D.C.

Yamamoto, M. and J. Wong. 1974. Simple chemical method for isolating bone fragments in minced fish flesh. J. Food Sci. 39(6): 1259-1260.

Table 1
Yield of mechanically separated flesh
from buffalofish, tilapia,
and channel catfish

Fish Species	Average size (lb)	Average yield (%)
Buffalofish	4.4	50.5
Tilapia	0.5	39.7
Channel catfish	1.5	43.7

Table 2
Average whiteness values of minced flesh from buffalofish, tilapia, channel catfish, and ocean perch measured with the Hunterlab Color Difference Meter[1/]

Fish	Whiteness Value			
	Scaled	Non-scaled	Depigmented	Intact Muscle
Buffalofish	42.4	41.4		
Tilapia	45.5	44.1		
Channel catfish			49.1	
Ocean perch				52.0

[1/]Average of 6 samples of each species

Table 3
Effects of pre-process washing and scaling
on bacteria counts of mechanically deboned buffalofish[1/]

Condition of fish	Scaled		Non-scaled	
	Tap water	50 ppm chlorine	Tap water	50 ppm chlorine
Fresh	1.70×10^3	3.28×10^3	2.96×10^4	4.51×10^3
Iced, 11 days	7.36×10^3	9.66×10^3	2.14×10^4	4.86×10^4

1/Col/g, geometric mean of three collections

Table 4
Effects of pre-process washing and scaling on bacteria counts of mechanically deboned tilapia[1/]

Condition of fish	Scaled		Non-scaled	
	Tap water	50 ppm chlorine	Tap water	50 ppm chlorine
Fresh	7.55×10^3	6.92×10^3	1.02×10^4	1.02×10^4
Iced, 13 days	2.91×10^5	1.25×10^5	1.03×10^6	5.95×10^5

[1/]Col/g, geometric mean of three collections

Table 5
Average percentages of calcium and bone in flesh mechanically separated from buffalofish, tilapia, and channel catfish[1/]

Fish	Calcium (%)	Bone		
		Scaled (%)	Non-scaled (%)	Depigmented (%)
Buffalofish	0.046	0.066	0.071	
Tilapia	0.064	0.115	0.158	
Channel catfish	0.052			0.091

[1/] Average of 15 samples of each species

THE EFFECT OF WASHING ON COLOR AND TEXTURE OF MINCED CROAKER

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Croaker (Micropogon Undulatus) makes up more than 50% of the total industrial bottomfish landings of the Gulf of Mexico. The available quantity of croaker potentially available from the Gulf, however, exceeds the present demand for human consumption; consequently, new products need to be introduced to better utilize the potential of this resource. The objectives of these experiments were to investigate the effect of washing on the color and the texture of minced croaker, after a short period of frozen storage, and to provide some guidelines for future research studies.

The results show that the color of minced croaker can be improved by washing the minced flesh with cold tap water. The ratio of water to fish was 2, 3 or 4 times the weight of minced fish. The minced fish was washed 1, 2 or 3 times for 2 minutes, then the slurry was drained until the weight of the sample was about 3% less than the weight of the original sample. The largest increase in the lightness of the sample was noted after the first wash with 2 parts water and 1 part fish. Further increase in the number of washes removed pro-oxidant material and slightly improved the color of the minced croaker.

There was no change after seven weeks of storage at 0°F. However, the TBA number increased slightly. The total solids lost during washing was ranged from 0.5% to 5.5% of the weight of minced fish.

There was no significant change in the total microbial count of the minced fish samples during washing and after storage.

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FUNCTIONAL PROPERTIES INFLUENCING TEXTURE

Abstract

This paper presents a review of the present status of the relationship of functional property measurements on raw minced fish tissue to finished product texture. The functional property methods which have been used most often to evaluate proteins are water absorption, water holding capacity, foaming capacity and stability, protein solubility, emulsifying activity and capacity, emulsion stability, gel-forming capacity and stability. Research investigations have indicated that the myofibrillar proteins are responsible for the gel-forming capaicity of fish tissue. However, a direct relationship between final product texture and myofibrillar protein content has not been clearly established. Of the other functional property methods, water holding capacity is the only method which has indicated a high correlation with finished product texture in studies at North Carolina State University. Extensive research work is being conducted at North Carolina State University to relate sensory profile texture data to instrumental methods on products prepared with fish tissue. The results of these studies have indicated a relatively high correlation between the selected character notes identified by a texture profile panel and the combined instrumental methods of shear energy, product modulus and hysteris loop. Further work is needed on the development of improved methods for measuring the functional properties of raw minced tissue and their relationship to final product texture.

FUNCTIONAL PROPERTIES INFLUENCING TEXTURE

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Introduction

Those chemical and physical properties of proteins which affect the ultimate texture of finished food products have been described as functional properties; viz water absorption, water holding capacity, foaming capacity and stability, protein solubility; emulsifying activity and capacity and stability; gel-forming capacity and stability. The preparation of food products in which muscle tissue is used as a major raw material source establishes the need to determine selected functional properties of the proteins in order to obtain the desired texture of the finished product. We must keep in mind that regardless of the degree of precision obtained in measuring the functional properties of raw muscle proteins, the ultimate texture of the food product will be greatly affected by the processing technique employed. Techniques such as freezing, drying, chilling, curing, cooking, comminuting, mixing and pumping will greatly influence the functionality of the muscle proteins in the food system and consequently will influence the final product texture. This is also true for such factors as essential food additives used in conjunction with the muscle tissue. Therefore, these factors must be taken into consideration when expressing functional property values of proteins in relation to finished product texture.

There are major differences in the functionality of muscle proteins when used in a comminuted food system as compared to intact muscle tissue.

This discussion will be limited to comminuted food systems. For a detailed coverage of the developments in the field of comminuted meat systems the reader is referred to reviews by Gorbatov and Gorbatov (1974), Sulzbacher and Swift (1970), Gordon (1969a) and Gordon (1969b), Saffle (1968) and Webb (1974), Hamm (1975). In addition to the research work accomplished on the measurement of the functional properties of red meats and poultry, there has been an extensive amount of research done on the functional properties of fish muscle tissue. Japanese, Canadian and U. S. workers have studied various protein fractions and developed methods of measuring their functionality in comminuted systems (Takagi and Wataru, 1972; Teeny and Miyauchi, 1972; Umemoto and Taguchi, 1972; Kudo et al., 1973; Miller and Groniger, 1976; Wang and Kinsella, 1976; Webb et al., 1975. Investigations conducted during the past 20 years, as reported in these reviews, have resulted in significant contributions in the efficient utilization of various protein sources, especially for those derived from muscle tissue. Even with the extensive amount of work accomplished, there has been only a limited amount of productive results published on the direct relationship of muscle protein functional properties to finished product texture. At this point it is extremely difficult to objectively evaluate raw minced fish muscle tissue and subsequently project the ultimate texture of a finished product. This is especially true when various types of additives and processing regimes are used. Thus, even though relatively high correlations are obtained between a specific functional property value for raw tissue and a texture rating of the finished product, the data are of limited value in the development of the desired texture of a food product under practical conditions. However, the data are of value in comparing the relative properties of different protein sources, especially for basic properties such as amount of soluble protein. In recent years there has been increased emphasis upon the utilization of more diverse sources of food proteins for the preparation of comminuted food products. Research has been focused upon the utilization of such sources as plant proteins, mechanically deboned muscle tissue, whey, blood and various meat and fish by-products. However, work needs to be done on the standardization of methodology for measuring functional properties in order to adequately describe the potential value of protein sources in comminuted food systems before significant improvements in refinement and standardization of food proteins can be realized. Ultimately the protein functionality must be objectively measured in order to specify within a reasonable degree of accuracy the desired finished product texture.

Relationship of Functional Property Measurements to Finished Product Texture

Numerous methods have been developed and are currently being used to evaluate the functional properties of protein sources for food products (Shimizu et al., 1962; Saffle and Galbreath, 1964; Webb et al., 1970; Kushtalov and Saduakason, 1971; Morrison et al., 1971; Umemoto, 1971; Belova, 1974; Wagenknecht and Tuelsner, 1974; Miller and Groninger, 1976; Wang and Kinsella, 1976). The most commonly used methods are protein solubility; water-holding capacity; emulsifying activity, capacity and stability, sol viscosity; foaming capacity and stability and degree of gelation. The specific methods employed are based upon the ultimate use intended for the protein source. Protein solubility, emulsifying capacity and water-holding capacity have been most widely used to determine the functionality of muscle protein in comminuted food systems. It has been established that the salt soluble proteins (myofibrillar proteins) are those that are primarily responsible for obtaining the desired textural properties in muscle protein based gel and emulsion type comminuted products (Hegarty et al., 1963; Trautman, 1970; Swift, 1965; Tasi et al., 1972). However the sarcoplasmic and connective tissue proteins are known to play a role in determining the ultimate finished product texture, but their role has not been clearly defined.

Myosin has been identified as a primary emulsifying agent in comminuted products but a comminuted system is not totally an emulsion in the true sense of the definition. Apparently a fairly high proportion of emulsification occurs in comminuted food systems but other states are known to exist. Comminuted food systems have been defined by Kotter and Fischer (1974) as consisting of a genuine solution, gel solution, suspension, emulsion and foam. Ivey et al. (1970) reported that emulsifying capacity increased with the degree of dilution of the continuous phase in a model system. On the basis of the denaturation principle we would expect the protein in a gel or emulsion system to be relatively inefficient due to the high concentration of protein. This is based upon the fact that as the level of water is increased a more efficient emulsification is obtained (Morrison, 1971). Goethart (1971) reported that significant correlationswere not obtained for comparisons made between the emulsifiying capacity of dilute emulsions versus concentrated emulsions for both model and practical systems. Van den Oord et al. (1973) stated that the emulsifying capacity test has never been accepted as a practical method of determining the fat emulsifying properties of proteins. This statement is perhaps too radical as the relative values are being used in computerized red meat sausage formulas in the U. S. but his statement does indicate the lack of confidence in this method.

Ravesi and Anderson (1969) stated that the amount of extractable protein in frozen stored fish muscle is often used as a criteria of its textural quality. However, they further stated that accessment of the texture of fish muscle by an organoleptic panel often shows poor correlation with the amount of extractable protein. Umemoto (1971) reported that protein solubility has previously been used as an index of protein denaturation in red meats and poultry but a significant relationship was not obtained until considerable denaturation had occurred. It was concluded that initial changes in the functional properties of muscle tissue may be determined in greater detail by measuring changes in the amount of gel fraction in protein rather than the amount of extractable myofibrillar proteins. Umemoto and Kanna (1971) reported that when fractionating tissue into the sarcoplasmic and myofibrillar proteins, the gel component existed in the myofibrillar fraction. According to Shimizu et al. (1954) maximization of myosin solubility is the key factor in reinforcing the gel strength of fish sausage. Even though relationships have been established between protein solubility and gel-forming capacity of fish muscle, there is a wide difference of opinion among research workers as to the appropriate method for measuring the gel-forming fraction which contributes directly to the ultimate texture of a comminuted product. According to Simidu et al. (1958) and Connell (1964) the degree of protein extractability differs widely among species. Also type and level of lipid components determine the degree and rate of protein denaturation. On the basis of previous investigations, it can be concluded that protein extractability *per se* does not give a very high relationship with all parameters of product texture in comminuted muscle foods. This is especially true when water binding additives are used in the system. Other measurements of functionality such as water-holding capacity, emulsifying capacity and stability and viscosity of the sol have been investigated to relate the functionality of the tissue to finished product texture. The results have indicated a lack of correlation of these techniques with product texture.

We conducted a study using minced fish from six species to determine the relationship of selected, classical functional property measurements (viz. salt soluble protein, water-holding capacity, emulsifying capacity) of the raw tissue to the individual textural character notes of a cooked gel product as identified by a trained texture profile panel (Webb et al., 1975). The protein fractional components (viz. non-protein nitorgen, sarcoplasmic nitrogen, myofibrillar nitrogen and stroma nitrogen), water-holding capacity values, and emulsifying capacity values of the minced tissue indicated significant differences among species. The data presented in Table 1 indicate a lack of significant correlation between most of the texture character notes, as determined by a trained texture profile panel, on the minced fish gel product and water-holding capacity and emulsifying capacity values. Similarly low correlations were obtained between the level of salt soluble protein and the texture ratings in this study. It is noteworthy that water-holding and emulsifying capacity values have been widely used by the meat industry to access the potential functionality of muscle proteins. However, we found that these methods had very poor relationships to the individual textural character note ratings for the minced fish gel product. The greatest difficulty in developing reliable methods to determine the functionality of protein sources in gel and emulsion systems is the changes which occur during processing. Thus, methods have been developed which may truly access the emulsifying capacity, soluble protein level, etc. of a raw muscle tissue but such factors as comminuting, heating and additives profoundly modify the proteins so that a direct relationship to finished product texture is difficult to establish. It is evident that a considerable amount of work needs to be accomplished on developing methods for determining the functionality of fish muscle tissue in order to predict with a relatively high degree of accuracy the ultimate texture of products prepared with minced fish tissue. If we are to develop new products and more diverse uses for fish muscle proteins, it is imperative that these proteins be described in terms of their functionality in a food system. However, the need for developing precise techniques for measuring the functionality of the raw tissue must preceed the standardization of fish muscle protein sources.

Effect of Processing on Functional Properties of Muscle Proteins in a Food System

Numerous workers have developed model systems and various techniques for measuring the functional properties of raw tissue for ultimately relating these to practical processing situations. At North Carolina State, we are interested in studying the effect of specific processing systems on the finished product texture and in turn relating these to the results of functional property measurements of the raw muscle tissue. Currently we are investigating the basis for a reduced gel forming capacity and texture of mechanically separated fish muscle tissue as compared to hand separated tissue. In a study reported by Hardy (1973) emulsifying capacity was significantly higher for mechanical separated tissue than hand separated fish tissue; whereas there was no significant difference in the cook stability of the two treatments. In this study cooked emulsions prepared from hand and mechanically deboned croaker tissue had significantly lower texture ratings for the mechanically processed croaker tissue as evaluated by the texture panel and the Instron shear using the Kramer cell. Thus, a lack of correlation was obtained between these functional property measurements and texture values.

Defining of Texture by Instrumental Analyses

Up to this point it has been indicated that the functional properties of protein sources (specifically muscle proteins) need to be described in terms of their contribution to product texture. We not only have difficulty in describing the functional properties of muscle proteins but methods of describing texture of the finished product in objective terms have been lacking. Perhaps one of the greatest difficulties in obtaining a high degree of relationship between functional property measurements and finished product texture is the failure to adequately measure texture. We are conducting research on the measurement of texture of gel and emulsion-type muscle protein based food products. Our approach has been to train and develop a texture profile panel to the highest level that is attainable by modern technology. The panel has been trained to a degree that we feel highly confident in using their results as the basis for defining texture. This system defines texture in terms of the individual character notes of a food product. As the panel defines the textural characteristics of a food product in terms of individual character notes, simultaneous analyses are made to measure the texture of the food product by a variety of mechanical instruments. Correlations are our best estimate of the degree of comparisons between the panel and the instrumental methods. The results of this approach for gel and emulsion products are illustrated in Table 2. These results indicate the potential for developing a series of instrumental measurements to measure product texture.

Through a combination of instrumental methods it is possible to more completely describe the textural characteristics of food products. We believe that this approach will ultimately result in the more complete description of the texture of a food product. Ultimately one should be able to specify the precise textural charactersitics desired for a food product, stipulate the functional properties required in the raw materials and by a specific processing system predict the final product texture.

REFERENCES

Belova, Z. I. 1974. Effect of degree of fish muscle comminution on water-retention capacity. Trudy Vesoyuznogo Nauchno-issledovatel'skogo Institute Morskogo Rybnogo Khosyaistva I Okeanografii 95.

Connell, J. J. 1964. Fish muscle proteins and some effects on them of processing, p. 255. In H. W. Schultz and A. F. Anglemier (ed.), Symposium on Foods: Proteins and Their Reactions. The AVI Publishing Co., Inc., Westport, Conn.

Goethart, R. L. D. 1971. Determination of emulsifying properties of some non-meat proteins and the relation to sausage emulsions. Report of the 17th European Meat Conference, Bristol, England.

Gorbatov, A. V. and V. M. Gorbatov. 1974. Advances in sausage meat rheology. J. Texture Studies 4.

Gordon, A. 1969a. Emulsification in comminuted meat systems. I (A Review). Food Processing Industry 38(459).

Gordon, A. 1969b. Emulsification in comminuted meat systems. II (A Review). Food Processing Industry 38(459): 50.

Hamm, R. 1975. On the rheology of minced meat. J. of Texture Studies 6(3):281.

Hardy, E. R. 1973. Influence of mechanical separation on the functional properties of fish muscle tissue. M. S. Thesis, N. C. State Univ., Raleigh, N. C.

Hegarty, G. R., L. J. Bratzler, and A. M. Pearson. 1963. Studies on the emulsifying properties of some intracellular beef muscle proteins. J. Food Sci. 28.

Ivey, F. J., N. B. Webb and V. A. Jones. 1970. The effect of disperse phase droplet size and interfacial film thickness on the emulsifying capacity and stability of meat emulsions. Food Tech. 24.

Kotter, L. and A. Fischer. 1974. The influence of phosphates or polyphosphates on the stability of foams and emulsions in meat technology. Personal communication.

Kudo, G., M. Okada and D. Miyauchi. 1973. Gel-forming capacity of washed and unwashed flesh of some Pacific coast species of fish. Marine Fisheries Review 35(12).

Kushatalov, G. N. and T. S. Saduakason. 1971. Capacity of fish tissue to bind water when heated to moderate temperature. Rybnoe Khozyaistvo 47.

Miller, R. and H. S. Groninger, Jr. 1976. Functional properties of enzyme-modified acylated fish protein derivatives. J. Food Sci. 41.

Morrison, G. S., N. B. Webb, T. N. Blumer, F. J. Ivey, A. Haq. 1971. Relationship between composition and stability of sausage-type emulsions. J. Food Sci. 36.

Ravesi, E. M. and M. L. Anderson. 1969. Effect of varying the extraction procedure on the protein extractability of frozen-stored fish muscle. Fishery Industrial Research 5.

Saffle, R. L. and J. W. Galbreath. 1964. Quantitative determination of salt-soluble protein in various types of meat. Food Tech. 12.

Saffle, R. L. 1968. Meat Emulsions. In "Advances in Food Research" (C. O. Chichester, E. M. Mark and G. F. Stewart, eds) 16. Academic Press, N. W.

Shimizu, Y., W. Shimidu and T. Ikeuchi. 1954. Studies on jelly strength of kamaboko. IV. Influence of salts. Bull. Jap. Soc. Sci. Fish. 20.

Shimizu, Y., Y. Hosokawa and W. Simidu. 1962. Studies on "Ashi" of kamaboko. XIII. Changes in viscosity of fish muscle sol during heating. Bull. Jap. Soc. Sci. Fish. 28.

Simidu, W., U. Simidu and H. Terasima. 1958. Studies on muscle of aquatic animals. XXXVIII. The influence of frozen storage on muscle protein of yellowtail (Seriola quinqueradiata). Bull. Jap. Soc. Sci. Fish. 23.

Sulzbacher, W. L. and C. E. Swift. 1970. Processing factors and emulsion characteristics. 16th European Meeting of Meat Research Workers, Vol. 16, Varna, Golden Sands, Bulgaria.

Swift, C. E. 1965. The emulsifying properties of meat protein. In "Proc. Meat Ind. Research Conf." (O. E. Kolari and W. J. Aunan, eds). Am. Meat Sci. Assoc. and Am. Meat Inst. Foundation, Chicago, Ill.

Takagi, I. and Wataru. 1972. On rheological properties and structure of kamaboko - III. Thermodynamical components in elastic force of expanding kamaboko. Bull. Jap. Soc. Sci. Fish. 38.

Teeny, F. M. and D. Miyauchi. 1972. Preparation and utlization of frozen blocks of minced Black Rockfish muscle. J. Milk and Food Technol. 35.

Trautman, J. C. 1970. Method of extracting salt soluble protein from post-rigor meat. U. S. Patent 3,523,800.

Tsai, R., R. G. Cassens and E. J. Briskey. 1972. The emulsifying properties of purified muscle proteins. J. Food Sci. 37.

Umemoto, S. 1971. Studies on gel fraction in fish muscle protein extracts. V. Changes in protein extractability of fish muscle during cold storage. Bull. Tokai Reg. Fish. Res. Lab. No. 68, Tokyo, Japan. pp. 81-85.

Umemoto, S. and K. Kama. 1971. Studies on gel components in fish muscle protein extracts. I. Preliminary experiments on properties of gel components. Bull. Tokai Reg. Fish. Res. Lab. No. 65, Tokyo, Japan.

Umemoto, S. and T. Osamu. 1972. Studies on gel fraction in fish muscle protein extracts - VII. Actin component in the gel fraction. Bull. Jap. Soc. Sci. Fish. 38.

van den Oord, A. H., P. R. Visser and B. V. Oss. 1973. Beschaffenheit and verteilung von fett in zerkleinerten fleischwaren. Die Fleischwirtschaft 53.

Wagenknecht, W. and M. Tuelsner. 1974. Binding of water in fish muscle and its variation. Fischerei-Forschung 12.

Wang, J. C. and J. E. Kinsella. 1976. Functional properties of novel proteins: alfalfa leaf protein. J. Food Sci. 41:286.

Webb, N. B., F. J. Ivey, H. B. Craig, V. A. Jones and R. J. Monroe. 1970. The measurement of emulsifying capacity by electrical resistance. J. Food Sci. 35.

Webb, N. B. 1974. Emusion technology. Proc. of the Meat Ind. Res. Conf., AMSA and AMIF, Chicago, Ill.

Webb, N. B., A. J. Howell, F. B. Thomas and V. N. M. Rao. 1975. Compositional functional properties of minced fish tissue. Presented at the 35th annual meeting of the Inst. of Food Tech. Abstract No. 250.

Table 1--Coefficients of correlation between texture profile panel data and instrumental shear values on a minced fish gel product from six species[a,b]

	Elasticity	Firmness	Cohesive-ness	Uniformity	Denseness	Graininess	Coarseness
Shear energy	0.5151	0.8917**	0.6160	-0.7490	0.9365**	0.4334	0.7800*
Maximum Force	0.2308	0.7338*	0.3587	-0.3307	0.8569**	0.6991	0.9150**
Water-Holding Capacity	0.0413	-0.0651	0.1410	0.8333*	-0.0606	-0.6196	-0.6937
pH	0.0894	0.5702	0.3033	0.1688	0.7242	0.3170	0.4708
Emulsifying Capacity	-0.0933	0.0926	-0.0177	-0.4793	0.1164	0.5595	0.5822

[a]Species studied were: bluefish, flounder (deboned frames), mullet, shad, spot and trout. Evaluation for proximate composition, pH and emulsifying capacity were taken on raw tissue, whereas texture profile panel and instrumental shear data were taken on a cooked gel product.

[b]*deontes significant at $p = 0.05$
**denotes significant at $p = 0.01$

Table 2--Coefficients of correlation among texture profile character notes and instrumental rheological measurements for minced fish and beef emulsions and gels.

Evaluation Phase	Character Notes	LEE Kramer Shear Values	Modulus Instron Curve	Hysteris Loop	Extrusion Rheometer
I	Elasticity	0.178	-0.548**	0.195	-0.548**
II	Firmness	0.686**	-0.044	-0.245	0.025
	Cohesiveness	0.443	-0.224	-0.172	-0.281
	Uniformity	0.187	0.105	-0.284	0.031
	Denseness	0.622	0.247	-0.468*	0.106
	Graininess	-0.101	0.503**	-0.204	0.520**
	Coarseness	0.644**	0.218	-0.386*	0.191
III	Chewiness	0.616**	0.159	-0.385*	-0.018
	Moisture Release	-0.173	-0.798**	0.488*	-0.727**
	Cohesiveness of Mass	0.217	-0.429*	0.146	-0.375*
	Coarseness of Mass	0.517**	-0.250	-0.079	-0.233
	Graininess of Mass	-0.107	0.586**	-0.290	0.601**
	Oiliness	-0.206	0.501**	-0.299	0.238
	Moisture Persistence	-0.002	-0.622**	0.416*	-0.466*
IV	Particles	-0.176	0.425	-0.254	0.398*
	Oiliness	-0.133	0.673**	-0.417*	0.413*

*Significant at p = .05
**Significant at p = .01

SELECTED TEXTURAL PROPERTIES OF COOKED MINCED ATLANTIC CUTLASS FISH STICKS

ABSTRACT

Textural properties of cooked minced Atlantic Cutlass and Cod fish sticks were evaluated using (a) compression, (b) puncture and (c) Kramer Shear Press cell. Based on statistical analysis of data, the Kramer Shear Press cell was found to provide more indicators of textural properties than either the compression or puncture apparatus. Significant difference between Cod and Cutlass fish was found for sample thickness and width, force, area under force-deformation curve, apparent modulus of elasticity ($P<.01$), and deformation ($P<.05$).

SELECTED TEXTURAL PROPERTIES OF COOKED MINCED ATLANTIC CUTLASS FISH STICKS

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Introduction

Our world population today stands on the brink of famine. Each day literally thousands of people die of starvation. At least 60 percent of all the 2.5 billion people living in the poorer, developing world are malnourished (Hatfield, 1976). One can have enough food to stay alive but malnourishment, particularly protein deficiency, makes him much more susceptible to disease and death. It is a well known fact that protein deficiency during a mother's pregnancy and first months of an infant's life can cause permanent brain damage (Suter, 1976). Protein as an essential component in the human diet is one of the most expensive to obtain.

Fish is high in food value because of its high protein content of 17-19 percent and due to its quality of protein (Suter, 1976). The protein fraction contains several different proteins, including enzymes, contractile proteins, and structural proteins. About 65-75 percent of the total protein is constituted by myofibrillar protein in which myosin is the major protein. Sarcoplasmic protein constitutes about 10-20 percent of the total protein and approximately 8-22 percent total protein is composed of globulin X. Structural protein constitutes less than 10 percent of the total protein (Cobb, 1975a).

Fish is a significant food source in most countries of the world. In many of the developing countries, fish is the primary source of protein. The above is true partly because other forms of protein simply are not available. Beef and pork, for instance, are forbidden in some countries due to religious traditions.

There are, however, certain fish which are not being utilized at all. These fish are generally referred to as "trash fish", that is, fish caught incidental to regular fishing operations such as shrimping. They are considered a nuisance by both commercial and sport fishermen. An estimated 660,000 metric tons of trash fish in one year were caught and discarded during Gulf shrimping operations (Cobb, 1975b). Of these trash fish, Atlantic Cutlass fish (trichiurus lepturus) constitute a significant percentage. They are found in less than one percent by number in brown shrimping grounds but in over 15 percent in white shrimping grounds. Fishermen complain that these fish cause significant economic loss due to their interference in regular fishing operations. They not only clog nets thus damaging them, but, in the case of tuna fishing, the Cutlass fish swimming fairly close to the surface snatches away the bait before it can reach the tuna in the lower depths of water.

Atlantic Cutlass fish have large mouths with long, very sharp pointed teeth able to inflict serious injury. When processed, the carcass yield of Atlantic Cutlass fish averages about 50 percent, which is above average for many commercial fish (Cobb, 1975c). The resultant white flesh, with a relatively low fat content is considered a good potential human food source by many in the fish industry. Protein composes an average of 18 percent of the entire fish.

Consumer acceptance studies were conducted by the National Marine Fisheries Service to tentatively evaluate the marketing potential of minced Atlantic Cutlass fish sticks. Based on the favorable response by the consumers in the above studies, it was decided to compare the textural properties of cooked Atlantic Cutlass fish sticks with some commercially available cooked minced fish sticks.

The objectives of this research were to:

1. Measure the textural properties of cooked minced Atlantic Cutlass fish sticks.
2. Compare the textural properties of cooked minced Atlantic Cutlass fish sticks with cooked commercial grade minced Cod fish sticks.

Theory

Tests to determine the textural properties of the cooked minced Atlantic Cutlass fish sticks included (a) compression,

(b) puncture and (c) Kramer Shear Press Cell. Orientation of the structured texture did not permit core sampling without excessive damage to the fish stick. Additional tests are planned to measure the binding properties of the cooked minced fish sticks.

Compression Tests

The term compression test refers to tests in which a specimen is subjected to a gradually increasing axial load until failure occurs. Mechanical properties such as apparent modulus of elasticity, toughness, stiffness, force and deformation to points of inflection and bioyield can be obtained from the force-deformation curve produced when the material specimen is subjected to axial compression by a flat plate or a spherical indentor (Funderburk, 1975).

Elasticity

Mechanical properties of a body tending to return them to their original state or form after a load is removed are called elastic. The apparent modulus of elasticity for compression of flat surfaced specimens between two parallel rigid plates is

$$E = \frac{\sigma}{\varepsilon} = \frac{F/A}{\Delta L/L} = \frac{\text{stress}}{\text{strain}}$$

where: F = force, Newtons (N)

A = cross-sectional area of specimen in contact with the flat plate, cm^2

L = initial thickness or length of the specimen, cm

ΔL = deformation of specimen in direction of loading, cm

σ = stress due to loading, N/cm^2

ε = strain due to loading, cm/cm

It can be seen from the above equation that the apparent modulus of elasticity represents a relationship between force per unit area (stress) to deformation per unit length (strain). It is an index of the relationship of force (toughness) to deformation (elasticity) due to loading.

Point of Inflection

The typical force-deformation curve for specimens of various foods under compression loading is first concave up and then concave down (Fig. 1). When the force-deformation curve becomes linear, the point at which the behavior is essentially elastic, the second derivative of the slope becomes zero. When the second derivative is no longer zero, that point on the curve is called the point of inflection. This point, designated as PI, may be obtained by placing a straight edge on the curve and determining the point at which the slope begins to decrease (Funderburk, 1975).

Bioyield Point

At the point of inflection on the force-deformation curve the loaded specimen shows visible or invisible signs of failure in the microstructure. Such failure will continue until a maximum loading force occurs, followed by a decrease in loading. The maximum loading force immediately following the point of inflection is the bioyield point.

Puncture Tests

Puncture tests were first devised to test the firmness of fruit. The Magness-Taylor fruit pressure tester consisted of a plunger either 7/16 inch (11 mm) or 5/16 inch (8 mm) inch in diameter attached to a calibrated spring which was graduated in pounds (Mohsenin, 1970). Being manually operated, the instrument reading was obviously subjective and depended on the operator. To eliminate the "human element" from the reading of this instrument, Pflug in 1960 employed a mechanical press and automatic recording (Mohsenin, 1970). Recently universal testing machines have been used to press the Magness-Taylor pressure tester tip into fruits.

Puncture test results give an indication of the relationship between toughness and elasticity for a small localized area. Hence, several tests can usually be conducted on a single sample.

Kramer Shear Cell

The Kramer shear press is an attempt to combine all textural measurements in one testing machine (Mohsenin, 1970). The press is normally connected to some type of loading machine to provide a constant loading rate which can be controlled and monitored. The shear bars are attached to the crosshead of the shear press of any compression testing machine with adequate load capacity. In lowering of the crosshead, the shear bars pass through the sample placed in the cell. The sample is first compressed and then extruded through the slots at the bottom of the cell.

Problems sometimes encountered with the Kramer Shear Press cell usually involve myrofibrals not being completely sheared or cut and becoming lodged between shear bars of the test cell. The above condition will cause the loading force to be abnormally high. Thorough cleaning of the test cell after each test is therefore recommended.

Experimental

Preparation of Samples

Atlantic Cutlass fish obtained from commercial fishermen in Corpus Christi, Texas were used in this study. The fish were processed, pre-cooked, packaged and frozen at the Texas Agricultural Experiment Station Research Center in Corpus Christi.

Pre-cooked minced Atlantic Cutlass fish sticks were packaged in five pound boxes, sealed and frozen at -5°C. Overnight shipment of the frozen fish sticks, packed in dry ice, was made by commercial bus lines. The samples were then held in a freezer at -9°C until tests were completed.

Immediately prior to the actual testing, no more than ten fish sticks were baked simultaneously at 215°C for 16 minutes. The samples were cooled to room temperature (25°C) and the width and thickness were measured. Textural tests included (1) compression, (2) puncture and (3) shear-compression (Kramer Shear Press cell).

Commercial minced Cod fish sticks, used as control, were obtained at a local supermarket and stored in a freezer at -9°C. The procedure for baking and textural testing of the Cod fish sticks was the same as that used for the Atlantic Cutlass sticks except that the commercial sticks were cooked for only 12 minutes.

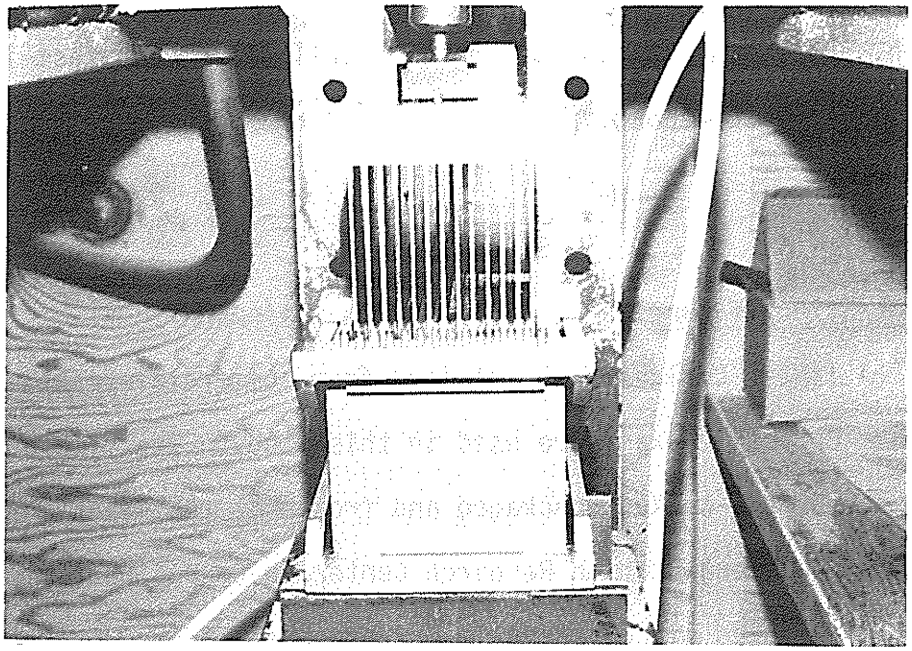

Fig. 1 Testing machine with Kramer Shear Cell in place.

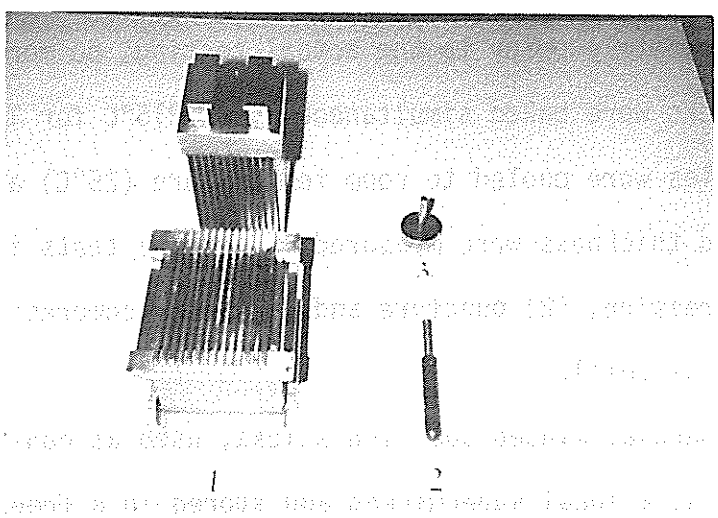

Fig. 2 Kramer Shear Press Cell (1), puncture probe (2), and compression plate (3)

Testing Machine

The test apparatus (Fig. 1) consisted of a loading machine, force and deformation transducers and an X-Y recorder (Mohsenin, 1963). This unit consisted of a Bellows-Valvair *BNEM-5c-60 double acting air motor with a factory mounted double acting Hydro-Check unit which included two precision control valves and stop check solenoid valves. The precision control Hydro-Check unit was connected in line with the piston rod of the air cylinder which was mounted on an arbor stand. The Hydro-rate accuracy was within $\pm$ 0.5 inch for loads less than 90 Newtons at temperatures in the range of 10 to 40 degrees C.

Both force and deformation output signals were fed into an electronic X-Y recorder. The plotter was designed to draw the relationship of two variables in the form of curves on 11 x 17 inch (279 x 432 mm) cartesian coordinate paper. Two DC pre-amplifiers, one for each axis, were employed to provide 14 inputs ranging from 0.5 millivolt per inch to 10 volts per inch. Each test yielded a force-deformation curve with pre-set calibrated scales on the X-Y recorder.

Test Cells

The Kramer Shear Press test cell (Fig. 2) was used to perform the shear-compression tests (Voisey, et al., 1970). This consists of a box with 10 slots in the bottom and in the lid and a 10 bladed cutter which is driven into the box. The sample is placed in the box, and the 10 blades then compress it until the

*Mention of brand names in this paper does not in any way constitute endorsement of the product.

blades shear the material and extrude it through the slots in the bottom and between the moving blades.

Puncture tests (Fig. 2) were performed using a 7/16 inch (11 mm) diameter puncture probe. The puncture probe is a length of tool steel chrome-plated with a spherical tip 11 mm in diameter. The compression table was installed in the base to support the sample. Indentation in the sample was continued to a depth of 15 mm.

A round steel plate, 3/4 inch (19 mm) in diameter (Fig. 2) was used to perform the compression tests. A flat compression table was used to support the sample. Compression of the specimens was continued to a distance within 5 mm of the support table.

Results

Compression Tests

Statistical analysis of the variables measured in the compression tests is given in Table 1. Only values at the point of inflection were used since no measurable bioyield point for the Cutlass fish was obtained. Significant difference ($P<.01$) between the Cod and Cutlass fish sticks was found for both sample thickness and apparent modulus of elasticity. The higher value of the apparent modulus of elasticity, indicating a higher force-deformation ratio, implies that greater force was required for the Cutlass fish sticks to produce a given deformation than was for the Cod. The greater thickness of the Cutlass fish sticks also provided for a larger flesh-breading ratio, which partially explains the larger force required.

Table 1. Means, coefficient of variation and level of significance of compression tests conducted on cooked minced Cod sticks and Cutlass fish sticks.

Fish Type	Measured or Calculated Property	Mean Value	Coefficient of Variation (%)	F Value
Cod	Sample thickness (cm)	0.40	7.7	246.91**
Cutlass		0.58		
Cod	Apparent modulus of elasticity[a] (N/cm^2)	15.8	28.5	9.75**
Cutlass		20.8		

[a] Values measured to point of inflection of force-deformation curve.

** $P<.01$

Puncture Tests

Statistical analysis of puncture test variables is given in Table 2. Sample thickness, force, and force-deformation ratio were found to be significantly different ($P<.01$) between the Cod and Cutlass fish, thus agreeing with the results of the compression tests.

Table 2. Means, coefficient of variation and level of significance of puncture tests conducted on cooked minced Cod fish sticks and minced Cutlass fish sticks.

Fish Type	Measured or Calculated Property	Mean Value	Coefficient of Variation (%)	F Value
Cod	Sample thickness (cm)	0.40	5.8	284.25**
Cutlass		0.63		
Cod	Force (N)[a]	0.73	36.3	34.16**
Cutlass		1.35		
Cod	Deformation (cm)[a]	0.101	18.9	1.46
Cutlass		0.094		
Cod	Force/deformation ratio (N/cm)[a]	7.90	28.8	50.14**
Cutlass		14.17		
Cod	Area under force-deformation curve (cm^2)[a]	15.0	42.9	1.63
Cutlass		17.5		

[a] Values measured to point of inflection of force-deformation curve.

** $P<.01$

Kramer Shear Press Tests

Statistical analysis of Kramer Shear Press tests is presented in Table 3. Significant difference between the Cod and Cutlass fish sticks was found for sample thickness and width, force, area under force-deformation curve, apparent modulus of elasticity ($P<.01$), and deformation ($P<.05$). The higher value of the apparent modulus of elasticity for the Cutlass fish is in accord with the results of the compression and puncture tests. The area under the force-deformation curve is an index of work required to produce a given deformation. Work is frequently associated with overall textural properties.

Conclusions

Statistical analysis of all experimental results indicated (a) a significant ($P<.01$) difference between the thickness of the Cod and Cutlass fish sticks, (2) a larger ($P<.01$) force-deformation ratio for the Cutlass fish sticks than the Cod in every set of tests, and (3) the Kramer Shear Press cell was found to provide more indicators of textural properties than either the compression or puncture apparatus.

Sensory evaluation and additional textural tests are needed to evaluate the meaning or implication of the above results.

Table 3. Means, coefficient of variation and level of significance of Kramer Shear Cell tests conducted on cooked minced Cod sticks and Cutlass fish sticks.

Fish Type	Measured or Calculated Property	Mean Value	Coefficient of Variation (%)	F Value
Cod	Sample thickness (cm)	0.43	5.4	408.35**
Cutlass		0.62		
Cod	Sample width (cm)	0.98	6.1	193.36**
Cutlass		1.30		
Cod	Force (N)[a]	4.3	9.2	116.28**
Cutlass		5.9		
Cod	Stress (N/cm^2)[a]	0.23	11.6	1.48
Cutlass		0.24		
Cod	Deformation (cm)[a]	0.135	6.9	5.4*
Cutlass		0.142		
Cod	Area under force-deformation curve (cm^2)[a]	6.6	11.7	82.16**
Cutlass		4.6		
Cod	Apparent modulus of elasticity (N/cm^2)[a]	4.0	19.4	35.36**
Cutlass		5.2		

[a] Values measured to point of inflection of force-deformation curve.
* P<.05
** P<.01

REFERENCES

1. Cobb, B. F. III. 1975a. Lecture notes: Fish proteins. Texas A&M University.
2. Coff, B. F. III and Yeh, Chia-Ping. 1975b. Improvement of texture, taste and shelf-life in minced Atlantic Croaker. Unpublished report.
3. Cobb, B. F. III. 1975c. Personal communication. Texas A&M University.
4. Funderburk, T. G. 1975. Evaluation of selected grain sorghum varieties in relation to the modulus of deformability. Unpublished ASAE student paper.
5. Hatfield, N. 1976. The reality of world hunger. The Student.
6. Mohsenin, N. N. 1970. Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York. pp. 319-343.
7. Mohsenin, N. N. 1963. A testing machine for determination of mechanical and rheological properties of agricultural products. Bulletin 701. The Pennsylvania State University College of Agriculture, Agricultural Experiment Station, University Park, Pennsylvania.
8. Suter, C. B. 1976. Personal communication. Texas Agricultural Extension Service. Texas A&M University.

9. Voisey, P. W., D. C. MacDonald, M. Kloek and W. Foster. The Ottawa textural measuring system. Engineering Research Service, Research Branch, Agricultural Canada, Ottawa.

ROLLER EXTRACTION OF CRAB MEAT

ABSTRACT

The application of pressure rollers for the extraction of meat from crustacea has been in use for many years in the shellfish industry. The meat from the walking legs of lobsters is squeezed out by rollers in Maine and the Canadian Maritimes, and a system of roller extraction has also been in common use in Alaska for the removal of leg meats from King Crab.

Within the last few years, a relatively new technology has evolved on roller extraction of snow crab meat on the West Coast. These systems require a precooking of the crab sections at a relatively low temperature 160-200^{o}F and finish cooking of the extracted meats in steam. This procedure appears to have evolved from the method of King Crab processing used in Alaska.

This concept of roller extraction was investigated for Atlantic crab species. Data on roller design, cooking requirements, yield, and meat quality are presented.

The concept of roller extraction for meat removal from the North Atlantic red crab (Geryon quinquedens) appears to be particularly successful. On a laboratory scale, high quality body meats and whole leg meats can be extracted automatically. Meat yields averaged 20-23 percent on a live weight basis which compare very favorably with hand picking.

Preliminary studies on the use of rollers to extract blue crab meats also show considerable promise. Live crabs were blanch precooked in hot water (5 min. at 170^{o}F) followed by debacking, cleaning, roller extraction, and a finish cook in steam (3 min. at 212^{o}F). This process resulted in good quality shell-free flake meat with yields comparable to hand picked control samples.

Various problem areas encountered during the research and industry application of this processing concept are also discussed.

ROLLER EXTRACTION OF CRAB MEAT

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Introduction

The application of pressure rollers for the extraction of meat from crustacea has been in use for many years in the shellfish industry. The meat from the walking legs of lobsters is squeezed out by rollers in Maine and the Canadian Maritimes, and a system of roller extraction has also been in common use in Alaska for the removal of leg meats from King Crab.

Within the last few years, a relatively new technology based on roller extraction has been used for the production of snow crab meat on the West Coast. These systems require a precook of the crab sections at a relatively low temperature 160-200^{o}F and a finish cook of the extracted meats in steam. This procedure appears to have developed from the method of King Crab processing used in Alaska.

During our work on the development of the deep sea red crab fishery, we investigated many different concepts for automatic meat removal including rollers. The results of these tests showed that rolling was not acceptable for fully cooked sections.

Problems of shell fragments in the meat and the breaking up of the marus sections were predominant. Further experimentation, however, using the double cooking system similar to that used for snow crab indicated that these problems could be largely eliminated.

The following describes our research activities on the roller extraction of meats from red crab and some preliminary data on the use of this concept for other crab species.

Machine Characteristics

One advantage of using rollers for squeezing out crab meat is that the equipment is relatively uncomplicated and in the simplest form is two mechanically driven rollers, as shown in the first drawing in Figure 1. The problems with this system are associated with the mechanical feeding of the rollers. A conveyor belt does not give enough positive momentum to consistently feed the legs or shoulder sections across the gap to the squeeze rollers, and there are some problems with the meat recovery from the rollers. One method of improving the system would be by adding a feed roller as shown in the second drawing in Figure 1. This roller provides a positive feed for the sections and also acts as a preliminary crusher for the sections which enhances the feeding of the rollers.

The third drawing shows a further modification where the crusher or feed roller and the top squeezing roller are combined into one large roller which serves both purposes. Our results indicated that this configuration was the best for positive feeding of both legs and shoulder sections on a laboratory scale.

Meat Removal

In the extraction of crab meat by pressure rollers, the roller material, the plane of the rollers, and wetness of the rollers, the speed of the rollers, and the spacing of the rollers are all interdependent variables.

Various combinations of rubber and stainless steel rollers were tested. In general, rubber coated rollers provided for better automatic feed, but results definitely showed that smooth surfaced stainless steel rollers on the bottom allowed the meat to clear the rollers more quickly. When the meats were dragged through the squeezing rollers, a poor particle size resulted.

The plane of the rollers in relation to each other was also very critical in terms of the meat clearing the rollers. The meat from the merus sections of red crabs had a great tendency to be caught by the lower roller when the rollers were positioned directly on top of one another. Positioning the rollers at a plane of $\sim 45^{\circ}$ from vertical allowed the meats to clear more quickly producing a better yield of whole leg meats. Since the legs are rolled at an angle, the gap between the conveyor belt and the pressure rollers can also be reduced which increases the feeding characteristics, especially short and broken legs.

In all cases, a constant flow of water is necessary to keep the rollers wet and slippery. The amount of water is relative to the roller configuration, and the best rule of thumb is the minimum amount of water necessary to do the job.

The roller and conveyor speeds in linear feet/min. are critical to the overall production volume; however, when the rollers are too fast, the meats do not have time to clear and have a tendency to be pulled through the rollers. In our tests, we found roller speeds up to 40 feet per minute to be satisfactory. In all cases, the conveyor feed rate and the roller speed must be the same.

Meat Quality

The primary variables affecting the quality of crab meat extracted by pressure rolling are the precooking time and temperature and the amount of water used in the extraction process.

The precooking time and temperature have a major affect on meat flavor. Our results indicate that much of the natural crab flavor comes from the cooking of the flesh in the shell. In general, we found that crab meat extracted in the raw state has no flavor at all and increased cooking improves the flavor substantially.

However, as I mentioned before, the precook time and temperature is also very critical for proper roller extraction of meats. In this case, the effect of increased cooking is negative rather than positive. As the meat becomes more cooked, the meat solidifies and rather than being extruded through the cartilage it has a tendency to break up the cartilage and shell material during rolling. So, by increasing the precook time and temperature, the shell content of the meats is increased and the breaking up of leg meats is more predominant.

It is therefore necessary to find the optimum precook time and temperature that will produce the minimum defects with the maximum flavor; or as an option, use the most efficient precook for optimum extraction and add flavor enhancers to bring up the flavor of the finished product. In our research, we determined that the optimum precook for red crab was about 4 minutes at 160°F for shoulder sections and 140°F for 4 minutes for legs. Finish cooking was carried out in 212°F steam for 2.5 minutes. Although there is some flavor loss in comparison with hand picked meat, a dip in 2.5 percent salt and .5 percent citric acid produced highly acceptable products.

The time of contact in water during processing is also important in terms of flavor loss. Samples of red crab meats were extracted by rolling without any water, with the minimum water necessary, and with a relatively large amount of water simulating a 15 second fluming of the meats. These samples were tested for flavor intensity in comparison with hand picked meats, and these results indicated that the samples treated with the least amount of water were more comparable to hand picked meats.

Figure 2 shows the processing flow diagram for red crab determined experimentally in this study, including the average yields on a live weight basis. Using these conditions, whole leg meats and a flake style body meat could be obtained consistently. The average yields were considerably higher than those obtained by hand picking and bacteria levels were very satisfactory.

Similar studies have been carried out using the dual cook process and roller extraction for blue crab. For blue crab meat extraction, the processing flow diagram determined experimentally is as shown in Figure 3. Since blue crabs are very difficult to handle in the live state, the crabs were first treated for five minutes in 170°F water followed by cooling and debacking. The meats were then extracted by rolling, and the resulting semi cooked meats were finished cooked in steam (212°F) for two to three minutes.

Meat yield data were collected from the roller extraction procedure and compared to yield data obtained by hand picking meats from the same lot of crabs processed by retorting (10 min. at 250°F). In all cases, the meat yields were equivalent averaging about 10 percent.

Total plate counts on both the hand picked meats and the roller extracted meats obtained from the same lot of crabs showed a range of 10^3 - 10^4 organisms per gram for roller extracted meats compared to 10^4 - 10^6 organisms per gram for the hand picked meats.

In general, the meat produced by roller extraction is different from hand picked meats. The recovered meat is very white in color, the flavor is slightly bland, and the texture is generally drier. The particle size is similar to that of flake meat, and the meat is virtually shell free in comparison to commercially picked flake meat.

Flavor studies designed to improve the flavor of rolled meats are still in progress. However, it has been determined that dip treatments in salt and other flavor enhancers such as MSG and Ribotide improved the flavor substantially.

In conclusion, it appears that roller extraction using the dual cook concept represents a substantial improvement in crab meat mechanization especially for those species similar to red crab and snow crab.

Blue crab meat extraction by rollers also shows considerable promise for mechanical extraction. The flavor and texture of rolled blue crab meat does not achieve that of hand picked meats; however, the overall quality is certainly acceptable, the meat is relatively shell free, and in light of the other available forms of mechanization this concept could represent a reasonable option for the industry.

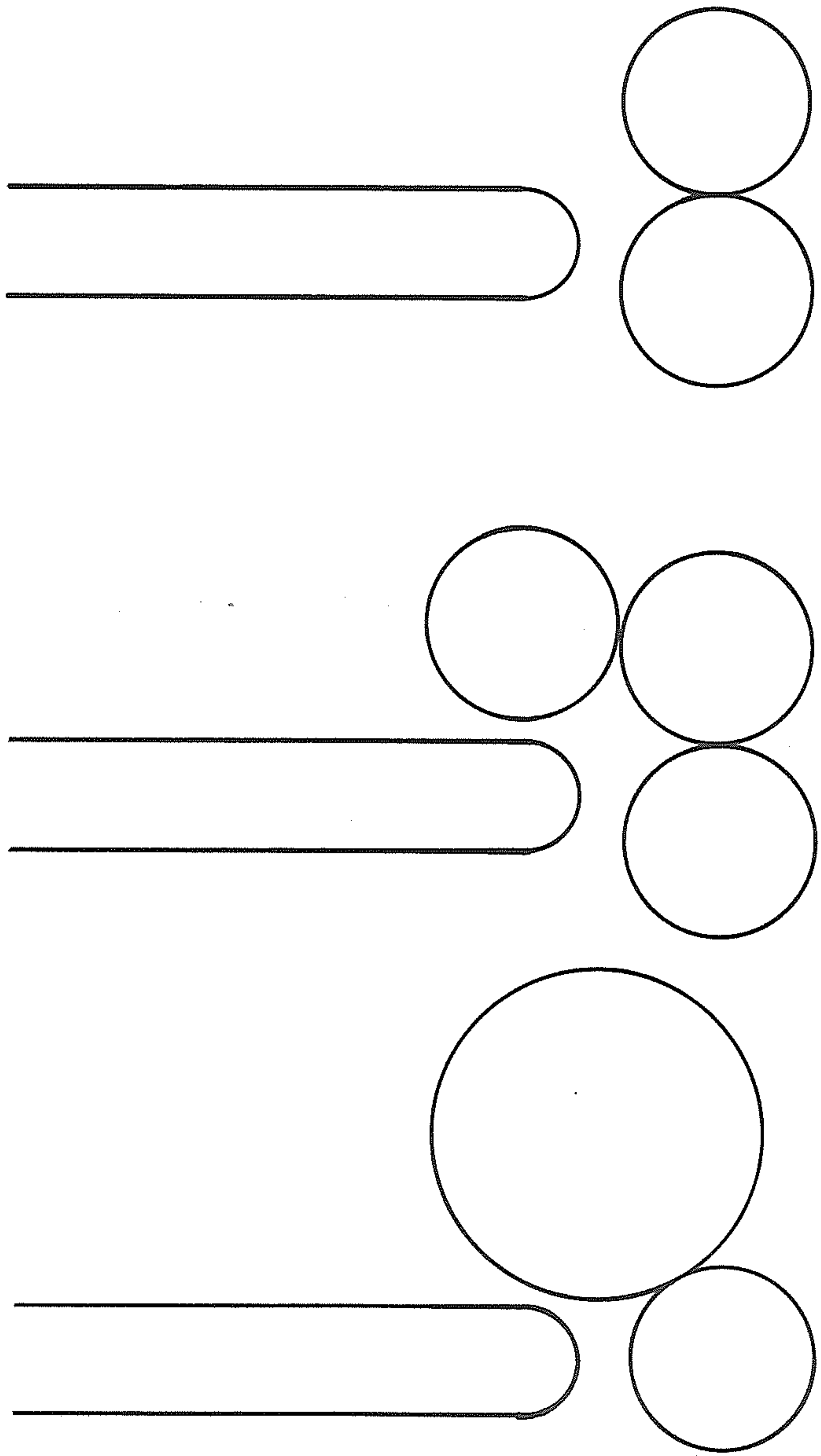
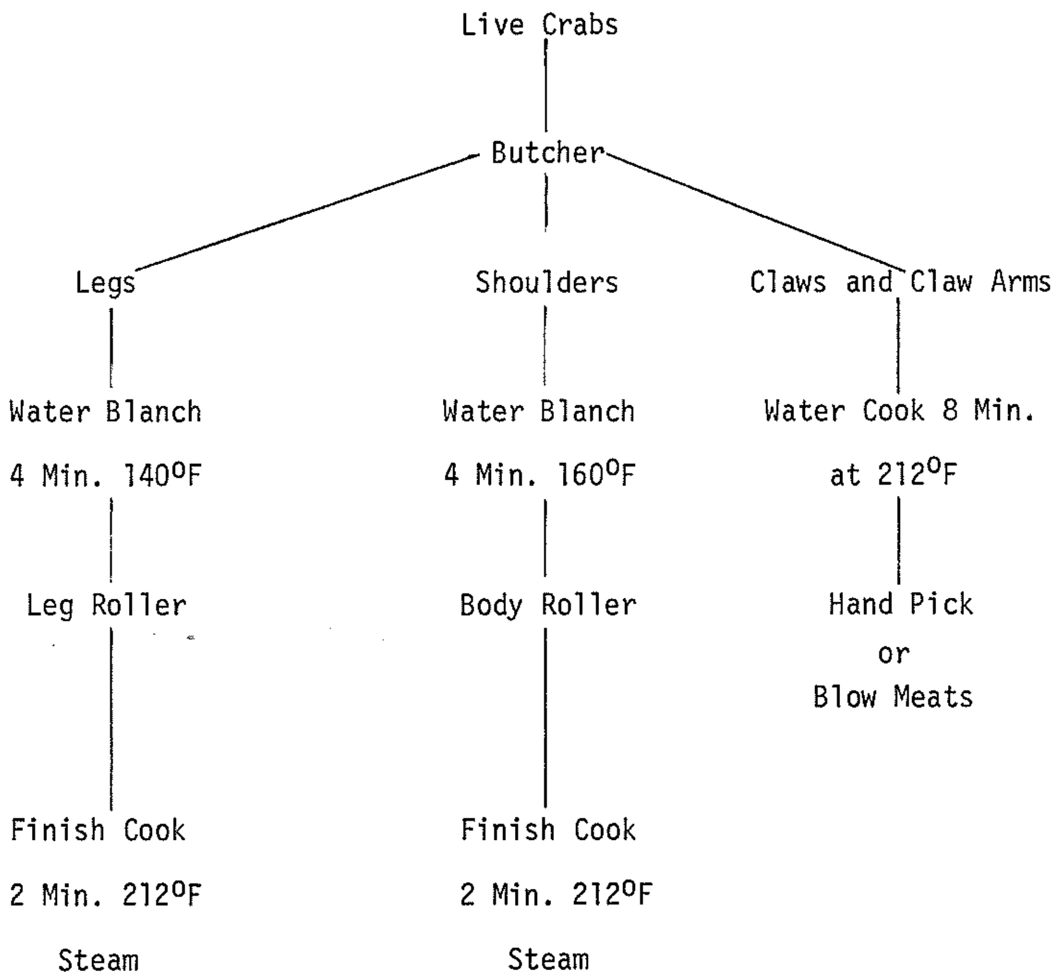


Fig. 1--Various roller configurations tested.



YIELD:

8.0% 10.5% 5.0%

TOTAL 23%

Average Total Plate Count 10^3

Fig. 2--Process flow diagram for red crab

Live Crabs

Water Blanch 5 Min. at 170°F

Cool to Room Temp.

Deback and Clean Bodies

Roll Meats

Finish Cook Meat in Steam
for 3 Min. at 212°F

Dip Cooked Meat in
1.5% NaCl Solution

Average Meat Yield	Average Quality	Average Total Plate Count
~10%	7.0 (9-Point Hedonic Scale)	$10^3 - 10^4$

Fig. 3--Process flow diagram for blue crab

THE ECONOMICS OF THE COMMERCIAL DEVELOPMENT OF GULF OF MEXICO BOTTOMFISH

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The bottomfish and groundfish stocks of the Gulf of Mexico may be the largest underutilized fishery resource in the world today. Because of their characteristic short life span and small size, these species have been difficult to use for direct human consumption through filleting and other conventional processes. A smaller portion of the potential yield of croaker has been utilized by the petfood industry and still smaller quantities of croaker and other species have gone into human consumption as pan dressed products and into fishmeal manufacturing.

Early estimates of the potential maximum annual harvest of these fish, making conservative allowances for seasonal variations, indicate that minimum industry of about $50 million value at the boat level, and approximately $65 million sales at the processing level. These figures are based on current prices for industrial fish and are limited to extremely safe yields that could not damage the resource by any measure. At these yields, there would be no problem in delivering a minimum average catch of 50% purity on these species.

There are some significant advantages and attractive aspects of the bottomfish resource of the Gulf of Mexico. These stocks should be relatively easy to manage. They are shortlived and have natural sanctuaries at sea where the bottom is untrawlable, like the shrimp fishery, and as long as the estuaries are protected, they should be difficult to seriously damage by overfishing. These species also are vulnerable to a well-known proven system of capture. As a trawl fishery, it offers an alternative to the large shrimp trawler fleet. Most shrimp trawlers could convert quickly to groundfish trawling involving basically the same kind of technology. The experience of shrimp trawler captains with groundfish tends to understate the resource since their feeling for the abundance of these fish and their seasonal patterns is based on their avoidance, not on purposeful catch. In this area, it is somewhat dangerous to rely only on the experience of the shrimp industry to date. Fortunately, groundfish stock assessment has been underway by the Southeast Fisheries Center, NMFS.

There are few historic fishing rights among domestic fishermen and no precedent of foreign fishing. Also, there are relatively few sport-commercial conflicts involved in this fishery offshore. It is important to remember that under our new extended jurisdiction legislation, the U.S. is compelled to make unused fish surpluses available to nations who want to use them. If trawl fleets are displaced elsewhere under worldwide extended jurisdiction, there is a strong likelihood that our resources, heretofore unattractive, will become comparatively attractive to foreign fishing effort. Without an effective development program leading to full utilization by American fishermen, it could be difficult to retain the benefit of this abundant resource for the U.S.

Also, there are, of course, some problems and constraints. The small size of these fish requires application of flesh separator technology and the development of the minced fish into attractive and valuable products. Also, most of these species have no preacceptance of their species name in any conventional product form. Very few of them are known as species at the consumer level or in the institutional markets. In the immediate future, most of the new minced meat products will have to be species specific, in that our legal labeling flexibility to blend and mix species, even of like properties, will be limited. This situation may change over time, however, as extended and modified meats become more necessary and commonplace.

Another potential problem arises in that the firms currently manufacturing or using conventional fishblocks are not physically located in the South. The major cutters and breaders of fishblocks are currently located in the North and are somewhat removed from the resource. The groundfish resources of the Gulf are not as well known to some of these companies as might be expected. This presents a communication challenge and a major opportunity for Gulf producers to determine their own destiny. Also, there is very little we can do to reduce or make use of the incidental catch of these bottomfish by the shrimp industry. Although it is tempting to consider how this current waste might be profitably utilized, there is no way, within the foreseeable future, to effectively overcome the logistics of collecting these small quantities of groundfish from shrimp trawlers spread over the Gulf to collect into a central point for processing.

The purpose of this paper is to approximate the economic feasibility of using these resources through a directed fishery and to relate their potential (1) to the purity with which they can be caught and (2) to their physical meat yield in processing.

The key assumptions behind this analysis are very conservative. The basic premise is that the major, early market for minced bottomfish would be in conventional fishblock product forms. Since the block market would be species-specific, this analysis does not consider blended products. It is further assumed that the larger fish would be sorted and graded out of the general catch and would be marketed at the highest and best purpose.

Competitive products including minced cod and minced pollock are assumed to be more costly to produce in the future as demand increases against a fixed supply. It is also assumed that ultimately these fish can be handled and chilled in a seawater system or a system of comparable cost. Handling at sea is a very large part of the cost of the raw material and this analysis assumes a low cost system.

Although the major resource under consideration is made up of the bottomfish of the Gulf, mullet have been included in the list because of their abundance and potential availability of carcasses from roe processing.

The species listed in Table 1 are ranked according to their yield. There are no estimates of the yield for long spined porgies, at present, but, attempting to be conservative and knowing something about their configuration, their yield is estimated at only 31%. The costs represented in column 3 are in direct relationship to the weight of the whole fish, 2.7¢ a pound for mechanical scaling, heading and evisceration. These costs are a function of scale and, in this example, are based on 200 processing days per year employing one 10 hour shift per day, of which eight hours are actual operating time. These costs are essentially constant for all species.

TABLE 1

MINCED FISH COSTS

			Processing Costs Per Lb. Finished Product 1/			
Species	Meat Yield	Required to make 1 lb. meat	Scaling, Heading, Evisceration (@$.027/lb. RW)	Packaging, Freezing, Storage 2/	Selling Expense and Margin	Total Processing Cost
Cutlassfish	52%	1.923/lbs.	.052	$.056	$.015	$.123
Mullet	42	2.381	.064	.056	.015	.135
Whiting	39	2.564	.069	.056	.015	.140
White Trout	38	2.632	.071	.056	.015	.142
Spot	35	2.857	.077	.056	.015	.148
Croaker	33	3.003	.081	.056	.015	.152
Porgy	31 3/	3.333	.090	.056	.015	.161

1/ 200 operating days per year

2/ 30 days storage

3/ Estimate

The second cost column is constant for each pound of finished meat, regardless of species. The cost of packing, freezing and storing for 30 days have changed recently, due to the rapid increase in the cost of power, and may not be applicable for all areas.

An arbitrary 1½¢ was allocated for selling expense and operating margin for the processing firm. Total processing costs are estimated in column 5 to range from 12¢ a pound for cutlassfish to 16¢ a pound for long spined porgy.

Assuming that all of these species result in finished products comparable in quality to minced cod, the selling price in column 1 of Table 2 is 25¢ per pound, the average price of minced cod at present. After subtracting total processing cost from Table 1, a residual return to the raw material in column 2 ranges from almost 13¢ for cutlassfish to almost 9¢ on porgy. The last three columns indicate, at different degrees of purity of catch, what the processor could pay for whole fish at the exvessel level. Although catches of 100% purity would be rare, catches of 70% purity are common for croaker in the central Gulf, and could be achieved for periods of up to two months or so for many other species. Exvessel values range from $92 for cutlassfish, through $57 for white or gray trout, to below $55 for spot, croaker and porgy. The dotted line indicates an approximate current breakeven point at the boat level. It appears that a 50% pure catch of cutlassfish is clearly attractive and that a 50% pure catch of whiting and white trout would not be too far out of reason. Croaker are currently priced at $55 to $60 a ton based on a 70% pure catch in the petfood industry.

TABLE 2

MINCED FISH VALUES,
BOAT LEVEL

Species	Per Lb., Finished Product			Return to Boat		
	Selling Price	Total Processing Cost	Return to Raw Material	100% Purity	70% Purity 1/	50% Purity 2/
Cutlassfish	$ .250	$ .123	$ .127	$ 132	$ 92	$ 76
Mullet	.250	.135	.115	96	67	58
Whiting	.250	.140	.110	86	60	52
White Trout	.250	.142	.108	82	57	50
Spot	.250	.148	.102	72	50	46
Croaker	.250	.152	.098	66	46	42
Porgy	.250	.161	.089	54	38	36

1/ Assuming 30% incidental catch value is only enough to offset the cost of sorting.

2/ Assuming 50% incidental catch value covers the cost of sorting and contributes $.005/lb. revenue to the vessel.

Table 3 is intended to place current minced cod and pollock prices against the background of historic fillet block levels. The highest price for minced meat occurred when cod fillet blocks were at their alltime high in the winter of 1973-74. During that period, cod fillet blocks were in the range of 80¢ per pound, minced cod blocks were about 40¢ per pound, and minced pollock blocks of variable quality averaged about 33¢ per pound. The low point came in the summer of 1975 when cod fillet block prices were down. Minced cod blocks fell to 19¢ per pound and minced pollock blocks disappeared from the market. Their normal relationship to cod would have placed their price at about 16¢ per pound, but that would have been below the breakeven cost of production. Parenthesis were used in Table 3 to indicate where pollock prices would have been at their normal relationship to cod prices. The current price of 25¢ is much closer to the alltime low than it is to the alltime high. As the world economy recovers from the recent recession, as the cost of catching cold water northern species increases under the inefficiencies introduced by limited effort under extended jurisdiction, and if some resources continue to decline from past overfishing, competitive cod prices are likely to trend upward.

As Table 2 illustrated the effect of purity of catch on bottomfish values, holding price constant, Table 4 illustrates the impact of competitive prices holding purity of catch constant at 70%. Over the range of 20¢ to 40¢ per pound for minced cod, Table 4 reflects the price per ton that could be paid by the processor to the vessel after covering all costs and a normal profit. If minced cod prices recover into the range of 30¢ or 35¢ a pound and minced bottomfish are truly competitive in quality, extremely attractive prices could

TABLE 3

COMPARATIVE BLOCK PRICES (PER LB.)

COD					
Fillet Blocks	$ .80	$ .73	$ .66	$ .60	$ .55
Minced Blocks	.40 1/	.35	.30	.25 2/	.20 3/
POLLOCK					
Minced Blocks	.33	.29	.25	(.20) 4/	(.16) 4/

1/ Winter, 1973-74

2/ February, 1976

3/ Summer, 1975

4/ Based on few or no quotes

TABLE 4

RETURN TO BOAT
AT
VARIOUS COMPETITIVE PRICES
($ per ton, 70% purity)

	Minced Cod Price Per Lb.				
Species	$ .20	$ .25	$ .30	$ .35	$ .40
Cutlassfish	22	92	162	232	302
Mullet	-3	67	137	207	277
Whiting	-10	60	130	200	270
White Trout	-13	57	127	197	267
Spot	-20	50	120	190	260
Croaker	-24	46	116	186	256
Porgy	-32	38	108	178	248

be paid to the boat. In this price range, all species become attractive candidates for development.

It is risky to assume that all of these species could be caught for more than a few weeks of the year with 70% purity. Table 5 reflects the situation if the catch is only 50% pure.

In this case, porgies become attractive only in the 35¢ to 40¢ a pound price range. Since a directed trawl fishery for porgies would be in somewhat deeper water further from shore, production costs would be generally higher than for brown shrimp. It may prove unattractive even at 40¢ per pound for the product returning $82 per ton to the boat. Although less profitable than with a 70% pure catch, all other species appear attractive above 30¢ per pound.

Another way of considering economic feasibility in Table 6 is to assume price to the vessel and different levels of purity and examine the minimum selling prices for finished products that would result. Assuming $70 a ton to the vessel for a 70% pure catch and subtracting processing costs and margins, the processor could sell the cutlass-fish product for about 22¢ a pound, but would require about 33¢ a pound for porgy.

Among the key determinants of economic feasibility are meat yield, length of season, purity of catch, price of minced cod and pollock, species and ingredient product labeling requirements, and any unique properties each species might possess when used alone or as an extender, modifier, or binder in formulation with other meats. If perhaps 3 species could be identified whose seasonal catch rates exceed 50% purity for 2 to 3 months per year and do not peak together, a viable commercial fishery appears likely to develop.

TABLE 5

RETURN TO BOAT
AT VARIOUS COMPETITIVE PRICES
($ Per Ton, 50% Purity)

	Minced Cod Price Per Lb.				
Species	$ .20	$ .25	$ .30	$ .35	$ .40
Cutlassfish	50	76	102	128	154
Mullet	37	58	79	100	121
Whiting	33	52	72	92	111
White Trout	32	50	70	89	108
Spot	28	46	63	81	98
Croaker	26	42	59	76	92
Porgy	22	36	52	67	82

TABLE 6

MINCED FISH VALUES
(70% Purity Catch = $70 Per Ton Exvessel)

		Exvessel Price (Per Ton)			Per Lb. Finished Product		
Species	Requirement	100% Purity	70% Purity	50% Purity	Cost of Fish	Processing Cost 1/	Total Cost
Cutlassfish	1.923 lb.	$100	$ 70	$ 50	$.096	$.123	$.219
Mullet	2.381	100	70	50	.119	.135	.254
Whiting	2.564	100	70	50	.128	.140	.268
White Trout	2.632	100	70	50	.132	.142	.274
Spot	2.857	100	70	50	.143	.148	.291
Croaker	3.003	100	70	50	.150	.152	.302
Porgy	3.333	100	70	50	.167	.161	.328

1/ Including Margin

It is extremely important to recognize that some species have some highly unique properties which make it extremely valuable in specialized uses. Croaker, for example, is considered the premium species for the manufacture of surimi in Japan. These high value markets must be identified and exploited initially.

Although there are other species ready for development in the Gulf, the bottomfish represent the largest opportunity and should be targeted for rapid development.

MARKET POTENTIAL FOR FISH AS AN EXTENDER IN MEAT PRODUCTS

ABSTRACT

This paper analyzes the market potential for fish used as an extender in meat products. The growth in the fresh and frozen meat product market to 1980 is estimated, and probable meat products are selected into which fish can be substituted. Using a variable rate of substitution, from 5-15%, quantities are estimated for the total amount of fish to be substituted. In addition, exvessel prices are calculated for the fish raw material given a range for the finished product price, costs for a pilot minced flesh plant, and a range of return on investment for the plant. The analysis indicates fish can compete as an extender, creating a considerable margin for profit on the part of fishermen, fish processors, and meatpackers.

MARKET POTENTIAL FOR FISH AS AN EXTENDER IN MEAT PRODUCTS

Vito J. Blomo
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Whether or not the United States will have its fishing jurisdiction increased from 12 to 200 miles, the search for sources of plentiful and inexpensive proteins will continue. The extended fishing jurisdiction does give the United States the opportunity to utilize vast resources of now underdeveloped fish species. These species are underutilized because they have either little consumer appeal in their present (fresh) form, or have handling and economic problems in transforming them into other traditional forms.

The species which have the above problems, yet offer a great potential for supply, are Alaskan pollock, North Atlantic red hake, and Gulf of Mexico croaker, mullet and mackerel. While there is little question of these species' biological potential, the relevant issue here is their economic potential. It is evident that they have little economic potential now, if they continue to be utilized in traditional forms. However, several new uses and products with these species as components may change them into a more valuable resource.

New products and uses for the above-mentioned species include (1) a fish paste suitable for sandwiches and dips, (2) minced and reformed flesh to resemble and have the characteristics of specialty items such as shrimp tails, and (3) a substance which could extend the amount of beef or pork used in products like sausage while retaining flavor and nutritional content. In actuality, these new uses and products for underutilized fish are established and popular consumption items in other cultures, particularly Japan, where there is a more intensive utilization of all protein sources.

The purpose of this report is to investigate the potential for fish as an extender in meat products in the United States. Preliminary studies have already been completed on fish used in a paste or spread, and a plant is under construction for the manufacture of such a product for the Japanese market (Greenfield, 1973). The use of fish in simulated specialty items like shrimp or lobster tails is hindered at present because of labeling requirements set by the Food and Drug Administration. Therefore, of the three new products and uses mentioned, fish used as an extender is the most viable for an analysis.

The objectives of this report are to:

(1) identify meat products which could utilize fish as a meat extender,

(2) estimate the present size and market growth of these meat products,

(3) estimate present input prices of the meat products and prices at which fish inputs could economically be substituted,

(4) estimate edible and raw weight of fish used in all markets, and

(5) depending on a range of profit margins for fish handlers, estimate exvessel prices and revenue to fishermen.

The Market for Meat Products

The market for meat products is the largest segment of the food industry. The primary inputs for this market are beef, pork, lamb, chicken, and turkey. They are classified as products because in many cases they are already cooked, ready to eat. Products include smoked and dried beef and pork items, sausage, chili, hamburger, ground beef, frozen foods-dinners, meat pies, deviled ham, meat stew, spaghetti meats, and a variety of soups, and luncheon meats. For a more complete list see USDA (1974).

From a food technology viewpoint, the most appropriate products into which fish can be substituted would be products whose flavor is not an important selling point and whose ingredients are usually blended together. This requirement would tend to rule out products such as smoked and cured hams and beef, bacon, sliced ham, and chopped beef. Products well suited for this requirement would include sausage, franks and weiners, bologna, luncheon meat, hamburger, and ground beef. Vegetable protein (usually soy) is already used to some extent as an extender in some of these products (Gallimore, 1974). In areas of relative abundance of fish supplies, processors may be very interested in fish as an extender if it can compete on price or nutritional points with extenders like soy vegetable protein.

The size of the meat products market in selected product categories is indicated in Table 1 for the period 1970-74. The rate of growth for each product during this period is also indicated as well as a projection to 1980 for each product by a time trend analysis. It is evident that the total market for these six products alone is quite large -- almost 6 billion pounds. The rate of growth is also

Table 1--Market for selected meat products prepared & processed under Federal inspection, production 1970-74 and forecasts to 1980.

Product	Production (000 lbs)					% Rate of growth/yr 1970-74 3/	1980 Fore-Cast 4/ (000 lbs)
	1970	1971	1972	1973	1974		
Fresh finished sausage	562335	678114	738888	724014	819180	8.2	1,152,178
Franks & weiners	1138392	1242684	1259618	1256239	1380817	4.0	1,654,270
Bologna	652580	698078	740071	746891	807033	4.9	1,015,096
Sliced other 1/	741171	816319	875146	885121	959647	6.0	1,260,079
Hamburger	290137	365791	432610	517293	491337	14.0	862,553
Ground beef	709610	793484	974093	1127325	1400078	17.1	2,372,743
Total 2/	4094230	4594470	5020430	5256880	5858090	8.5	8,316,920

1/ Includes sliced sausage, sliced loaves, sliced ham, sliced lucheon meat, etc.

2/ Some rounding in total

3/ Calculated by regressing log Production = f(Time), ordinary least squares (O.L.S.)

4/ Calculated by regressing Production = f(Time), O.L.S.

Source: Livestock and Meat Statistics, U.S.D.A.-ERS, Statistics Bulletin No. 543, Supplement for 1974, p 151 phenomenal, from a low of 4.0% per year for franks and weiners to 17.1% per year for ground beef. Using 1970-74 as a base, it is projected that this market produces over 8 billion pounds in 1980. Although the projections are dramatic because of the use of a straight line time trend, even halving the increase would leave a sizable growth.

Manufacturers and retailers (who may have their own private labels) compete on the basis of price, quality of product, and other factors. The first two points refer to the prices of the ingredients and their influence on the product's price and quality. Some manufacturers and retailers prefer to use lower priced ingredients in order to obtain the consumer's dollar through the economic buying motive. Others prefer to use ingredients of premium quality, and therefore price, so that the consumer's dollar is obtained through a quality-conscious buying motive. A fish extender would fulfill a manufacturer's desire for a nutritionally quality product since it has a higher percent of protein per gram than beef or pork. If the fish extender were competitively priced, and depending on the manufacturer's or retailer's advertising emphasis-- "high protein" instead of "real beef" for a hamburger patty or luncheon meat-- the merchandiser could cater to a higher-priced market and earn higher profits.

Ingredient prices for the six meat products vary from \$.10 per pound for lungs to \$1.25 per pound for blade meat. The median of ingredient prices is in the \$.50 per pound range. The major ingredient prices for each product is presented in Table 2. Also included in this table is the wholesale price of soy vegetable protein. As one can see, the prices do vary considerably. However, a factor of equal importance to manufacturers is an assurance that there would

Table 2--Input prices for selected meat products, October 1975, Chicago wholesale markets.

Input	Sausage	Franks & Weiners	Bologna	Hamburger	Ground Beef	Sliced other
	Product					
	¢/lb.					
Lean Beef	70	70	70			
Frozen Boneless Beef						
Shank				75	75	
Shoulder				75	75	
Fresh Boneless Beef: Chucks				71	71	
Variety Beef						
Tongues		65	65			
Cheeks		53	53			
Hearts		30	30			
Lungs		10	10			
Pork						
Skinned Jowls	56					56
Livers						20
Pork Fat	25		25			25
Soy Flour		16	16			
Soy Protein Concentrate		32		32	32	32

Source: The National Provisioner, Chicago, Ill., Nov. 8, 1975, p.29.

be adequate supplies of the ingredient always on hand, even with fluctuating prices. This has not been one of the strong points of the fishing the fishing industry, but with proper freezing facilities this problem should be eliminated and provide everyone from fishermen to handlers a stable income.

Fish as an Input

Based on the above input prices, fish should be priced between 30¢ per pound and 60¢ per pound to be competitive with the usual inputs. This range would price fish into the lowest-priced inputs and take it into a higher range justified by its protein per gram content. To compete with soy vegetable protein, fish should be priced between 5¢ per pound and 11¢ per pound, considering soy's over 60% protein content per gram and minced fish flesh's 20%.

The sales potential for fish used as an extender in the meat products market varies depending on the characteristics desired in the end-product. In tests with commercial meat processors, the Pacific Resource Utilization Center (NMFS) replaced up to 15% of the lean beef used in several types of processed meat products: Franks, bolognas, loaves, and meat patties (Pacific Resource Utilization Center, NMFS, 1975). It was found that it (1) functioned as a binder as well as does lean beef, (2) resulted in identical yields and keeping quality, (3) resulted in more tender and moist meat patties (all-meat or meat-soy), and (4) caused a slight but detectable change in product flavor when tasted alongside all-meat controls. The flavor was not that of fish; it was simply a shift in flavor and was actually less noticeable than flavor changes caused from some commonly used extenders.

Assuming 15% is the upper replacement level and arbitrarily choosing 5% as the lower replacement level, then for 1974 the sales potential lies between 220 million and 659 million pounds (75% of finished product weight; the other 25% is water). In 1980 the sales potential would lie between 311 million pounds and 935 million pounds. To obtain round weight, one should multiply the above figures by 2.22.

To calculate exvessel prices for this fish, and also gross revenue, it is necessary to go through several steps. The steps are as follows and require the following data to solve the exvessel price:

Price Range for
Finished Fish Product

1 minus

Operating Costs/lb.
Fixed & Variable

2 equals

Gross Profit/lb.

3 minus

Exvessel price/lb.

4 equals

Net profit/lb.

5 divided by

Average investment/lb.

6 equals

Return on investment

The price range for the fish extender is given, and the values for the other variables are taken from Greenfield (1973). Since the above sequence essentially reduces down to the last four operations, the exvessel price should be sensitive to changes in the return on investment rate, as:

Gross profit - exvessel price = net profit

(Gross profit - exvessel price) - avg. investment = return on invstm.

which reduces down to Exvessel price = Gross profit - (avg. invstm. *return on investment)

Therefore, the rate of return on investment is varied between 5% and 25%; the 25% should compensate managers for the higher risk of a new business and the possibility of less than full-year operations. The following table presents the range of exvessel prices for fish to be used as an extender with various rates of return on investment.

Table 3--Estimated exvessel prices for fish, round weight, to be used as an extender.

Rate of return on investment	Exvessel price	
	Competing with meat	Competing with soy
5%	\$448 - \$1048	0 - \$68
15%	\$414 - \$1014	0 - \$34
25%	\$380 - \$ 900	0

Source: see Appendix for calculations.

How do the above prices compare with current prices for the species likely to be caught? Records show that during 1972-74 Alaskan pollock varied between \$170/ton and \$274/ton, for Atlantic red hake \$112-\$125/ton, croaker \$220-246/ton, mackerel \$320-\$462/ton, and mullet \$170-\$228/ton. Thus, anywhere within the finished price range of \$.30 to \$.60 per pound, the calculated price appears higher than current exvessel prices. Prices which would be competitive with soy protein result in either a very low, or no price at all to the fisherman, with the exception of one case.

To calculate gross revenue for fishermen, it would vary between $92.8 million, using the lowest sales potential (raw weight) and lowest exvessel price ($380 per ton), and $1087 million, using the highest sales potential and highest exvessel price.

Conclusion

The results indicate that at the present time, fish is in a good situation for use as an extender in meat products. This is due to the wide variability of price which could be charged for the finished product, while insuring an adequate price to fishermen for supplying the basic ingredient. The analysis shows that even at high rates of return on investment, exvessel prices are more than adequate. When fish does become a popular extender, processors will be forced through competition to lower their rate of return and pay higher prices to fishermen. The fact that there are large gaps between current and calculated exvessel prices, and between the fish extender and meat prices, shows there is considerable margin for profit on the part of the fishermen, fish processors, and meat packers. Also, it should be noted that on this basis, current prices for soy protein rule out fish as a competitor. Fish may still be economical to use on a functional basis, either by itself or in combination with soy.

A rule of thumb when substituting extenders into products is that the extender should be priced no higher than the lowest priced input. Using this as a reference, higher prices in general for the current ingredients of meat products would put fish into an even better competitive position and further encourage the start of a new industry and fish use.

APPENDIX

Calculations for exvessel price of fish, raw weight, to be used as an extender:

1. Price range for Finished Fish Product $.30 - $.60/lb.
2. Operating Costs/lb.1/&2/ $.068
3. Average investment/lb.2/&3/ $.168

Exvessel price (unknown - "X"), competing with meat:

A. 5% return on investment

Gross profit - X = net profit
Net profit - avg. investment = 5%
X = $.30 & $.60 - ($.168 x .05) - ($.068)
X = $.224/lb. - $.524

B. 15% return on investment

X = $.30 & $.60 - ($.168 x .15) - ($.068)
X = $.207 - .507/lb.

C. 25% return on investment

X = $.30 & $.60 - ($.168 x .25) - ($.068)
X = $.190 - $490/lb.

1/ Greenfield, p.18.
2/ Assumes a plant operating 200 days/year, processing 4900 tons raw fish.
3/ Greenfield, p.19.

APPENDIX

Calculations for exvessel price of fish, raw weight, to be used as an extender:

1. Price range for Finished Fish Product $.05 - $.11/lb.
2. Operating Costs/lb.1/ & 2/ $.068
3. Average investment/lb.2/& 3/ $.168

Exvessel price (unknown - "X"), competing with soy protein concentrate:

A. 5% return on investment

Gross profit - X = net profit
Net profit - avg. investment = 5%
X = $.05 & .11 - ($.168 x .05) - ($.068)
X = $0.00/lb. - $.034

B. 15% return on investment

X = $.05 & $.11 - ($.168 x .15) - ($.068)
X = $0.00/lb. - $.168/lb.

C. 25% return on investment

X = $.05 & $.11 - ($.168 x .25) - ($.068)
X = 0.00/lb.

1/ Greenfield, p.18.
2/ Assumes a plant operating 200 days/year, processing 4900 tons raw fish.
3/ Greenfield, p.19.

REFERENCES

Gallimore, W. 1974, "Sales of Soy-Ground Beef Blends in Selected Stores," National Food Situation, USDA-ERS, NFS-147, pp. 26-31.

Greenfield, J. 1973, "The Japanese Surimi Market" presentation before Southeast Regional Meeting in New Orleans, National Marine Fisheries Service.

Pacific Utilization Research Center, 1975, "Use of Fish Flesh in Meat Patties" National Marine Fisheries Service, NOAA, Seattle, Washington, Progress Report, pp. 1-2.

USDA 1974, Livestock and Meat Statistics, Supplement for 1974, Economic Research Service/Statistical Reporting Service/ Agricultural Marketing Service, Statistical Bulletin No. 543.

AN ECONOMIC ANALYSIS OF EFFORT AND YIELD IN THE FLORIDA SPINY LOBSTER INDUSTRY WITH MANAGEMENT CONSIDERATIONS

ABSTRACT

Spiny lobster effort-yield relationships were estimated. Results suggest the industry is currently at maximum sustained yield. Further economic analysis of the lobster fishery assessed the efficiency and profitability at current fishing levels. The economic models were used to provide estimates of yields, costs and returns for alternative levels of fishing effort.

AN ECONOMIC ANALYSIS OF EFFORT AND YIELD IN THE FLORIDA SPINY LOBSTER INDUSTRY WITH MANAGEMENT CONSIDERATIONS

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Introduction

The spiny lobster industry in Florida achieved tremendous growth during the past two decades and is presently second in importance in the State in terms of dockside value. In 1974 Florida lobstermen landed 10.9 million pounds valued at $13.4 million which accounts for over 90 percent of U. S. landings of spiny lobsters (the remainder is landed from California waters).[1] Approximately one-half of the lobsters landed in Florida during the 1970's were caught in foreign waters, principally from the Bahamian grounds.

Considerable increase in fishing effort has been responsible for a substantial part of the increased landings. Several measures for approximating fishing effort are available for analysis. The number of fishing firms is approximated by the number

[1] With the exception of the data obtained from personal surveys or unless otherwise noted, all landings data reported are either taken directly or computed from [Florida Department of Natural Resources, Annual Issues] or [National Marine Fisheries Service, Annual Issues].

of vessels and boats since most all lobster fishing firms in Florida operate one craft. In addition, the number of fishermen, gross tonnage of vessels in the industry and the number of traps fished are available measures of fishing effort. Increases in effort devoted to the lobster fishery has been considerably more than the increase in landings. For example, the number of traps increased 633 percent from the 1952-56 period to the 1969-73 period while landings increased only 319 percent. The result of these trends is a decrease in per trap landings at an annual rate of 3.3 pounds per trap between 1952 and 1973.

Decreasing catch per unit of effort and other biological indicators such as a decline in the average size of lobsters caught has caused much concern in the industry and on the part of management personnel regarding the possibility of over-exploitation of the lobster resource. Both state and Federal government and university personnel are responding with numerous research projects in the biological, physical and social sciences designed to provide information on which sound management decisions can be based. The purpose of this paper is to present the economic analysis of fishing effort-yield relationships and the associated costs and returns. An application of the economic models to current management problems resulting from the Bahamian government's decision to not allow Florida fishermen to fish on their continental shelf is presented in the final section.

Economic Analyses

Economic analysis performed consisted of two steps. First, the effort-yield relationship over time was estimated to investigate the effect on landings of increased effort both at the intensive and extensive margins while biological stock is free to vary. Second, for a given stock of lobster, a cross-sectional sample of lobster fishing firms was analyzed to determine variations in effort, landings, costs and returns. These two models may be used jointly to predict consequences of current proposed management programs or other changes in the industry.

Effort-Yield Relationships

Since the objective of the analysis was to provide a model which could be used in management decisions for the Florida lobster industry, only the effort and catch rates for fishing activities in Florida waters were analyzed. Foreign caught lobsters and effort employed in foreign waters were not included. The Florida Keys (Monroe County) area accounts for over 85 percent of Florida's landings from domestic waters and consequently was chosen as the data base for analysis. The 1963-73 period was studied.

A reciprocal form production function relating yield to effort was estimated. This mathematical form was chosen because it allows catch to reach a maximum level but does not allow total landings to decrease as effort is increased further. Florida's management program provides for a minimum size limit and prohibits the taking or stripping of egg-bearing females. Both programs tend to assure a minimum stock and thus justify the model chosen. In addition, some biological studies by the Florida

Department of Natural Resources conclude that the Caribbean stock is the source of Florida lobsters [Ingle, 1963]. This suggests that our level of fishing effort will not necessarily affect future Florida populations which were spawned in the Caribbean.

Both the number of firms and the number of traps fished were included as measures of fishing effort. Number of firms was estimated to be the total number of boats and vessels in the industry each year. Mean seasonal water temperature was included as a proxy to adjust for changes in environmental conditions which significantly affect effort-yield relationships.

The form of the model and the estimated parameters and standard errors are given in equation (1)

$$Q = 29{,}110{,}000 - \underset{(361{,}100{,}000)}{1{,}420{,}000{,}000}\frac{1}{X_1} - \underset{(209{,}800{,}000)}{434{,}000{,}000}\frac{1}{X_2} - \underset{(176{,}600)}{251{,}650}X_3 \qquad (1)$$

where:

Q = total pounds landed,

X_1 = traps per firm,

X_2 = number of firms in the industry,

X_3 = mean water temperature for the season.

Each parameter is statistically significant. Overall explanatory power of the model is approximately 90 percent ($R^2 = .89$). Marginal effects on landings of increasing effort through additional firms entering the industry or through additional traps fished per firm, or through changes in water temperature holding other variables constant are determined by equations (2), (3) and (4). Mean levels of the variables and their marginal impacts are shown in Table 1.

$$\frac{\partial Q}{\partial X_1} = \frac{1,420,600,000}{X_1^{\ 2}} \tag{2}$$

$$\frac{\partial Q}{\partial X_2} = \frac{434,000,000}{X_2^{\ 2}} \tag{3}$$

$$\frac{\partial Q}{\partial X_3} = -\ 251,650 \tag{4}$$

Table 1. 1973 levels of firm and trap variables and marginal impacts on landings of changes in independent variables

Item	1973 average of explanatory variables	Effect on Q at current levels of X_1, X_2, and X_3 resulting from a one unit change
		-------- pounds per unit change -------
Traps per firm	429	7,719
Firms	399	2,726
Mean water temperature	77.59°F	-251,650

Effects on landings of additional traps fished per firm or additional firms fishing in the industry at current levels of effort are presented in the last column in Table 1. One additional trap per firm (number of firms held constant at 399 firms) at 1973 levels of effort (429 traps) would give a marginal increase in total industry output of 7,719 pounds or approximately 19 pounds per trap. The addition of one new firm to the industry, holding traps per firm constant, would increase total industry output by 2,691 pounds. These increases are below the averages presently attained in the industry. Average catch per trap was 32 pounds and average catch per firm was 13,514 pounds in the Florida Keys in 1973. Thus, additional traps in the industry and/or additional firms in the industry would produce positive effects but since the marginal increase is smaller than the current average catches per unit of effort, average catch per unit of effort would decrease.

The analysis suggests that present Florida Keys lobster landings are near a maximum sustained level for all practical purposes and surely with respect to maximum economic yield levels. Landings for 1973 were estimated to be 83 percent of the maximum that could be achieved if traps per firm approached infinity, holding number of firms constant. Alternatively, a 150 percent increase in number of firms of the size in existence in 1973 would increase output only approximately 8 percent.

Effort-yield relationships over time indicate the effects of increased effort on landings. The decreasing average and marginal returns per unit of effort are due to normal decreasing returns to proportions generally encountered in production economics and are due to any external negative effect increased fishing effort has on the biological stock. With these estimated parameters we can predict consequences of increased effort on landings in physical units. To predict current cost and return consequences on the industry from changes in effort, cost and returns analyses were considered at a given resource stock level. Using data from a cross-sectional survey allows the assumption of a constant stock for purposes of analyzing production, cost and returns relationships for one season.

<u>Cross-sectional Cost and Returns Analysis</u>

A survey of 25 Florida Keys lobster boat and vessel captains was conducted during the fall of 1974 to obtain cost, production, and returns data for the 1973-74 season. The captains interviewed were chosen in a statistical manner to insure that the industry was accurately represented with respect to boat and vessel size and fishing area. Only captains earning more than 50 percent of their income from lobster fishing and only captains based in Florida Keys ports and fishing in the Gulf and Atlantic waters adjacent to the Florida Keys were included in the survey. The data collected are currently being used to estimate continuous production and cost functions. Cost and returns analyses have been completed for the industry average and by four boat and vessel size groups [Prochaska, 1976]. However, to be consistent with the industry time series analysis of effort-yield relationships presented above, only the costs and returns analysis representing the average for the industry is presented in the paper.

Average lobster landings per lobster fishing firm interviewed for the 1973-74 season was 12,828 pounds (Table 2). Dockside value of these landings was $13,848 which accounted for over 50 percent of the total value of landings by the firms surveyed. Stone crab and finfish make up the remainder of the total $21,952 earned by the average firm from fishing.

Trap costs were the most important cost item. The annual

Table 2. Cost and returns analysis for Florida Keys lobster boats and vessels[a]

Item	Industry Average
Returns:	
Lobster:	
Pounds	12,828
Dollars	13,848
Crab ($)	3,378
Other ($)	4,731
Total	21,952
	---- Dollars ---
Trap costs[b]:	
Traps lost	1,534
Trap depreciation	1,846
Total trap cost	3,380
Other variable cost	3,595
Other fixed cost	2,040
Total cost	9,015
Net returns to lobster fishing[c]:	
Above total variable cost	8,719
Above total cost	4,833

[a]Based on a survey of twenty-five lobster boats and vessels for the 1973-74 season.

[b]Traps lost are normally part of variable costs and trap depreciation if part of fixed costs but both are entered separately here for the purpose of the following analysis.

[c]Cost and net returns include only the cost associated with lobster fishing and the returns from lobster sales only.

variable cost of traps to the firm was due to traps lost to the environment (human and natural). Trap losses averaged $1,534 per firm per year (Table 2). Fixed costs (depreciation) associated with traps was $1,846 per firm per year. In total, traps accounted for over 37 percent of total costs. Other variable costs for fuel, oil, labor, gear, etc. averaged $3,595 per year.[2] The remaining fixed costs were $2,040.

Net returns from lobster fishing to the owner for his labor, management and investment was $4,833 for the 1973-74 season. This does not include the returns the owner may receive in other occupations or from other fishing enterprises. The $4,833 net return is nominal when considering the average captain worked approximately 735 hours during the 1973-74 season. An average crewman would have received $5,130 for this amount of labor.

Application to the Bahamian Situation

Recently, the Bahamian government declared the spiny lobster a creature of their continental shelf. This restricted American fishermen from fishing the Bahama banks. One alternative for some of the lobstermen displaced from their traditional fishing grounds was to employ their resources in the Florida Keys lobster fishery. The possibility of this alternative brought considerable concern on the industry because indications are that the Florida Keys fishery is already fished at optimum capacity. The remainder of this paper analyzes the potential effect of additional firms and/or traps fishing in the Florida Keys.

The number of full-time lobster boats displaced from the Bahamian fishery is estimated to be 260. Approximately 160 boats have the physical characteristics which would allow them to fish

[2] For detailed estimates see [Prochaska, 1976].

in the Keys area. Using equation (1) for prediction and assuming that 160 firms previously fishing the Bahamian continental shelf entered the Keys fishery with an average of 429 traps per firm, total industry landings would be 5,498,996 pounds (Table 3). This additional effort would increase industry output by only 311,332 pounds which would reduce landings per trap from 30.31 pounds to 22.93 pounds. This assumes that prior to the entry of the new firms there were 399 firms in the industry and that each new firm would fish the 1973 average number of traps used in the Florida Keys, that is, after the entry there would be 559 firms each fishing 429 traps.

The average number of traps per firm would probably increase with the entry of new firms. These new lobstermen to the Keys region who previously fished foreign waters are most likely full-time fishermen (earn at least 50 percent of their income from lobster fishing). Full-time fishermen included in the survey of the 1973-74 season averaged 618 traps per firm. If we assume the new firms each employ 618 traps, the industry average (full and part-time lobstermen) will be 483 traps after the entry. Predicted landings in this case would be 5,869,217 pounds and the landings per trap would decline to 21.74 pounds (Table 3). Average landings per trap in this case would only be 72 percent of what they had been prior to the entry of the additional firms.

Net revenue effects on full-time lobster fishermen can be estimated using the data in Table 2 and assuming the 28 percent reduction in landings estimated above. The average full-time lobsterman would average landing 10,006 pounds valued at $9,971

Table 3. Estimated production of spiny lobsters in the Florida Keys for alternative levels of fishing effort

Firms (boats/vessels)	Traps per firm	Landings: Predicted	Landings: Change from original position	Landings: Catch per trap
399	429	5,187,664[a]		30.31
559	429	5,498,996	311,332	22.93
559	483	5,869,217	681,553	21.74

[a]This estimate compares favorably with the actual 5,247,409 reported for 1973.

(at 1973 prices). With no change in fishing effort per firm, total cost per firm would be unchanged ($9,015 from Table 2), leaving only $956 net profit for a return to the owner's labor, management and investment. Average cost per pound landed would increase from $.70 per pound to $.90 per pound. This deteriorating profit position might encourage firms to intensify production (add more traps) to offset the decline in catch. It is obvious from the above analysis that this would only lead to further deterioration in net revenue because of the declining catch rate per trap as more traps are fished per firm. Annual trap cost averaged $5.47 and other variable costs per trap averaged $5.82 for a total of $11.28 per trap during the 1973-74 season. One additional trap per firm would yield a marginal increase in landings equal to 10.85 pounds (increasing traps to 484 per firm and using equation (2) for prediction with 559 firms). The price of lobsters to the fishermen would have to be equal to $1.04 to pay for variable costs and would leave nothing to the boat, captain and investment. If the price per pound exceeds $1.04, the marginal trap per firm would add net returns to the captain's labor, investments and management inputs. However, as traps are added, the marginal return will decline per trap (see equation (2)). The overall effect of additional traps per firm would be to raise the return to the captain-owner above the $956 return but still leave the total return less than the $4,833 previously earned, given that the price exceeds $1.04 and firms expand traps per firms until marginal cost equals marginal revenue.

The exact estimate of the effect of additional effort in the Florida Keys fishery of course depends on precise estimates of changes in effort. The effects can be simply determined using the above models, given other estimates of changes in the number of firms or traps per firm. Estimates of effort used here appear realistic but "reasonable" variations in the estimated change in effort will still show considerable effects on production, cost and revenues in the fishery.

The Bahamian situation was used in this paper to point out a serious problem facing the industry and to demonstrate the usefulness of economic models for anlayzing the effect of changes in fishing effort that could result from political and natural causes. Other direct uses of the model include analysis of alternative programs which limit effort through restricting the number of traps and/or firms in the industry. Alternatively, biological estimates of the maximum sustained yield could be given as a starting point from which the above analysis could be used to predict alternative combinations of firms and traps consistent with the estimates of maximum sustained yield.

REFERENCES

Florida Department of Natural Resources, Annual Issues. "Summary of Florida Commercial Marine Landinds," Tallahassee, Florida.

Ingle, R. M., B. Eldred, E. A. Eldred, and H. W. Sims. 1963. "On the Possible Caribbean Origin of Florida's Spiny Lobster Populations," Florida State Board of Conservation, Technical Series No. 40, Marine Laboratory, St. Petersburg, Florida.

National Marine Fisheries Service, Annual Issues. "Fishery Statistics of the United States," U. S. Department of Commerce, Washington, D. C.

Prochaska, F. J. and J. S. Williams. 1976. "Economic Analysis of Cost and Returns in the Spiny Lobster Fishery," Florida Sea Grant Marine Advisory Bulletin (in press), University of Florida, Gainesville, Florida.

PUBLICLY SUPPORTED SEAFOOD PRODUCT DEVELOPMENT RESEARCH: RESOURCE OR MARKET ORIENTATION?

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The change in thinking in the business community in the last 30 years regarding the selling function has been dramatic. In the past, many businesses concentrated on managing production aspects of their enterprise with relatively less emphasis on sales except as a means to get rid of the product. In the post-war environment of a rapidly expanding economy modern concepts of marketing management were developed. More emphasis was placed on studying market opportunities first and then developing products to meet these perceived needs. This philosophy of market emphasis has come to be known as "the marketing concept" (Kotler, 1972).

Recognizing this concept of marketing, this paper examines publicly supported product development research. The motivations and directing forces which guide this product development research will be examined and implications drawn for directing future research activities.

A dilemma exists in choosing the emphasis for product development research. One can start with a given set of resources, develop a product and then attempt to market it. Alternatively, the consumer market can be examined carefully, identifying needs and product opportunities without concern for the resources available to produce the product. Obviously, neither approach practiced in a strict manner can be efficient in directing product development research. Some middle ground must be sought.

If the publicly supported product development research projects are examined, it may be observed that most have emphasized the utilization of some available fishery resource. The objectives are often stated in terms of finding an acceptable product which utilizes some readily available species or byproduct from an existing fishery (incidental catch, processing plant waste, etc.). Only a very few give primary emphasis to studying consumer attitudes or market needs.

Resource Emphasis

Seafood product development has traditionally been influenced by two situations in the industry. One of these is that capital invested in the industry is tied to specific fishery resources while the other is the nature of market channels and organization.

Resource Based Investment

The apparent over-capitalization which exists in many fisheries is one factor influencing the nature of seafood product development efforts. For the fisherman with an investment in the resource in the form of underutilized fishing vessels it is very rational in the short-run for him to pressure research agencies to find ways of using fish which he knows are there and not being used. This leads to a classic emphasis on selling what you can produce instead of producing what you can market profitably. One cannot really fault the person who has an investment tied up in the basic production capacity for encouraging public agencies to find ways for him to utilize it better.

This phenomenon is not unique to the seafood industry. In agriculture much the same emphasis is apparent in the activities of publicly funded product development researchers. The several Utilization Laboratories of the USDA have done a great deal of work in developing both new utilization systems and new product concepts. Many of these new products have not been successful because the primary emphasis was on utilizing a specific resource (peanuts, cotton, oranges, etc.) rather than on satisfying a market need.[1/]

Locked-in resources also may be in the form of existing but underutilized processing facilities and even established sales and distribution systems. These represent investments, the existence of which may influence the direction of product development more than the market opportunities do.

Inadequate Market Organization

An efficient marketing system provides information and signals to the producer describing the nature of products and services desired by the consumer. It has been often observed that market channels in the seafood industry are poorly organized and inadequate to compete in a complex food marketing system such as now exists in the United States (Gillespie and Gregory 1971; O'Rourke and Deloach 1971). The seafood marketing system then fails to provide producers with clear signals. At production level then relatively greater emphasis is placed on those considerations which are most clearly understood. Marketing considerations play a minor role because they are not clearly understood. Fishermen generally have not developed strong marketing organizations to seek out a better understanding of the market place.

Other Considerations

The perceived shortage in world food supplies and the potential for meeting this with currently "wasted" fish resources is a philosophy which has contributed to the emphasis on resources in seafood product development.[2/] The economic viability of utilizing these resources is often overlooked. This economic viability depends both on market considerations and costs of developing and delivering the product. But the fact that the fish is there is often enough to stimulate research on how to use it to make more food available. Concern is overlooked for whether people have the income to spend on it or any preference for the product.

So the interests of fishermen and research personnel with ideas of expanding available food sources coincide to initiate product research efforts.

The concept of taking available resources, producing a product and selling it to the consumer is not entirely inappropriate. Certainly many business firms with large marketing departments and extensive resources for advertising can often persuade consumers to accept and adopt their product (Galbraith, 1967). The power of modern advertising tools is certainly quite substantial.

The strength of the marketing organization includes several components; a basic market orientation or philosophy, a large amount of money to spend on promotion and advertising, a good coordinated marketing organization, and good management. The problem arises in that producers (fishermen) do not have access to this type of marketing strength. Often the output of the product development process is not really that far away from some opportunities in the market. It just needs an organization to carry the product to the market and convince not just consumers but also wholesale and retail level decision-makers that the product can fill a market need. Producers have no organization with resources and control mechanisms to support a modern product introduction. Thus, these new products will not reach a high level of success or the benefits will accrue to those who take on the marketing tasks.

It may be possible where over-capitalization exists for some benefits of expanded markets to accrue to the producer even though a marketing firm undertakes the marketing phases of the product development and introduction. Any additional sales which producers can make where some contribution to overhead is achieved will be of benefit to producers in this situation. But in the long run they still have no control over markets and they may find themselves again in a tight economic position.

Marketing Emphasis

A marketing orientation as opposed to a resource emphasis stresses the seeking out of market needs prior to investing in technical product research and certainly prior to investing in production facilities. Market surveys, consumer studies, evaluation of trends in currently produced products are all part of the market research process. If product needs among consumers can be identified, then the availability of adequate market channels and distribution systems needs to be assured. The development of a new product must be preceded by the delineation of a market environment conducive to its acceptance and success.

It is clear, however, that a pure market approach as described above is not likely to occur. Certainly in the extreme case market opportunities entirely unrelated to the firm's (producer's) interest may be uncovered. It is of no value to find out that a ready market exists for a left-handed monkey wrench if you are only in a position to produce seafood products. So the market needs survey is obviously going to be constrained somewhat by the resources available to, and the interests of, those doing the survey.

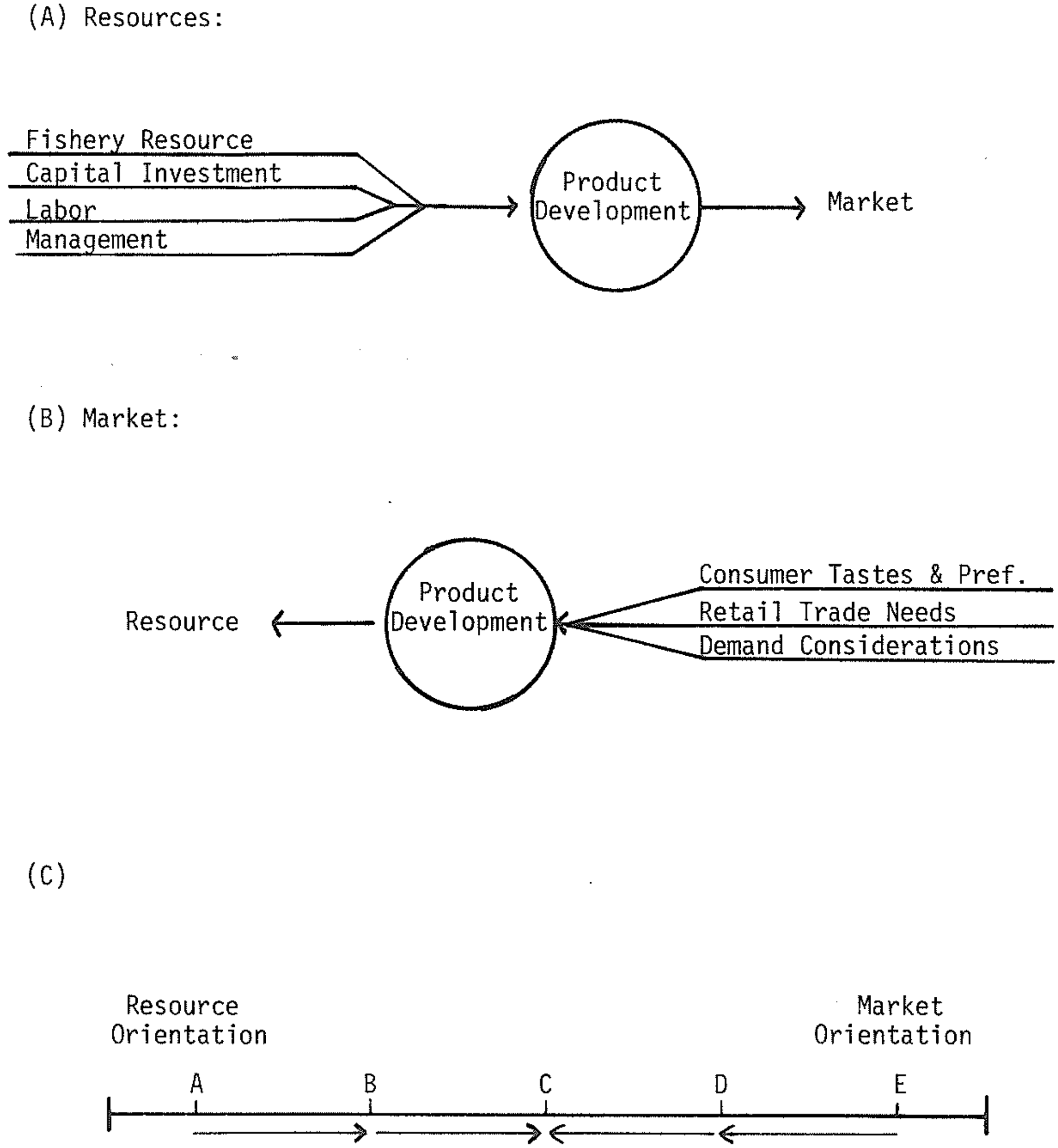
A Conceptual View

In essence a dilemma exists. One horn of this dilemma is a position where the resource is emphasized at the expense of market considerations (Figure 1.A). The other is a position of emphasizing marketing considerations without weighting the importance of resource constraints (Figure 1.B). In reality neither of the extremes are actually taken. Resource oriented product development takes place with some thought for the market into which the resulting product will fit. Also, a market oriented approach certainly considers the constraints of the resources available to the involved parties.

This trade-off process may be viewed as an iterative research procedure where progress at various stages proceeds along a continuum as illustrated in Figure 1.C. Research on product development may begin anywhere along this continuum depending on the forces shaping the initial interest in it. In a resource oriented environment the initiation might occur at point A. At some point in the technical research process, consideration will be given to some of the market considerations. Then the next phases would occur at B and additional emphasis on marketing results in a final position at C.

An alternative way of getting to point C is to start with an emphasis on the market. Through successive stages of research one narrows down the prospects by giving weight to resource constraints such that you move toward C. It is possible that no

Figure 1. A conceptual approach describing two views of publicly supported seafood product development research.



middle ground will be found and product development should be terminated. This is a possibility regardless of the end of the continuum at which the research was initiated.

The question then is one of efficiency in the research process and minimizing the costs of developing a successful new product. While a balance must be reached it should be recognized that extensive technical research can be very costly. Extensive development of the physical product itself only to find no place for it in the market is an expensive mistake. It may well make sense to emphasize the marketing considerations first if these questions can be answered at less cost.

Summary and Conclusions

Publicly supported product development research in the seafood industry generally emphasizes the resource base more than the market. This is the result of the traditional production orientation of fishermen and the fact that often they have underutilized capital tied to the harvesting of fish. Also, an inadequate market system provides no guidelines or clear signals to the producer regarding what his market emphasis should be.

It is clear that greater emphasis should be placed on marketing considerations in the research process. Expensive development efforts resulting in unmarketable products can be avoided. Resolving marketing questions first won't assure successful product introduction but the costs of the search and research process will be considerably less. It is also clear that a more aggressive approach to marketing on the part of producers would be beneficial if the returns from successful product development are to accrue to them.

FOOTNOTES

1/ There are other reasons for products failing to be successful. Often because of the public nature of the development, no private company is willing to invest in the development of markets for it; thus, the product never gets off the shelf.

2/ Wasted in the sense of not being utilized for human consumption. From a biological point of view they may not be wasted because they may form a vital part of the food chain.

REFERENCES

Galbraith, J. K. "The New Industrial State." Boston: Houghton Mifflin Company, July 1967.

Gillespie, S. M. and J. L. Gregory. "A Study of the Marketing Channels for Fresh Finfish in the Texas Fishing Industry." Center for Marine Resources, Texas A&M University, TAMU-SG-71-220, September 1971.

Kotler, P. "Marketing Management: Analysis Planning and Control." Second Edition. Prentice-Hall Inc. Englewood Cliffs, New Jersey, 1972.

O'Rourke, A. D. and D. B. DeLoach. "The California Fresh and Frozen Fishery Trade." California Agricultural Experiment Station Bulletin No. 850, June 1971.

Technical Article No. 12658 of the Texas Agricultural Experiment Station.