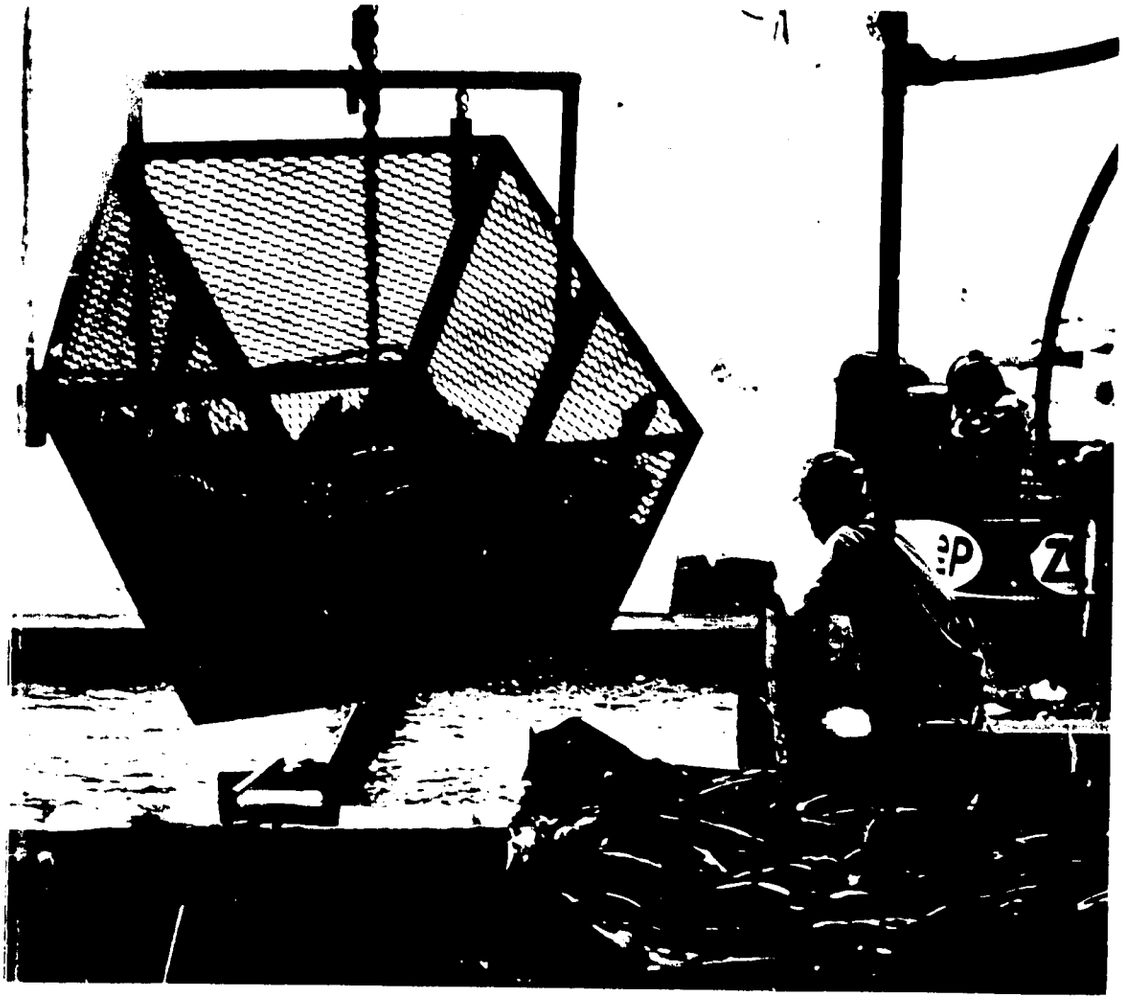


Processing Farm-Raised Catfish

SOUTHERN COOPERATIVE SERIES
BULLETIN 193 OCTOBER 1974

PROCESSING FARM-RAISED CATFISH

A Report from the
Processing and Marketing Subcommittee
of Project S-83

SOUTHERN COOPERATIVE SERIES
BULLETIN 193

Edited by

R. T. Lovell and G. R. Ammerman

Contributions from

**G. R. Ammerman, T. S. Boggess, R. T. Lovell,
E. W. McCoy and C. A. Oravetz**

**Participating and Cooperating Agencies in
Regional Research Project S-83
"Catfish Production, Processing, and Marketing"**

Auburn University
University of Arkansas
University of Florida
University of Georgia
Kerr Foundation
Louisiana State University
University of Massachusetts
Mississippi State University
North Carolina State University
Clemson University
University of Tennessee
Texas A & M University
Virginia Polytechnic Institute and State University
Tennessee Valley Authority
United States Department of Agriculture —
Agricultural Research Service
Economic Research Service
Cooperative State Research Service
United States Department of Commerce —
National Marine Fisheries Service
United States Department of the Interior —
Fish and Wildlife Service

Additional copies of this bulletin may be obtained by writing the Department of Research Information, Alabama Agricultural Experiment Station, Auburn University, 110 Comer Hall, Auburn, Alabama 36830.

PREFACE

At the 1973 annual meeting of the Technical Committee of Regional Research Project S-83, "Catfish Production, Processing, and Marketing" (United States Department of Agriculture, Cooperative State Research Service), the subcommittee on Processing and Marketing Technology agreed that a report containing an evaluation of the present state of catfish processing and relevant technical information on catfish processing and marketing, would be useful to the catfish industry.

The objective of this report is to bring together existing technical and commercial information from all available sources and present it in practical terms so that it will be of immediate value to catfish processors and other persons having interest in the utilization of catfish as a food.

This report was prepared by members of the Processing and Marketing Subcommittee of Project S-83 and cooperating personnel from the United States Department of Commerce and United States Department of the Interior.

CONTENTS

Page

PREFACE 5

DESCRIPTION OF THE FARM-RAISED CATFISH PROCESSING INDUSTRY 7
- Present Size 7
- Growth 7
- Direction of the Industry 8
- Present Markets 9
- Potential Markets 9
- Needs of the Industry 10

STATE OF THE ART OF CATFISH PROCESSING 11
- The Applicable Act 11
- Grounds 11
- The Building 11
- The Receiving and Holding Areas 12
- Water Disposal 12
- Personnel 12
- Ice-Hauling Catfish from Pond to Processing Plant 13
- Receiving 15
- Cleaning 15
- Skinning 15
- Sizing the Fish 15
- Battering and Breading 15
- Product Handling 16
- Labeling Practices 16
- Handling Practices 17
- Microbiological Standards 17
- Freezing Fresh Dressed Fish 18
- Precooked Frozen Catfish 18
- Fresh, Dressed Catfish: Ice-Packed vs. Chill-Packed 19
- Environmental Protection Agency (EPA) Regulations Concerning Liquid Waste Discharge 19

PROCESSING ECONOMICS 21
- Supply of Catfish for Processing 22
- Market Demand for Catfish 22
- Economics of Processing 23
- Seasonal Processing 25

ECONOMIC UTILIZATION OF PROCESSING WASTE 31
- Chemical Evaluation of Catfish Waste 31
- Biological Value of Catfish Waste in Fish and Animal Feeds 32
- Feeding Nondried Catfish Waste 33
- Drying Catfish Processing Waste 34
- Catfish Processing Waste in Pet Foods 36

THE OFF-FLAVOR PROBLEM IN FARM-RAISED CATFISH 37
- Characteristics of Off-Flavor Compounds 38
- Other Types of Off-Flavors 40
- What to do About Off-Flavor 40
- Evaluating Fish for Off-Flavor 42

COMMERCIALLY SMOKED CATFISH 43
- Federal Government Regulations 43
- Smoking Unskinned Catfish 44
- Smoking Skinned Catfish 46

CHEMICAL AND NUTRITIONAL VALUES FOR FARM-RAISED CATFISH 48

NEW DEVELOPMENTS IN CATFISH PROCESSING AND MARKETING 51
- New Products 51
- New Methods in Processing 53

PUBLISHED INFORMATION 55

DESCRIPTION OF THE FARM-RAISED CATFISH PROCESSING INDUSTRY

Present Size

THE 1973 TOTAL PRODUCTION of the major farm-raised catfish processing plants was approximately 19.6 million pounds live weight. These data represent eight companies or individuals for a total of 11 separate processing plants. To those familiar with the farm-raised catfish industry, eight operators and 11 plants may indicate a decline rather than an increase in processing capabilities compared to the 16 processing plants doing business in June 1972. Processed production, however, increased in 1973 as in all successive years since processing data was first collected. The 19.6 million pounds represents only the major plants or those with a high production capacity of approximately one million pounds per year.

Many small processing plants in operation are unaccounted for in total industry processed production. There could be 20-30 of these small plants with a combined production of several million pounds. The processing segment of the farm-raised catfish industry presently accounts for ⅓ to ½ of the total production of farm-raised catfish. It also remains as a major market outlet for those engaged in commercial catfish production. Total production of farm-raised catfish in 1973 was 49.8 million pounds.[1]

Growth

The year 1973 marked the sixth year that processors furnished this ready market outlet for the industry (only three processing plants reported any production at all prior to 1968[2]). In 1970, the first year processing figures were collected, production was 5.7 million pounds (live weight). In 1971, production had climbed to 11.2 million pounds and by the end of 1972, totals amounted to 18.2 million pounds.

The growth of catfish processing has been hampered by a lack of complete utilization of plant capacity and, in many instances, production has never risen beyond 50 percent. Attempts to correct this situation have been made by several processors

---

[1] Compiled by Charles A. Oravetz, Fishery Marketing Specialist, National Marine Fisheries Service, United States Department of Commerce.

[2] RUSSELL, JESSE R. "Catfish Processing—A Rising Southern Industry."

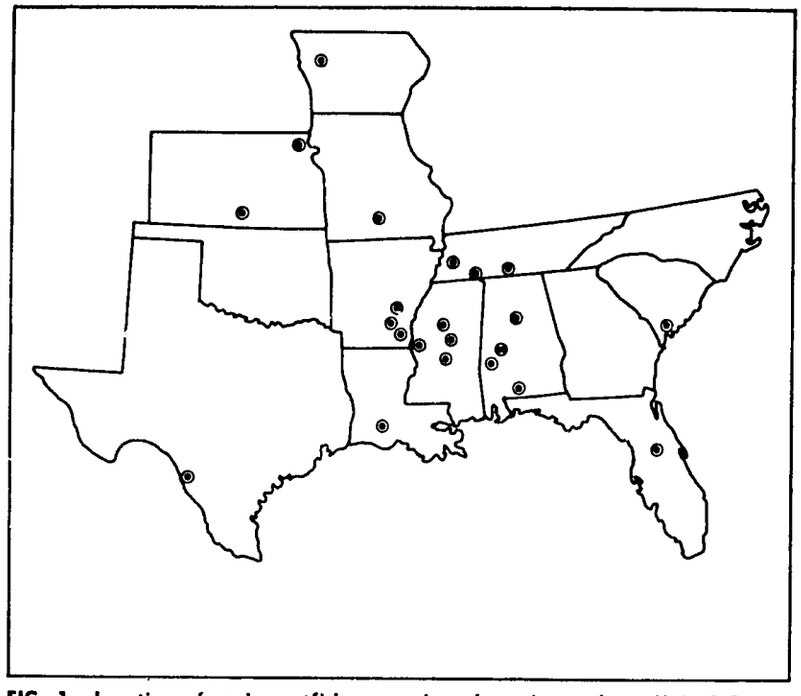


FIG. 1. Location of major catfish processing plants in southern United States, 1974.

by experimentation with other species of fish, seasonal processing, etc., but little progress has been made.

There have been few technological advances in processing. Many plant operations are still performed by hand. Because of these factors, future growth in processing probably will be slow and controlled.

Direction of the Industry

The future of processing is directly related to and dependent upon the overall growth pattern of catfish production. Historically, this has been the case in that both production and processing experienced their boom years in 1969-1972. In 1972, when feed prices started to climb, and other production costs steadily increased in relation to prices received, farm-raised catfish producers who were unwilling or unable to withstand these increases left the business. This was also true of the processing industry – thus the reduction in processing plants. Processing expansion will occur when further expansion comes from pro-

ducers. Many smaller processors will continue to market only what they produce. The multiple producers will expand only as markets develop and thus will the processors. Processors have long asked for a constant, year-round supply of fish. Until this is available, market development will be somewhat restricted. Processors in the future may contract for and help finance additional tonnage. This will have an impact on farm production.

Present Markets

Markets, both past and present, have largely favored the beheaded, gutted, and skinned fresh product because of the high acceptability in traditional markets. Future expansion will depend on other market forms, both fresh and frozen.

The South and Midwest have been the best and largest market areas. In many cases these markets are not adequately served by processors. Existing markets should be further saturated before entering new areas. The distribution of farm-raised catfish is now handled primarily through brokerage firms and food distributors. This is a practical method for a developing industry. As progress is made, the need for more direct selling may become evident.

Potential Markets

Further industry expansion should result in more diversified and sophisticated marketing practices. The potential markets for farm-raised catfish are many and varied. The military market, largely untapped, is substantial. Commissaries and the food service clubs or the officers' and non-commissioned officers' messes, could be handled on an individual basis. The military exchange system offers other opportunities, both domestic and foreign. Additionally, troop feeding could be investigated when supplies are available and guaranteeable.

National restaurant chains are another untapped market. Many supermarket chains that are being sold on a regional basis offer opportunities on a national scale. Catering services and public and private food service establishments offer good outlets for farm-raised catfish.

Finally, the foreign market may offer the greatest potential of all. As our balance of trade becomes less favorable, there is pressure by governments to encourage exportation of American goods. Devaluation of U.S. currency has made it easier for foreigners to

compete for these goods. Also, the increasing demand, coupled with diminished supply of seafoods, make the foreign market ideally suited as buyers of a high quality, protein food that can be produced under controlled conditions.

Needs of the Industry

Before expansion into other markets can begin, many details in all phases of the industry must be clarified. The foremost need of the processors is increased efficiency in production techniques. Processors are solely dependent upon an adequate supply of consistent quality catfish produced under favorable economic conditions. The supply must further be available at the proper time and place to satisfy market demands.

Processing technology gains must be made to ensure adequate profit margins and efficiency of operations. Continued work in demand creation and consumer education must be maintained as a supplement to the efforts in these areas by industry.

Additional profit opportunities in processing should be realized whether they be from the sale of by-products, diversification in the species or product forms marketed, and certainly the increased use of plant capacity.

STATE OF THE ART OF CATFISH PROCESSING

The Applicable Act

CATFISH PROCESSORS must operate under the Federal Food, Drug and Cosmetic Act, which has, as its main purpose, to prohibit movement in interstate commerce of adulterated or misbranded food, drugs, devices, or cosmetics. There are many other requirements of this act, but the one of great concern to the catfish processor is that dealing with good manufacturing practices, which states that a food will be liable to seizure if it has been prepared, packed, or held under unsanitary conditions whereby it may have been contaminated or may have been rendered injurious. With this understanding of the Food and Drug Act of importance in this area, each factor involved in good manufacturing practices should be examined to see how processors might comply with the requirements of the act.

Grounds

Good manufacturing practices require that grounds be neat, clean, orderly, free from weeds, rubbish, unused equipment, abandoned equipment, or other materials which would afford breeding places or refuges for rodents, insects, or other pests. Dusty roads, yards, and parking lots may contaminate food as it is received and processed. Such conditions must be eliminated. Poorly drained areas should not be allowed as mold and other materials may be tracked into the plant. Such areas also encourage flies, mosquitoes, and odor-producing microorganisms.

The Building

The processing plant should be large enough to permit normal activities of processing the fish without development of crowded conditions or situations difficult to clean. Sufficient storage should be required, so that equipment not in use, supplies, and other materials can be stored separate from the processing plants to prevent contamination of foodstuffs. Floors, loading platforms, and other surfaces should be constructed of materials easily cleaned. Such materials can be concrete, tile or other impervious materials, which will not become water-soaked and contaminated with organic substances that promote growth of microorganisms. Pipes, light fixtures, and other overhead equipment should be installed

compete for these goods. Also, the increasing demand, coupled with diminished supply of seafoods, make the foreign market ideally suited as buyers of a high quality, protein food that can be produced under controlled conditions.

Needs of the Industry

Before expansion into other markets can begin, many details in all phases of the industry must be clarified. The foremost need of the processors is increased efficiency in production techniques. Processors are solely dependent upon an adequate supply of consistent quality catfish produced under favorable economic conditions. The supply must further be available at the proper time and place to satisfy market demands.

Processing technology gains must be made to ensure adequate profit margins and efficiency of operations. Continued work in demand creation and consumer education must be maintained as a supplement to the efforts in these areas by industry.

Additional profit opportunities in processing should be realized whether they be from the sale of by-products, diversification in the species or product forms marketed, and certainly the increased use of plant capacity.

STATE OF THE ART OF CATFISH PROCESSING

The Applicable Act

CATFISH PROCESSORS must operate under the Federal Food, Drug and Cosmetic Act, which has, as its main purpose, to prohibit movement in interstate commerce of adulterated or misbranded food, drugs, devices, or cosmetics. There are many other requirements of this act, but the one of great concern to the catfish processor is that dealing with good manufacturing practices, which states that a food will be liable to seizure if it has been prepared, packed, or held under unsanitary conditions whereby it may have been contaminated or may have been rendered injurious. With this understanding of the Food and Drug Act of importance in this area, each factor involved in good manufacturing practices should be examined to see how processors might comply with the requirements of the act.

Grounds

Good manufacturing practices require that grounds be neat, clean, orderly, free from weeds, rubbish, unused equipment, abandoned equipment, or other materials which would afford breeding places or refuges for rodents, insects, or other pests. Dusty roads, yards, and parking lots may contaminate food as it is received and processed. Such conditions must be eliminated. Poorly drained areas should not be allowed as mold and other materials may be tracked into the plant. Such areas also encourage flies, mosquitoes, and odor-producing microorganisms.

The Building

The processing plant should be large enough to permit normal activities of processing the fish without development of crowded conditions or situations difficult to clean. Sufficient storage should be required, so that equipment not in use, supplies, and other materials can be stored separate from the processing plants to prevent contamination of foodstuffs Floors, loading platforms, and other surfaces should be constructed of materials easily cleaned. Such materials can be concrete, tile or other impervious materials, which will not become water-soaked and contaminated with organic substances that promote growth of microorganisms. Pipes, light fixtures, and other overhead equipment should be installed

so as not to permit condensate or dust to drop into the food product being conveyed through the plant. All surfaces that come into contact with food should be constructed of impervious, readily cleaned materials, such as stainless steel, rubber, or similar materials. All areas where trimming and sorting is done must be well-lighted and ventilated. Windows, doors, and other entry ports must be screened.

The Receiving and Holding Areas

These areas should be separated from the processing plant by solid walls, having only the necessary opening for passage of people and materials from one area to the other.

The plant must have adequate toilet and hand-washing facilities for the number of people working in the plant. These facilities should be well lighted, ventilated, supplied with soap, paper towels, and toilet tissue, and kept sanitary at all times. All toilet facilities must be separated from the processing room by an alcove and equipped with self-closing doors. Hand-washing facilities should be located outside the toilet but inside the processing plant in full view of supervisory personnel. Signs that all personnel must wash before returning to work should be posted in prominent places.

Water Disposal

Skins, heads, and other offal must be removed from the processing area continuously and stored so not to promote breeding of flies or development of offensive odors. Waste water should be impounded and treated to meet the requirements of the Environmental Protection Agency before being discharged into streams.

Personnel

A processing plant may be well designed, maintained, and constructed, and still be operated in an unacceptable sanitary manner. The key to successful operation under the appropriate act involves a two-fold sanitization procedure. The plant should be cleaned on a continuous basis during operation. The plant must also be shut down 4 hours of every 24 hours for a thorough scrub-down and sanitization. No plant operation can be successfully cleaned unless the management and all employees are interested in a sanitary program. Employees should be instructed in the

sanitation requirements of proper management. The clean-up crew should be composed of people who are respected by others in the plant. No person with communicable diseases, or sores or open wounds should be allowed to work in any capacity. All personnel should be required to wear caps or hairnets. Clean clothing should be required, and, where practical, white uniforms should be provided and maintained by the management. Personnel should be instructed that no eating, drinking, smoking, chewing, or the use of snuff will be tolerated within the food processing building. Expectoration shall be absolutely forbidden inside the processing plant.

Ice-Hauling Catfish from Pond to Processing Plant

Most harvested catfish are transported alive to the processing plant. Live-holding at the plant until the fish are processed has advantages in that self-grading in the holding tanks is possible and it assures high quality fish at processing. A disadvantage of live-hauling is that fish injured during harvest may die during handling and not be acceptable for processing. Also, there is a continuous risk of losses in transit, particularly during warm weather.

Ice-hauling is a feasible alternative to live-hauling for catfish to be processed. Most marine fish are transported from catch site to processing plant or market packed in ice. Melting ice is a heat absorbing process and the flow of water from melted ice carries heat away. Whole fish properly iced and packed undergo relatively little bacterial deterioration during the first few days. Studies at the Georgia Agricultural Experiment Station showed that catfish properly handled could be held on ice for up to 24 hours before processing and still yield a very satisfactory product. Further holding on ice up to 96 hours (4 days) caused slight darkening of color and flavor deterioration, but the product was still acceptable. As compared with catfish held alive until processed, those held on ice were somewhat darker in appearance, had dark blood vessels in the flesh, and did not skin as easily. After being held on ice for 48 hours (2 days) catfish were very difficult to skin. A study sponsored by the United States Department of the Interior (USDI) indicated that ice-hauling was a satisfactory practice for handling catfish and that fish to be skinned by hand or machine should not be held on ice longer than 3 to 4 days.

When ice-hauling catfish, excessive pressure will bruise the fish and damage the appearance of the flesh. Ice-packing of marine fish and shrimp is usually done in crates, tubs, or in tiers separated by boards. This distributes weight among the crates or tiers and reduces weight on fish near the bottom of the cargo. Field observations have shown that catfish ice-packed at depths in excess of 24 inches show tissue damage.

Another precaution in ice-hauling is to ensure adequate ice contact with fish, which is influenced by method of loading, temperature, and holding time. Ideally, packed fish should be in contact with ice on all surfaces. In packing, put down ice initially, then add fish and ice alternately. Use crushed ice to minimize bruising and ensure good ice-fish contact. There should be a drain at the bottom of the holding container.

The amount of ice required in hauling fish is determined by temperature of fish, insulation barrier from outside temperature, and time required for hauling. In an insulated truck where outside heat is minimized, the following points may be considered regarding the amount of ice required to cool fish to a desirable storage temperature of 35° F:

(a) 0.0069 pounds of ice required to lower the temperature of a pound of fish 1° F;

(b) with ideal heat absorption by the ice from the fish, 0.33 pounds of ice will lower the temperature of 1 pound of fish from 80 to 35° F upon complete melting in 4 to 6 hours depending on size of fish and contact with ice;

(c) assuming the heat transfer is not ideal and the ice must last longer than 12 hours, the amount of ice should be tripled to give a 1:1 ratio of fish to ice if fish are near 80°F when loaded;

(d) 0.12 pounds of ice will lower the temperature of 1 pound of fish from 50 to 35°F in 2 to 4 hours, thus a fish to ice ratio of 2:1 is adequate when the fish are loaded at 50° F.

Skinning difficulty is apparently the greatest disadvantage of ice-hauling, although some processors are following this practice. More research is necessary on this problem. Also, research is needed on methods and equipment for ice-packing to minimize fish damage. Deterioration is not a serious problem if fish are processed within 48 hours and are kept cold at all times prior to processing.

Receiving

Live hauled fish received at the plant should be kept alive in well aerated water until processed. Any deformed, diseased, or otherwise abnormal fish should be discarded before they reach processing lines.

Cleaning

The fish should be stunned by the application of electrical shock, and heads removed by use of a band saw. The body cavity should be opened, and entrails removed and conveyed through a vacuum tube into a holding tank outside the processing plant wall. It is best if the beheading, gutting, and rinsing operations should be separated from the remainder of the processing plant by a wall. Containers used to hold fish parts should be emptied and cleaned at least once every 3 hours in order to prevent the proliferation of bacteria or development of bad odors.

Skinning

The skin should be removed from the fish as soon after beheading and evisceration as possible. Hand-skinning, the use of Townsend membrane skinners, or use of sodium hydroxide are all acceptable, but most commercial plants at this time are using Townsend skinners. All fish skinning equipment should be thoroughly cleaned and sanitized once every 24 hours and periodically cleaned at break time throughout the day.

Sizing the Fish

The skinned fish may be sorted into proper size lots, either by hand or by use of continuous weighing equipment. When weighing equipment is used, it should be thoroughly cleaned every 24 hours and more often if practical.

Battering and Breading

If battering and breading is to be practiced, fish should be rinsed with water at or below 50° F just prior to application of these materials. Precautions must be taken in removing breading and battering materials from containers to ensure that no contamination occurs. In instances where batter mix has been packed in double layer sacks, the outer layer should be removed and discarded before the material is poured into mixing and blending

tanks. The prepared batter should be kept below 50° F and in no case should it be held at room temperature for more than 4 hours without being discarded and the containers being cleaned and sanitized. If batter must be held overnight or for several hours during the processing day, temperature must be reduced to 40° F or below. Even under the best conditions, such material should be discarded at least every 12 hours and at the end of the shift and equipment should be thoroughly cleaned and sanitized. The breading may be held and used so long as it is sifted through ¼-inch or smaller mesh screen and screened out material discarded. Breading in the equipment at the end of the day's operation may be used the next day if it is sifted, placed in frozen storage, and used within 20 hours from the close of the previous day's operation.

Product Handling

Fish should be moved through the plant as rapidly as is possible. The elapsed time from killing until the time they are placed in the freezer or in cold storage or iced should not exceed 2 hours. Preferably this operation should take no more than 20 minutes. The freezing equipment should have the capacity to reduce temperature of the fish to 32° F within 12 hours and to produce a frozen product within 24 hours. Obviously, the size and shape of the package will have a profound effect on the time required to freeze the produce. However, regardless of the type, shape, or size of the package, the above conditions should be met. Frozen fish should be held at not higher than 0° F at all times throughout loading, shipping, and retailing. Each freezer and cold storage compartment should be fitted with an automatic control for regulating the temperature or an alarm which will indicate a rise in temperature. Such compartments should have indicating and recording thermometers both of which have accuracy of plus or minus 2 degrees Fahrenheit.

Labeling Practices

Good manufacturing practices include incorporation of proper labeling and a code which will identify the product to both the processor and the Food and Drug Administration. Permanently legible codes should be placed on each package and the shipping carton to identify the date of pack, the company, and the plant where the product was packed. Other useful information which

should be incorporated into the code for the benefit of the processor are items such as lot identification, packing lines in multiple-line plants, and source of raw fish for processing. The label must include the name and address of the manufacturer, packer, or distributor, an accurate statement of quantity of contents and usually the ingredients used in producing the final product. Good manufacturing practice regulations do not require but urge the processor to put directions on the food package concerning maintenance of proper temperature of refrigerated and frozen perishable products.

Handling Practices

No frozen catfish should be distributed through marketing channels incapable of maintaining the frozen product at 0° F. No lot of catfish should be shipped if the temperature is above 0° F at the time of shipment. Frozen foods should be stored on skids or pallets, allowing at least 2 inches of air space between the floor and product. Stacking should be at least 6 inches away from the wall and at least 12 inches from the ceiling. This will provide free circulation of refrigerated air about all of the product. Obviously, if walls of the storage room are maintained at 0° F, these requirements are not as important. All frozen-foods delivery trucks should maintain the product temperature at 0° F or lower at all times. Vehicles should be pre-cooled before loading frozen catfish. The produce should be loaded in such a manner to ensure free circulation of refrigerated air at the front, rear, top and bottom and around both sides of the load. Employees engaged in hauling and handling frozen fish should be instructed of the perishable nature of the product and should be encouraged to handle fish quickly to ensure that the temperature not rise above 0° F during handling.

Microbiological Standards

Microbiological standards are important for all frozen foods, but particularly so for pre-cooked frozen foods normally consumed without thorough cooking by the housewife. When the processor offers pre-cooked or partially pre-cooked frozen fish, quality control must be based on maintaining the product with a standard plate count of not more than 50,000 colonies of bacteria per gram and a coliform plate count of not more than 10 colonies per gram. The product should not contain any sta-

phylococcus organisms capable of producing the enzyme coagulase. If such products should contain any organisms of the salmonella-shigella typhoid group they will be considered "adulterated" and, therefore, illegal by Food and Drug Administration.

Freezing Fresh Dressed Fish

Fish for freezing should be processed as described elsewhere in this report. They should be packaged in polyethylene pouches and frozen at −20° F in a blast freezer. If held at a constant temperature of 0° F or below and kept from dehydrating, a whitish appearance will develop on the fish, but the flavor and overall acceptance will remain reasonably stable over a 12-month period. Obviously, sealing the pouches with a vacuum will result in some improvement of the shelf life, but simply sealing the pouches or folding the top to prevent dehydration is sufficient to preserve the fish for up to 12 months.

Precooked Frozen Catfish

To prepare this product, the fish should be beheaded, eviscerated, skinned, rinsed, and otherwise dressed as has been described previously. The fish should then be battered and breaded with a good commercial product according to the directions furnished by the company or by use of a product specially developed by the food processor. The fish should then be fried in stabilized cooking oil at 375° F for 10 minutes. After frying, fish should be either (IQF) individually-quick-frozen at −20° F in a blast freezer or packaged and then quickly frozen in a −20° blast freezer. A sealed 1.5 mil polyethylene bag is a good package for the pre-cooked frozen product. Treatment of the catfish with propyl-gallate, an antioxidant, prior to cooking will be beneficial in retarding oxidative rancidity. Such an anti-oxidant will be particularly beneficial when the cooking medium is hydrogenated corn oil or lard. If properly prepared, quickly frozen, and stored at 0° F, precooked channel catfish should be excellent for up to 12 months of storage. Pre-cooked frozen channel catfish offers convenience to the housewife, as it can be heated and served without further cooking. Obviously, normal care and handling must be exercised after the fish has been cooked. Poor handling may result in microbiological contamination and a potential hazard to health, since the fish is not subjected to sufficient heat prior to serving to destroy toxigenic or pathogenic organisms

or microbial toxins. This is true of most pre-cooked foods which are heated and served without rigorous heat treatment.

Fresh, Dressed Catfish: Ice-Packed vs. Chill-Packed

Channel catfish which have been beheaded, eviscerated, and skinned, as previously described, may be sold fresh in the following forms: iced without packaging, iced in packages, or packaged (tray) and refrigerated. Iced, unpackaged channel catfish may be expected to have a noticeably paler and duller color after 5 days storage. Fish which have been packaged in a meat type tray and ice-packed will generally retain their good appearance for a longer period of time. By the eleventh or twelfth day after slaughter, regardless of whether the fish have been packaged or not, ice-packed fish will have reached their maximum acceptable shelf-life. After about the tenth day, there will be a noticeable deterioration in flavor. The concentration of bacteria on the surface of processed fish affect directly and to a high degree the keeping quality of ice- or chill-packed dressed catfish.

Refrigerated, or chill-packed, dressed catfish do not keep as long as ice-packed fish The maximum acceptable storage life of packaged, refrigerated, dressed catfish, which have been processed under sanitary conditions, is approximately 8 days or three-fourths that of dressed catfish properly packed and stored in crushed ice.

Environmental Protection Agency (EPA) Regulations Concerning Liquid Waste Discharge

If waste water from the processing plant does not empty into a public or private sewage disposal system, the discharge becomes the concern of EPA. EPA is administering the National Pollution Discharge Elimination System (NPDES), which involves issuing permits to industries to empty liquid waste into streams, in all states in the South and Southeast except in Mississippi and Georgia where state agencies are responsible for the program.

EPA has recently promulgated guidelines and standards for the basis of the issuance of permits for the discharge water from farm-raised catfish processing plants. The guidelines became effective June 26, 1974 as presented in the Federal Register Vol. 39, No. 124, Part II.

The guidelines state that farm-raised catfish processing plants that discharge water into streams must by July 1, 1977 achieve effluent limitations which are attainable using the best *practicable* control technology, and by 1983 achieve effluent limitations attainable by the best *available* technology. EPA contends that effluent limitations for 1977 can be met without aeration lagoons, that is, with grease traps, screens, and good manufacturing practices; however, the effluent limitations for 1983 are based on aerated lagoon systems.

The effluent limitations guidelines for 1977 and 1983, in pounds effluent per 1,000 pounds of seafood, are as follows:

		Maximum for one day	*Av. of daily values for 30 consecutive days not to exceed*
1977	Total soluble solids	28	9.2
	Oil and grease	10	3.4
	pH	6.0-9.0	....
1983	Total soluble solids	11	5.7
	Oil and grease	.9	.45
	pH	6.0-9.0	....
	BOD	4.6	2.3

For information concerning obtaining an NPDES permit, catfish processors should first consult the state water pollution control agency and Extension food technologists at the Land Grant Universities.

PROCESSING ECONOMICS

THE EIGHT COMPANIES with eleven processing plants operating in 1973 were faced with two types of costs: fixed costs of plant, equipment, and other capital items, and variable costs of labor, supplies, utilities, and other items. Fixed costs include all actual and imputed expenses that accrue even if the plant does not operate. The remaining costs vary with the level of operation. As with any economic activities, an optimum level of production exists for each processing plant. At the optimum level the combination of fixed and variable costs results in a minimum total cost per unit of output. The concept is illustrated in Figure 2. Marginal cost per unit represents the additional cost of processing one unit of output. At Point A all costs, both fixed and variable, are covered and the processing firm is making normal profits. At Point B only the variable costs are covered with no returns to investment. Between the two points it is cheaper to operate than to close down even though the processing firm is losing money. For many of the processing firms in the industry the selling price for fish has been somewhere between Point A and Point B. Al-

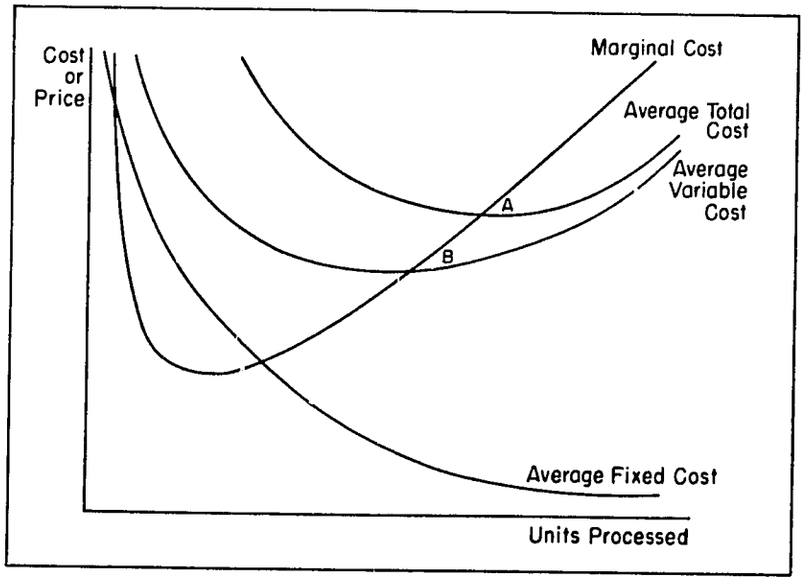


FIG. 2. Relationship between level of plant operation and profit as influenced by fixed and variable operational costs.

though the firms sustained losses, the variable costs were covered and losses were lower than they would be if the firm did not operate. Over the past several years several firms ceased operation or merged with other firms after sustaining processing losses.

Individuals or firms entering into catfish processing must consider both the available supply and the market demand for fish. Both should influence the size facility to build.

Supply of Catfish for Processing

During the brief history of the industry, catfish production has been highly seasonal with stocking during the spring and harvest during the fall and winter months. As a result the available supply of catfish during the summer months was limited and competition between processors to obtain the available supply typically increased price. One means of ensuring a stable supply of fish is vertical integration of production and processing. The processor can acquire – by lease, purchase, or contract – sufficient production acreage to ensure operation of the plant during the summer months. A plant with sufficient capacity to process 10,000 pounds (liveweight) per 8-hour shift, operating 5 days per week for 50 weeks per year requires a stable supply of 2,500,000 pounds (liveweight) per year. Considering a holding capacity of 3 days supply, a firm would require constant delivery of relatively uniform size fish in increments of 30,000 pounds (liveweight) every 3 days.

Assuming production of 2,000 pounds per acre under moderate management conditions, the firm would require harvest from 15 acres every 3 days during the entire year. Total acreage of 1,250 would be needed to operate one shift and 2,500 acres would be needed to operate two shifts. The amount of acreage necessary for year round capacity operation is relatively small; however, since a crop of fish is needed every 3 days, the timing of harvest is crucial.

Market Demand for Catfish

Both domestic and foreign markets exist for catfish while numerous market forms are feasible in each of these. Presently the domestic market utilizes all of the catfish processed. With substantial increases in output inroads in the export market could be made. Catfish can be fresh, frozen, dried, smoked, or canned in form. Although the present demand for fresh and frozen cat-

fish is sufficient to move all the available production, smoked catfish represents a highly desirable specialty product. Economic evaluation of investments in equipment, however, would be necessary before recommendations regarding the feasibility of large scale production could be made. Canned catfish represents a product that should compete favorably with tuna and salmon. The amount of investment and the quantity of product necessary to penetrate the canned fish market would be comparable to that of these industries. Until substantial overproduction exists in catfish, the primary competitor for catfish canners would be processors who market fresh and frozen catfish.

Economics of Processing

Fixed investments for catfish processors generally can be broken into the broad categories of land, buildings, and equipment. Each varies by processor depending upon location, size of structures, and degree of mechanization. Land usage, at a minimum, requires sufficient space for holding facilities, buildings, and parking. Building could include the processing plant with incorporated cold storage, dry storage for supplies, office space, and restrooms. Investments in harvesting equipment include tank trucks, seines, scales, and related items. The equipment within the plant can include: electric shockers, band saws for beheading, suction devices for removal of entrails, skinning machines, brush washers, automatic sorting machines, packaging machines, blast freezers, deboning machines, filleting equipment, conveyer lines to move the product from one station to another, office equipment, and cold storage vehicles to transport the product to market. A plant can operate without many of the equipment items.

As with other industries labor and capital have a high degree of substitutability. Hand labor can be used for all functions except weighing and freezing. In evaluating inclusion of an item of machinery in a plant the relative cost and efficiency of the equipment compared to hand labor should be compared. With interest at 8 percent per year the opportunity cost of any item of equipment is $80 per $1,000. In addition, depreciation per $1,000 on equipment with a 10-year life is $100 per year. Thus, the fixed cost per $1,000 of equipment with a 10-year life is $180 per year. Assuming a wage rate of $2.00 per hour an item of equipment would have to replace more than 90 hours of labor before it would

be profitable. For example, a $5,000 skinning machine utilizing two persons per shift would be profitable only if the marginal value of the additional number of fish skinned exceeded the value of those that could be skinned by hand by $900 of labor time. A cost comparison budget of labor versus machine use is presented below. Only differential cost items are included in the budget.

COMPARATIVE ANALYSIS OF MACHINE VERSUS HAND SKINNING OF CATFISH AT VARYING COST AND OUTPUT LEVELS AT 100 PERCENT CAPACITY

Item	Machine cost[1]			Item	Labor rate[1]		
	A 2,500	B 4,000	C 5,000		I 2.00	II 2.50	III 3.00
	Dol.				*Dol.*		
Depreciation	250	400	500	Wages	4,000	5,000	6,000
Opportunity cost	200	360	400	Interest on operating capital	320	400	480
Maintenance	25	40	50	Overhead	2,000	2,500	3,000
Utilities	20	20	20		6,320	7,900	9,480
Taxes & insurance	10	10	10				
Total	505	830	980				

[1] Assumed for example purposes.

Assuming three levels of machine and labor costs the substitutability of capital for labor can be determined. Under the given conditions cost of acquiring a machine even at the highest level is lower than hiring an additional worker. However, direct cost is not as important as cost per unit of productivity. In the matrix of substitutability presented below comparative productivity ratios are given. The marginal productivity of the additional hired labor must exceed by the factor given in the table before hiring would be efficient. At point CI, for example, if a man using a skinning machine can process 10 more pounds per hour than a man without a machine, and hand skinning averages over 64 pounds per hour, machine purchase would be inefficient.

MATRIX OF SUBSTITUTABILITY OF CAPITAL FOR LABOR AT VARYING LEVELS OF MACHINE AND LABOR COST

Machine cost	Labor cost		
	I	II	III
A	12.5	15.6	18.8
B	7.6	9.5	11.4
C	6.4	8.1	9.6

Other costs enter into consideration if the plant does not operate at close to capacity. The machine costs remain relatively fixed while labor costs vary directly with the number of hours of operation.

For a plant operating at 50 percent of capacity the machine cost, labor cost and substitution ratios would be as shown below.

COMPARATIVE ANALYSIS OF MACHINE VERSUS HAND SKINNING OF CATFISH AT PLANTS OPERATING AT 50 PERCENT OF CAPACITY

Machine cost	Labor cost		
	I 3,160	II 3,950	III 4,740
A 485	6.5	8.1	9.8
B 810	3.9	4.9	5.9
C 960	3.3	4.1	4.9

At the 50 percent level the ratios are cut almost in half and machine skinning must be extremely efficient to be profitable. Clearly the scale of operation and efficiency of capital and labor must be evaluated before costs are fixed in machine acquisition.

Many other factors besides cost enter into the decision process. The availability and quality of the labor force are important considerations. Technological change and rate of obsolescence of equipment also must be considered. In addition, the interaction of various types of equipment must be analyzed. Use of a bandsaw with a skilled operator for beheading necessitates additional labor for removal of viscera. Use of a skinner requires additional labor for removing skin missed by the machine. Seldom will the introduction of an item of machinery leave the labor forces static with only an increase in output resulting.

Catfish production and processing displays many aspects of resource fixity. In effect, many factors once committed to catfish cannot readily be shifted to other endeavors. Examples would include ponds, nets, and hauling tanks in production and holding tanks, skinners, and other items in processing. In a young volatile industry innovators stand to reap substantial profit by rapidly assimilating new technology. Innovators also sustain considerable risk in committing resources to long-term investments. Careful appraisal of long-term trends in the industry should be made before long term capital investments are made. Any firm with a major portion of costs covering fixed investments is not able to rapidly adjust to changes in its industry.

Seasonal Processing

Catfish have certain biological constraints in production. Two of the more important from a processor's standpoint are, first,

the inverse relationship between stocking rate and growth of individual fish; and second, the decline in growth rate when water temperature drops below 70 degrees. If consumers were equally willing to purchase fish of varying sizes neither factor would enter into consideration; however, the present major market for farm raised catfish is the institutional sector. Purchasers in this market specify a fish with a dressed weight from 6 to 16 ounces. With a dress-out percentage from 55 to 60 percent, processors require a liveweight catfish from 10 ounces to a pound and one-half. In addition, the consumer sector does not exhibit a stable demand for catfish year round.

To produce catfish year round in the Southeast requires stocking and harvesting during the summer months and some overwintering of catfish. Several alternative methods of production are available. Typically, 4-to 6-inch fingerlings are stocked in March or April and one to 1½ pound fish are harvested during the winter months. Since the rate of growth declines and feed conversion ratios increase during the colder weather, a fish overwintered and harvested in March costs approximately 3 cents per pound more than a fish harvested in November. The opportunity cost or price of holding the fish 3 additional months increases the cost per fish approximately 1 cent more, as shown below. The cost, of course, varies depending upon the rate of growth during the winter and the feed conversion rate. But in any case, additional time is required to turn over operating capital.

Cost Per Pound for Overwintering Catfish
Dec.-Jan.-Feb.

Item	*Quantity*	*Rate*	*Cost*
Additional feed (lb.)	.100	0.12	0.012
Additional labor (hr.)	.005	2.00	1.010
Interest (cents)	.326	.02	0.0065

Not only are direct costs increased by carrying catfish through the winter, but also death loss is increased when the fish are finally harvested during the summer. Processors have, in the past, bid up the price during the summer months to obtain the scarce supply of available fish; however, they have often encountered a farm-management bottleneck. On farms where catfish enterprise is programmed for spring stocking and fall or winter harvest, these two time periods have released labor available for the catfish enterprise. With summer harvest the catfish enterprise may not fit within the farm operation. A solution to this

problem would be increased net returns from catfish production to a level sufficient to bid labor and other resources away from alternative farm enterprises. With the prevailing prices of cotton, rice, and soybeans, it is unlikely that resources will be moved into catfish production in the short term.

While increased profits for producers represent one means of ensuring year round production, the net effect of that increase – higher prices to consumers – limits market penetration. Catfish competes with beef, pork, and seafood for the consumer dollar. At existing market prices catfish may be a better nutritional buy than other sources of protein; however, lack of production and marketing capability has limited consumer awareness of the product. This lack of awareness makes it difficult to predict how the market would respond to a price increase.

Assuming processors purchase catfish at 45 cents per pound, the processed weight cost is 76 cents per pound. Unless or until an economic return can be obtained for the offal, the processor's costs must be added to the dressed weight cost. In a 1972 study of processor costs, a differential of $.14 per pound existed between operation of facilities at 36 percent of capacity and operation at 100 percent of capacity. At the lower operating level, labor was inefficient when less than day batches were processed since set-up and clean-up costs were essentially constant. With increased labor and material costs the 1974 marketing costs would be substantially increased. Processing costs excluding the cost of fish approximate $.35 per pound, a charge that could be cut in half if plants operated at capacity with full utilization of labor resources. Assuming a standard markup of 20 percent for the remainder of the marketing chain, the consumer price would be $1.58, as shown below. A recent limited consumer marketing study indicated an optimum retail price of $1.19 with an anticipated 70 percent sales increase if price could be reduced to $.99 per pound. At a sale price of $1.19 per pound the upward bound limit of U.S. sales would be approximately 109 million processed pounds or 188 million pounds liveweight, a quantity six times that necessary for capacity operation of existing catfish processing plants.

Derivation of Market Price for Processed Catfish

Level	*Price*
Farm	$0.45
Processor	.76
Wholesaler	1.11
Retailer	1.32
Consumer	1.58

While one way to minimize fixed costs for processors would be through year-round capacity operation, this solution is dependent on an increased supply and an increased market demand. Perhaps a more practical way of dealing with the processor's problem – desiring a stable supply of fish from seasonal production and for a seasonal demand – might be processing on a seasonal basis. With the present processing capacity the entire production could be processed between August and April. The August production would require stocking larger fingerlings or partial harvesting of larger fish from ponds. The seasonal labor force budgeted from other farm production enterprises would be available for the catfish enterprise during the winter months.

Redistribution of the summer processing to the winter months does not substantially increase the quantity processed in any month. Processing is increased, however, during most of the months when consumer demand is highest. The high demand period in May significantly reduces inventory soon after termination of the processing season. About 32 percent of the yearly processing is in inventory at the termination of seasonal processing. After 2 months the inventory is reduced to 6 percent of total processed weight, Table 1.

With seasonal processing ice-pack fish would not be available during a 4-month period of the year. However, research has demonstrated the keeping quality of frozen catfish, and consumers in major market areas are accustomed to frozen-fish products. In addition frozen fish can be marketed at a lower cost than ice-pack fish. Two cost factors enter into seasonal processing consideration. First is the cost of storing the fish. Though storage costs are dependent upon the amount of fish produced, in general, the cost is less than 3 cents per pound for large quantities in excess of one-half million pounds. The second cost item is the reduction in variable and fixed costs per unit for capacity operation during the 8-month season over year-round processing of the same quantity. Cost would be reduced about 13 cents per pound for a net reduction of approximately 10 cents.

TABLE 1. MONTHLY INDUSTRY SALES AS A PERCENTAGE OF TOTAL SALES AND MONTHLY INVENTORY AS A PERCENTAGE OF TOTAL PROCESSED WEIGHT FOR SEASONAL OPERATION BY MONTH AND SEASON

Month	Pct. of total processing completed	Industry sales as pct. of total sales	Monthly inventory as pct. of total processed weight	Cumulative inventory as pct. of total processed weight
	Pct.	*Pct.*	*Pct.*	*Pct.*
Aug.	11.2	6.1	5.1	5.1
Sept.	12.0	7.9	4.1	9.2
Oct.	12.8	6.9	5.9	15.1
Nov.	12.7	8.7	4.0	19.1
Dec.	11.5	7.5	4.0	23.1
Jan.	11.2	8.2	3.0	26.1
Feb.	13.3	12.3	1.0	27.1
March	15.3	10.4	4.9	32.0
April	.....	13.3	—13.3	18.7
May	.....	6.5	— 6.5	12.2
June	.....	6.3	— 6.3	5.9
July	.....	5.9	— 5.9	....
	100.0	100.0		

At the three levels of processing price would vary with a 14-cent reduction by seasonal processing and further 18-cent reduction by year round full-capacity operation, as shown below:

Processing at Various Capacity Levels

Item	*36 percent year round*	*66 percent year round*	*100 percent year round*
Farm-live wt.	.45	.43	.45
Processor	.76	.74	.76
Wholesaler	1.11	1.01	.88
Retailer	1.32	1.20	1.05
Consumer	1.58	1.44	1.26

To move significant quantities of catfish into retail sales, substantial cost reductions must be made. Substantial cost reductions are feasible only at the levels of production and processing. At the producer level, even with prevailing feed, fingerling, land, and labor prices, proper management techniques should allow production of catfish at a cost below 30 cents per pound. At the processor level, obtaining an economic return from the offal would decrease the return necessary from the dressed catfish. Other efficiencies in production could be made with increased volume of product. An overall decrease of 5 cents in processing costs would result in a retail price approximately equal to the present processor cost when operating at 100 percent capacity, as shown below. The demand for catfish at 86 cents per pound would far exceed production, and – if the economic signals work – price

would be bid up inducing shifts from lower valued products into catfish production.

Processing at 100 Percent Capacity under Present and Advanced Techniques

Level	*Present*	*Advanced price*
Farm	.43	.30
Processor	.76	.52
Wholesaler	.88	.60
Retailer	1.05	.72
Consumer	1.26	.86

Catfish production, processing, and marketing are still in their infancy. The best form of production and finished product have not been determined. The relatively high demand elasticities exhibited in consumer tests, however, indicate catfish sales might be substantially increased by price changes and promotion. Yet, before the product can be promoted, sufficient supply must be available to meet the forthcoming demand.

ECONOMIC UTILIZATION OF PROCESSING WASTE

WASTE COMPRISES at least 40 percent of the volume of product which enters catfish processing plants. This represents a potential source of nutrients of considerable value to livestock, pet, and fish feeds, especially with fish meal decreasing in supply.

To date the catfish industry has not made profitable use of catfish waste, mainly because of scattered and erratic supply and because of the lack of technical information concerning value of waste and methods of utilization. Wastes from poultry and livestock processing plants are recycled into feeds for food animals. This appears to be an economical use of catfish processing waste. Several research studies have shown that catfish waste has considerable nutritional food value for animals and can be fed in dried or nondried form.

Chemical Evaluation of Catfish Waste

Tables 1 and 2 show data from a number of chemical evaluations of catfish waste which reflect its nutritional value. The values vary considerably as the fat content of the fish changes with season. In the fall when fish have been heavily fed, the fat content of the waste is higher than the average value in Table 1, and the protein and ash contents are correspondingly lower than the averages shown. The high fat content of waste makes it difficult to dry without extracting the fat or adding a fat absorbent prior to drying.

The large amount of bone makes the waste a valuable source of minerals for animal or fish feeds. The fat can be extracted and marketed for various industrial uses or can be used as an energy supplement for animal or fish feeds. The amino acid profile indicates that it is a valuable source of animal protein but should rank somewhat below fish meal for being slightly lower in the sulfur amino acids (methionine and cystine), isoleucine, and lysine.

TABLE 1. NUTRIENT COMPOSITION OF CATFISH PROCESSING WASTE[1]

	Range	Average	Product
	Pct.	*Pct.*	
Protein	27 -49	42	Dried waste
Fat	30 -60	35	Dried waste
Ash	14 -23	16	Dried waste
Calcium	5 - 7	5.4	Dried waste
Phosphorus	2.4- 3.4	2.8	Dried waste
Water	60 -70	67	Wet waste

[1] Source: Fisheries Annual Report, Auburn University Agricultural Experiment Station, 1973.

Chemical tests have shown that uncooked catfish waste contains an enzyme which destroys thiamine if the thiamine and raw waste are held together for several hours at a warm temperature. Consequently, if raw catfish waste is fed to fish or other animals, a supplemental source of thiamine should be fed separately.

TABLE 2. AMINO ACID COMPOSITION OF PROTEIN FROM CATFISH WASTE, MEAT AND BONE MEAL, AND FISH (MENHADEN) MEAL[1]

Essential amino acid	Catfish waste	Meat and bone meal	Fish meal
	(Percent protein)		
Arginine	8.97	7.92	6.52
Histidine	2.44	1.78	3.14
Isoleucine	4.39	3.35	6.70
Leucine	7.20	6.13	8.15
Lysine	7.61	6.88	8.65
Methionine	2.35	1.38	2.94
(Cystine)[2]	.38	1.19	1.53
Phenylalanine	4.63	3.55	4.40
Threonine	5.21	3.55	4.73
Tryptophan	.80	.39	.98
(Tyrosine)[2]	3.04	1.58	2.61
Valine	5.66	4.74	5.87

[1] Most of the amino acid values were taken from "Nutrient Requirements of Trout, Salmon, and Catfish," Nutrient Requirements of Domestic Animals No. 11, National Academy of Sciences. 1973.

[2] Amino acids in parentheses are not essential but cystine will substitute for part of methionine and tyrosine will substitute for part of phenylalanine.

Biological Value of Catfish Waste in Fish and Animal Feeds

Catfish waste is an excellent source of protein in fish feeds although not quite equal in nutritional value to fish meal. In a study at Auburn University Agricultural Experiment Station, catfish waste was fed in dry and moist feeds and compared with a feed containing an equal amount of marine fish meal protein. All

feeds contained 32 percent total protein with 40 percent of the protein coming from fish meal or catfish waste. The feeds with catfish waste produced approximately 80 percent as much fish as that containing marine fish meal. Another study, with catfish fed in raceways, conducted at the Southeastern Fish Cultural Laboratory at Marion, Alabama, showed that feeds containing 20 percent catfish waste meal produced 87 percent as much fish as feeds containing an equal amount of protein from marine fish meal.

Catfish waste meal is a satisfactory substitute for meat scrap or meat and bone meal in swine rations. A feeding study at Auburn University demonstrated that when 6.5 or 13 percent catfish waste meal replaced an equal amount of protein and minerals from meat and bone meal in swine production-type feeds, growth was equal or slightly superior to that from feeds containing meat and bone meal. A fishy type off-flavor was not found in the pork when as much as 13 percent catfish waste was fed until the time of slaughter.

Biological value of meat and bone meal protein was found to be approximately 50 percent of that of catfish waste protein when each was fed as the primary protein to catfish fingerlings. A comparison of essential amino acid contents of these two materials (Table 2) probably explains the superiority of catfish waste protein.

The chemical composition of the fat (oil) in catfish is quite different from that of marine fish oil (Table 4 in "Chemical and Nutritional Values of Farm-Raised Catfish" section page 50); namely, in that catfish fat is considerably less polyunsaturated than marine fish oils. In fact, catfish fat resembles livestock or poultry fat more than it does marine fish oil. This is largely explained by diet differences between farm-raised catfish and sea fish. Because of the chemical properties of catfish fat, it does not affect flavor of food animals consuming relatively large quantities of it. Catfish fed up to 9 percent catfish fat in their feed did not acquire undesirable flavor and maintained good quality when frozen for up to 12 months. Catfish fed an equal amount of marine fish oil had unacceptable flavor.

Feeding Nondried Catfish Waste

Laws in almost all states in the United States forbid uncooked garbage or waste materials to be fed to swine that are grown

for food purposes. Thus, if catfish processing waste is fed to swine without first being dried, it must be cooked prior to feeding. Moist experimental feeds containing nondried catfish waste provided excellent growth with rats, indicating that they should allow for suitable gains when fed to swine. In a situation where catfish waste could conveniently be heated, ground, mixed with dry ingredients, and fed to swine daily, this could be an economical method for using non-dried catfish waste. Based upon laboratory studies, either of the following formulas should provide a nutritious and palatable diet for growing swine:

	No. 1 *Pct.*	*No. 2* *Pct.*
Heated catfish waste (wet)	33	50
Corn or equivalent	39.5	34.5
Soybean meal (44% protein)	27.3	15.3
Swine vitamin and trace mineral mix	0.2	0.2

Feeding nondried processing waste directly back to catfish is not a good practice. Indiscriminate use of processing waste may provide a source of disease, especially if the waste comes from another farm. Also, nonground raw waste when fed alone is not efficiently consumed and fouls the water.

The use of pasteurized processing waste as an ingredient in moist fish feed provided satisfactory growth for catfish and may be practical under some conditions. One problem associated with feeding moist feeds is water stability. A satisfactory binding agent in the formula and partial (surface) drying of the extruded moist pellets will ensure adequate stability until the feed is consumed. The nondenatured protein in unheated waste provides good binding property to the feed after extrusion and surface drying. When heated waste is used, hydrocolloidal compounds such as carboxymethyl cellulose, alginates, or kelp meal are satisfactory; or, gelatinized wheat, corn or rice starch may suffice. The hydrocolloids are expensive and so is the heat treatment necessary to gelatinize the starch.

Drying Catfish Processing Waste

A flow scheme for a catfish waste drying operation is shown in Figure 3. It includes removing the fat prior to drying because of the large percentage of fat usually found in the waste. The fat can be added back with dried waste when it is put into fish or animal feeds, or the fat can be used for other purposes. The

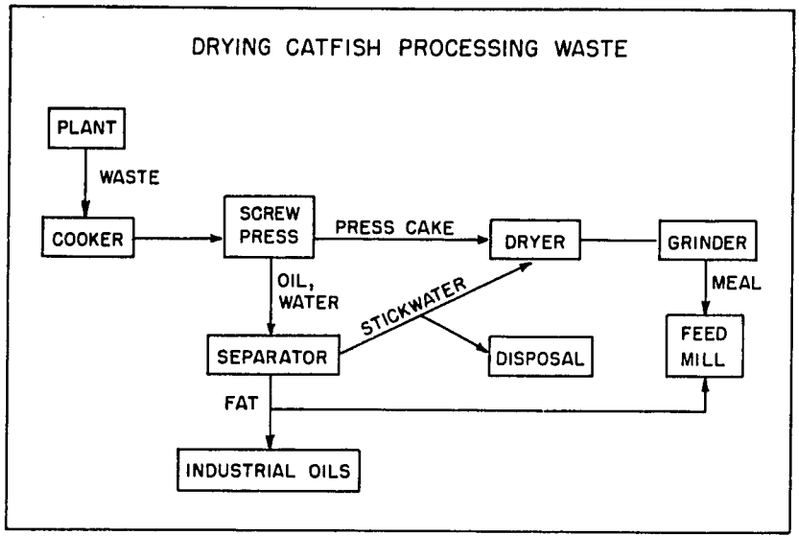


FIG. 3. Flow Diagram showing the optimum drying process for catfish processing waste wherein the oil is separated prior to drying, the soluble protein is recovered and the water may be evaporated instead of being discharged in plant effluent. The system includes a pre-cooker and screwpress for removing the oil prior to drying. The water which initially is separated with oil can be added back in the dryer and reduce plant waste water treatment and also allow for recovery of soluble protein. The catfish oil can be added back in the manufacture of fish and animal feeds.

stick-water is added back to the press-cake and all of the moisture from the waste is evaporated in the dryer. This eliminates the problem of disposing of effuent from the drying operation. By this method 1 ton of processing waste, from 2.5 tons of fish processed, should yield .27 to .30 ton of dehydrated waste solids. The dehydrated solids will consist of approximately 70 to 76 percent meal and 24 to 30 percent separated fat. The composition of the meal will vary with season, size of fish, and other factors, but should have average values of approximately 56 percent protein, 10 percent fat, 21 percent inorganic matter, and 10 percent moisture.

The cost of drying catfish waste varies considerably with the volume of material processed per year. With high volume plant use the cost of reducing a pound of wet waste into meal and fat in 1974 was estimated to be 0.8 to 1.0 cent, assuming the waste is available to the drying plant at no cost. Presently no single processing plant has enough waste for high volume operation of

a drying plant, thus costs of purchasing and/or transporting additional waste must be included.

Catfish Processing Waste in Pet Foods

The nutrient composition of catfish processing waste indicates that it would be a valuable ingredient in dog or cat foods. Catfish waste, when heated, has a more meaty than fishy flavor. Also, the fact that catfish fat is less sensitive to oxidative deterioration than marine fish fats should allow for better keeping quality of canned or low-moisture pet foods containing catfish waste than that of products made with marine fish parts. Canned catfish from experiments has proven to be highly acceptable when offered to both cats and dogs.

Several of the larger catfish processing plants operate relatively consistently the year round, with yearly volumes in excess of 2 million pounds of fish. The proximity of four plants in Mississippi and two in Alabama should make the processing waste supply accessable for inland pet food processing.

THE OFF-FLAVOR PROBLEM IN FARM-RAISED CATFISH

ONE OF THE MOST serious problems in the catfish processing industry is that of off-flavors, especially an "earthy-musty" type of flavor that fish may absorb from the pond environment. In the early stages of marketing of farm-raised catfish for food, fish with this bad flavor reached consumers and significant damage was inflicted upon the market potential of cultured catfish. Processors quickly became aware of the importance of keeping such fish out of market channels and have since implemented quality control programs to reduce the likelihood of this happening. Generally, the catfish processor and the farmer evaluate fish from a pond before harvesting. If off-flavor is detected, the farmer must wait until the flavor problem clears up before the fish can be processed. This presents schedule problems for producer as well as processor. Also, in spite of cautious evaluation procedures, off-flavored fish occasionally are not detected because of variation in flavor among fish in a pond.

Catfish farmers are now generally aware of the off-flavor problem and are in position to appreciate the processor's evaluation of the flavor of fish that are to be processed; however, disagreement between the two on this subject is not completely a thing of the past.

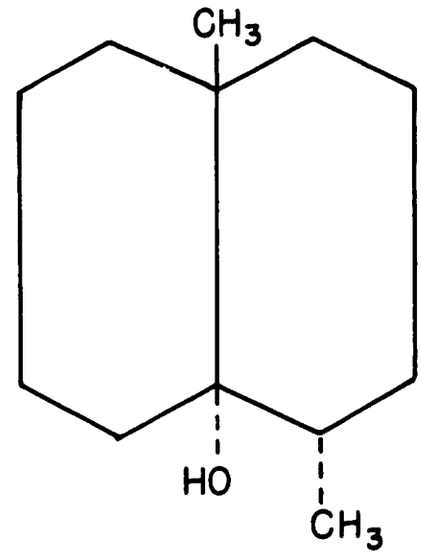
Although a great amount of research has been directed toward identifying causes and finding cures for the earthy-musty flavor in catfish, effective control measures for its prevention in intensively fed culture ponds are still elusive. In static ponds where large amounts of nutrients are applied to grow fish, an abundance of aquatic organisms will grow in the enriched aqueous environment. Among these are species of blue-green algae and actinomycetes which, under certain environmental or growth phase conditions, are responsible for synthesis of off-flavor compounds which by various means may find their way into the fish's body.

Until controls are developed which selectively restrict growth of specific organisms in a highly enriched culture pond, the possibility that pond raised catfish may have off-flavor will exist. Presently, the most encouraging information that can be given to catfish farmers and processors is that *off-flavor will disappear from the fish.* When fish remain in the pond, the off-flavor may

disappear within a week or it may presist for several months. When affected fish are placed in clean water the flavor compounds leave within days. Thus, by separating the source of off-flavor from fish, flavor improves quickly.

Characteristics of Off-Flavor Compounds

The "earthy-musty" flavor compounds are produced by a few species of blue-green algae and a few species of actinomycetes. These compounds have been noted on many occasions in water from public reservoirs. Chemically they are essentially all related in structure to geosmin (Figure 4). These compounds are



Trans-1, 10-dimethyl-trans-9-decalol
(geosmin)

FIG. 4. Geosmin and several other earthy-musty smelling compounds of similar chemical structure have been isolated from natural waters and fish having this type of odor and also from laboratory cultures of blue-green algae and actinomycetes.

produced by the growing organisms but under variable environmental conditions. For example, temperature, dissolved oxygen, dissolved minerals, soil type, sunlight, and nutrients may affect the ability of blue-green algae to produce flavor compounds. Also, actinomycetes, which grow on decomposing organic matter, have been observed to have definite oxygen, temperature, or life cycle restrictions for synthesizing the earthy-musty flavor compounds. It should be pointed out that only few species of blue-green algae or actimomycetes produce off-flavor compounds.

Most cases of off-flavor in catfish probably are caused by species of blue-green algae. Most blue-greens do not affect fish flavor; in fact, these algae have several benefits. Algae are the initial source of natural pond foods, they form dense blooms which prevent weed growth, and produce oxygen for the pond during photosynthesis. Algae-related off-flavor has been more prevalent in, though not restricted to, heavier clay soils such as are in the Mississippi River flood plain and Alabama Black Belt, rather than sandy, acid soils. It may occur at any time from early spring until late fall. Fish may absorb flavor compounds from water through the gills as well as through the digestive tract.

Actinomycete-produced off-flavor in catfish has been observed in late fall and winter. It is presumed to be the result of these

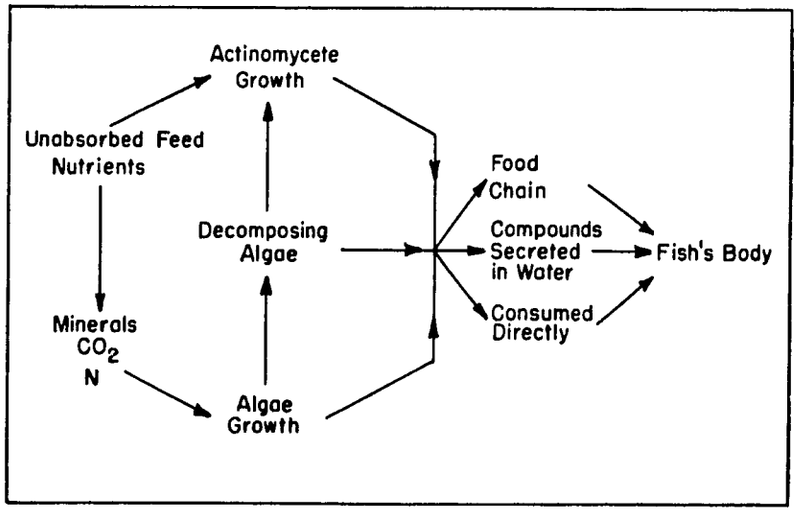


FIG. 5. Illustration of the influence of continuous infusion of fish feed into the pond on growth of geosmin-synthesizing organisms and subsequent absorption of the off-flavor compound by fish.

organisms growing on undigested feed on the pond bottom or decomposing organic matter, such as algae that have been killed by cool weather. Actenomycetes may also be responsible for off-flavor in warm weather when the problem is generally associated with blue-green algae.

Other Types of Off-Flavors

Possible but less important sources of off-flavor in cultured catfish are feeds, chemical contaminants, industrial or agricultural effluents and higher order plants and other animals in the pond.

Decomposing algae have been associated with putrid-like flavors, different from the "earthy-musty" type. This is presumed to be caused by fish eating dead algae cells and is related to decomposing compounds from decaying algae. This type of flavor has been found where algae cells die, clump together, and drift to a certain area of the pond and concentrate where fish can feed on the decaying material. This often occurs at summer's end when water temperature begins to decline.

What to do About Off-Flavor

Although practical methods for preventing off-flavor development in catfish ponds are not available, several measures may be taken to minimize the problem. They are as follows:

1. Do not process off-flavor fish. Off-flavor fish will recover, sooner or later, when the source of off-flavor is removed. It is important that the producer understands this and appreciates the fact that off-flavor is a serious and realistic problem and not a processor's excuse for not accepting fish.

2. Frequent exchange of pond water will minimize opportunity for development of off-flavor in fish by removing nutrients from the pond and reducing concentration of pond microorganisms which may produce off-flavor compounds.

3. Hold fish in clean water for 5 to 14 days. Removing fish from the pond where off-flavor developed and holding them in running water in tanks will remove the foreign flavor. The time required will vary with temperature and intensity of off-flavor. Studies at Auburn University demonstrated that at 60° F, 10-14 days were required for fish with moderate to intense off-flavor; whereas, at 75° F 6 days were adequate. One problem with holding fish in confinement where they are not fed is that they will lose about 9-12 percent of their weight during the period re-

quired to purge the off-flavor. In some cases it may be possible to expose fish to fresh water without removal from the pond, thus allowing continuation of feeding.

4. Continue feeding while waiting for off-flavor to clear up. If feeding is stopped, fish will continue to forage for food and may consume detritis and other materials in the pond which could aggravate accumulation of off-flavor compounds by fish.

5. Chemical control of blue-green algae has been explored by experiment stations and by fish farmers, but its effectiveness in controlling off-flavors is uncertain at this time. Poisoning algae is a hazardous undertaking, especially if there is no water reserve. Decomposition of the dead algae increases the oxygen demand in the pond and a sudden die-off of a heavy algae growth can reduce the oxygen in a pond to a lethal level. Chemical destruction of algae is only a temporary measure and does not eliminate the cause of growth. With profuse quantities of nutrients being put into the pond daily, continuous infusion of poison will be necessary to control growth of algae. More research is needed on control of algae growth in fish culture ponds, not only for the benefit of the flavor problem but because of the effect algae have on the dissolved oxygen in ponds.

6. Increasing turbidity, or muddiness, of pond water through mechanical agitation, aeration or with bottom feeding fish will suppress phytoplankton growth. Also, there is evidence that the suspended clay particles act as adsorbents for the off-flavor compounds in the water.

7. There are reports from the field that various additives have "neutralized" off-flavors in ponds. Agricultural lime added at the rate of 1 ton per acre and also hydrated lime at a rate of 50 pounds per acre have allegedly been responsible for removing off-flavor from catfish in ponds. Although these materials are nontoxic to fish and will alter the chemistry of the water, notably the alkalinity and carbon dioxide content which conceivably could affect the growth of the flavor-producing microorganisms, their efficacy in controlling off-flavor has not been proven under controlled conditions. Potassium permanganate, a strong oxidizing agent often used in ponds at a rate of 2-4 p.p.m. in treating fish diseases, is alleged to have been effective in neutralizing off-flavor compounds in fish ponds. Research results thus far have not produced conclusive results.

8. Smoking partially masks off-flavor in catfish. Intense earthy-musty flavor may still be perceived in smoked catfish by expert judges, but low to moderate concentrations of the compounds in fish flesh are covered up by the smoke flavor. Presteaming and canning in seasoned, smoke-flavored oil or brine solutions has been an effective processing technique with fish having a musty-earthy flavor.

Evaluating Fish for Off-Flavor

Traditionally the processor requests the farmer to bring fish to the plant for evaluation before the pond is harvested. The processor evaluates the fish and renders an opinion to the farmer. The following considerations will help to make this evaluation procedure most effective:

1. The processor should be cooperative with the farmer in evaluating the fish rather than vesting full responsibility to the farmer for delivering untainted fish. The farmer is inexperienced in evaluating fish for off-flavors and biased in his opinions. The processor should, of course, eliminate bias from his evaluation.

2. The fish should be sampled just prior to the time that the pond is to be harvested.

3. Fish should be sampled from several areas of the pond.

4. The fish should be dressed, placed individually in a covered double boiler or wrapped tightly in aluminum foil, without salt or seasoning, and steamed until cooked enough to eat.

5. To evaluate the fish, smell the head space vapor when the container is initially opened, then taste the flesh very close to the bone from areas near the tail and at the anterior end of the carcass.

6 The evaluator should be experienced in judging fish for the earthy-musty flavor. It is difficult and precarious to evaluate fish for off-flavor unless the evaluator is familiar with this quality. If the evaluator is not expert, he should have control fish for comparisons. Fish with no off-flavor and fish with distinct off-flavor should be kept on hand (in frozen storage). These control samples are also useful in demonstrating to a doubtful farmer that his fish have off-flavor.

7. The test with a steamed fish is more accurate than smelling the visceral cavity of a noncooked fish. The processor should feel an obligation to his customers and producers to conduct a thorough and precise evaluation of each pond of fish.

COMMERCIALLY SMOKED CATFISH

CATFISH SMOKED in any of a variety of ways ranks high in consumer appeal. The flesh contains enough muscular fat that it absorbs smoke flavor well, with or without the skin removed. The relatively saturated type of fat in catfish does not oxidize readily to cause undesirable flavors. Brined and "hot-process" smoked catfish offers a new type of consumer product with a great amount of commercial potential. In addition to a flavor that has wide acceptability, it can be stored in refrigeration for several weeks without deteriorating in quality. "Hot-process" smoking means using a relatively short smoking period with simultaneous cooking for a product containing relatively high concentrations of salt and moisture. Catfish may be smoked with or without skin.

Federal Government Regulations

Commercially smoked catfish that may move in interstate commerce must comply with certain federal regulations for smoked fish issued under the Federal Food, Drug, and Cosmetic Act which appeared in the Federal Register, Vol. 35, No. 221, Nov. 13, 1970. Specific requirements for smoked catfish, in addition to general requirements for good manufacturing practice, include the following:

1. Only wholesome fish, free of adulteration or detectable spoilage should be used.
2. Fish should be thoroughly washed before brining.
3. Viscera should be removed. (Head and skin may be left intact).
4. Fish should be brined at a temperature not higher than 38° F.
5. Hot-process smoked fish should be brined in such a manner that the final salt content of the loin muscle, expressed as percent salt in the water phase of the loin muscle, will not be less than 3.5 if the fish is heated to an internal temperature of 180° F for at least 30 minutes. Sugar and seasonings may be added to the brine solution, but not nitrates or nitrites.
6. Hot-process smoked fish may alternatively be brined in such a manner that the brine percentage in the loin muscle after processing is not less than 5.0 percent if the fish are heated to 150° F for 30 minutes.

7. The processor must use recording thermometers that measure temperatures in the smoking chamber and in the deepest part of the fish flesh.

8. During smoking the minimum heating requirements for the deepest part of the fish flesh is either 180° or 150° F for 30 minutes, depending on the brine concentration in the flesh.

9. The fish should be cooled to a temperature of at least 50° F within 3 hours after smoking and to 38° F within 12 hours. The fish should be held at 38° F or cooler during storage and distribution until consumed.

10. The package for the smoked fish should indicate that the product is perishable and must be stored at refrigeration temperature.

Processors intending to smoke catfish should consult local and state health regulations regarding food processing operations and also familiarize themselves with all aspects of the federal regulations previously discussed.

Smoking Unskinned Catfish

Catfish, ¾ to 1½ pounds in size, absorb smoke satisfactorily within 5 hours of smoking with skin on. The skin protects the flesh from drying out and it acquires a pleasing golden appearance. A procedure developed at Auburn University for hot-process smoking pound-size catfish is outlined below:

1. The head may or may not be removed. If the head is removed, it is sectioned at the gill aperture, with gills being removed with the head, leaving the pectoral girdle intact, as shown in Figure 6. The abdominal cavity is opened from just posterior to the pectoral girdle to the vent for removal of viscera. Skin and caudal fin (tail) are left intact and dorsal and pectoral spines are removed. One-inch slits are made in the skin on each side of the fish near the tail to prevent "blisters" under skin as fat accumulates and/or expands during heating.

2. The fish are washed in tap water, then washed in brine of approximately 40° salometer concentration[1] to remove blood and slime, and washed again in tap water before brining.

[1] Salometer measures percent saturation of brine with salt. A reading of 100 percent saturated with salt or approximately 26 pounds of salt in 100 pounds of brine at temperature of 60° F. Amounts of salt and water for various brines may be calculated if Salometer is not available.

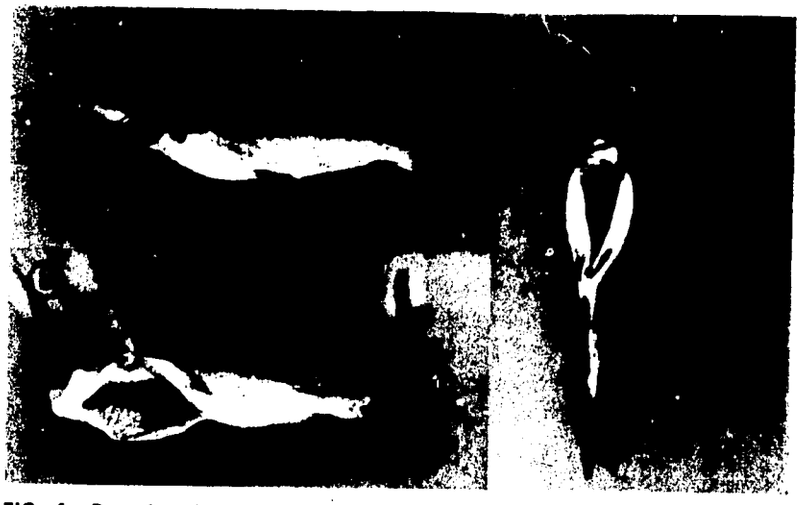


FIG. 6. Procedure for dressing catfish for smoking with skin: a) remove head at gill slits with gills removed and pectoral girdle left intact; remove spines; b) open abdominal cavity without cutting through pectoral girdle and remove viscera; slit skin near tail to prevent fat accumulation under skin; c) hang fish on bacon hooks with abdominal cavity open for smoking.

3. Brine strength required to yield a smoked fish with 3.5 percent brine in the loin muscle varies with size of fish, brining time and temperature, and smoking schedule (or amount of moisture lost in smoking). Soaking 1-pound catfish for 16-18 hours, in a refrigerator maintained at 37-39° F, in a 60° salometer concentration of brine (measured with salometer at 60° F) should yield the required salt concentration in the loin muscle of the smoked fish. Use approximately 200 pounds of brine per 100 pounds of fish.

4. After brining, the fish are rinsed (lightly) with water and hung in the smoker with the abdominal cavity held open. Temperature measuring devices are inserted next to the bone in the thickest section of fish in different areas of the smoker. Use hickory sawdust or chips for smoking.

5. If smoker has humidity control, use the following schedule: smoke for 1 hour at 100-110° F without added humidity; increase temperature to 160-170° F for 1 hour; increase temperature to 190-200° F and relative humidity to 78 percent until internal temperature of fish reaches 180° F; reduce smoker temperature to 180° F and hold for 15 minutes, then turn off humidifier and allow smoker temperature to recede to 100° F; allow smoking to

continue until the entire smoking process has taken 5 hours. Remove fish, air cool for 30 minutes, and refrigerate for 3 hours at 37-40° F.

6. For smokers without humidifiers, the following schedule should be satisfactory: maintain smoke from the time fish is put in until it is removed; increase temperature gradually until internal fish temperature of 180° F is reached in approximately 3½ to 4 hours (temperature of smoker 200-220° F); gradual heat increase is important without humidity control, to prevent splitting of fish; when fish temperature reaches 180° F reduce temperature to 190° F and hold for 15 minutes, then turn heat off; continue smoking for a total of 5 to 5½ hours; remove fish, air cool for 30 minutes and refrigerate for 3 hours at 37-40° F.

7. Package after fish have cooled for 3-5 hours. Unpackaged fish dry out and pick up surface contamination. Keep refrigerated until consumed.

8. Notes: Important critera for properly smoked catfish are the salt content in the final product and internal heating requirement for fish during smoking. The procedure for meeting these requirements will vary with the smoking technique used; thus, a processor who plans to market smoked catfish should determine the necessary brining and processing schedule for his facility that will allow for compliance with the regulations. Humidity controlled smokers are convenient but not necessary. Temperature recording devices for measuring internal fish and smoker temperatures are mandatory. Refrigerators for brining and for product storage are also necessary.

Smoking Skinned Catfish

A procedure was developed at the Georgia Agricultural Experiment Station for smoking dressed catfish weighing approximately 10 ounces. The same requirements were adhered to in processing the dressed catfish as were followed with the unskinned catfish, i.e., holding the internal fish temperature at 180° F for a minimum of 30 minutes and providing for a brine concentration in the loin muscle of the finished product of at least 3.5 percent. The procedure is as follows:

1. Brine conventionally dressed whole catfish for 24 hours at 38° F in a brine solution composed of 9 pounds of sugar and 9 pounds of salt in 72 pounds of water. Approximately 200 pounds

of brine should be used per 100 pounds of fish. Stir occasionally and keep all fish submerged.

2. Begin smoking at a temperature of 115° F inside the smoker and maintain this condition for 3 hours (the internal fish temperature will increase to approximately 90° F); gradually increase smoker temperature to 170° F over 19 hours (flesh temperature should reach 140° F); increase smoker temperature to 192° F over 3 hours and maintain for 1.5 hours (this should allow internal fish temperature to reach 180° F and remain there for 30 minutes).

3. Remove from smoker, cool, and package. Store in refrigeration.

Frozen catfish are satisfactory for smoking. Other ingredients may be added to the brine solution for flavor; however, if brine strength is measured by salometer, it should be done prior to the addition of sugar or other solutes.

Smoked catfish has considerable potential as a delicacy food, commanding a high price and entering new markets, because of its appealing appearance and flavor, and the fact that it does not have the small muscular bones that other popular smoked species have. The yield of smoked catfish expressed as a percentage of original live weight is approximately 45 percent when the skin is left intact and the head removed. Approximately 42 percent of the original weight is marketed when the fish is dressed prior to smoking.

CHEMICAL AND NUTRITIONAL VALUES FOR FARM-RAISED CATFISH

CATFISH, as compared with red meat animals, would generally be considered to be high in protein and relatively low in fat. The composition of catfish flesh varies appreciably, as indicated in Table 1, with season, size of fish, type of feed, and other factors. This variation is primarily related to the wide range in fat content. The dressing percentage and composition of moisture, protein, fat, and ash of the edible portion of farm-raised catfish, shrimp, red meat, and poultry are compared in Table 1.

The nutritive values required for nutritional labeling of a commercial food are shown in Table 2.

The quality of the protein in catfish muscle is high and comparable with that in milk (casein) and warm blooded animal muscle. Table 3 shows the essential amino acid composition of the protein in catfish, beef, marine fish (haddock), and cereal grain and the FAO/WHO recommended amino acid pattern for human nutrition. Catfish protein contains slightly less of the valuable sulfur amino acid, methionine, than marine fish or red meat, but it is a valuable source of lysine which is the most deficient amino acid in cereal grains.

The fat in catfish is considerably different chemically from marine fish fat; in fact, it resembles the fat from livestock more than it does marine fish oil (Table 4). The chemical relationship is not unexpected considering the similarity in diets of feedlot animals and farm-raised catfish and the effect that food has on depot fat composition. Fat composition of cultured channel catfish fed different sources of fat, of marine fish (herring) fat, and of beef fat are compared in Table 4. Note the effect that diet has on fatty acid composition of catfish fat. The marine fish contains much higher quantities of polyunsaturated (20:5 and 22:5 and 22.6) fatty acids than do catfish fed the practical or vegetable oil diets. The relatively low content of polyunsaturated fatty acids, which oxidize easily, explains why the flavor of farm-raised catfish remains stable in frozen storage over long periods of time.

A large amount of information has been collected on chemical and nutritive values for farm-raised catfish at several experiment stations; namely, in Mississippi, Georgia, and Alabama. The

values presented in tables in this section are in general agreement with those obtained at the different stations.

TABLE 1. DRESSING PERCENTAGE AND CONTENTS OF MOISTURE, PROTEIN, FAT AND ASH IN EDIBLE PORTION OF CULTURED CATFISH, BEEF, PORK, AND POULTRY

Food animal	Dressing percentage	Percent of edible portion			
		Moisture	Protein	Fat	Ash
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Cultured catfish[1]	60	72-77	15-18	4-10	1.1
Shrimp[2]	40	82.4	17.8	0.1	1.9
Pork[2]	65	50-57	13-16	25-32	1.0
Beef[2]	58	55-59	15-19	11-25	1.0
Poultry[2]	72	75	19	4.5	1.0

[1] Harvest-size channel catfish weighing .75 to 1.5 pounds; source, Fisheries Annual Report, Auburn University Agricultural Experiment Station, 1972.
[2] Source: Composition of Foods, Agriculture Handbook No. 8, USDA.

TABLE 2. COMPOSITION OF FARM-RAISED CATFISH, 100 GRAMS, EDIBLE PORTION[1]

Component	Description	Quantity
Water	Raw: Fall harvested	72.4%
	Spring harvested	76.2%
Food energy[2]	Raw: Fall harvested	146 calories
	Spring harvested	115 calories
Protein	Raw: Fall harvested	16.9 grams
	Spring harvested	18.5 grams
Fat	Raw: Fall harvested	8.7 grams
	Spring harvested	4.0 grams
Carbohydrate	Raw	0
Ash	Raw	.9 grams
Calcium	Raw	11 milligrams
Phosphorus	Raw	168 milligrams
Iron	Raw	1.1 milligrams
Sodium	Raw	51 milligrams
Potassium	Raw	270 milligrams
Vitamin A	Raw	0
Thiamine	Raw	0.05 milligrams
Riboflavin	Raw	0.12 milligrams
Niacin	Raw	3.7 milligrams
Ascorbic acid	Raw	0
Cholesterol	Raw	58 milligrams

[1] Edible portion represents whole dressed carcass, weighing approximately 300-350 grams, with bones removed. Source: Fisheries Annual Reports, Auburn University Agricultural Experiment Station, 1970, 1971, 1972, and to be published, 1974.
[2] Calculated: (protein × 4.27) + (fat × 9.02).

TABLE 3. ESSENTIAL AMINO ACID COMPOSITION OF CHANNEL CATFISH, MARINE FISH (HADDOCK), BEEF, AND CEREAL (RICE)[1]

Amino acid	Percent of protein				
	Catfish	Haddock	Beef	Rice	FAO pattern
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Arginine	6.3	5.7	6.1	8.8	
Histidine	2.8	1.9	3.6	2.3	
Isoleucine	4.3	5.4	5.0	4.4	4.0
Leucine	9.5	7.5	7.8	8.6	7.0
Lysine	10.5	8.6	8.7	2.8	5.5
Methionine	1.4	2.8	2.7	1.4	3.5[2]
Phenylalanine	4.8	3.7	3.8	4.8	6.0[3]
Threonine	4.8	4.2	4.5	3.6	4.0
Valine	4.7	5.6	5.2	6.4	5.0
Tryptophan	0.8	0.9	1.0	0.1	1.0
Total essential	49.9	46.3	48.4	43.2	
Nonessential	50.1	53.7	51.6	56.8	

[1] Sources: catfish, Fisheries Annual Report, Auburn University Agricultural Experiment Station, 1971; haddock and beef, *Fish as Food*, Academic Press, 1962; rice, Tables of Feed Composition, NRC/NAS, Washington, D.C., 1969; FAO pattern of amino acids, Protein Requirements, WHO Technical Series No. 301, 1965.
[2] Methionine + cystine.
[3] Phenylalanine + tyrosine.

TABLE 4. FATTY ACIDS COMPOSITION OF FAT FROM CHANNEL CATFISH FED THREE TYPES OF DIETS, FROM MARINE FISH (HERRING) AND FROM BEEF[1]

Fatty acid	Catfish			Marine fish (Herring)	Beef
	Practical diet	Fish oil diet[2]	Soybean oil diet[2]		
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
14:0	1.7	4.8	1.0	8.0	4.0
16:0	24.4	18.2	19.2	18.0	25.0
16:1	4.4	3.7	1.3	9.0	5.0
18:0	4.7	4.5	5.0	2.0	19.0
18:1	51.0	30.0	30.0	17.0	36.0
18:2	7.2	12.1	36.6	2.0	6.0
18:3	.1	.8	1.1	trace	1.0
18:4	.8	1.1	1.0	3.0	----
20:1	----	.5	1.5	9.0	----
20:2	----	----	----	----	----
20:3	----	----	----	----	----
20:4	1.5	1.4	1.9	trace	----
20:5	----	4.3	----	9.0	----
22:1	----	----	----	12.0	----
22:2	----	trace	trace	----	----
22:3	----	----	----	----	----
22:4	----	trace	----	----	----
22:5	trace	2.3	.3	1	----
22:6	2.2	11.0	.8	9	----

[1] Sources: catfish, Fisheries Annual Report, Auburn University Agricultural Experiment Station, 1972; marine fish and beef, Fish Oils-Fatty Acid Composition, Fisheries Industrial Research Vol. 5, No. 1, 1969.
[2] Fish oil diet contained 9% menhaden oil. Soybean oil diet contained 9% soybean oil.

NEW DEVELOPMENTS IN CATFISH PROCESSING AND MARKETING

New Products

SMOKED CATFISH and precooked, frozen, breaded catfish are two products with considerable market potential that have previously been discussed in this report. Others that have been explored in various experimental laboratories are the following:

A. Canned catfish – The consensus of a survey conducted by Mississippi State University, involving cities located throughout the United States, indicated that canned channel catfish was nearly as acceptable as canned salmon. Canning technology for channel catfish was developed at the Mississippi Agricultural and Forestry Experiment Station and the following recommendations have been presented:

1. Dressed fish may be steamed for 3 to 4 minutes and the flesh separated from the bones or the fish may be sectioned for canning without removing the bones.

2. Solid-pack the flesh into approximately 1-pound cans, size 303 x 406. Can construction should be of 85-pound plate with interior coating of C-25 enamel and 55-844 sealing compound at the ends.

3. Steam evacuate the cans and close.

4. Process the cans for 65 minutes at 250° F in a stationary retort or 35 minutes at 260° F in an agitating steritort at 5 r.p.m. These processes yields F_0 values of 6.5 to 7.5 process time. There was no deterioration of the inside of the can after 10 months storage at 100° F.

B. Component of minced fish products – By far the highest volume fish product marketed in the United States is fish sticks which are rather bland, boneless, breaded cakes of nonspecific species of fish flesh, sold frozen in precooked or uncooked forms. The supply of fish flesh for these products, which is imported fish blocks from cod and other lean marine species is decreasing rapidly. This has elevated prices of fish sticks and offers a potential market for freshwater species in this type of product. Equipment is currently available that does an effective job of separating flesh from skin and bones from almost any species of fish. This will allow minced (deboned) flesh from low value freshwater species to be used for products like fish sticks. Catfish flesh was

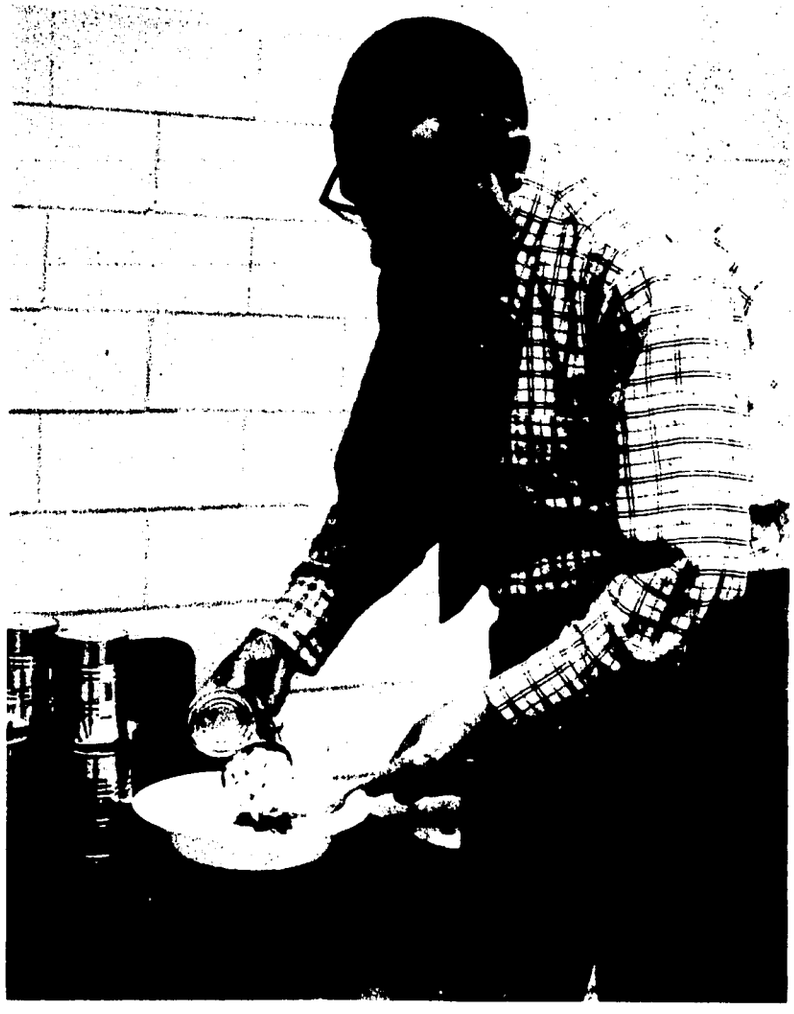


FIG. 7. Canned channel catfish was found to be a highly acceptable product, nearly equal to canned salmon, by consumers in cities in various areas of the United States.

found to be a valuable ingredient in such products either as minced flesh or when intact (non-deboned) catfish muscle was added to improve texture. Low value fish or fish that may be grown as a complementary species with catfish, such as carps, tilapias, or buffalo, may be processed as minced flesh and serve as the primary source of fish in the fish cake, whereas catfish, a

high value fish, may be added in proportions varying from 25 to 50 percent to improve texture, appearance and flavor. The frames (backbone, rib bone) from which catfish flesh has been filleted may be passed through the bone separator and the minced catfish flesh recovered quite efficiently.

C. Albino catfish – There are pronounced differences in carcass appearance between albino and conventionally colored channel catfish. The dermal membranes of the albino are almost white and give the flesh a lighter, more pink appearance versus a gray appearance for the conventionally pigmented fish. Consumer evaluation tests revealed a decided preference for the albino catfish. The facts that albino channel catfish can be propagated and that they grow at a similar rate to the pigmented channel, justify more emphasis on production of the albino for processing.

New Methods in Processing

One of the most important needs of catfish processors is automated equipment in the plant; however, the relatively small size of the industry will not justify the large amount of money and time required to develop such equipment. Developments in other areas processing areas which may be beneficial are the following:

1. Stunning – Immobilization of catfish, prior to beheading, by alternating current (A.C.), immersion in carbon dioxide (CO_2)-saturated water, bleeding, and icing were evaluated at the Georgia Agricultural Experiment Station. All methods were effective in immobilizing the fish, whereas electrical shock and icing produced fish of poorest quality. The bleeding (without stunning) and carbon dioxide immobilization techniques produced decidedly the best appearing product. The CO_2 method, which probably would be more practical to use in processing plants, consists of immersing the fish in CO_2-saturated water for 3 to 5 minutes. It precludes muscular contraction and allows adequate bleeding after the fish is beheaded.

2. Chemical skinning – A method was developed and patented by the Mississippi Agricultural and Forestry Experiment Station, Mississippi State University, for removing the skin with a sodium hydroxide solution. Information regarding use of this procedure is available from that source.

3. Hypoxanthine assessment of freshness of catfish – Hypoxanthine is an end-product compound produced in fish muscle after

death as a result of post-mortem breakdown of adenosine triphosphate, the functional materials in muscular contraction. Hypoxanthine level increases with time after death and its rate of increase closely parallels rate of spoilage of fish flesh. It can be measured accurately and conveniently and was found at the Georgia Agricultural Experiment Station to be a reliable index of the freshness of dressed catfish. The use of a reliable objective (chemical) indicator such as this could replace the subjective (smell) method for evaluating the freshness of processed catfish.

PUBLISHED INFORMATION

Catfish Processors Workshop

PROCEEDINGS of annual workshops 1971-1974 are available from Mississippi Agricultural and Forestry Experiment Station or Mississippi Cooperative Extension Service, Mississippi State, MS 39762.

Hauling, Stunning, Skinning

AMMERMAN, G. R. 1972. U.S. Patent No. 3706333. Fish Skinning Process. U.S. Government Patent Office, Washington, D.C.

AMMERMAN, G. R., W. G. LEE, S. R. DRAKE, J. B. MAGEE, AND W. POOLKASEM. 1973. Catfish Processing. Miss. Agr. and Forestry Exp. Sta. Tech. Bull. 68.

BOGGESS, T. S., JR., E. K. HEATON, A. L. SHEWFELT, AND D. W. PARVIN. 1973. Techniques for Stunning Catfish and Effects on Quality. J. Food Science 38:1190-1193.

ECONOMIC DEVELOPMENT ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE. 1970. A Program of Research for the Catfish Farming Industry. Technical Assistance Project, prepared under the direction of Fish and Wildlife Service, U.S. Department of the Interior.

LEE, W. G. 1971. The Skinning and Flavoring of Channel Catfish. M.S. Thesis. Miss. State Univ., MS 39762.

LEE, W. G. AND G. R. AMMERMAN. 1971. Better Means of Processing Catfish Sought. Miss. Farm Res. Vol. 34, No. 11.

Keeping Quality: Iced, Frozen

AMMERMAN, G. R., W. G. LEE, S. R. DRAKE, J. B. MAGEE, AND W. POOLKASEM. 1973. Catfish Processing. Miss. Agr. and For. Exp. Sta. Bull. 68.

BEUCHAT, L. R., E. K. HEATON, AND T. S. BOGGESS, JR. 1973. Preservation of Channel Catfish with Some Selected Chemicals. J. Food Sci. 38:531-535.

BOGGESS, T. S., JR., E. K. HEATON, AND A. L. SHEWFELT. 1971. Storage Stability of Commercially Prepared and Frozen Pond-Raised Catfish. J. Food Sci. 36:969-973.

BOTTA, J. R. AND J. E. RUTLEDGE. 1974. Assessment of Some Chemical Indices of Texture and Flavor of Frozen Stored Channel Catfish. Special report, Department of Food Science, Louisiana State University, Baton Rouge, La. 70803.

DRAKE, S. R. 1971. A Study of Packaging, Storage Temperature and Storage Length on Quality of Channel Catfish. M.S. Thesis, Miss. State Univ., MS 39762.

DRAKE, S. R. AND G. R. AMMERMAN. 1971. Shelf-Life. The Catfish Farmer Magazine. 3(5):23.

DRAKE, S. R. 1973. Shelf-Life of Pre-Cooked Frozen Channel Catfish as Affected by Various Processing Variables. Ph.D. Dissertation. Miss. State Univ., MS 39762.

DRAKE, S. R. 1974. Polyphosphates and Package Requirements in Precooked Channel Catfish. Miss. Agr. and For. Exp. Sta. Info. Sheet 1232.

GREIG, R. S. AND J. R. DONAHUE. 1969. Frozen Capabilities of Channel Catfish. U.S. Dept. of the Interior, Bureau of Commercial Fisheries, Information Sheet, N.P.

HEATON, E. K., J. PAGE, J. W. ANDREWS, AND T. S. BOGGESS, JR. 1972. Changes in Quality of Channel Catfish Held on Ice Before and After Processing. J. Food Sci. 37:841-844.

MAGEE, J. B. 1972. Storage Stability Studies of Fresh Dressed Catfish. Proc. 2nd Ann. Catfish Processors Workshop, Miss. State Univ., MS 39762.

LOVELL, R. T. AND D. F. LEARY. 1972. Influence of Dietary Fats on Chemical and Sensory Changes in Frozen Catfish at 3, 6, and 12 Months. Fisheries Ann. Rep., Auburn Univ. (Ala.) Agr. Exp. Sta., Auburn, Ala. 36830. p. 33.

Marketing

GILLESPIE, S. M. 1971. An Experimental Study of Seafood Merchandising Strategies in a Supermarket. Sea Grant Program of Texas A&M University, TAMU-SG-71-221.

GREENFIELD, J. E. 1970. Catfish Marketing – 1970. Special report, Bureau of Commercial Fisheries, U.S. Department of Commerce, 5 Research Drive, Ann Arbor, Mich.

JONES, W. G. 1969. Market Prospects for Farm Catfish Production. Presented at Comm. Fish Farming Conf., University of Georgia, Athens, Ga.

JONES, W. G. 1969. Marketing Considerations, Economics and Market Potential for Farm Catfish. Presented at 99th Ann. Meet. of Amer. Fish Soc., New Orleans, La., Sept. 11-13, 1969.

MORRISON, W. R. 1971. Products and Packaging. Presented at the Catfish Production and Marketing Conference, Muscle Shoals, Ala., June 30, 1971.

RAULERSON, R. C. 1972. Opportunities for Catfish Farming in the South. Atlanta Economic Review, Nov.-Dec., 1972, pp. 41-43.

MCCOY, E. W. 1973. Catfish Marketing and Related Production Factors. Agr. Exp. Sta. Cir. 206. Auburn Univ. (Ala.) Agr. Exp. Sta., Auburn, Ala.

RAULERSON, R. C. AND W. K. TROTTER. 1973. Demand for Farm-Raised Catfish in Supermarkets: Analysis of a Selected Market. Marketing Res. Rep. No. 993. Economic Research Service, USDA.

TROTTER, W. K. 1973. Report on Marketing Research to Catfish Farmers of America. Special report, Economic Research Service, Richard B. Russell Agricultural Research Center, USDA, Athens, Ga.

WHITE, E. D. 1973. The Market Potential for Catfish. Unpublished report, Marketing Economics Division, Economic Research Service, USDA, Albany, Ga.

Nutritive and Chemical Composition

BEUCHAT, L. R. 1973. Hypoxanthine Measurement in Assessing Freshness in Channel Catfish. J. Agr. Food Che. 21(3):453-455.

BOGGESS, T. S., JR., E. K. HEATON, AND A. L. SHEWFELT. 1970. Some Quality Comparisons Between Pond and Raceway Catfish. Proc. Assoc. Southern Agr. Workers. Ann. Conv., p. 110.

HEATON, E. K., T. S. BOGGESS, JR., AND DR. R. LANDES. 1971. Some Evaluations of Quality of Channel Catfish. Amer. Fish Farmer, July, 1971, pp. 5-6.

HEATON, E. K., T. S. BOGGESS, JR., AND R. E. WORTHINGTON. 1973. Quality Comparisons of Albino and Regular (Gray) Channel Catfish. J. Food Sci. 38:1194-1196.

MILLER, J. 1973. Nutritive Value of Cooked Catfish as Determined by Rat Growth and Lipid Metabolism. Nutr. Rep. Int. 7(3):141-149.

LOVELL, R. T. 1970. Some Chemical and Sensory Aspects of Freshwater Catfish (Genus *Ictalurus*). Proc. Assoc. Southern Agr. Workers Ann. Conv., p. 111.

WORTHINGTON, R. E., T. S. BOGGESS, JR., AND E. K. HEATON. 1972. Fatty Acids of Channel Catfish (*Ictalurus punctatus*). J. Fish. Res. Board Con. 29:113-115.

WORTHINGTON, R. E. AND R. T. LOVELL. 1973. Fatty Acids of Channel Catfish: Variance Components Related to Diet, Within Diets and Variability Among Fish. J. Fish Res. Board Can. 30:1604-1608.

YOUNG, CLYDE T. 1970. Amino Acid Composition of Catfish Muscle. Proc. Assoc. Southern Agr. Workers Ann. Conv., p. 112.

Off-Flavor

IREDALE, D. G. AND K. J. SHAYKEWICH. 1973. Masking or Neutralizing the Muddy Flavor in Rainbow Trout (*Salmo gairdneri*) by Smoking and Canning Processes. J. Fish. Res. Bd. Canada 30(8):1235-1239.

LOVELL, R. T. 1972. Fight Against Off-Flavor Inches Ahead. Fish Farming Industries 4(1):21.

LOVELL, R. T. 1972. Factors Affecting Flavor in Cultured Catfish. Catfish Farmer Magazine 3(6):7.

LOVELL, R. T. AND L. A. SACKEY. 1973. Absorption by Channel Catfish of Earthy-Musty Flavor Compounds Synthesized by Cultures of Blue-Green Algae. Trans. Amer. Fish. Soc. 102(4):774.

LOVELL, R. T. 1973. Environment-Related Off-Flavors in Intensively Cultured Fish. Proc. of Tech. Conf. on Fish. Products, Dec. 4-11, 1973, Tokyo, Japan. FAO (United Nations) Publ. FIL:FP/73/E-46.

LOVELL, R. T. 1973. Comparison of Organoleptic Quality of Largemouth Bass Fed Natural and Artificial Diets. Fisheries Annual Report, Auburn University (Ala.) Agr. Exp. Sta., Auburn, Ala. 36830 p. 23.

SHUMWAY, D. L. AND J. R. PALENSKY. 1973. Impairment of the Flavor of Fish by Water Pollutants. Ecological Research Series, EPA-R3-73-010. Office of Research and Monitoring, U.S. Environmental Protection Agency, Washington, D.C. 20460.

Plant Sanitation

MCCASKEY, T. A., R. T. LOVELL. 1973. Technique for Bacterial Analysis of Processed Channel Catfish. II. Enumeration of Surface Bacteria on Dressed Catfish. Proc. of 70th Ann. Meeting of Assoc. of Southern Agr. Workers. p. 147.

LANE, P. 1970. Recommendations for the Sanitary Operation of Plants that Process Fresh and Frozen Fish. Special report, Bureau of Commercial Fisheries, U.S. Department of Commerce, Gloucester, Mass.

LOVELL, R. T. AND T. A. MCCASKEY. 1973. Technique for Bacterial Analysis of Processed Channel Catfish. I. Determination of Surface Area of Dressed Catfish. Proc. of 70th Ann. Meeting of Assoc. of Southern Agr. Workers. p. 146.

PUBLIC HEALTH SERVICE, U.S. DEPARTMENT OF HEALTH EDUCATION AND WELFARE AND FISH AND WILDLIFE SERVICE, U.S. DEPARTMENT OF THE INTERIOR. 1967. Sanitation Standards for Smoke Fish Processing: Part 1, Fish-Smoking Establishments – 1967 Recommendations. Public Health Serv. Publ. No. 1587. Price 20 cents, U.S. Government Printing Office, Washington, D.C. 20402.

Processing Economics

ECONOMIC DEVELOPMENT ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE. 1970. A Program of Research for the Catfish Farming Industry. Technical Assistance Project, prepared under direction of Fish and Wildlife Service, U.S. Department of the Interior.

MCCOY, E. W. AND A. B. SHERLING. 1973. Economic Analysis of the Catfish Processing Industry. Auburn Univ. (Ala.) Agr. Exp. Sta. Cir. 207.

RUSSELL, J. R. 1972. Catfish Processing – A Rising Southern Industry. Agric. Econ. Rep. No. 224, Economic Research Service, USDA, Washington, D.C. 20250.

SCHULER, G. A. 1971. Hold That Catfish Flavor (Leaflet No. 116). Foods, Hands and Bacteria (Bull. 693). Cooperative Extension Service, University of Georgia, Athens, Ga.

Processing Technology: Canning, Freezing, Ice-pack, Packaging, Pre-cooked Frozen, Mechanical Deboning

AMMERMAN, G. R., W. G. LEE, S. R. DRAKE, J. B. MAGEE, AND W. POOLKASEM. 1973. Catfish Processing. Miss. Agr. and For. Exp. Sta. Bull. 68.

DRAKE, S. R. 1971. A Study of Effect of Packaging, Storage Temperature, and Storage Length on the Quality of Channel Catfish. M.S. Thesis. Miss. State Univ., MS 39762.

DRAKE, S. R. 1971. A Shelf-Life Study Concerning Precooked Frozen Channel Catfish as Affected by Various Processing Variables. Ph.D. Dissertation. Miss. State Univ., MS 39762.

ECONOMIC DEVELOPMENT ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE. 1970. A Program of Research for the Catfish Farming Industry. Technical Assistance Project, prepared under direction of Fish and Wildlife Service, U.S. Department of the Interior.

FROZEN FOOD COORDINATING COMMITTEE. 1970. Code of Recommended Practices for the Handling of Frozen Food. Presented at Ann. Meet. of Inst. of Food Tech., San Francisco, Calif., May 25, 1970.

LEE, W. G., C. S. RAO, AND G. R. AMMERMAN. 1972. A Special Report on a Meat Bone Separator. The Catfish Farmer Magazine. Vol. 4, No. 6, p. 17.

POOLKASEM, W. 1971. Freeze-Dried Channel Catfish. M.S. Thesis. Miss. State Univ., MS 39762.

POOLKASEM, W. AND G. R. AMMERMAN. 1971. Freeze-Dried Channel Catfish. Proc. 2nd Ann. Catfish. Proc. Workshop, Miss. State Univ., MS 39762.

Processing Waste Utilization

BEUCHAT, L. R. 1974. Preparation and Evaluation of a Microbial Growth Medium Formulated from Catfish Waste Peptone. J. Milk and Food Tech. 37:277-281.

ECONOMIC DEVELOPMENT ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE. 1970. A Program of Research for the Catfish Farming Industry. Technical Assistance Project, prepared under direction of Fish and Wildlife Service, U.S. Department of the Interior.

LOVELL, R. T. 1971. Evaluation of Catfish Offal Meal and Catfish Oil in Fish Diets. Fisheries Ann. Rep., Auburn Univ. (Ala.) Agr. Exp. Sta., Auburn, Ala. 36830. p. 1.

LOVELL, R. T. 1971. Growth of Rats Fed Fermentation – Preserved Catfish Offal – Corn Diets. Fish. Ann. Rep., Auburn Univ. (Ala.) Agr. Exp. Sta., Auburn, Ala. 36830. p. 16.

LOVELL, R. T. 1972. Use of Catfish Waste in Fermentation – Preserved Diets and in Dry-Pelleted Diets Compared with Fish Meal for Growing Channel Catfish. Fisheries Ann. Report, Auburn Univ. (Ala.) Agr. Exp. Sta., Auburn, Ala. 36830. p. 13.

LOVELL, R. T. 1973. Put Catfish Offal to Work for You. Fish Farming Industries, Oct.-Nov., 1973. p. 21.

LOVELL, R. T. 1973. Catfish Waste Meal as a Source of Animal Protein in Swine Rations. Fisheries Annual Report, Auburn Univ. (Ala.) Agr. Exp. Sta., Auburn, Ala. 36830. p. 3.

LOVELL, R. T. AND H. K. DUPREE. 1973. Replacement Value of Catfish Waste Meal for Marine Fish Meal in Catfish Feeds. Fisheries Annual Report, Auburn Univ. (Ala.) Agr. Exp. Sta., Auburn, Ala. 36830. p. 9.

Smoking

BOGGESS, T. S., JR., E. K. HEATON, AND L. R. BEUCHAT. 1973. A Procedure for Processing Smoked Channel Catfish. J. Milk and Food Tech. 36(9):469-473.

DUDLEY, S., J. T. GRAIKOSKI, H. L. SEAGRAN, AND P. M. EARL. 1970. Sportsman's Guide to Handling, Smoking and Preserving Great Lakes Coho Salmon. Cir. 346. Bureau of Commercial Fisheries, Fish and Wildlife Service, U.S. Department of the Interior.

DOUGHERTY, J. B. AND H. L. SEAGRAN. 1966. Steps to Effective Sanitation in Smoked-Fish Plants. Cir. 259. Bureau of Commercial Fisheries, Fish & Wildlife Service, U.S. Department of the Interior, Washington, D.C.

FEDERAL REGISTER. 1970. Smoked and Smoke-Flavored Fish. Rules and Regulations: Part 128a-Fish and Seafood Products. Vol. 35, No. 221, Nov. 13, 1970.

LOVELL, R. T. 1972. Smoked Catfish. Fisheries Ann. Rep., Auburn Univ. (Ala.) Agr. Exp. Sta., Auburn, Ala. 36830. p. 40.

PUBLIC HEALTH SERVICE, U.S. DEPARTMENT OF HEALTH EDUCATION AND WELFARE AND FISH AND WILDLIFE SERVICE, U.S. DEPARTMENT OF THE INTERIOR. 1967. Sanitation Standards for Smoked-Fish Processing: Part I, Fish – Smoking Establishments – 1967 Recommendations. Public Health Service Publ. No. 1587. Price 20 cents, U.S. Government Printing Office, Washington, D.C. 20402.

SEAGRAN, H. L., J. T. GRAIKOSKI, AND J. S. EMMERSON. 1970. Guidelines for Processing Hot-Smoked Chub. Cir. 331. Bureau of Commercial Fisheries, Fish & Wildlife Service, U.S. Department of the Interior.