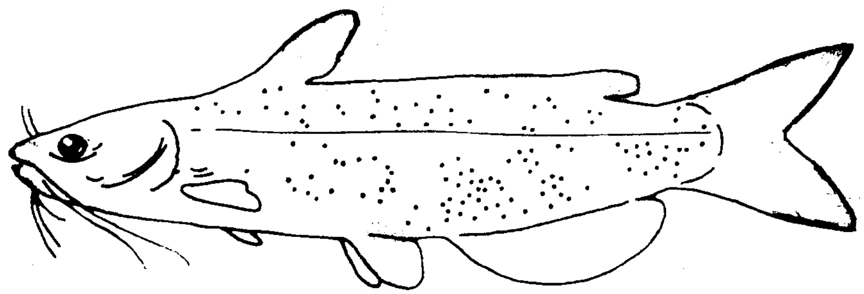
CHANNEL CATFISH

PRODUCED IN KANSAS PONDS FOR PROFIT AND PLEASURE



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Channel Catfish

Produced in Kansas Ponds for Profit and Pleasure

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INTRODUCTION

Channel catfish, widely distributed in warm-water lakes and streams, grow rapidly to catchable and edible size; can be caught with a wide variety of baits and lures during most of the year; provide considerable resistance at the end of the fishing line; and are a food delicacy. For those reasons, many sportsmen find catfish attractive.

Large numbers of catfish fry can be obtained from relatively few spawners; the fish take prepared dried granules and pellets; when stocked in large numbers in ponds, they usually will not become overpopulated and stunted there; and they grow and survive well in properly stocked ponds when given supplemental food. Catfish are therefore considered desirable for commercial production.

Channel catfish are less hardy than bullheads or carp. Like bass and bluegill, however, they respond to changes in water temperature, low levels of oxygen, increased carbon dioxide, and other undesirable physical conditions. Like most fishes, channel catfish must be handled carefully and not injured. When taken from water, they should be returned as quickly as possible. Severe stress or injury could result in disease or death.

Some fish-pond operators are involved primarily in obtaining eggs (embryos), hatching tiny fish, and feeding them until they become fingerlings of various sizes. Other operators buy fingerlings and feed them until they are of edible or fishing sizes (12 to 16 ounces or more). Still others who prefer a fully integrated operation, produce fry and process the final product.

To date emphases in catfish research have been on fish nutrition, digestion, and metabolism. For many years the Kansas Fish and Game Commission has been successfully hatching millions of channel catfish and rearing them to fingerlings. The Commission has focused on obtaining information on feeding newly hatched fish, on methods of producing numerous fish large enough to escape most predators when stocked in lakes where other species are present, and on selecting faster-growing fish.

More recently, there have been cooperative investigations by the Kansas Agricultural Experiment Station at Kansas State University, the Kansas Fish and Game Commission, the Bureau of Sport Fisheries and Wildlife, and the National Marine Fisheries Service. Experiments have been conducted in farm ponds and in 28 l/7-acre ponds at the Tuttle Creek Fisheries Research Laboratory located on land licensed from the U.S. Army Corps of Engineers below Tuttle Creek Dam.

Our data from these investigations should be valuable both to sportsmen and to commercial fish producers. This report expands on, and supersedes, *Producing Channel Catfish* by Tiemeier and Deyoe (1973c).

CONSIDERATIONS IN LOCATING, CONSTRUCTING, AND MAINTAINING PONDS FOR CHANNEL CATFISH

Constructing ponds and other rearing facilities

Ponds

There are advantages to having several rows of rectangularly shaped ponds with a large water-supply pipe between rows and smaller pipes to each pond, each with drainage pipes that empty into separate ditches at either end (Fig. 1). Each pond should be a separate unit so it may be managed as such. Water should not pass from one pond to another, to avoid spreading parasites and diseases. When it is necessary to treat fish, only those in one pond should be (and can be) treated at a time. Also, each pond can be drained, fish removed, pond repaired, or changes made without affecting any other pond. In addition, having the long axis of the pond parallel to the prevailing direction of summer winds stimulates water movement and increases supply of dissolved oxygen.

Drain pipe in ponds. The pipe used to drain a pond should be low enough to permit all water to drain from the pond and should be sufficiently large to allow the pond to be drained within a reasonable time and the fish in the pond to pass through the pipe. Data on pipe sizes can be obtained from the Soil Conservation Service or from an engineer planning the pond. Except when the pond is being drained, the end of the drain pipe inside the pond must be covered with screen to exclude the channel catfish, for catfish seeking places to hide will enter open pipes and suffocate. The easiest way to harvest fish, after preliminary seining, is to permit them to pass

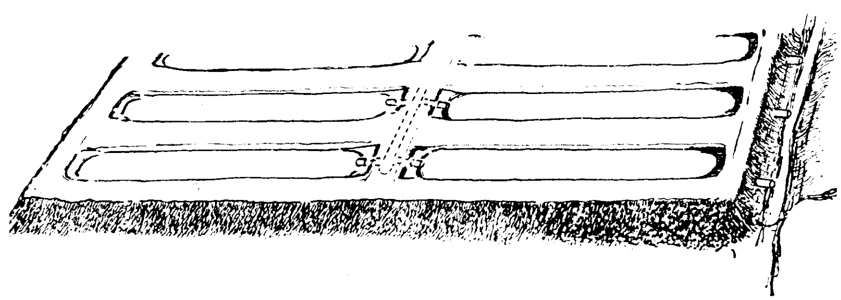


Figure 1. *Rows of ponds showing large center water-supply pipe, smaller pipes to each pond, and drain pipes.*

through the drain pipe into a basin at the end of the pipe (Fig. 2). The basin may be of concrete or other permanent material or it may have a base of wood with wire above the base. When a drain valve is opened and fish are not disturbed, most, if not all, fish go through the pipe with the water. They can then be dipped into buckets and hauled to a loading truck or, if the pond is large and contains many fish, they can pass into a mechanical elevator or otherwise be carried into a loading truck.

Pond slope. Probably the best slope for sides of ponds is 3 to 1, a slope that usually can be maintained and also permits easy access to all pond areas. Pond bottoms should be smooth and sloped toward the drain. Particular care should be taken to assure that all water will flow to the drain, thus avoiding small pockets of shallow water containing fish difficult to harvest.

Pond depth. Channel catfish grow well in water no more than 3 or 4 feet deep during summer months; but in winter, water should be 6 to 8 feet deep to provide sufficient oxygen below a thick ice cover. During much of the summer, water 6 or more feet deep, in small ponds, may become deficient or devoid of oxygen, and then the fish will not do well.

Pond size. Anyone owning a pond containing water can get into the fish-feeding business, but anyone planning to derive much income from it should plan eventually to have 60 acres or more of water under intensive production. Sixty to 100 acres now can provide a sizeable income and apparently can be managed by one family, with additional help during busy seasons.

Persons not familiar with handling fish should plan to begin operations in several ponds, then expand if an aptitude for rearing fish prompts them to do so. Rearing and feeding fish, a highly technical, demanding occupation, requires considerable “know how” for success.

Ponds of less than 1 acre to more than 100 acres have been used to produce channel catfish. Large ponds, though they cost less per acre of water than do small ones, have several disadvantages. If parasites or diseases break out in one large pond, it is difficult to treat the fish. Resulting losses can be large. A 50-acre pond, stocked with 1,500 to 2,000 fingerlings per acre, gives 75,000 to 100,000 fish to harvest at one time—a difficult job. Ponds of 5 to 20 acres, more manageable than larger ponds, in time will more than pay their added cost of upkeep. In determining size of individual ponds, a rule-of-thumb is to have no pond larger than one that can be harvested and processed in a day. Numerous fish confined in a small pond area being drained can stir mud, deplete oxygen supply, or acquire an undesirable flavor.

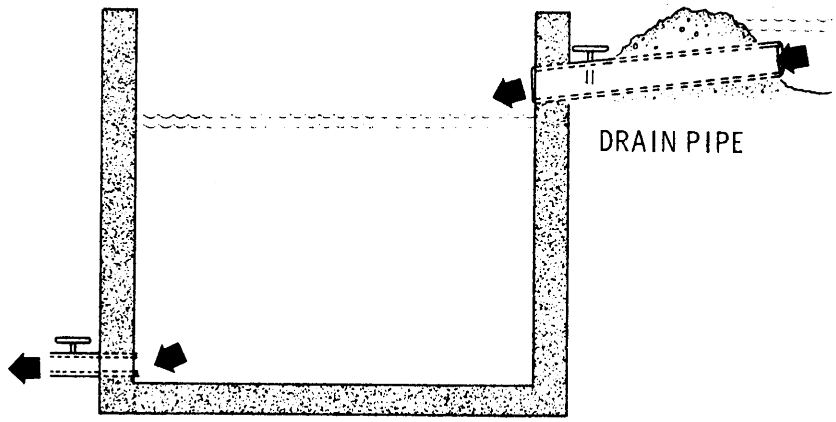


Figure 2. *Basin to catch fish at end of drain pipe from pond. Fish can be removed from this tank.*

Raceways

Within the past few years, channel catfish producers have constructed long ditches or canals—such as have been used for many years by producers of trout—for growing their fish. To do that large volumes of warm water must be readily available because fish are stocked at a high rate, which produces large amounts of waste products. Raceways have these advantages: Minimum land and water areas are required, and the water temperature can be maintained sufficiently high to produce fish the year round. These are disadvantages: Large volumes of water must be available, additional crowding of fish could cause stress to the fish, and failures in the water supply could result in loss of thousands of fish.

Closed systems

In closed- or confinement-rearing systems, a series of tanks are placed near each other in a building. Fish are stocked at a high rate, and warm or heated water flows continuously through these tanks. Because the supply of heated water usually is limited, a water-purification system involving use of a filter is required. Producing fish in such a system may be costly, and the novice may experience problems in maintaining water quality.

Cage culture

When it is not feasible to harvest fish by seining or draining water areas, some producers confine fish in wire cages, from which they can readily harvest the fish. No more fish can be produced in the cages than in the body of water without cages. If other fishes also are present in the water, they may have access to some of the feed. To reduce feed losses from the cage, the producer should supply the more expensive floating feed to the caged fish. Thus, cost of cages and feeds could increase production cost.

Water supply

There are advantages and disadvantages to wells or streams as water sources. In either instance, it is imperative that the source provide sufficient fresh water when it is needed most, as during a hot, dry summer.

The quantity of water that can be provided by a good well can be determined. Proper pumping equipment is essential for obtaining water at the lowest cost in expenditure of energy. Well water is often 60°F or less. However, the flow into a pond may be regulated to prevent sudden changes in pond-water temperature. Well water is generally free of parasites and disease organisms, but often it is more expensive to pump than is water from a stream.

Stream water, which tends to be warmer than well water during the growing season, may be similar to pond water in temperature. Sometimes inadequate to supply ponds during the hottest and driest summer months, stream water also can be polluted with industrial or agricultural wastes toxic to fish. Undesirable wild fish, as well as disease organisms and parasites, may be introduced into ponds when water is pumped from a stream. All such factors on water supply should be considered before pond construction begins. We have had considerable success in keeping down populations of wild fishes from streams by installing Saran* socks around the ends of the feeder or inlet pipes (Fig. 3). Saran is

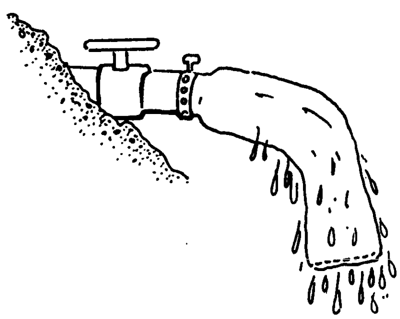


Figure 3. *Saran socks around the water-supply pipes will filter out nearly all tiny fish.*

a tough, durable plastic available in any length at 36 inches wide. Socks can be sewn with nylon thread into desirable sizes on a sewing machine. The socks can be fastened to pipes with a rubber strip and an adjustable clamp. Periodically they should be removed and cleaned.

*Available from the National Filter Media Corporation, 1717 Dixwell Avenue, New Haven, Conn. 06500.

Soil characteristics

The soil should be studied thoroughly before deciding where to locate rearing ponds. The Soil Conservation Service personnel, generally familiar with an area's soil characteristics at the surface, if asked to do so will make soil borings to determine characteristics of deeper soil layers. If soil will not retain water, another area should be considered. It is difficult to maintain adequate water if much seepage occurs. Some ponds have been sealed by bentonite (100 pounds per 100 square feet) or salt (16 to 20 ponds per 100 square feet) spread over the pond bottom or by other chemicals, sheets of polyethylene plastic, or other materials. Such added costs should be avoided.

Dissolved oxygen

Dissolved oxygen is important for fish survival. Placing a fish in a wire container and then placing the container with the fish in a body of water for several days is one way to check its survival, and thus to determine whether fish can live in that water. If water is too salty, too alkaline, too low in oxygen, or otherwise unsuitable, fish will grow poorly or die.

Anyone initiating a feeding program should be aware that large fish, large amounts of feed given daily, increased temperature, cloudy weather, and little movement of air can deplete dissolved oxygen to the point that fish die. Opening the drain valve and pumping in fresh water is the recommended treatment. Amount of oxygen is usually least just before daylight because during darkness respiration of plants and animals in water decreases oxygen. During daylight oxygen is released into the water as a byproduct of photosynthesis by tiny aquatic or other green plants.

Several methods to increase dissolved oxygen in pond waters have been tried. One way is to suspend long hoses with holes into the water, then permit air pumped into the hoses to bubble through the water. Tremendous quantities of air must be pumped, at considerable expense, to increase dissolved oxygen from 3 to 4 parts per million (ppm) in 1 acre-foot of water. If hoses are too near mud and organic matter on the pond bottom, bubbles of air will put such material into suspension, resulting in a greater oxygen demand and thus decreased dissolved oxygen.

Large-capacity agitators are available to suspend into pond waters to add oxygen. But an acre-foot of water is such a large volume that even if the agitators supply oxygen needed for fish to survive, supply may still be inadequate for fish to grow well.

Some pond owners have installed pumps in or around ponds and sprayed water over their ponds. However, 1 acre-foot of water is 326,000 gallons, so even a sizeable pump likely would have little effect. Moving water in or supplying air to each pond requires energy and numerous pieces of equipment—all of which increases costs. We, therefore, urge all potential pond operators to consider the problem of providing sufficient dissolved oxygen before building or stocking fish ponds. A pond should be built so that if dissolved oxygen becomes low, a valve on the drain pipe can be opened to supply water under pressure at the other end. Partially draining ponds removes deep water low in oxygen and high in carbon dioxide. It also can remove decaying organic material that adds to the oxygen demand.

In our experimental ponds, we periodically test water for dissolved oxygen early in the morning, particularly during July and August. If early-morning readings at 3 feet are as low as 4 parts per million of dissolved oxygen, we take oxygen readings often. Then, if readings reach 3 ppm or lower, we open drain valves and start pumping water into the ponds. That has permitted us to operate 28 ponds at stocking rates to 6,000 fingerlings per acre with few signs of distress caused by oxygen deficiency. A browning of the water often indicates dissolved oxygen is low or will soon be low.

Often several inches below the surface, oxygen is 5 or 6 ppm, while 3 or 4 feet down it is 3 ppm or less. Warm water (75°F) naturally contains or holds less oxygen than does cooler water (65°F), but channel catfish grow better at the higher temperatures. Channel catfish grow well in ponds in which about 5 ppm of dissolved oxygen are maintained in water 6 inches below the surface at 10 a.m. during the middle of the summer.

An inexpensive test kit to determine dissolved oxygen levels is available from several supply houses. This kit is small, simple to use, and lightweight.

STOCKING AND REARING CHANNEL CATFISH

Fish can be stocked at any time of the year, but they are handled more safely and easily in the fall or winter when it is cool or cold. Though fish are more resistant to the stress of handling and hauling during the growing season, more fish can be hauled in a fish truck when temperatures are low. Stocking ponds in the fall provides fingerling fish when feeding time approaches in spring; providing oxygen under the ice is no problem during winter. Several thousand fingerlings per acre ready for feeding in the rearing ponds in the spring possibly are more nearly free of parasites and diseases than fish taken in the spring from a pond containing 40,000 to 50,000 fish per acre. Some producers of fingerling fish, however, recommend that ponds constructed in late summer or fall should not be stocked until the next spring to permit the pond water to be conditioned for fish.

Number of fish stocked depends on objectives of the stocking program. Within limits, the more fish stocked, the more pounds of fish produced per acre of water. At the end of the feeding season, however, fingerlings stocked at 1,500 per acre will be larger than those stocked at 5,000 per acre. No more than 2,000 fingerlings per acre should be stocked when one plans on rapid growth to a l-pound, marketable size. Fingerlings from fry stocked in June at 25,000 per acre have averaged 2/3 ounce each by September 1; those stocked at 70,000 per acre, only slightly more than 1/3 ounce.

In recent years, we have found it to be more equitable and data obtained to be more comparable if we stock experimental ponds with fingerlings under 6 inches long at 30 to 40 pounds per acre and larger fish at 50 to 60 pounds per acre.

How to designate ages for channel catfish

To provide a common language for designating ages for channel catfish, the following system has been devised: fish hatched in 1979 would be called young-of-the-year or age group 0; these fish would be age group I in 1980; age group II in 1981, and so on.

Probably the simplest way to determine the age of a channel catfish of unknown age is to make thin cross sections of the large bone in the pectoral fin and project the image on a screen or observe the cross sections under a scope. Differences in transmission of light indicate concentric rings or annuli produced for each year of growth. Because this bone grows by depositing material on the outside of that of the previous year, the first year's growth would be on the inside.

Length-weight relationships of fed and nonfed channel catfish

Age of fishes may not be directly correlated with length and weight. Tiemeier and Elder (1960) reported that age group V channel catfish from a pond of high population were only 7.7 inches long and weighed 2.2 ounces; these fish were small and slender but did not appear to be starving. In another farm pond, where natural food was abundant and population low, mean weight of age group V fish was 3 pounds.

During more than 10 years of studying, Tiemeier (1966) weighed and measured 7,124 channel catfish. He took data on 4,691 channel catfish that had been fed pelleted rations for various times; and similar data from 2,433 fish in ponds that had not been given supplemental rations.

Fish measured 3.0 to 18.0 inches long, with measurements grouped on the basis of l/2-inch increments. Data on weight were grouped as follows: 1) 1 to 29 grams into intervals of 5 grams; 2) 30 to 119 grams, 10 grams; 3) 120 to 199 grams, 20 grams; 4) 200 to 799 grams, 40 grams; and 800 to 1,199 grams, 50 grams. Mean weight of the two groups (that is, fed and nonfed), which began to diverge when fish reached about 5 1/2 inches long, indicated fed fish were heavier than fish not fed (Table 1 and Fig. 4).

These data provide a standard for comparing fed and nonfed fish. Fed channel catfish of a certain length will usually weigh more than those taken from a lake or stream. Most fed fish must be about 14 inches long before they will weigh a pound; 15 inches long if they have not been fed. A few fish may weigh a pound when they are 12 1/2 inches long (Tiemeier *et al.*, 1970).

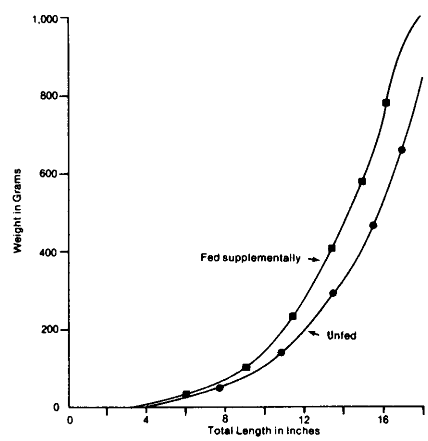


Figure 4. *Length-weight relationships of fed and nonfed channel catfish. (See also Table 1.)*

Hatching channel catfish

Several techniques are used to obtain fry. Breeder-size fish (3 to

8 pounds), both sexes but usually more females than males, are stocked in ponds. Ten-gallon cream cans are placed around a pond's edges with the open ends pointed toward open water. When water temperature increases to 70° F, males clean the cans and if temperature continues to increase, females begin to lay eggs and males release sperm. Masses (10,000 or so) of fertilized eggs stick together in a mass called a spawn. Such masses are taken into the hatchery and placed in screened cages in troughs with running water and a paddlelike agitator over each spawn. In about 7 days, depending on water temperature, eggs hatch. Yolk material is absorbed in a few days and the tiny fry are stocked in ponds. (We do not hatch eggs at the Tuttle Creek Fisheries Research Laboratory but obtain fry or fingerlings from the Kansas Fish and Game Commission.)

The technique just described can be modified by placing a male in a screened-enclosure pen around the edges of the pond and then placing a 10-gallon can inside the enclosure. When spawning temperature is achieved, a female is stocked in the enclosure. After spawning, the female is removed. The spawn can be removed and embryos hatched in the hatchery or the male can be allowed to care for them until the young fry escape into the pond.

Hormones have been used successfully to obtain fry earlier in spring than is usual and hence larger fingerlings at the end of the first growing season. Early spawn also have been obtained where heated water is available. However, suitable water would have to be available for these early spawns to permit the tiny fry to survive and grow.

Hatching channel catfish is highly technical and hazardous. Unless an operator plans to use 100,000 or more fingerlings per year, he might find it more economical to buy fry or fingerlings.

We have stocked 72 ounces of l-week-old fry per surface acre in June and recovered fingerlings at 70,000 per acre in October after feeding fines, granules, and pellets formulated for fry (Diet Z-13). Individual fish have averaged 45 per pound; lower stocking rates have produced larger fingerlings but fewer pounds of fish per pond and acre of water.

Table I. *Length and weight of supplementally fed and nonfed channel catfish.*

Length at midpoint (inches)	Supplementally fed: Weight in grams Mean	Range	Number in group	Non fed: Weight in grams Mean	Range	Number in group
3.2	6.5	5-19	5	4.5		1
3.7	6.2	5-19	35			
4.2	10.8	5-19	30	14.5	10-19	7
4.7	14.1	5-29	29	14.7	10-29	50
5.2	21.2	10-29	58	16.4	10-39	21
5.7	29.2	10-49	55	23.9	10-39	34
6.2	35.6	20-59	81	31.2	20-39	12
6.7	41.4	20-79	135	47.5	20-89	27
7.2	48.9	20-89	190	54.7	40-99	45
7.7	60.0	40-99	237	54.7	40-69	85
8.2	71.0	50-139	285	67.2	50-89	110
8.7	86.2	50-179	221	75.2	50-99	89
9.2	105.3	80-239	157	92.5	70-119	108
9-7	131.4	80-199	167	110.3	80-159	100
10.2	160.3	90-319	180	126.5	90-179	153
10.7	194.6	120-319	218	144.1	100-199	164
11.2	223.5	140-359	300	167.8	90-239	214
11.7	259.2	120-349	318	186.7	100-319	191
12.2	299.2	140-479	316	219.7	120-319	231
12.7	327.4	180-519	235	240.7	160-359	130
13.2	395.9	280-639	232	292.3	160-439	91
13.7	440.2	320-719	297	352.5	160-519	93
14.2	480.0	180-719	257	373.8	160-479	80
14.7	531.4	360-719	231	406.7	240-559	69
15.2	589.9	400-759	158	462.3	320-599	98
15.7	651.3	400-899	114	503.4	360-679	70
16.2	733.8	560-949	71	542.4	400-759	54
16.7	779.6	520-999	44	595.7	480-799	42
17.2	897.5	760-1149	20	642.8	520-1099	51
17.7	974.5	950-1199	15	763.3	600-899	13

WHAT, HOW, AND WHEN TO FEED CHANNEL CATFISH

Formulating feeds

Supplemental feeds commonly are fed to poultry, swine, cattle, and other livestock to increase their growth and production. Though fitting formulations to type of performance (eggs, milk, growth) may involve special problems, benefits of supplementing natural feedstuffs or of supplying complete rations are widely recognized. Feeds for fish also must contain the proper quantities of protein, energy, vitamins, minerals, and bulk to produce good growth; a balance of the amino acids in the protein must be provided as well.

Under natural conditions, available food limits fish growth and production. When fish are numerous and food is limited, fish are stunted or grow slowly. Stocking rates and production can be increased significantly by supplemental feeding. Tiemeier and Elder (1960) increased growth of stunted fish and fish in heavily stocked ponds by giving them supplemental feeds. Deyoe *et al.* (1965) demonstrated that channel catfish survived and grew well when given supplemental feed in heavily stocked, plastic-lined ponds. Plastic lining improved experimental conditions.

The primary objective of most fish growers is to produce fish economically. Because the cost of feeds is generally the primary expense, we directed our research toward producing feeds that would provide good results at the least cost. From 1964 to 1975, we fed to channel catfish in our experimental ponds 78 different feed formulations, containing protein in amounts ranging from 18 to 40% and energy levels of 750 to 1,300 kilocalories per pound of feed. Each ration treatment involved fish in 2, 3, or 4 ponds. To measure performance, survival, and weight gained, we weighed samples of 50 fish biweekly and weighed and counted all fish when they were removed in the fall.

Our data indicated that good-to-excellent growth and feed-conversion rate can be obtained by giving fish feeds containing 25% or more protein, provided adequate energy is available and the amino acids are balanced. Good results were not obtained with feeds containing 17% protein. Feeds should contain 850 kilocalories per pound (based on metabolizable energy values provided in tables for poultry feeds). Studies show that channel catfish can digest and absorb at least some starches as sources of energy. Fats and oils were not readily digested by fish maintained at temperatures of 50 to 60°F.

Data provided in Table 2 indicate good-to-excellent results were obtained by feeding a variety of rations containing 23.2 to 34.2% protein. For all treatments survival, use of protein, and energy were excellent.

Tiemeier and Deyoe (1973b) reported that fingerlings will grow well, survive well, and use feed efficiently if given feeds that contain low percentages of or even no animal proteins, provided the feeds contain adequate amounts of amino acids, vitamins, and minerals from vegetable or other sources (Table 3). Vegetable proteins may be less expensive than animal proteins, and if substituted to provide sufficient quantities of the necessary amino acids, they should reduce the cost of producing fish.

Complete formulation of rations Z-57, Z-51, Z-58, and Z-13 given in Tables 4 and 5 show composition of typical rations that have been devel-

Table 2. *Data on stocking, survival, and feed efficiency of channel catfish. (Deyoe and Tiemeier, 1972.)*

Feed formula number	Z-14	Z-14A	Z-14	Z-43	Z-43	Z-47	Z-14	Z-43	Z-49	Z-55	Z-56	Z-47
Floating or sinking feed	Sink	Float	Sink	Float	Float	Float	Sink	Float	Sink	Float	Sink	Float
Year of experiment	1968	1968	1970	1970	1970	1970	1971	1971	1971	1971	1971	1971
Percentage protein[1]	25.6	23.2	25.8	26.5	26.5	33.9	24.9	26.0	29.4	29.4	33.3	34.2
No. of fish stocked	500	500	231	211	228	205	361	360	351	337	349	341
No. of ponds stocked	3	3	2	2	2	2	3	3	3	3	3	3
Stocking size, grams[2]	9.7	9.7	23.6	25.8	23.9	26.6	10.1	10.1	10.4	10.8	10.4	10.7
Daily feeding rate, %	3	3	3	( )[3]	3	3	3	3	3	3	3	3
Mean % survival	99.8	99.2	99.8	99.1	99.3	100	99.4	98.9	95.9	98.9	98.7	99.9
Mean lbs. feed/lb. gain	1.13	1.23	1.41	1.22	1.22	1.06	1.22	1.17	1.20	1.08	1.06	1.11
Mean grams protein/lb. gain[1]	131	129	151	141	141	163	138	138	160	144	160	172
Mean Kcals./lb. gain[4]	960	1045	1199	1159	1159	1113	1037	1112	1106	996	1113	1166

[1]Analyses made using A.O.A.C. methods,

[2]454 grams = 1 pound.

[3]Fish fed to satiation twice daily in 15-minute feeding periods.

[4]Based on analyses tables for poultry feeds.

Table 3. *Proximate analyses and results obtained with feeds containing various levels of plant and/or animal proteins when fed to fingerlings. (Tiemeier and Deyoe, 1973b.)*

Feed formula number	Z-14	Z-16	Z-14	Z-34	Z-35A	Z-14	Z-45	Z-46	Z-14	Z-50	Z-51	Z-52
Year of experiment	1965	1965	1968	1968	1968	1970	1970	1970	1971	1971	1971	1971
Percentage protein[1]	25	25	25	25	25	25	25	25	25	25	25	25
Percentage protein[2]	25.6	27.3	25.1	23.7	20.7	25.8	23.6	22.9	24.9	26.1	22.0	25.4
Percentage fat	5.2	3.4	3.8	2.6	4.6	3.3	2.5	1.6	4.4	4.7	7.0	3.5
Percentage fiber	7.7	5.9	7.6	8.8	6.8	6.5	10.6	9.9	5.6	6.8	6.5	7.9
Percentage ash	8.6	9.1	8.9	8.8	6.3	8.3	6.0	7.2	8.0	9.8	12.8	8.7
Percentage moisture	10.0	11.4	10.1	8.7	10.0	9.7	10.8	12.6	8.9	8.6	7.7	8.6
Metabolizable energy (Kcals/lb.)	850	850	850	850	850	850	850	850	850	850	850	850
No. of ponds stocked	3	3	3	3	3	3	2	2	3	2	2	2
No. of fish stocked/pond	950	950	500	500	500	231	251	243	361	375	376	348
Stocking size, grams	2.3	2.3	9.7	9.7	9.7	23.6	24.4	24.1	10.1	10.5	10.5	11.3
% daily feeding rate	4	4	3	3	3	3	3	3	3	3	3	3
Mean % survival	97.8	94.2	99.8	99.6	98.7	99.8	98.8	98.0	99.4	98.7	98.5	99.0
Mean lbs. feed/lb. gain	1.04	1.09	1.13	1.18	1.65	1.41	1.72	1.51	1.22	1.41	1.21	1.25
% protein from animal sources	40.3	11.0	40.3	2.1	0.0	40.3	0.0	14.0	40.3	36.6	40.1	0.0
Mean grams protein/lb. gain[2]	121	135	129	127	155	165	184	157	138	167	121	144
Mean Kcals/lb. gain[2]	884	927	961	1029	1403	1199	1462	1284	1037	1199	1029	1063

[1]Based on analyses tables for poultry feeds.

[2]Based on A.O.A.C. determinations for protein.

oped recently and have given good performances.

Requirements used to formulate rations for fry and larger fish are given in Table 6. All rations were formulated by computer on a least-cost basis.

Selecting ingredients in feed formulations must be based on nutrients supplied, availability of the ingredients, cost, and possible harmful materials in the ingredients. Processing conditions in the manufacture of different ingredients could affect nutrient availability. Though most meat meals are well processed, overheating or poor control of processed materials may lower a meal's quality.

Certain ingredients may have contaminants, such as insecticide or herbicide residues. Generally, one must depend on the original supplier to maintain the quality of the ingredients. If, for example, a producer of alfalfa meal uses alfalfa on which an insecticide has been used improperly, all users of the meal product will unknowingly produce feeds contaminated with insecticide residue.

Some ingredients and feeds may become moldy because of humidity or moisture during processing and storage, and some molds produce toxic materials. Therefore, any moldy ingredients or feeds should be considered as undesirable; besides being less palatable than fresh ingredients, they likely contain mold toxins. Ingredients such as cottonseed meal may contain natural materials toxic to some animals; for example, gossypol and certain fatty acids in cottonseed oil can be toxic to poultry, swine, and fish. Hence, use of such ingredients to supply nutrients in rations must be limited; used in relatively large amounts, they could depress growth.

For pelleting and extrusion processing, adding binders or increasing starch levels could improve the quality of the final product.

We have fed newly hatched fry a ration (Z-13) prepared from 3/16-inch-diameter pellets containing 35% protein and 1,040 kilocalories per pound. We use a crumble roll to break pellets into small particles (crumbles), those less than 1/16-inch in diameter, then screen from the larger crumbles. The small particles (fines) are fed to tiny fry as soon as they will feed. As the fish grow they are fed the larger crumbles, and when they are 5 to 8 inches long we begin feeding the full-sized 3/16-inch-diameter pellets.

Table 4. *Composition of several feed formulas for channel catfish. (Tiemeier and Deyoe, 1973c.)*

Ingredients (in pounds, "percentage protein" excepted)	Fingerling and larger fish			Fry
	Z-57	Z-51	Z-58	Z-13
Percentage protein[1]	22	25	30	35
Soybean meal (50%)	---	184.0	---	---
Soybean meal (44%)	186.6	---	516.8	1,043.5
Alfalfa meal (17%)	321.6	200.0	---	224.5
Meat and bone meal	216.4	132.0	304.4	---
Distillers' dried grains with solubles	100.0	84.0	100.0	100.0
Fish meal	---	176.0	---	200.0
Fat	12.8	62.0	29.0	18.0
Wheat bran	291.4	808.0	---	197.0
Wheat midds	727.4	---	385.0	---
Blood meal	---	36.0	---	---
Ground sorghum	---	176.0	22.6	109.0
Ground wheat	---	---	460.6	---
Premix A[2]	123.8	122.0	161.6	81.0
Premix B[2]	20.0	20.0	20.0	17.0
Total pounds	2,000	2,000	2,000	2,000

[1]Based on feed-analyses tables for poultry.

[2]See Table 5 for information on premixes.

Table 5. *Composition of premixes per ton of feed for channel catfish. (Tiemeier and Deyoe, 1973b.)*

Ingredients	Feeds			
	Z-57	Z-51	Z-58	Z-13
	Premix A (lbs.)			
Dicalcium phosphate	103.4	112.0	83.2	58.5
Salt	8.4	10.0	7.8	10.0
Ground limestone	12.0	---	9.4	22.5
Blood meal	---	---	61.2	---
Total pounds	123.8	122.0	161.6	81.0
	Premix B (grams)			
Vitamin A (10,000 IU/gram)	220	200	200	200
Vitamin D (15,000 IU/gram)	20	20	20	20
Vitamin B_{12} (20 mg./lb.)	228	228	228	228
B-complex (1233)[1]	228	228	228	228
Methionine	1,452	368	3,542	2,951
Lyamine-50 (50% lysine)	2,180	---	---	3,859
Ground grain	4,752	8,036	4,862	232
Total grams	9,080	9,080	9,080	7,718

[1]Contains per pound: 8 g. riboflavin, 14.72 g. d-pantothenic acid, 24 g. niacin, and 80 g. choline chloride.

Feed processing

Feeding supplemental rations to fish presents problems not encountered with many other animals. Because feed must be placed in water, the amount not consumed is difficult to determine or estimate.

Various processing factors influence stability of feed in water. Though methods of processing pellets used in feeding tests of channel catfish at Kansas State University have proved satisfactory, several procedures may be suggested to improve pellet stability in water.

We conducted tests on pellet stability in 1965. Formulations were prepared by using the normal procedure to produce fish rations requiring fibrous ingredients ground through a 1/8-inch hammermill screen. Ingredients included wheat bran and other wheat by-products. Formulations, commonly mixed in a horizontal ribbon-type mixer, were made into pellets 3/16-inch in diameter and approximately 1/4-inch long. During the pelleting process, mash was conditioned 160 to 170°F and some starch was gelatinized, depending on the formulation. Higher temperatures may produce more durable pellets.

Table 6. *Restrictions used in computer formulations of feeds for channel catfish. (Tiemeier and Deyoe, 1973c.)*

Items	Fingerling ration (%)	Fry ration (%)
Protein	25	35
Methionine	0.52	0.90
Methionine + cystine	0.85	1.30
Lysine	1.33	1.80
Arginine	1.48	2.10
Tryptophan	0.30	0.42
Threonine	0.50	0.93
Valine	0.50	1.00
Histidine	0.5	0.76
Leucine	1.21	2.50
Isoleucine	0.68	1.30
Phenylalanine	1.50	1.45
Metabolizable energy (Kcals/lb.)[1]	850	1040
Animal protein sources (minimum)	0.0-5.0	
Fat	3.5-7.0	3.5-7.0
Fiber (maximum)	10.0	10.0
Calcium [2]	1.5-2.8	2.0
Phosphorus [2]	0.75-1.4	1.0
Vitamins [3]		

[1] Metabolizable energy values used in calculating poultry rations.

[2] Calcium and phosphorus ratios should be maintained at 2 parts of calcium to 1 part "available" phosphorus, Available phosphorus: phosphorus from animal and mineral sources plus 1/3 of that from plant sources.

[3] Vitamin levels from natural sources and added vitamins: vitamin A 10,000 IU/lb.; riboflavin 4.25 mg./lb.; pantothenic acid 12.7 mg./lb.; niacin 56.2 mg./lb.; choline chloride 698.5 mg./lb.; vitamin B_{12} 10.6 mcg./lb.; folic acid 0.29 mg./lb.; and ascorbic acid 45 mg./lb.

Natural, compared with supplemental, foods in fish stomachs

Our studies on food habits of channel catfish fry indicate they prefer natural food items when readily available. We determined quantities of natural and of supplemental foods in the stomach of fingerlings (Farney, 1972) by 1) analyzing the gastric contents of supplementally fed fingerlings and comparing the amounts of natural food with amounts of supplemental food and 2) determining the variety and amount of natural, as opposed to supplemental, feed at 6-hour intervals after feeding.

Fingerlings were stocked into 3 plastic-lined ponds (nos. 2, 8, and 10) at our laboratory. Mean weight of fish when stocked on 6 April was 75 fish per pound. Fish were given a formulated sinking feed at 3% daily, 6 days each week.

Stomach samples were obtained biweekly by randomly selecting 30 fish from a seine haul of the 3 ponds, starting 18 May and continuing to 22 August. Stomach contents from fish in each pond were collected and dried, then items were identified and each was weighed. The stomach contents were separated into natural food, supplemental food, and miscellaneous items such as sand and detritus.

To determine food consumption and percentage composition of the stomach contents at 6-hour intervals after feeding, we seined 20 fish from one pond 6, 12, 18, and 24 hours after feeding. Stomach contents were analyzed as above described. Two replicates were conducted on successive weeks.

Percentages of natural food (Table 7) found in stomach contents on 13 and 27 July and 22 August were significantly higher ($P < .10$) than those found on other dates and indicated that the larger fingerlings might have ingested considerable quantities of natural foods when available. Invertebrates were the most abundant natural food items found, both numerically and by weight, with chironomid larvae numerically the most abundant; trace amounts of vegetation were ingested by the fingerlings.

Stomach contents make up a decreasing percentage of the total weight of fish (Table 8) as the length of time between feeding and sampling is increased, indicating that young channel catfish consume supplemental feed as soon as it is presented.

Table 7. *Mean percentage by weight of 3 components in stomachs of fingerlings. (Farney, 1972.)*

Date	Pond 2 Natural food	Pond 2 Supplemental feed	Pond 2 Misc.	Pond 8 Natural food	Pond 8 Supplemental feed	Pond 8 Misc.	Pond 10 Natural food	Pond 10 Supplemental feed	Pond 10 Misc.	Mean, all ponds Natural food	Mean, all ponds supplemental feed	Mean, all ponds Misc.
	%											
18 May	7	93	0	7	93	0	26	74	0	13	87	0
1 June	20	80	0	26	73	1	16	84	0	21	79	+
15 June	1	99	0	2	98	0	10	90	0	4	96	0
29 June	1	99	0	5	95	0	5	95	0	4	96	0
13 July	3	97	0	63	37	0	47	53	0	38	62	0
27 July	33	67	0	66	34	0	78	22	0	59	41	0
10 Aug.	1	99	+	+	100	+	1	99	0	1	99	+
22 Aug.	88	12	0	12	88	0	2	98	0	34	66	0
Overall mean	19	81	0	23	77	0	23	77	0	22	78	0

Feeding channel catfish fry

Some of our plastic-lined experimental ponds were stocked with week-old fry in 1968 and 1969 to determine effects of certain treatments on food habits and growth. Ponds had been drained and cleaned, by sweeping, several days previously and filled with water the day they were stocked to decrease loss to predaceous insects.

In 1968 fry in one pond received supplemental feed and the other pond was enriched with the fertilizer 0-46-0 three times during the summer, but no feed was given until late in the summer.

In 1969 fry were stocked into 4 ponds and treated as follows: 1) The control pond, no. 2, was not enriched nor were the fish fed; 2) pond no. 4 was enriched with 4 applications of the fertilizer 18-46-0 at 50 pounds per acre, and the fish were not fed; 3) fish in pond no. 6, which was not enriched, were fed; and 4) fish in pond no. 8, enriched as was pond no. 4, were fed as in pond no. 6 (Bonneau *et al.,* 1972).

Supplemental feed was formulated to contain 35% protein and 1,050 Kcals/lb and was given at 5% daily originally and at 3% later in the summer. Early in the study, feed was applied in finely ground form (fines), later as crumbles. Weekly samplings of fish, benthos, plankton, and water provided data for determining treatment effects.

Data obtained in 1968 indicated growth was greater initially in the enriched pond than in the nonenriched pond in which fish were fed (Fig. 5A), but in 1969 (Fig. 5B) growth was greater initially in the 2 nonenriched than in the enriched ponds.

Supplemental feed was first detected in stomachs of fry sampled when they were 5 weeks old and ranged in weight from 1 to 2.24 grams. Fry in ponds 6 and 8 foraged primarily on chironomid larvae before accepting supplemental feed (Table 9).

Fish in pond 2 (no feed, no enrichment) increased only slightly in weight between 1 and 22 July, so on 23 July a feeding program was begun (Fig. 5B). Immediate acceptance of supplemental feed by these fish indicated no extensive learning process was required.

Feeding habits of young-of-the-year channel catfish varied with availability of food items. Analyses

Table 8. *Percentage by weight of food in stomachs of catfish and composition of contents at 6, 12, 18, and 24 hours after feeding. (Farney, 1972.)*

Time interval (hrs.)	Mean % stomach content of total weight[1]	Percentage by weight Natural food	Supplemental feed
6	5.68	0	100
12	2.87	1	99
18	1.79	1	99
24	0.26	18	82

[1]20 fish taken on 2 dates (40 total) for each time period.

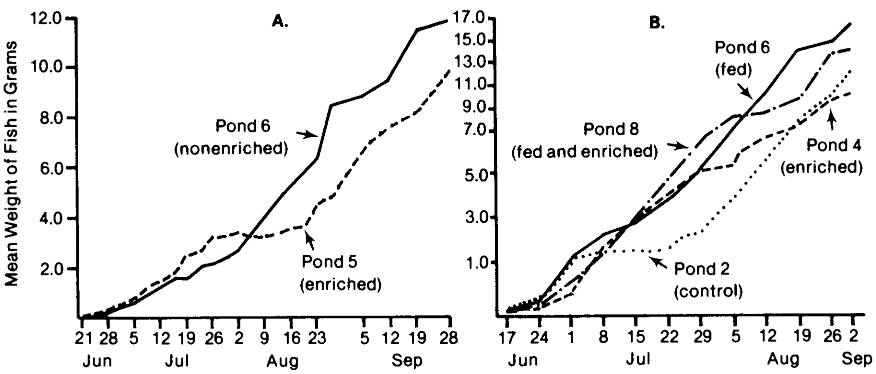


Figure 5. Mean weight (grams) of fry on indicated sampling dates (A) in 1968 and (B) in 1969.

Table 9. Total volume and percentage by volume of plankton, chironomids, and supplemental feed in stomachs of fry sampled from control pond (no. 2), fertilized pond (no. 4), fed pond (no. 6), and fed and fertilized pond (no. 8) in 1969. (Bonneau, 1972.)

	Ponds (identified by number)															
	Volume (ml.) of food in stomachs				% plankton				% chironomid				% feed			
Date	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8
17 June	.20	.10	.13	.11	100	40	54	64	0	60	46	36	0	0	0	0
24 June	.44	.31	.36	.35	4	3	3	3	96	97	97	97	0	0	0	0
1 July	.48	.95	1.05	.84	17	5	5	5	83	95	95	95	0	0	0	0
8 July	.36	2.12	4.60	1.30	6	1	1	2	94	99	2	48	0	0	97	50
15 July	.30	1 70	2.80	2.80	40	41	2	4	60	59	3	14	0	0	95	82
22 July	.40	.80	400	4.00	75	25	2	1	25	75	3	2	0	0	95	97
24 July	3.90	-	-	-[2]	5	-	-	-	3	-	-	-	92	-	-	-
29 July	4.00	1.10	8.30	6.20	2	93	1	1	3	7	2	3	95	0	97	96
5 August	8.40	1.30	12.40	8.70	2	77	1	1	3	23	2	1	95	0	97	98
6 August		9.60	-	-	-	3	-	-	-	2	-	-	-	95	-	-
12 August	6.80	2.50	13.60	9.70	1	2	1	0	2	5	1	95	97	93	98	5
19 August	12.20	3.60	21.70	5.20	1	1	1	1	1	98	1	2	98	1	98	97
26 August	12.90	9.20	14.60	12.60	1	1	2	1	1	1	0	1	98	98	98	98

[1]% chironomids includes other insects, gastropod, and ostracods.
[2]- Indicates no samples were taken.

of stomach contents indicated fry, after accepting supplemental feed, consumed many natural food items in direct proportion to their availability.

Fry in continually fed ponds, 6 and 8, were approximately 5 weeks old when they first accepted supplemental feed, which thereafter comprised most of the food they ate and was responsible for their consistent growth rate. The advantage of supplemental feed became especially apparent as the fry became larger and the demand for food increased. In the absence of supplemental feed in ponds 2 and 4, nonavailability of adequate natural food limited growth.

We recommend that to provide fry with their natural food items they be stocked into ponds as soon as the yolk material has been absorbed. Providing supplemental feed will insure its availability when the fish require additional food. The small fry can be protected by providing them a mesh-cloth-covered metal can into and out of which they can move to escape larger predators that cannot get into the cans.

Efficiency of feeding different levels of proteins to fingerlings of various sizes

In 1972 experiments were designed to evaluate results obtained by these means: 1) Feeding 1 ration containing a low level of protein and energy given at 3% of the fish weight and another, higher in protein and energy given at 2 1/4%, with fish in both regimens to receive similar quantities of protein and energy; 2) feeding 1 ration containing 26.6% protein and another ration containing 28.9% protein; and 3) feeding rations high in proteins to small fish and then low-protein rations, compared with 4) feeding low-protein rations to small fish and then high-protein rations to them.

On 6 April 1972, we stocked each of 12 ponds at our laboratory with 5 pounds of fingerlings. Mean weight of fish was 75 per pound and mean stocking rate was 375 fish per pond, or 2,610 fish per acre.

On 15 May 1973 we stocked each of 15 ponds with 7 1/2 pounds of fingerlings. Mean weight was 60 per pound stocked at 450 fish per pond, or 3,100 fish per acre.

Fish were fed daily, 6 days a week—beginning 1 May and lasting to 14 September, or for 118 days, in 1972; and from 16 May to 27 September in 1973.

Regimens were 3 ponds for each treatment. (Formulations for the rations are presented in Tables 14 and 15.) These, then, were the experiments:

1) To evaluate feeding a low-protein-ration feed given at 3% of the fish weight compared with feeding a higher-protein ration at 2 1/4%, we fed Z-51 (26.6% protein) ration to fish at the rate of 3% daily and a Z-68 (32.8% protein) ration at 2 1/4%.

Feeding the 26.6% protein ration produced 36.9% more pounds of fish with 88.7 pounds more feed. However, conversion rate was better at the 2 l/4% feeding rate (Table 10).

2) To evaluate feeding 2 rations containing different levels of protein, we fed fish in 3 ponds Z-51 (26.6% protein) ration at 3% in 1972. Ration Z-58, with 28.7 and 28.9% protein, was fed at 3% to fish in 3 ponds in 1972 and again in 1973 (Table 11).

Feeding Z-58 produced 46.5 pounds more fish and had a better rate of feed conversion than did ration Z-51, 26.6% protein, given fish at the same feeding rate (Table 12).

3) and 4) Fingerling fish were stocked into 12 ponds and fed a) high-protein rations at 3% early in the season and then low-protein rations; and b) low-protein rations at 3% early and then high-protein rations. Rations were changed 27 June when mean weight of fish was 1 ounce.

Comparing data from experiments in which the protein levels were varied for small and larger fish indicated that similar quantities of feed produced similar rates of feed conversions and pounds of fish (Table 12). Those fish given the higher-pro-

Table 10. *Feeding a low-protein ration at 3% daily compared with feeding a high-protein ration at 2¼% daily.*

Regimen	Lbs. of fish produced[1]	Conversion[2] (lbs. feed/lb. gain)	Lbs. of feed given[1]
	Low-protein ration		
Z-51, 26.6% protein fed @ 3%	273.0	1.29	352.7
	High-protein ration		
Z-68, 32.8% protein fed @ 2¼%	236.1	1.12	264.0
Difference	36.9	0.17	88.7

[1]Total for 3 ponds.
[2]Mean for 3 ponds.

Table 11. *Feeding 2 rations containing different levels of protein, compared.*

Regimen	Lbs. of fish produced[1]	Conversion[2] (lbs. feed/lb. gain)	Lbs. of feed given[1]
	26.6% protein ration		
Z-51, 26.6% protein fed @ 3%	273.0	1.29	352.7
	28.7 and 28.9% protein rations		
Z-58, 28.7% protein fed @ 3%	325.4	1.07	347.4
Z-58, 28.9% protein fed @ 2%	313.5	1.12	352.7
Mean	319.5	1.10	350.1
Difference	46.5	0.19	2.6

[1]Total for 3 ponds.
[2]Mean for 3 ponds.

Table 12. *Feeding high-protein rations early in season, then low-protein rations; compared with feeding low-protein rations early, then high-protein rations—all fed at 3% rate.*

Regimen	Lbs. of fish produced[1]	Conversion[2] (lbs. feed/lb. gain)	Lbs. of feed given[1]
High-protein rations early, then low-protein rations			
Z-62, 38.7% protein early; then Z-51, 24.9% protein	277.2	1.25	347.4
Z-58, 28.7% protein early; then Z-51, 24.9% protein	293.7	1.18	347.4
Z-69, 36.8% protein early; then Z-51, 26.6% protein	262.5	1.34	352.7
Mean	277.8	1.26	349.2
Total lbs. of protein given: 279.6 or 93.3 lbs. per regimen			
Low-protein rations early, then high-protein rations			
Z-57, 22.2% protein early; then Z-51, 24.9% protein	258.1	1.35	347.4
Z-51, 26.6% protein early; then Z-69, 36.8% protein	305.6	1.15	352.7
Mean	281.9	1.24	350.5
Difference	4.1	0.02	1.3
Total lbs. of protein given: 210.1 or 105.2 per regimen			

[1]Total for 3 ponds.
[2]Mean for 3 ponds.

tein feeds late in the season were given more pounds of protein but growth was only slightly greater. We found no advantages in either of the feeding methods.

Various protein sources as nutrients for fingerling channel catfish

Experiments were designed to evaluate growth, survival, and feed efficiency of fingerling channel catfish by feeding them rations containing various sources of proteins.

Twenty-four experimental ponds were stocked in 1972 with 5 pounds of fingerlings each. Mean weight of fish was 75 per pound and mean stocking was 371 fish per pond, or 2,582 fish per acre. Fish were fed daily, 6 days a week, beginning 19 April and terminating 3 October (132 feedings).

All rations were calculated to contain 30% protein and similar levels of energy and minerals. Rations (except Z-58 and Z-78) were designed to have 50% of the protein from a single source and the remaining 50% from other sources. Ration Z-58 had been used for years with excellent results and was used as our standard. Z-76 was the only ration to contain fish meal. Z-78 was designed to contain equal amounts of protein from alfalfa meal, feather meal, corn gluten, blood meal, meat and bone meal, and peanut meal to provide 50% of the protein; the remaining 50% was provided from other sources.

Regimens consisted of 3 ponds for each treatment; all fish were fed at 3% daily, 6 days a week. (Protein levels noted in the regimens here indicate data obtained from proximate analyses, but all were designed to have 30% protein.)

These were the rations for the regimens:

1) Z-58, 29.4% protein, the control (Tables 13 and 14);
2) Z-70, 30.1% protein (primary source, blood meal);
3) Z-71, 25.6% protein (primary source, feather meal);
4) Z-73, 30.3% protein (primary source, corn gluten);
5) Z-74, 27.4% protein (primary source, meat and bone meal);
6) Z-75, 29.6% protein (primary source, peanut meal);
7) Z-76, 26.7% protein (primary source, alfalfa meal); and
8) Z-78, 29.2% protein (designed to contain levels of protein from alfalfa meal, meat and bone meal, feather meal, corn gluten, blood meal, and peanut meal).

Data on survival and gains are presented in Table 15. Proximate analyses of rations indicated that a level of 30% protein was not achieved in all feeds. Rations Z-71, Z-74, and Z-76 were several percentages below the calculated values, which resulted from variations in levels of proteins in the ingredients.

Mean survival of fish in the 3 ponds in each treatment consistently was in excess of 95% (Table 15), which was considered excellent. Best rate of feed conversion (1.16) was obtained by feeding our control, Z-58 (Table 13), or standard feed in which the principal sources of proteins were soybean meal and meat and bone meal. Poorest rate of food conversion (2.24) was obtained when feeding a high level of alfalfa meal in the ration Z-76. Results from feeding any of the 7 other rations did not approach those obtained by feeding Z-58, the control.

When Taggart (1974) force-fed various protein sources to channel catfish and later recovered the amino acids in the serum of the blood, he found that when fish were maintained at 75°F, greatest increases were obtained after feeding soybean meal, then albumin, meat and bone meal, fish meal but that there were no increases after feeding whole egg meal. Increases in serum glucose levels were found after feeding fish meal and meat and bone meal, but no increases were noted after feeding soybean meal, blood meal, or whole egg meal (Tables 30 and 31).

These data indicate that certain proteins are not readily digested and consequently can not be efficiently used as sources of energy or for maintaining body tissues. Taggart (1974) found many direct correlations between the level of certain essential amino acids in the protein source and the level of that amino acid in the serum after force feeding. The levels of methionine in feather meal and soybean meal were low, and subsequently the level in serum postfeeding was also low; generally the reverse was also evident. That information would suggest that certain

Table 13. *Ingredients (in pounds per ton) in rations for channel catfish.*

Ingredients	Rations									
	Z-62	Z-68	Z-69	Z-70	Z-71	Z-73	Z-74	Z-75	Z-76	Z-78
	. . . . .lbs									
Soybean meal (44%)	186.8	480.0	194.0	226.0	210.0	306.0	274.0	336.0	---	438.0
Alfalfa meal (17%)	---	---	---	408.0	440.0	492.0	510.0	136.0	---	342.0
Alfalfa meal (22%)	---	---	---	---	---	---	---	---	1,230.0	222.0
Fish meal (60%)	901.0	2.0	4.0	---	---	---	---	---	198.0	---
Meat and bone meal (50%)	38.8	308.0	252.0	---	---	---	600.0	---	---	100.0
Feather meal	---	---	---	---	354.0	---	---	---	124.0	58.0
Corn gluten	55.4	---	238.0	---	---	500.0	106.0	172.0	---	84.0
Wheat gluten	---	---	---	---	---	---	---	---	36.0	---
Blood meal	---	200.0	200.0	376.0	---	---	---	---	8.0	62.0
Peanut meal	---	---	---	---	---	---	---	640.0	16.0	112.0
Wheat	542.0	---	---	---	---	---	---	---	---	---
Wheat bran	---	44.0	620.0	---	---	---	---	---	---	138.0
Wheat shorts	---	---	---	84.0	146.0	62.0	210.0	---	---	---
Wheat midds	---	---	---	726.0	670.0	330.0	114.0	398.0	---	---
Sorghum	---	680.0	272.0	---	---	130.0	156.0	118.0	---	312.0
Corn	---	---	---	---	---	---	---	---	278.0	---
Distillers' dried solubles	100.0	200.0	200.0	---	---	---	---	---	---	---
Fat	54.6	---	---	---	---	---	---	---	---	---
Salt	6.8	---	---	8.0	10.0	10.0	---	---	---	---
Dicalcium phosphate	14.00	---	---	86.0	80.0	84.0	10.0	86.0	48.0	60.0
Limestone	8.6	66.0	---	66.0	70.0	66.0	0.4	74.0	12.0	52.0
Brewer's yeast	---	---	---	---	---	---	---	---	30.0	---
Dried whey	72.0	---	---	---	---	---	---	---	---	---
Premix	20.0	20.0	20.0	20.0	20.0	20.0	19.6	20.0	20.0	20.0
Total pounds	2,000.0	2,000.0	2,000.0	2,000.0	2,000.0	2,000.0	2,000.0	2,000.0	2,000.0	2.000.0

amino acids should be included in the premixes of the rations to provide a balance in the essential amino acid levels. When feather meal constituted 50% of the protein in ration Z-71 (Table 13), growth responses were poor. That information would support our findings obtained by force feeding this protein source.

Minerals, calcium, and phosphorus in feeds

Calcium and phosphorus are known to be important in the maintenance and growth of vertebrate animals. Therefore, the calcium and phosphorus concentrations in entire fish and fat-free skeletons were determined for fingerling channel catfish stocked in ponds and fed 1 of 3 rations from 9 June to 2 November (Dove *et al.*, 1976): 1) Z-14, containing 1.5% calcium and 0.9% phosphorus, with the primary sources of proteins from fish meal, meat and bone meal, and soybean meal; 2) Z-46, containing 0.78% calcium and 0.38% phosphorus, with the primary sources of proteins from soybean meal and meat and bone meal; and 3) Z-45, containing 0.315% calcium and 1.75% phosphorus, with all proteins from plant sources.

Fingerlings were sampled monthly and analyses made for calcium and phosphorus in entire fish and in lipid-free skeletons.

Calcium values in the entire fish and in the skeletons declined in all treatments during the fishes' rapidly growing season of 9 June to 25 September. Phosphorus contents in entire fingerlings and in the skeletons also declined in all treatments during the rapidly growing season.

These results indicated that calcium and phosphorus in the 3 rations and in the pond water were not available in adequate amounts.

Data on survival and production (Table 16) indicated that survival was excellent in all treatments but that gain with the all-plant protein ration (Z-45) was considerably less than that obtained with the other rations.

Table 14. *Vitamins, amino acids, and other ingredients (in grams per ton of feed) in catfish rations.*

Ingredients	Rations									
	Z-62	Z-68	Z-69	Z-70	Z-71	Z-73	Z-74	Z-75	Z-76	Z-78
	.. grams									
Vitamin A (10,000 IU/g.)	200	200	200	200	200	200	200	200	200	200
Vitamin D_3 (15,000 IU/g.)	20	20	20	20	20	20	20	20	20	20
Vitamin B_{12} (20 mg./li.)	228	228	228	228	228	228	228	228	228	228
B-complex (1233)	228	228	228	228	228	228	228	228	228	228
Methionine	---	---	---	1,618	154	138	108	172	---	214
Ground grain	8,404	8,404	8,404	6,786	8,250	8,266	8,114	8,232	8,404	8,190
Total grams	9,080	9,080	9,080	9,080	9,080	9,080	8,898	9,080	9,080	9,080
Total pounds	20	20	20	20	20	20	19.6	20	20	20

Larger channel catfish (mean wt., 4 oz.) were stocked in ponds and given feed containing higher concentrations of calcium and phosphorus. Rations were: 1) 5.0% calcium and 2.5% phosphorus; 2) 2.8% calcium and 1.8% phosphorus; and 3) 1.64% calcium and 1.0% phosphorus (Launer, 1973a).

Entire fish and lipid-free skeletons were analyzed biweekly, from 18 May to 14 September, for levels of calcium and phosphorus.

Results from feeding the 3 rations indicated that 1) the higher levels of calcium and phosphorus were not directly related to calcium and phosphorus in the larger fish, but that 2) fish fed the ration having the intermediate levels of calcium and phosphorus had the greatest weight gains, although 3) their feed conversions were similar to those of fish fed the ration having the highest levels of calcium and phosphorus.

Vitamins C and D_3 in rations for channel catfish

Vitamin C is necessary for fish to form skeletons, and vitamin D is involved in calcium and phosphorus metabolism in all vertebrate animals.

Fingerling channel catfish were stocked in our experimental ponds and fed a ration: 1) deficient in vitamin C (ascorbic acid); 2) deficient in vitamin D_3 (cholecalciferol); or 3) containing both vitamins (Launer *et al.*, 1978).

Levels of calcium and phosphorus in eviscerated bodies and in fat-free skeletons were determined for fingerling fish biweekly during the feeding (May to September) and nonfeeding (September to February) periods.

Fish on the 3 rations showed no significant difference in weight gain, feed conversion, or survival. The results indicated that vitamin C is not an essential ingredient in rations for channel catfish in a pond-culture system. Under those conditions, the added vitamin C did not improve calcium and phosphorus retention by the fish (Figs. 6 and 7). The study also indicated that dietary vitamin D_3 did not improve growth or calcium and phosphorus retention in channel catfish.

Table 15. *Results obtained by feeding various sources of proteins to fingerling channel catfish.*

Ration	Protein[1] %	Survival[2] %	Total gain[3] (lbs.)	Conversion Rate[4]	Conversion Rank (%)
Z-58 control	29.4	96.0	344.6	1.16	100.0
Z-78 combined	29.2	96.2	264.2	1.51	76.7
Z-70 blood meal	30.1	97.7	252.6	1.58	73.3
Z-75 peanut meal	29.6	95.9	250.8	1.60	72.8
Z-74 meat and bone	27.4	97.5	250.4	1.60	72.7
Z-73 corn gluten	30.3	95.3	211.3	1.89	61.3
Z-71 feather meal	25.6	96.9	197.4	2.03	57.3
Z-76 alfalfa meal	26.7	95.5	178.8	2.24	51.9

[1]Determined by A.O.A.C. methods.
[2]Mean for 3 ponds.
[3]Total for 3 ponds.
[4]Lbs. of feed/lb. of gain.

Table 16. *Survival, pounds of gain per pond, and rank in gain obtained by feeding rations containing different amounts of calcium and phosphorus. (Dove et al., 1976.)*

Rations	No. fish[1] stocked	Survival (%)	Total gain (lbs.)	Gain rank (%)
Z-14	462	99.8	109.8	100
Z-45	503	99.8	89.7	81.9
Z-46	496	98.0	102.3	93.2

[1]Mean per pond.

Feed additives

In livestock certain additives are included in feeds to improve growth and quality of the livestock food products. In many instances additives are not present in the feed in sufficient quantities to do that adequately, so certain other ingredients are added also. As an example, synthetic female sex hormones having estrogenic activity commonly have been included in feeds for fattening cattle and have generally produced excellent results.

Some manufacturers of feeds for channel catfish have been concerned with the effects of elevated temperatures and pressure on the vitamins in the feed ingredients and those in the premix provided as additional sources of vitamins. Should conditions of heat and pressure destroy vitamins, the finished product (the floating feed) would then be deficient in those essential ingredients.

Because supplemental feeds may pass through the digestive tract of channel catfish rather quickly, we decided to include some digestive enzymes in the feeds to enhance digestion. Also, we speculated, would adding a synthetic female sex hormone with estrogenic activity improve growth?

Twelve pounds of fingerling channel catfish were stocked into each pond in 1970 and 8 pounds per pond in 1971. (Data on numbers of fish, number of ponds stocked, and mean weight of fish are given in Table 18.) We think results can be compared more equitably if original stockings are based on identical weights of fish (Deyoe and Tiemeier, 1973).

All rations were formulated to contain 25% protein and 850 Kcals/lb., except that rations Z-43 and Z-48 contained 950 Kcals/lb. of metabolizable energy. The additional digestive enzymes and hormone were included in the premixes (Table 17). These were the rations:

1) Z-14, our standard sinking ration, as our control;
2) Z-44, similar to Z-14 except that the premix contained low levels of the starch-digesting enzyme, Liquifase—20, and the

Table 17. Contents (in grams) of various ingredients in premixes.

Formula number	Z-14	Z-44	Z-53	Z-54
	grams			
Vitamin D3 (15,000 IU/gram)	--	--	--	20
Vitamin A (10,000 IU/gram)	--	--	--	200
Vitamin B12 (proferm 20)	228	228	228	228
Ground grain sorghum	7,808	6,438	4,614	7,578
B-complex (1233)[1]	228	228	228	228
Methionine	816	816	816	816
Liquifase-20[2]	--	462	924	--
Rhozyme P-53[3]	--	908	1,816	--
Lipase	--	--	454	--
Ralgro[4]	--	--	--	10
Total grams	9,080	9,080	9,080	9,080
Total pounds	20	20	20	20

[1]Contains per pound: 8 grams riboflavin; 14.72 grams d-pantothenic acid; 24 grams niacin; and 80 grams choline chloride.

[2]Contains starch-digesting activity. From Clinton Corn Products Co., Clinton, Iowa.

[3]Contains protein-digesting activity. From Rohm and Haas, Philadelphia, Pa.

[4]An estrogenic material obtained as a metabolite of the fungus, **Gibberila zeae.** From Commerical Solvents Corp., Terre Haute, Ind.

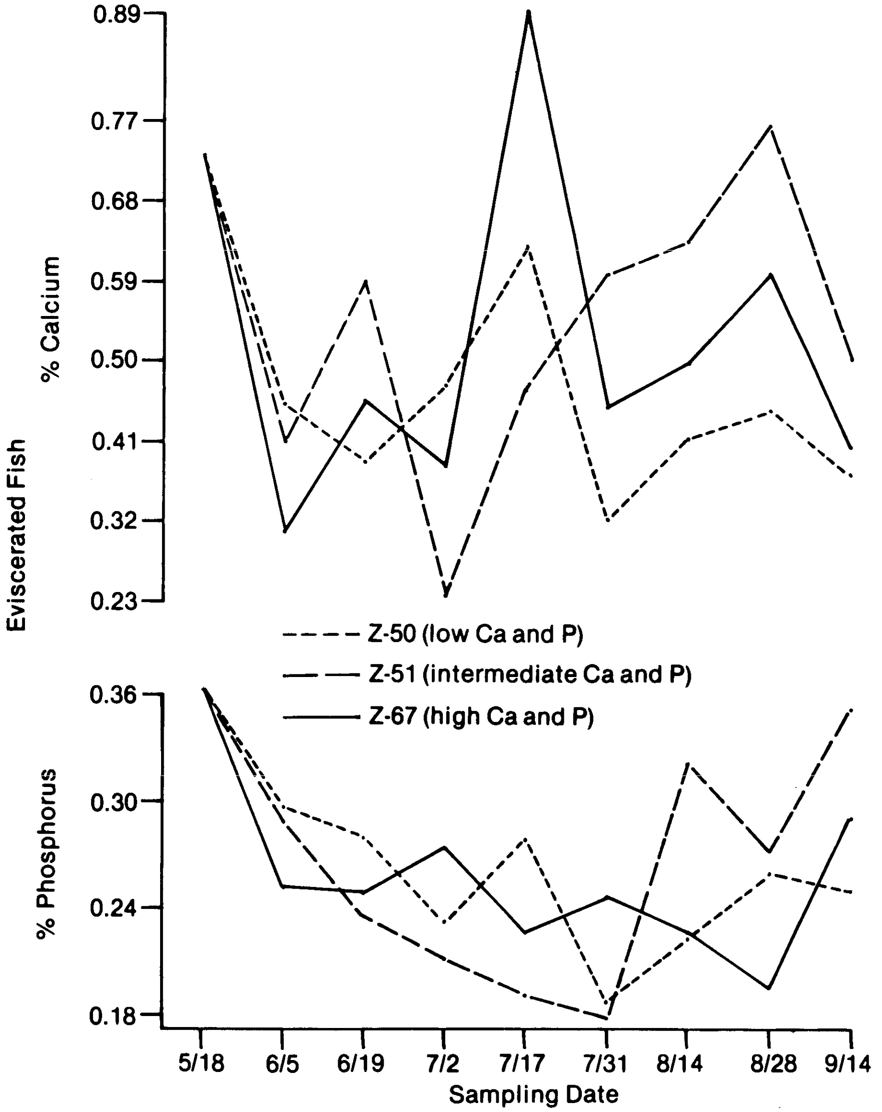


Figure 6. *Mean percentages of calcium and phosphorus in age group II fish fed 1 of 3 rations. Determinations were made 18 May and biweekly thereafter until 14 September. Fish were fed 6 days a week from 21 May to 14 September.*

protein-digesting enzyme, Rhozyme—P-53, sinking pellets;

3) Z-43, a commercially prepared floating feed containing additional vitamins in the premix;
4) Z-48, floating feed, pellets sprayed with starch solution containing the vitamins (with vitamins applied providing these levels per pound of feed: vitamin A—4,000 IU; vitamin D[3]—2,000 IU; vitamin E—5 IU; vitamin K—2 mg.; thiamine—4 mg.; riboflavin—5 mg.; calcium pantothenate—16 mg.; niacin—92 mg.; folic acid—2 mg.; and vitamin B[12]—6 mg.);
5) Z-53, sinking pellets, containing twice the quantities of Liquifase—20 and Rhozyme P-53 as did Z-44 and the fat-digesting lipase; and
6) Z-54, sinking pellets, containing the synthetic female sex hormone Ralgro in the premix (Table 17).

Data on stocking, survival, and efficiencies of using the various feeds are presented in Table 18. Survival in all regimens was excellent. Considering the many variations in the rations fed in 1970 and 1971, along with temperature and other variables, we compared results obtained with the various feeds within each year rather than between years.

If we compare the 3 items included in efficiencies of using feeds— 1) mean pounds of feed per pound of gain, 2) mean grams of protein per pound of gain, and 3) mean kilocalories per pound of gain–for the control feed (Z-14) with Z-44 containing the added enzymes (Table 18), we notice similar results.

Comparing results obtained in 1970 by feeding the floating feed (Z-43) not containing the additional vitamins after extrusion reveals that feed-conversion rates were nearly identical with those of the control (Table 18).

Feed efficiencies obtained in the 1971 experiments indicated no improvements were obtained by feeding

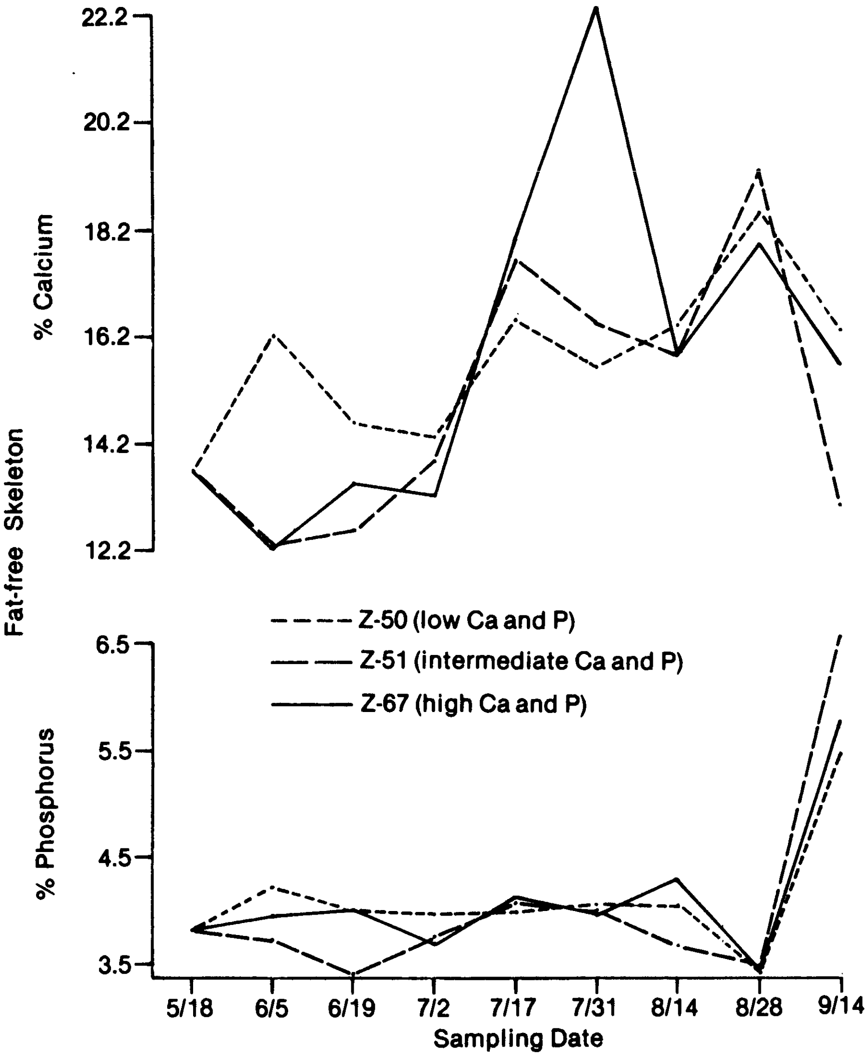


Figure 7. *Mean percentages of calcium and phosphorus in skeletons of age group II fish fed 1 of 3 rations. Determinations were made 18 May and biweekly thereafter until 14 September. Fish were fed 6 days a week from 21 May to 14 September.*

Table 18. *Data on stocking, survival, and use of feeds.*[1]

Formula number	Z-14	Z-44	Z-43	Z-48	Z-14	Z-53	Z-54
Year of experiment	1970	1970	1970	1970	1971	1971	1971
No. of fish stocked/pond	231	222	211	221	386	344	364
No. of ponds stocked	2	2	2	2	3	2	1
Stocking size, grams[2]	23.6	24.6	25.8	24.7	10.1	10.6	10.0
Mean % survival	99.8	98.0	99.1	99.8	99.4	99.3	99.2
Means lbs. feed/lb. gain	1.41	1.36	1.22	1.26	1.22	1.26	1.31
Mean grams protein/lb. gain[3]	165	146	142	156	133	144	149
Mean Kcals./lb. gain	1,199	1,156	1,159	1,197	1,037	1,071	1,114

[1] Daily feeding rate, 3%.

[2] 454 grams = 1 pound

[3] Based on A.O.A.C. methods of protein analysis.

Z-53 containing the additional digestive enzymes, compared with feeding Z-14 (control). Twice the amounts of digestive enzymes were included in Z-53 (1971), compared with those in Z-44 fed in 1970 (Table 18). The fat-digesting enzyme was also included in Z-53.

Including the female sex hormone (at 10 grams per ton of feed) in ration Z-54 resulted in no improvements in growth and feed use.

We concluded that 1) including the digestive enzymes amylase, protease, or lipase in feeds for fingerling channel catfish fed in ponds did not improve the fishes' growth or the efficiencies of using supplemental feed; 2) adding vitamins to floating feeds processed by extrusion heat and pressure did not produce better growth or improve efficiencies of using floating feed; and 3) introducing a female sex hormone at 10 grams per ton of feed did not improve growth.

Using by-products of catfish processing and other fishes in formulating catfish feeds

Skoch (1970) incorporated these by-products of catfish processors: 1) raw offal-whole offal (head, skin, and viscera) unground; 2) pasteurized offal—whole offal (head, skin, and viscera), ground and heated by indirect heat to 90° C; 3) dry, rendered offal–same as pasteurized offal except that it was reduced to approximately 12% moisture by indirect heat; 4) press-cake offal–pasteurized offal pressed while hot into a cake; and 5) dried scrap —ground and cooked for 5 hours at 50 psi.

These products, used as the primary source of protein, were incorporated with dry ingredients into feeds for chickens and rats. The control was a feed containing menhaden fish meal.

When fed to chicks, the catfish by-products could be as effectively used as menhaden fish meal in promoting growth, and by-products were apparently well utilized.

Table 19. *Gain per pond, rate of gain, and conversion for fingerlings receiving rations at 3% or 2½% daily feeding rates, 1967. (Tiemeier* ***et al.,*** *1969.)*

Rations	Percentage of gain	Pounds of gain	Gain rate (pounds per acre)	Conversion rate
		3% daily feeding rate		
Z-31, 25% protein	799	113.8	793	1.54
Z-14, 18% protein	825	118.2	823	1.49
Z-28, 25% protein	728	103.7	723	1.69
Z-27, 18% protein	673	95.8	667	1.83
Mean 3% feeding	756	107.9[1]	752	1.64[1]
		2.5% daily feeding rate		
Z-29, 25% protein	654	93.1	649	1.57
Z-14, 18% protein	750	106.9	745	1.37
Z-30, 25% protein	664	94.6	659	1.54
Z-32, 18% protein	632	90.0	627	1.62
Mean 2.5% feeding	675	96.2	670	1.52

[1]Mean 3% feeding rate significantly higher than mean 2.5% feeding rate.

As feed for rats, dried scrap provided protein of lower nutritional quality than did that of menhaden fish meal (control). Cooking the scrap for 5 hours may have lowered the protein quality.

Floating rations were formulated to contain 1) meat scraps with no fish products, 2) 5% raw catfish plus meat scraps, or 3) 5% raw buffalo-carp mixture plus meat scraps (Pappas *et al.,* 1974).

The 3 rations were fed to channel catfish in cages. Gains were similar for catfish fed floating catfish rations containing raw catfish or buffalo carp and those fed a ration containing no raw fish products. Floating characteristics of the feeds were excellent.

Feeding rates

Fry generally are fed small food particles (fines) as soon as they are stocked into ponds. As previously indicated, they may not take the feed for several weeks, but the amount fed is so small the objective of having it available to them when their natural food supply becomes limited is well worth the expense. During the first part of the summer, they should be fed morning and evening, 7 days a week. As soon as an estimate can be obtained of their total weight, daily feeding rate is calculated at 5%. Larger fry, 3 to 4 inches long, are fed crumbles.

Daily feeding rates (6 days a week) for fingerling fish have ranged from 2 to 7% of total body weight. Tiemeier *et al.* (1969), who fed fingerling fish in 12 ponds at 3% daily and fish in 8 ponds at 2.5% daily, found that the 3% rate gave 18.1% larger fish, 12% greater percentage gain, and 12.2% more pounds of fish per acre but required 7.9% more feed to produce each pound of gain than did the 2.5% rate of feeding (Table 19).

Feeding fingerlings at 3% and 5% daily

Fingerlings use feeds more efficiently than do larger fish. As the fish grow, they require more energy and protein to maintain body metabolism. Most of our research was conducted for fingerlings. A conversion of 1 1/2 pounds of feed to produce a pound of fish to 8 or 10 ounces was considered excellent. To the l-pound size, 2 pounds of feed commonly was required.

Feed-conversion rates of less than 1 pound of feed to produce a pound of fish were obtained in experiments in which small fingerlings were fed at 3% daily. The results indicated that we might not have provided enough feed, that fish were ingesting considerable quantities of natural foods in the ponds, or that a combination of these and other factors was involved. We might have been able to produce larger fish if we had fed at a higher rate.

On 6 April 1972, we stocked each of 6 experimental ponds with 5 pounds of fingerlings. Mean weight of fish was 75 per pound. Mean stocking rate was 375 fish per pond, or 2,610 fish per acre. Fish were fed daily, 6 days a week beginning 1 May and ending 14 September (or for 118 days). Fish in 3 ponds were fed at 5% daily to 27 June and then at 3% for the remainder of the feeding period; fish in the 3 other ponds, at 3% daily for the 118 days. Mean weight of fish on 27 June was approximately 1 ounce. Feed used in both regimens was Z-58, a 28.7% protein, pelleted, sinking feed.

On 15 May 1973, we stocked each of 6 ponds with 7 1/2 pounds of fingerlings. Mean weight of fish was 60 per pound. Mean rate of stocking was 450 per pond, or 3,100 fish per acre.

In 1972 fish were fed daily, 6 days a week beginning 16 May and terminating 27 September (112 Days). Fish were fed at 5% daily to 1 July and then at 3%. Mean weight of fish on 1 July was 0.85 ounce. After 1 July all fish were fed at the 3% rate. Feed given in both regimens was Z-58.

Feeding at 5% early in the season (Table 20) resulted in feeding 30 1/2 more pounds of feed than when feeding the 3% rate and resulted in only 10 1/2 more pounds of fish, which was inefficient production.

Table 20. *Results obtained by feeding rations to fingerlings at 5% rate daily early in the season and then at 3%, compared with feeding at 3% the entire season.*

Year	Lbs. of fish produced[1]	Conversion[2]	Lbs. of feed given[1]
	Fed at 5% then at 3%		
1972	329.6	1.14	376.2
1973	330.7	1.17	385.3
Mean	330.2	1.15	380.8
	Fed at 3%, entire season		
1972	325.4	1.07	347.4
1973	313.9	1.12	353.1
Mean	319.7	1.10	350.3
Difference	4.7	0.05	30.5

[1]Total for 3 ponds.
[2]Mean for 3 ponds.

Feeding channel catfish of age group II

On May 4 one year we stocked 12 experimental ponds with 55 1/2 pounds (mean weight, 4 ounces) of channel catfish of age group II and fed them for 95 days.

Fish in 6 ponds were fed thus: 1) in 2 ponds, a 25% protein feed at 1 l/2% daily; 2) in 2 ponds, the same type of feed at 2% daily; and 3) in 2 ponds, a 25% floating feed to satiation in 2 daily feeding sessions of 15 minutes each (Table 21). In those ponds, fish fed at 1 l/2% had the best rate of feed conversion (1.57) but were considerably smaller than those fed under either of the other regimens (Table 21). Rates of feed conversion were 1.77 with the 25% protein sinking feed and 1.63 with the floating feed. Growth with the 25% protein sinking feed given at 2% was nearly identical with that obtained with the lesser amount of the floating feed.

Fish in the other 6 experimental ponds were fed thus: 1) in 2 ponds, a 20% protein sinking ration at 2% daily; 2) in 2 ponds, a 25% protein sinking ration at 2% daily; and 3) in the remaining 2 ponds, a 30% protein floating feed to satiation in 2 daily 15-minute feeding sessions (Table 22). Survival was excellent in all regimens (Table 22). Fish given the 30% protein floating feed to satiation gained 1.2% more than fish given the 25% protein feed at 2% daily and 9.8% more than fish given the 20% protein feed at 1 l/2% daily. Fish given the floating feed were satiated with less feed than were fish given the sinking feeds.

As fish become larger, daily feeding rate should be decreased from 3% (given to fingerlings) to 2% and possibly to less than 2% as the fish approach the 1-pound size. Data (Tables 21 and 22) indicate that more feed is required to produce a pound of gain with fish of age group II than with fingerlings. Fish producers, therefore, should receive more per pound for their fish that weigh more than 1 pound each.

Table 21. *Gain per pond, rate of gain, and rate of feed conversion for age group II channel catfish fed daily at 1½%, 2%, or to satiation[1].*

Feed	Feeding rate	Survival (%)	Pounds of gain per pond	Gain rank (%)	Conversion Lbs. gain/ lb. feed	Conversion Rank (%)
25% protein	1½%	97.2	92.9	86.3	1.57	100.0
25% protein	2%	100.0	106.3	98.8	1.77	88.7
25% protein	satiation [2]	96.7	107.6	100.0	1.63	92.9

[1]Mean of 2 ponds for each treatment.

[2]Floating feed given to satiation in two 15-minute daily feedings

Table 22. *Survival, gains, and feed conversion rates for age group II channel catfish given 20, 25, and 30% protein feeds.[1]*

Feed	Feeding rate	Survival (%)	Pounds of gain per pond	Gain rank (%)	Conversion Lbs. gain/ lb. feed	Conversion Rank (%)
20% protein	2%	100.0	97.1	90.2	1.94	87.1
25% protein	2%	100.0	106.3	98.8	1.77	95.4
30% protein	satiation	98.9	107.6	100.0	1.69	100.0

[1]Mean of 2 ponds for each treatment.

[2]Floating feed given to satiation in two 15-minute daily feedings.

Table 23. *Survival, gains, and feed-conversion rates for fingerling channel catfish given feed containing 25, 30, and 35% protein as sinking or floating pellets, 1971. (Tiemeier and Deyoe, 1972.)*

Feed	Survival (%)	Gain per fish, (grams)	Total gain (lbs.)	Lbs. feed per lb. gain
		Sinking pellets[1]		
Z-14, 25% protein	99.4	119.0	282.4	1.22
Z-49, 30% protein	95.9	128.5	284.8	1.20
Z-56, 35% protein	98.7	142.8	324.5	1.06
Total or mean	98.0	130.1	891.7	1.15
		Floating pellets[1]		
Z-43, 25.5% protein	98.9	124.8	293.4	1.17
Z-55, 30% protein	98.9	144.6	311.7	1.08
Z-47, 35% protein	99.9	137.9	309.5	1.11
Total or mean	99.0	135.8	914.6	1.13

[1]Data are means from 3 ponds for each treatment. Fish were fed at the same rate in all 18 ponds.

Floating and sinking feeds compared

Producing sinking pellets by compressing finely ground ingredients into desired pellet sizes adds little to the major cost of the processed product. It is more costly to produce floating pellets, made by subjecting finely ground ingredients to considerable heat and pressure until some of the ingredients become semiliquid, so that when pressure is released the material expands, trapping air among the feed particles. The major cost is for machinery and energy necessary for the extruding, or expanding, process.

Tiemeier and Deyoe (1972) have shown that survival, gains, and feed conversions are similar for fingerlings fed floating and those fed sinking pellets (Table 23). Floating feeds may be valuable as a management tool to determine 1) when fish will take feed (and how much) early and late in the feeding season; 2) how low contents of dissolved oxygen in the water affect feeding; 3) how low- and high-water temperatures affect feeding; 4) general vigor or health of fish during the feeding season; 5) amounts of feed to give fish in special circumstances such as when caged or in ponds having much rooted vegetation; and 6) how many fish are present and taking feed.

SOME FACTORS AFFECTING GROWTH AND SURVIVAL OF FISH

Growth rates

Factors determining growth rates include number of fish stocked per acre of water, water temperature (especially above 70°F), amount of food and oxygen available, and type of food. Growth rates in some farm ponds containing an abundance of natural food and stocked with 100 fish per acre may equal or exceed those in ponds where supplemental feed is given. However, the primary objective of a feeding program is to supplement the amount of natural food to obtain more pounds of fish per acre of water. In some instances, natural food may constitute only a small portion of the total food eaten by the fish.

At Manhattan, fish hatched 15 June were considered to have done well if they weighed 1/2 ounce by October, and when those fingerlings were stocked the next spring at 3,600 per acre, they averaged 5 ounces the following September. At lower stocking rates, much better results have been obtained, and in some instances in southern Kansas where water is warm longer than at Manhattan, fish have weighed 1 pound the second year, or more than 3 times the Manhattan average. Under excellent conditions, it should be feasible to produce a salable and edible-sized fish from fry in 12 months of feeding.

Channel catfish will take some feed when water temperatures are 55 to 60°F, but they apparently are unable to use most nutrients efficiently then. Suppes *et al*. (1967) reported that channel catfish placed in an outdoor pond or in indoor tanks maintained at 70°F in September were in good condition in May. No food of any kind was provided during the 8 months. Their energy came from stored body fat.

Self feeders and other feeding devices

Operators use various devices to feed fish. Some use an auger installed on a truck; they drive the truck along the sides of ponds and auger feed to the fish, as though filling bunks for cattle. We know of one feed storage tank so placed on the bank that an electrically driven auger equipped with an automatic time clock and a metering device can supply feed to a rotating disc, which scatters feed over the water. Another type of feeder can release a certain quantity of feed when fish nudge a feeding tray.

In any feeding program, an accurately weighed quantity of feed should be provided in each pond at approximately the same time each day. Probably many producers provide more feed than the fish can use efficiently. As the fish grow, however, they require more feed; so more feed per pond will be required later than early in the summer. Feed should not be placed in deep water that lacks oxygen, and it should be scattered rather than dumped in large piles. Often the only practical way to determine the welfare of fish in ponds is to observe feeding activity; swirls and movements in the water inform the producer that his fish are actively feeding and probably growing.

Effects of temperature on digestion

The body temperature of channel catfish approximates that of the surrounding water. Metabolism of cold-blooded animals, as fish, within limits increases with increases in water temperature and vice versa. The next questions are: What are the sources of energy to maintain the fish during the period of low water temperature? Should fish growers feed their fish when water temperatures are low? How does water temperature affect feeding, digestion, and growth?

Sources of energy

Age group II fish (mean wt. 2 1/2 oz.) were stocked into a pond and fed pelleted sinking feed from 22 April to 30 August. Biweekly determinations were made of percentage moisture, fat and protein content of eviscerated fish, livers, and viscera minus the livers during the feeding period (Suppes *et al.,* 1967). After 30 August, fish were transferred to a small observation pond to facilitate sampling during winter months. Mean water temperature in this pond during September to May was 48° F. On the same day (30 August) other fish were placed into 250-gallon tanks in an indoor laboratory. Tanks were equipped with agitators to maintain oxygen and supplied with charcoal-filtered water at 70°F. Monthly determinations similar to those made during the feeding period were made from 30 September to 2 May.

Results (Figs. 8 and 9) indicated fish bodies were the major fat-storage vessel. Fat and protein in fish bodies were major sources of energy during the nonfeeding period for both groups of fish. Fish bodies comprised more than 90% of the entire fish weight. If comparisons of storage capacity were made per gram of weight, viscera would be the major storage area for fat. Not only was more fat per gram contained in the viscera than in any other part of the fish, but also more of the fat decreased during the nonfeeding period. Because viscera comprised approximately 5% of the entire fish, their importance as a storage area and source of energy during starvation can be considered secondary.

Weight of livers averaged 1.78% of the body weight of fish held outside and 1.01% for those inside in tanks. Fat from the liver can not be considered a major source of energy for starving channel catfish.

Fish held at 48°F during the nonfeeding period did not use protein as a major source of energy. The decrease in protein for fish held at 70°F, however, indicated the protein was used for energy when fat reserves became low.

After starving 244 days, fish kept inside the tank remained relatively plump by the Coefficient of Condition (R), ranging from a low of 0.86 to a high of 1.15. Tiemeier (1966) considered any (R) values below 1.20

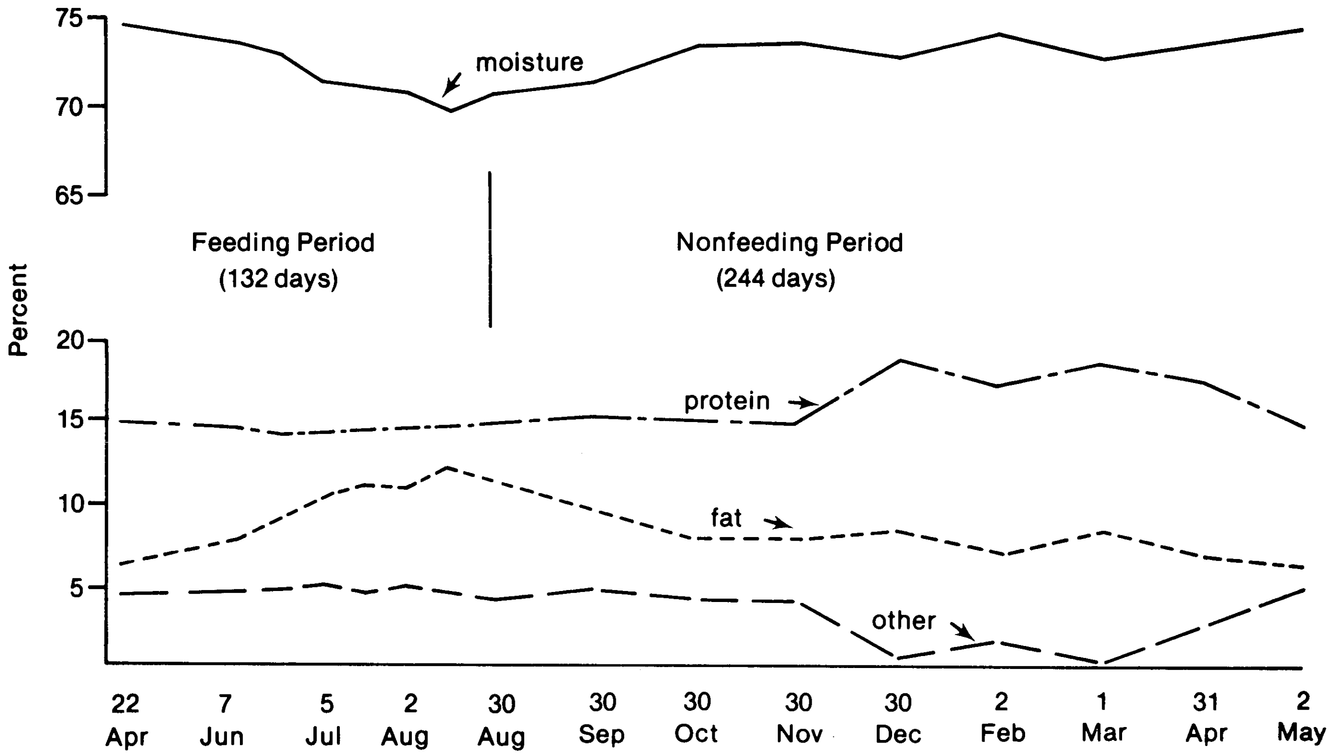


Figure 8. *Percentages of moisture, protein, and fat content of channel catfish held in an outdoor pond from 22 April 1965 to 2 May 1966. Fish were fed from 22 April to 30 August and starved from 30 August to 2 May 1966. Percentages were calculated on a wet basis.*

as poor for populations of farm-pond channel catfish weighed during the summer months. (Coefficient of Condition (R) equals weight in grams times 10 divided by total length in inches and 10ths cubed.)

Launer (1973b) conducted additional studies to determine crude fat and moisture in livers and eviscerated bodies of age group I channel catfish during feeding and nonfeeding periods; and livers and eviscerated bodies of age group II fish during a feeding period. Age group I fish were fed from May to September and not fed from September to February. Age group II fish were also fed only from May to September.

Percentages of moisture and crude fat in livers were not related in fish of either age group. Livers were not a major area of fat storage. Crude fat increased in bodies of catfish of both age groups during feeding periods but decreased in bodies of age group I during the nonfeeding period. During the feeding period, moisture levels in the bodies of fish of either age group showed no relation to the crude fat percentages, but they were inversely related to crude fat percentages in the bodies of age group I fish during the nonfeeding period and in the bodies of age group II fish during the feeding period. Body tissues (excluding viscera) were primary storage areas for fat.

Our studies indicated that large fingerlings and older fish can tolerate extended periods of starvation when stocked in ponds or in tanks at temperatures up to 70°F. However, the fish must have stored energy in the form of body fat during the feeding season.

Some growers have had difficulty maintaining small fingerlings (1/4 oz. or less) when stocked in large numbers in ponds during the fall. By April or May, the fish maybe in poor condition and losses may be heavy from diseases such as "Ich."

Rations for small fingerlings

On 23 March 1973, we stocked 12 pounds of fingerlings averaging 1/4 oz. in each of 9 ponds. We started feeding these fish 1 of 3 rations when surface-water temperature at 1 p.m. achieved 55°F.

One ration (soybean) contained primarily soybean meal, ground wheat, wheat mids, and meat and bone meal; another ration (corn starch) contained primarily corn starch, fish meal, blood meal, and glucose monohydrate; the third ration (dried whole egg) was primarily dried whole egg and corn starch.

The first feeding was 2 April and fish were first seined on 20 April, when stomach contents were analyzed for supplemental food. Fish given the soybean ration were in poor condition and showed no evidence of having been feeding. Fish given the corn starch ration were in good condition and their stomachs contained considerable quantities of sup-

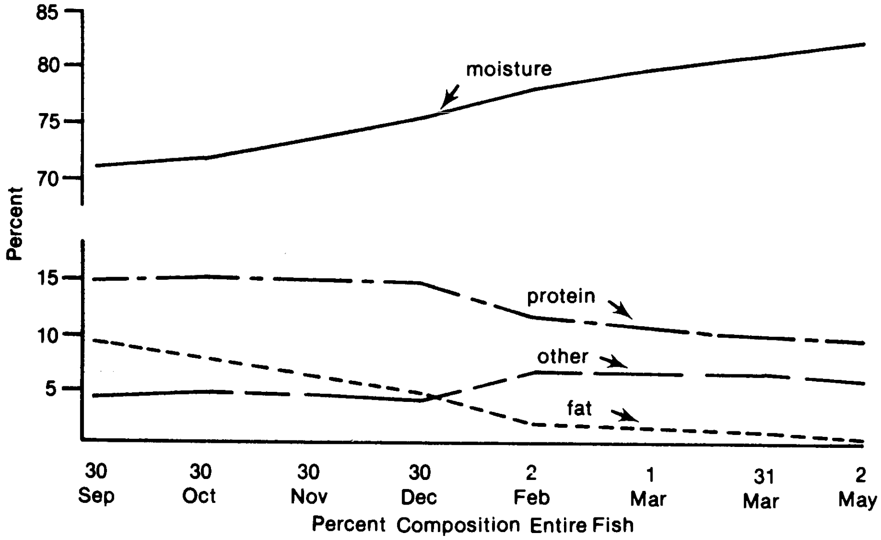


Figure 9. *Percentages of moisture, protein, and fat content of channel catfish held in tanks in the laboratory from 17 September 1965 to 2 May 1966. Fish were starved from 30 August to 2 May 1966. Percentages were calculated on a wet basis.*

plemental feed and insect remains. Fish given the whole-egg feed were in good condition and their stomachs contained supplemental feed and insect remains.

Because the results obtained by sampling on 20 April indicated the fish receiving the soybean ration had not been feeding, they were given the corn starch ration and those fish previously receiving the corn starch ration were given the soybean ration. Sampling of fish from all regimens on 27 April indicated all fish had been ingesting both supplemental and natural foods and were in good condition.

When all fish were removed and weighed on 14 May, we determined that fish in all regimens were in good condition and had gained weight, and no evidence of the disease "Ich" was noted. However, those fish given the soybean ration after 27 April indicated a poor rate of feed conversion.

These results indicated that small fingerlings will ingest certain supplemental and natural foods at temperatures of 50 to 60°F and that there is sufficient digestion at those temperatures to maintain them in good condition. However, the ingredients in the supplemental feeds must be easily digested and attractive to the fish.

Rate of digestion

To determine rate of digestion Shrable *et al.* (1969) stocked channel catfish averaging 12 ounces into 155-gallon tanks where water temperature could be thermostatically controlled at 50, 60, 70, 75, 80, and 85°F.

Each fish was force-fed 3 grams of pelleted feed by placing the pellets in its mouth and finger-forcing them into its stomach. Fish were then returned to the tanks. At intervals of 2, 4, 6, 8, 10, 12, 18, and 24 hours after feeding, groups of 5 fish were removed from the tanks, and after they had been killed, contents of stomach and intestines were recovered, dried, and weighed.

Results of that experiment (Table 24) indicated that food decreased fastest from the digestive tract at 80 to 85°F, but comparison of temperature means showed slight differences in rate of decrease in food passage at temperatures of 70 to 85°F. During an experiment conducted at 90°F, 12 of 30 fish died and the remaining fish were weak and sluggish. Evidently the added stress of handling at that temperature was too great.

During one summer we seined age group I channel catfish (mean wt., 7 1/2 oz.) from one of our experimental ponds 1 1/2 hours after the fish had been fed, as indicated by the distended belly. Two of each group of fish were killed and contents of their stomachs and intestines recovered and dried. Others of this group of fish were placed into troughs supplied with flowing pond water. At intervals of 4 1/2, 7 1/2, and 10 1/2 hours after feeding, 2 of the remaining fish were similarly treated.

Data in Table 25 indicate that only 11.2% of the food present in stomachs 1 1/2 hours after feeding remained 10 1/2 hours after feeding. Food was passed and/or digested most rapidly between 4 1/2 and 7 1/2 hours after feeding. Data on weight of intestinal contents indicated that considerable food material passed from the stomach into the intestines from feeding time to 1 1/2 hours later (Tiemeier and Deyoe, 1973a).

In 1966 channel catfish of age group III in a l-acre farm pond were being given a dry, pelleted feed daily at 7 a.m. On each of 4 days during the summer (June, July, August) when water temperature ranged from 75 to 85°F, a seine pulled through the pond 2 hours after the fish had been fed encircled more than 50 fish. (Mean weight of the approximately 200 fish was 13 ounces.) Immediately after each group of 50 fish had been seined, 10 fish were removed from the seine, weighed, and killed. From the fish that remained in the seine enclosure from the original seining, 10 more fish were taken at 4, 6, 8, and 10 hours after they had been fed in the pond. Once removed from the seine, the fish were weighed and killed, and then their stomachs and intestines were removed and the contents weighed, dried, and weighed again.

Food passed from the stomach, and/or gastric digestion (Table 26) occurred quite rapidly during the 8-hour period after feeding. Wet weight of stomach contents was similar to that in the intestines 2 hours after feeding, indicating considerable material had passed from the stomachs into intestines the first 2 hours after feeding. Twenty-one percent of the dry food by weight in stomachs and intestines 2 hours after feeding was present 8 hours later, or

10 hours after fish had been fed. More than 80% of the gastric contents had been evacuated 10 hours after fish had been fed (Tiemeier and Deyoe, 1973a).

Adding all data on weight of wet and dry material in the stomachs indicated gastric contents were 72% liquid. Similar comparisons of intestinal contents indicated 83.6% was moisture.

In another experiment, on each of 4 days when water temperature ranged from 71 to 82°F, 25 age group III fish (total 100) averaging 16 ounces were seined from a pond where the fish were being supplementally fed. Fish removed from the pond were maintained in a holding tank for 24 hours to permit their digestive tracts to be evacuated. Each fish was force-fed (by finger) 2 gelatin capsules containing 1 gram of finely ground feed. Total weight of feed and capsule was 2.3 grams.

After being force-fed, the fish from each day's seining were separated into 5 groups of 5 fish each and stocked into metal troughs supplied with a continuous flow of pond water. Fish in trough 1 were removed 2 hours after being force-fed and those in the other troughs at 4, 6, 8, and 10 hours after being fed. Fish were killed immediately, stomachs

Table 24. *Percentage of dry matter remaining in the stomachs and intestines of channel catfish maintained at 1 of 6 temperatures and killed at 1 of 8 time intervals after being fed. (Each observation represents an average from 2 groups of 5 fish.) (Shrable* ***et al.,*** *1969.)*

Hours after feeding	Temperature °F						Time means
	50	60	70	75	80	85	
2	91.45	102.02	84.21	91.92	89.19	92.07	91.81 [a]
4	94.70	99.72	75.52	65.49	55.94	75.87	77.86 [a,b]
6	88.81	93.20	84.17	60.83	41.56	71.12	73.28 [b,c]
8	78.88	95.51	61.92	71.47	55.88	60.06	70.62 [b,c]
10	74.29	82.41	57.01	81.12	40.23	44.01	63.18 [b,c]
12	75.67	77.77	60.80	65.44	40.21	38.58	59.74 [c]
18	42.23	29.86	51.79	29.60	27.53	17.62	33.10
24	33.17	25.35	13.57	11.97	6.02	4.21	15.71
Temperature means	72.40 [1,2]	75.73 [1]	61.13 [1,2,3]	59.72 [2,3]	44.57 [4]	50.44 [3,4]	——

[a,b,c,1,2,3,4] Common superscripts indicate means not significantly different at the 0.05 level.

Table 25. *Grams of dry food in stomachs and intestines of channel catfish at indicated time intervals after feeding, 1965.*

Date	Stomachs Hours after feeding				Intestines Hours after feeding			
	1½	4½	7½	10½	1½	4½	7½	10½
6/29[1]	8.28	4.26	0.51	0.78	2.13	1.32	0.39	1.43
7/13	7.48	6.98	0.90	0.16	1.91	1.93	0.56	0.12
7/27	5.19	5.35	0.84	0.09	2.89	3.25	0.92	0.37
8/10	1.89	0.62	0.24	0.00	2.32	1.56	0.29	0.07
8/18	11.90	5.67	1.61	2.87	1.43	1.10	0.51	0.81
Total	34.74	22.88	4.10	3.90	10.68	9.16	2.67	2.80
% of [2] original	100.0	65.9	11.8	11.2	100.0	85.8	25.0	26.2

[1]Each figure is amount from 2 fish.

[2]Amount 1½ hours after feeding was considered 100%.

Table 26. *Mean grams of feed in stomachs and intestines of age group III fish grown in a 1-acre farm pond, 1966.*

	Hours after feeding					Hours after feeding				
	2	4	6	8	10	2	4	6	8	10
Date	Wet feed in stomachs					Wet feed in intestines				
6/30[1]	43.5	55.4	20.0	24.8	15.9	59.2	54.0	49.4	48.5	17.2
7/12	203.9	101.1	70.0	32.9	35.5	162.3	126.9	79.5	50.7	32.0
7/26	126.2	76.0	52.8	25.0	12.3	140.6	109.6	70.3	31.1	28.5
8/4	97.0	81.9	53.5	20.9	26.8	124.3	83.0	85.5	69.2	44.9
Total	470.6	314.4	196.3	103.6	90.5	486.4	373.5	284.7	199.5	122.6
% of [2] original	100.0	66.8	41.7	22.0	19.2	100.0	66.8	58.5	41.0	25.2
	Dry feed in stomachs					Dry feed in intestines				
6/30	11.5	13.1	3.5	5.3	3.7	9.3	9.4	8.3	7.6	1.8
7/12	54.6	32.7	20.7	9.5	8.0	24.5	22.2	13.5	10.7	8.0
7/26	37.3	19.8	15.1	5.6	3.3	21.6	18.9	10.8	5.4	5.0
8/4	33.1	24.6	15.3	4.9	7.4	17.2	14.3	13.7	11.4	6.7
Total	136.5	90.2	54.6	25.3	22.4	72.6	64.8	46.3	35.1	21.5
% of [2] original	100.0	66.1	40.0	18.5	16.4	100.0	89.3	63.8	48.3	29.6

[1]Each figure is amount from 10 fish.

[2]Amount 2 hours after feeding was considered 100%.

Table 27. Mean grams of feed per stomach and intestine of age group III fish force-fed 2 grams of dry feed, 1966.

	Hours after force-feeding					Hours after force-feeding				
	2	4	6	8	10	2	4	6	8	10
Date	Wet feed in stomachs (grams)					Wet feed in intestines (grams)				
7/28 [1]	5.17	2.78	1.81	1.76	1.11	0.07	0.61	1.12	1.16	0.92
8/3	6.53	6.15	2.97	2.07	0.80	0.21	0.75	2.3	2.28	2.03
8/12	5.67	4.11	3.7	1.93	1.28	0.0	0.36	0.18	0.92	1.41
8/25	5.55	5.09	2.49	2.85	3.21	0.19	0.15	0.83	2.93	2.73
Mean	5.73	4.53	2.74	2.15	1.60	0.12	0.47	1.36	1.82	1.77
	Dry feed in stomachs					Dry feed in intestines				
7/28	1.59	0.95	0.53	0.54	0.25	0.02	0.13	0.16	0.20	0.15
8/3	1.81	1.39	0.79	0.48	0.43	0.13	0.07	0.26	0.27	0.21
8/12	1.98	1.86	1.44	0.51	0.33	0.00	0.05	0.02	0.11	0.21
8/25	1.77	1.58	0.64	0.66	0.87	0.02	0.01	0.21	0.30	0.28
Mean	1.79	1.45	0.85	0.55	0.47	0.02	0.07	0.16	0.22	0.21
% of original	77.8	63.0	37.0	23.9	20.4	0.08	3.0	7.0	9.6	9.1

Total % digested or excreted: 2 hours–22.1; 4 hours–34.0; 6 hours–56.0; 8 hours–66.5; and 10 hours–70.5.

[1] All data are means for 5 fish.

and intestines removed, and the contents weighed, dried, and weighed again.

Two hours after fish had been force-fed, 77.8% of the feed remained in their stomachs (Table 27). Ten hours after feeding, 79.6% of the feed had been digested or evacuated from the stomach; 9.1% was in the intestines. After 10 hours, 70.5% of the food had not been recovered from the digestive tract (Tiemeier and Deyoe, 1973a).

To determine the effect 68° F had on the rate food passes in the digestive tract, we individually fed 30 age group III fish averaging 10 ounces 3 grams of pelleted feed in the form of 3/8-inch-diameter pellets. Fish were separated into 6 groups of 5 each and placed into tanks where temperature was thermostatically controlled at 68°F. Groups of 5 fish each were removed 2, 4, 6, 8, 10, and 12 hours after feeding. Fish were killed, stomachs and intestines removed and their contents dried.

When these fish of age group II were force-fed 3 grams of dry, pelleted feed and maintained at 68°F (Table 28), 20.14% of the food had been digested or excreted within 2 hours and 52% within 12 hours (Tiemeier and Deyoe, 1973a).

To summarize the studies here discussed, we can state that when ingredients that have been finely ground and processed into pelleted feeds are fed to channel catfish, they move rather rapidly through the fish's digestive tract. The greater surface provided by the small (as opposed to large) food particles aids digestion and also results in more rapid passage through the gut. Water temperatures above 68°F enhance digestion and food passage, but a temperature of 90°F can adversely affect the fish. Data indicate channel catfish should be fed 6 or 7 days a week to maximize growth.

Digestibility of some feed ingredients

In various experiments, Taggart (1974) determined digestibility of several carbohydrate, lipid, and protein feed ingredients in channel catfish and the effects of water temperature and time after feeding on digestion of ingredients. Digestion end products in the serum (liquid portion of the blood) were measured to indicate feed-ingredient digestibility.

Channel catfish weighing 12 to 20 ounces each were maintained at 55 or 75°F and sampled for blood at 0, 1, 2, 4, and 8 hours after force-feeding known quantities of ingredients. Levels of blood glucose were determined for sera of fish fed glucose, sucrose, raw and cooked starches (corn, wheat, and potato), corn oil, lard, egg albumin, and soybean meal. Esterified fatty acids in the sera were determined for fish fed corn oil and lard.

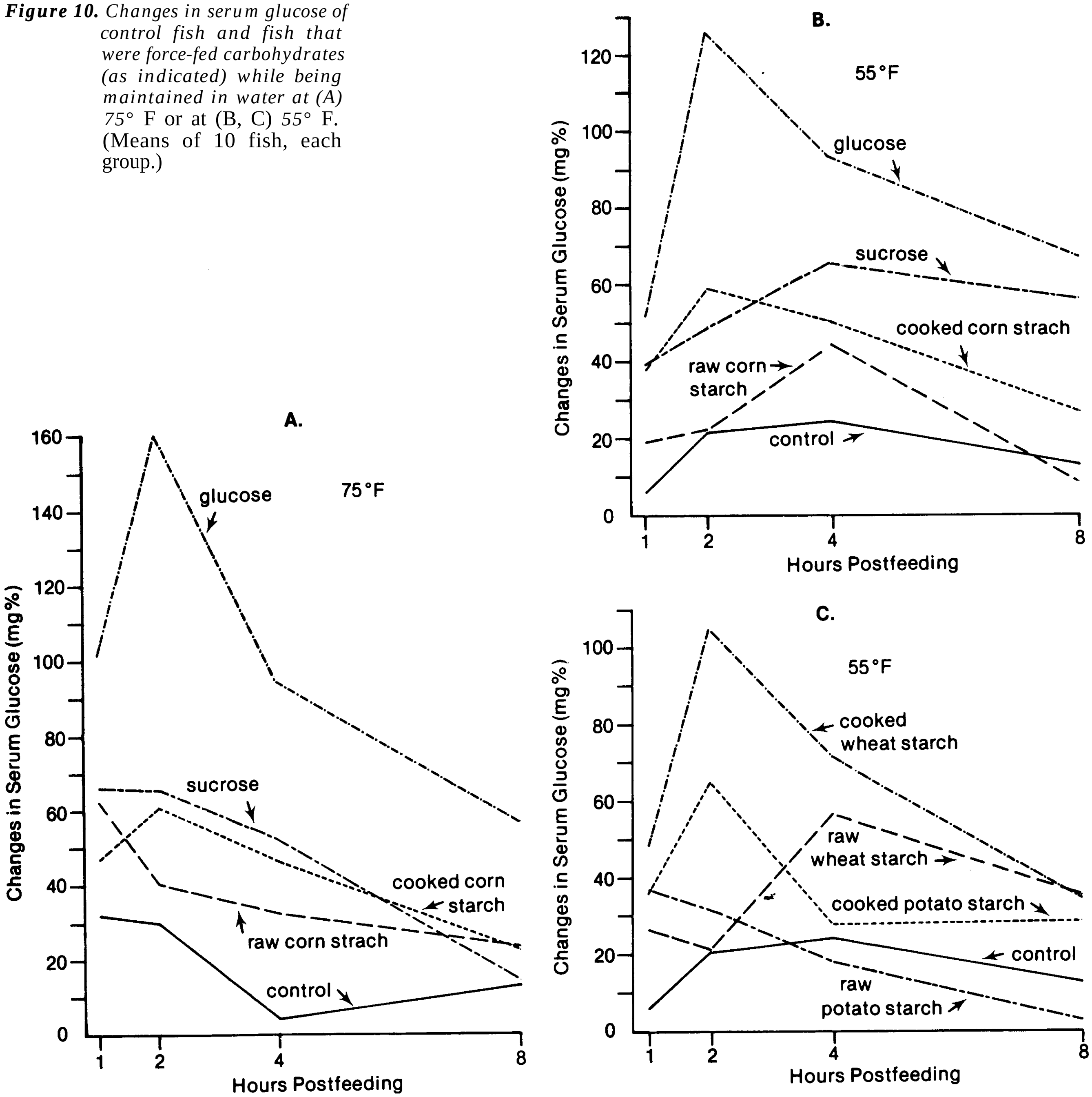
Results indicated: 1) Serum glucose increased with decreases in complexity of the carbohydrate fed (Figs. 10 and 11A); 2) channel cat-

Table 28. *Rate food passed in 16-ounce fish force- fed pelleted feed and maintained at 68°F. (Tiemeier and Deyoe, 1973a.)*

Post feeding, hours	Mean % by dry weight of food remaining			% digested and/ or excreted
	In stomachs	In intestines	Total	
2 [1]	78.60	1.26	79.86	20.14
4	62.55	3.66	66.21	33.79
6	61.60	9.86	71.46	28.54
8	28.77	29.22	57.99	42.01
10	18.66	29.77	48.43	51.57
12	27.13	20.80	47.93	52.07

[1] Mean for 5 fish at each time interval.

Figure 10. *Changes in serum glucose of control fish and fish that were force-fed carbohydrates (as indicated) while being maintained in water at (A) 75°* F or at (B, C) *55°* F. (Means of 10 fish, each group.)



fish digested carbohydrates more slowly at 55°F than at 75°F; 3) cooked starches increased serum glucose more than did raw starches; 4) corn oil and lard did not significantly affect serum esterified fatty acids or serum glucose—although fish maintained at 75°F had higher serum glucose and esterified fatty acids than did fish maintained at 55°F (Figs. 11A and llB); and 5) egg albumin and soybean meal had little effect on serum glucose (Table 29).

A further study determined the digestibility of 6 protein feed ingredients in channel catfish and effects of water temperature, dry-heating the ingredients, water temperature, and time after feeding on digestion of ingredients. The digestion end products, glucose and free amino acids, in the serum were measured to indicate feed-ingredient digestibility.

Channel catfish weighing 12 to 20 ounces were maintained at 55 or 75°F and sampled for blood at 0, 1, 2, 4, and 8 hours after force-feeding known quantities of the ingredients. Levels of blood glucose and free amino acids were determined for serum of fish fed blood meal, whole egg meal, fish meal, meat and bone meal, soybean meal, and albumin.

The denatured ingredients were obtained by dry-heating to 300°F for 1 hour, to determine whether that amount of heating (which could oc-

Figure 11. *(A) Serum glucose and (B) serum esterified fatty acids for control fish and fish that were force-fed corn oil or lard while being maintained in water at 55 to 75°F. (Means of 2 groups of 5 fish, each experiment.)*

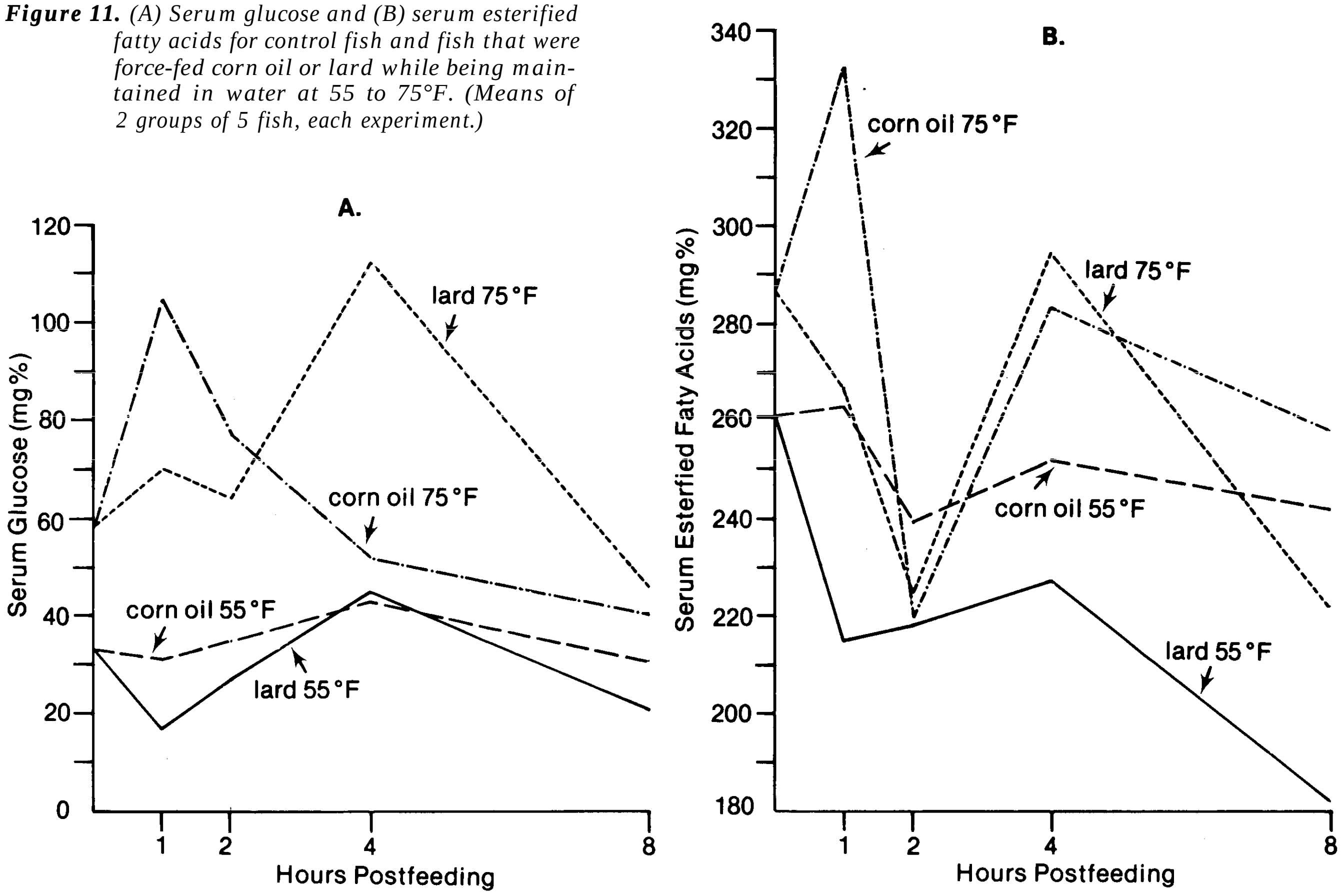


Table 29. *Serum glucose levels (mg%) for nonfed fish and fish force-fed soybean meal or egg albumin while being maintained at 55 or 75°F.*

Protein ingredient	Temperature °F	Levels of serum glucose (mg%)[1] Prefeeding 0	Hours postfeeding 1	2	4	8
Soybean	55	33.33	18.80	35.47	32.48	25.21
Soybean	75	58.33	72.22	68.80	48.72	46.15
Albumin	55	33.33	32.48	38.03	47.43	22.65
Albumin	75	58.33	38.03	44.44	56.84	82.48

[1]Each observation represents 1 analysis of the pooled sera from 10 fish.

cur in processing) would destroy the amino acids.

Data (Table 30) indicated that serum glucose levels in fish were elevated 2 hours after feeding and that by 8 hours afterward levels were back to normal. Some ingredients were more readily digested than others, and more digestion occurred at 75°F than at 55°F. Also, certain protein sources could be digested at 55°F. Comparing data on digestion of denatured ingredients and of ingredients not denatured (Tables 29 and 30) indicated that serum glucose levels were lower when fish were fed the denatured ingredients.

At 55°F the essential amino acid levels increased when fish were fed soybean meal, albumin, and blood meal (Table 31) but did not increase when fish were fed meat and bone meal, whole egg meal, or fish meal. There was a mean increase of 50% within 1 hour after feeding at 55°F, and the amino acids levels were usually back to normal within 4 to 8 hours except when soybean meal and albumin were fed.

At 75°F levels of amino acids increased most in the blood of fish that had been fed soybean meal and lowest in those fed whole egg meal (Table 31). Amino acids increased 48% (mean) 1 hour post-feeding, but generally decreased later except after fish had been fed fish meal and soybean meal.

For the denatured ingredients (heated for 1 hour at 300°F) fed at 75°F, essential amino acids in meat and bone meal and blood meal were used more efficiently by the fish after the ingredients had been heated (Table 31).

Chromic sesquioxide as an indicator in digestion studies

Fingerling channel catfish in a pond were fed a ration containing 0.37% of the dye chromic sesquioxide 1 day per week and then fed the ration without the dye the other days. Three trials, using 20 fish per trial, were conducted on days the fish were fed the feed containing the dye (Pappas *et al.,* 1973). Fish were collected 2 and 4 hours after feeding in the first trial, 4 and 6 hours after

Table 30. *Serum glucose levels (mg%) in fish at 0, 1, 2, 4, and 8 hours after being fed various proteins and while being maintained at 55 and/or 75°F.*

Protein source	Prefeeding 0	Levels of serum glucose (mg%)[1] Hours postfeeding 1	2	4	8	Rank
		Fish maintained at 55°F				
Blood meal	33.33	44.44	52.99	37.18	38.03	4
Whole egg meal		50.85	33.76	54.70	46.24	3
Fish meal		39.31	82.05	37.61	38.46	1
Meat and bone meal		35.04	88.88	36.32	30.77	2
Soybean meal		18.80	35.47	32.48	25.21	6
Albumin		32.48	38.03	47.43	22.65	5
Mean	33.33	36.82	55.20	40.95	33.56	
		Fish maintained at 75°F				
Blood meal	58.33	65.81	68.37	52.56	43.16	4
Whole egg meal		31.39	45.72	33.76	23.93	6
Fish meal		48.72	106.41	130.34	62.39	1
Meat and bone meal		55.13	121.79	103.84	66.66	2
Soybean meal		72.22	68.80	48.72	46.15	3
Albumin		38.03	44.44	56.84	82.48	5
Mean	58.33	51.88	75.92	71.01	54.13	
		Denatured ingredients fed to fish maintained at 75°F				
Blood meal	58.33	64.10	59.40	42.73	53.84	2
Whole egg meal		17.95	22.22	30.77	22.22	4
Fish meal		70.51	74.36	99.14	73.07	1
Meat and bone meal		75.21	60.68	32.47	49.14	3
Mean for denatured ingredients	58.33	56.94	54.17	51.28	49.57	
Mean for same not denatured	58.33	40.22	85.57	80.13	49.04	

[1] Each observation represents 1 analysis of the pooled serum from 10 fish.

Table 31. *Moles of total essential amino acids/100 moles of feed and micromoles/ml of serum for fish at 0, 1, 2, 4, and 8 hours after fish maintained at 55 and 75°F. had been fed (various ingredients).*

Ingredient	Level of amino acids in moles/100 moles of ingredient	Levels of total essential amino acids[1] in micromoles/ml of serum Prefeeding and hours postfeeding 0	1	2	4	8	Rank
		Fish maintained at 55°F					
Blood meal	46.869	.662	1.162	.737	.472	.426	3
Whole egg meal	40.487		.831	.920	.213	.382	5
Fish meal	33.889		.701	.532	.400	.462	6
Meat and bone meal	32.251		.710	.690	.499	.696	4
Soybean meal	42.459		1.606	1.508	.837	1.135	1
Albumin	47.225		9.63	1.076	.822	1.012	2
Mean		.662	.996	.796	.541	.686	
		Fish maintained at 75°F					
Blood meal		.938	1.346	1.374	.618	.723	5
Whole egg meal			1.196	1.014	.484	.373	6
Fish meal			1.281	.941	1.239	.731	4
Meat and bone meal			1.153	.830	.990	1.920	3
Soybean meal			1.610	1.662	1.882	1.714	1
Albumin			1.740	1.484	1.039	.910	2
Mean		.938	1.387	1.218	1.042	1.062	
		Denatured ingredients fed to fish maintained at 75°F					
Blood meal		.938	1.176	.998	1.139	.685	4
Whole egg meal			1.196	1.261	1.105	1.011	3
Fish meal			1.418	1.176	1.108	1.274	1
Meat and bone meal			1.069	1.042	.915	1.648	2
Mean for denatured ingredients		.938	1.215	1.119	1.067	1.155	
Mean for same not denatured		.938	1.244	1.040	.833	.937	

[1] Each observation represents 1 analysis of the pooled serum from 10 fish.

feeding in the second, and 6 and 8 hours after feeding in the third. The fish then were dissected and contents in the stomachs and intestines were collected separately. Contents from a single time period were combined, mixed, and freeze-dried before being chemically analyzed for the presence of the dye.

Digestion and absorption of protein, fat, and nitrogen-free extract (NFE) by channel catfish apparently started shortly after feeding. Absorption of protein, fat, and NFE started in the stomach within 2 hours; by 4 hours nearly 50% of the available nutrients had been absorbed. By 6 hours most of the feed had passed into the intestine where further digestion and absorption took place. Absorption values in the intestine reached 80% after 8 hours.

Fertilizing fish ponds

Fish-rearing ponds containing clear water often develop weeds. If rooted vegetation becomes abundant, fish are unable to feed properly, grow poorly, and are extremely difficult to harvest.

Early in the summer algal bloom can be produced by using inorganic fertilizers to control rooted vegetation. Applying 50 pounds per surface acre of a high-phosphate fertilizer early, and repeating every 10 days until a bloom develops, often will shade out vegetation.

For a heavy supplemental feeding program, however, inorganic fertilizers should be used sparingly, if at all. Fertility is added in the form of uneaten feed and waste products from the catfish. Heavy algal blooms may occur during middle and late summer. When algae mature and die, decomposition causes or contributes to severe oxygen deficiencies. When algal blooms become heavy, an attempt should be made to eliminate some fertility and algae by opening drains and pumping in fresh water.

Adding organic matter and manures to waters containing channel catfish is not recommended as a substitute for inorganic fertilizers or pelleted feeds. Manures usually cause blooms much sooner than inorganic fertilizers do, and taste of fish flesh is determined primarily by food fish eat and by chemicals in pond waters. A stinking pond produces stinking fish.

Turbid waters produce fewer algal blooms than clear waters do and may therefore be preferable. When they receive supplemental feed, channel catfish grow well in clear and turbid (within limits) ponds.

Growth of channel catfish stocked (in ponds) in various size and age combinations

In many species of farm livestock, the larger animals often inhibit the feeding and growth of the smaller animals in a feedlot. We investigated this phenomenon with channel catfish in our experimental ponds.

In 1965 we designed experiments to determine how growth of fish of age group II would be affected when fish were stocked in ponds as follows: 1) large and small fish, with equal total weights for each size category, and therefore fewer large fish than small fish in each of 2 ponds; 2) the same number of large fish in each of 2 ponds; and 3) the same number of small fish as in 2) in each of 2 ponds (Tiemeier and Deyoe, 1968).

Table 32. *Stocking and recovery data for small and large fish of age group II, 1965.*

	Stocking data			Recovery data			
Pond no.	No. of fish	Mean wt. (grams)	Total wt. (lbs.)	%	Mean wt. (g.)	Mean gain (g.)	Total gain (lbs.)
2	35 large	97.3	7.50	100	637	539.7	41.60
	67 small	51.3	7.50	97	433	381.5	54.49
Total			15.00				96.10
6	31 large	109.0	7.50	100	653	544.0	37.08
	66 small	51.6	7.50	100	462	415.4	60.39
Total			15.00				97.47
3	179 large	91.9	36.24	86	547	455.1	149.29
10	179 large	76.1	30.00	99.4	450	373.9	146.43
Total			66.24				295.72
8	179 small	61.3	24,18	100	383	321.3	126.82
12	179 small	60.9	24.00	100	397	336.1	132.53
Total			48.18				259.35

Accordingly, during April 1965 we stocked fish in ponds as follows: 1) equal weights (7 1/2 lbs.) total, each group of large fish (35) and of small fish (67) in pond no. 2 and identical total weights (7 1/2 lbs.) of each group (31 large fish and 66 small fish) in pond no. 6; 2) identical numbers of large fish (179) in ponds 3 and 10; and 3) identical numbers of small fish (179) in ponds 8 and 12.

Data (Tables 32 and 33) indicated excellent survival in all ponds. When equal weights of large and small fish but more small fish were stocked in ponds 2 and 6, considerably more pounds of gain and greater percentage gains were made by the more numerous small fish. When equal numbers of large (ponds 3 and 10) and small fish (ponds 8 and 12) were stocked, large fish gained more individually and collectively than did the small fish of the same age.

Total weight gain of the 489 surviving small fish (374.23 lbs.) was nearly identical with the gain of the 398 surviving large fish (374.40 lbs.).

In 1966 we stocked 200 age group I fish, mean weight of 16.3 grams or 28 per pound, with 50 age group III

Table 33. *Growth (in grams and pounds) and percentage gain of small and large age group II fish, 1965.*

	Stocking weight		Recovery weight		Weight gain		Percentage gain	
Pond no.	Mean (grams)	Total (lbs.)	Mean (grams)	Total (lbs.)	Mean (grams)	Total (lbs.)	All fish	Per fish
				Large fish [1]				
2	97.3	7.50	637	49.10	539.7	41.60	555	555
6	109.0	7.50	653	44.59	544.0	37.08	495	499
3	91.9	36.24	547	185.55	455.1	149.29	412	495
10	76.1	30.00	450	176.43	373.9	146.43	488	491
Total		81.25		455.67		374.40		
Mean	93.6		571.8		478.2		461	511
				Small fish [2]				
2	51.5	7.50	433	61.99	381.5	54.49	727	741
6	51.6	7.50	467	67.89	415.4	60.39	805	805
8	61.3	24.18	383	151.00	321.3	126.82	524	524
12	60.9	24.00	397	156.53	336.1	132.53	552	552
Total		63.18		437.41		374.23		
Mean	56.3		420		363.7		652	656

[1] 398 of 424 stocked large fish were recovered.
[2] 489 of 491 stocked small fish were recovered.

fish in ponds 3, 4, and 18; and 600 age group I fish with 50 age group III fish in pond 17.

In the 1966 experiments, differences in weight and age of fish were greater than in the 1965 experiments. Survivals were excellent for age group I fish but poor for age group III fish (Table 34). Individually, age group III fish gained more than did age group I fish, but total gain for the greater number of small fish was greater than for the large fish (Table 35).

These data for 1965 and 1966 indicate that growth and survival of young channel catfish were not inhibited by being stocked in ponds with the older and larger fish. Observations we made in a small pond stocked with channel catfish ranging in size from 2 to 18 ounces indicated that the larger fish did not intimidate the smaller fish. The first fish to find the feed was the one that fed.

Table 34. *Stocking and recovery data for age group I and age group III fish, 1966.*

	Stocking data			Recovery data			
Pond no.	No. of fish and age group ( )	Mean (grams)	Total weight (lbs.)	%	Mean weight (grams)	Mean gain (grams)	Total gain (lbs.)
3	50(III)	189.6	20.87	68.0	735	545.4	34.17
	200 (I)	16.3	7.17	94.0	219	202.7	83.51
Total			28.04				117.68
17	50(III)	181.9	20.03	66.0	661	479.2	28.01
	600 (I)	16.3	21.51	93.2	123	106.7	129.93
Total			41.54				157.94
4	50(III)	187.8	20.68	78.0	625	437.2	33.00
	200(I)	16.3	7.17	95.0	215.3	199.0	82.93
Total		27.85					115.93
18	50(III)	174.2	19.18	82.0	685.5	511.3	42.72
	200(I)	16.3	7.17	97.0	200.8	184.5	78.63
Total		26.35					121.35

Stocking minnows along with channel catfish

In their supplemental feeding program, certain fish producers have stocked minnows with channel catfish, harvesting and selling minnows periodically during the summer and channel catfish in late fall. To evaluate such a dual program, we stocked 350 channel catfish of age group II (8 to 10 inches long) and 20 fathead or blackhead minnows, *Pimephales promelas,* in each of 4 ponds during April 1967. Fish were fed, 6 days each week, pellets containing 18 or 25% protein at 2.5% of the total weight of the channel catfish. For channel catfish, rate of feed conversion ranged from 2.0 to 2.7 pounds of feed per pound of gain and rate of gain ranged from 721 to 974 pounds per acre. When we drained the ponds in early September, we found many fathead minnows. Minnows were found in the digestive tracts of some channel

Table 35. *Growth (in grams and pounds) and percentage gain of fish in age groups I and III as influenced by stocking combinations, 1966.* [1]

	Stocking weight		Recovery weight		Weight gain		Percentage gain	
Pond no.	Mean (grams)	Total (lbs.)	Mean (grams)	Total (lbs.)	Mean (grams)	Total (lbs.)	All fish	Per fish
				Age group I fish				
3	16.3	7.17	219	90.69	202.7	83.51	1,164	1,244
17[2]	16.3	21.51	123	151.48	106.7	129.93	604	655
4	16.3	7.17	215.3	90.10	199.0	182.93	1,156	1,221
18	16.3	7.17	200.8	85.80	184.5	78.63	1,096	1,132
Total		43.05		418.07		375.00		
Mean	16.3		189.5		173.2			
Mean of ponds 3, 4, 18			211.7	88.88	195.4	81.69	1,139	1,199
				Age group III fish				
3	189.6	20.87	735	55.04	545.4	34.17	164	288
17	181.9	20.03	661	48.04	479.2	28.01	140	263
4	187.9	20.68	625	53.69	437.2	33.00	160	233
18	174.2	19.18	685.5	61.90	511.3	42.72	223	294
Total		80.76		218.67		137.90		
Mean	183.4	20.20	676.6	54.67	493.2	34.48	171	269

[1] Except as noted, 200 group I fish and 50 group III fish stocked in each pond.
[2] 600 (instead of 200) fingerlings were stocked.

catfish. Under the conditions of our experiment, stocking the fathead minnow with the channel catfish resulted in no particular advantages to catfish production, even though. several thousand minnows were trapped, permitted to die, and then fed to the channel catfish. However, the minnows could be harvested and sold.

Table 36. *Results of experiments in which blue catfish and channel catfish were stocked together or separately, 1969.*

Species stocked	Lbs. of fish stocked	No. of fish stocked	Survival (%)	Weight gain Mean (grams)	Weight gain Total (lbs.)	Conversion	Rank (%)
Channels[1]	17	407	100.0	87.8	78.7	1.34	74
Channels[1]	22	616	97.8	60.9	80.3	1.32	75
Blues[2]	17	616	96.1	79.8	103.0	1.03	96
Mixed[1]	17	493	98.7	---	106.4	0.99	100
Mixed blues	8½	302	97.8	90.2	58.4	0.91[3]	
and channels	8½	191	100.0	114.1	48.0	1.10[3]	

[1]Mean of 2 ponds.

[2]Stocked in 1 pond.

[3]Assumes each species used 50% of the feed given.

Stocking blue catfish and channel catfish, together and separately

In 1969 fingerling channel catfish and blue catfish were stocked in ponds as follows: 1) 17 pounds of channel catfish per pond; 2) 17 pounds of (616) blue catfish per pond; 3) 8 1/2 pounds of channel catfish and 8 1/2 pounds of blue catfish together in one pond; and 4) 616 channel catfish (weighing 22 pounds) in one pond– to match the number of blue catfish (616 weighing 17 pounds) in another pond (Table 36).

Comparing the results of various regimens revealed the following:

1) Channel catfish stocked at 22 lbs. per pond individually grew 71.7% less than those stocked at 17 lbs. per pond, but total gain and rate of feed conversion were similar.
2) Blue catfish stocked at 616 (17 lbs.) per pond gained 31.0% more individually and 28.3% more total weight than did channel catfish stocked at 616 fish (22 lbs.); also feed conversion was 28.3% greater.
3) Blue catfish stocked at 8 1/2 lbs. individually gained 26.5% less but 21.6% more in total weight than did the larger channel catfish in the same ponds; also, they had an 11% better feed efficiency.
4) Blue catfish stocked at 8 1/2 lbs. per pond individually gained 15.5% less in weight but 46.8% more in total weight than did similarly stocked channel catfish; also they had a 46.2% better rate of feed efficiency.
5) Channel catfish stocked at 8 1/2 lbs. gained 9.5% more individually and 20.7% more in total weight than did channel catfish stocked at 17 lbs.; also they had a 31.7% better feed efficiency.
6) Blue catfish stocked at 17 lbs. (616) gained 30.1% individually and 29.5% more in total weight than did channel catfish stocked at 17 lbs.; also, their efficiency of feed use was 12.9% greater.
7) Channel catfish stocked at 17 lbs. per pond gained 2.1% more individually but 33.8% less in total weight than did fish from ponds stocked with a combination of the 2 species (at equal weights); the channel catfish in that pond also had a feed efficiency that was 35.7% less than that of fish in the pond containing the 2 species.

Some parasites and diseases of channel catfish

Hatcheries and rearing ponds often are more susceptible to problems of fish parasites and diseases than are bodies of water not heavily stocked. Fortunately in our experiments, we have had little difficulty except when overwintering too many fish in small ponds. Apparently during summer, when fish are feeding regularly and growing well, they are less susceptible than are fish in cold waters to diseases caused by parasites.

Observations indicate that channel catfish, at least up to 1 pound, spend considerable time in groups or schools. If parasites become established, they could readily infect most of the school. Fish growers should know something about diagnosing fish diseases and recognizing parasites and how to treat for them. Publications such as those by Davis (1956) and Clemens and Sneed (1958) can be consulted and facilities can be installed to help determine causes of fish losses.

These precautions can help prevent outbreaks of diseases: Examine fish carefully before stocking and treat if necessary; handle fish carefully to prevent injury or stress; do not crowd fish for long periods; maintain good water quality —ground water is usually free of fish parasites; attempt to determine cause of death and treat fish if dead fish are found; and expose bottoms of ponds to weathering for several months periodically, to help prevent diseases in the future.

Diseases caused by different kinds of protozoa are common and may kill channel catfish or severely weaken them. Information on diseases may be found in these sources: Davis (1956), Clemens and Sneed (1958), Allison (1957 and 1963), and Meyer (1966 and 1966a) Table 37 lists suggested treatments for certain diseases.

Channel catfish are especially susceptible to Ichthyophthiriasis, or "Ich." The organism that causes it is a ciliated, rounded, white protozoan nearly 1 millimeter in diameter. Symptoms are small, grayish-white swellings on fish body and fins. Swellings usually are sharply defined but may be fused on fish heavily infected. Before channel catfish die from Ich, they usually become extremely thin and sluggish and are easy to catch near edges of ponds.

Parasites already on fish cannot be treated because they are embedded in the skin or gills. Treatment is to kill parasites as they emerge from the skin. Several treatments may be required to control this persistent disease.

Trichodiniasis is caused by a saucer- or bell-shaped, ciliated protozoan that clings to its hosts by an adhesive disk. Symptoms are white, irregular blotches on head and dorsal surface of body, frayed fins, sluggishness, and loss of appetite. Treatment usually kills the parasites.

Costiasis is caused by a pear-shaped, flagellated protozoan usually abundant near the base of the dorsal fin and on gills of infected fishes. On channel catfish it may become a serious problem.

Numerous other parasites including worms and crustaceans as well as bacteria, viruses, and fungi may affect channel catfish. If your fish are dying and you are unable to determine the causes of death, contact an experienced fish grower and ask his advice.

Table 37. *Suggested treatments for indicated fish diseases.*

Chemical[1]	Dosage	Treatment procedure	Reference
		Ichthyophthiriasis	
Formalin	200 ppm	Daily for 1 hour	Meyer and Collar (1964)
Formalin	250 ppm	Daily for 1 hour	Davis (1956)
Formalin	15 ppm	1 treatment in ponds	Allison (1957)
Malachite green	0.1 ppm	1 treatment in ponds	Allison (1963)
Formalin	24 ppm	1 treatment in ponds	
			Meyer (1972)
Formalin plus malachite green	0.1 ppm	several in tanks	
		Trichodiniasis	
PMA	2 ppm	1 treatment for 1 hour	Clemens and Sneed (1958)
Formalin	10-15 ppm	1 treatment in ponds	Allison (1963)
Formalin	250 ppm	1 treatment	Davis (1956)
		Costiasis	
PMA	2 ppm	1 treatment for 1 hour	Clemens and Sneed (1958)
Formalin	250 ppm	1 treatment for 1 hour	Fish (1940)
Formalin	10-15 ppm	1 treatment in ponds	Allison (1963)

[1]For other sources of chemicals, inquire of chemical-supply companies near you. Suppliers of malachite green (water-soluble aniline green): E.H. Sargent and Co., Denver, Colo. 80200; J.R. Hess & Co., Topeka, Kans. 66600.

PREPARING CHANNEL CATFISH AS A FOOD DELICACY

Dressing percentages of channel catfish

Percentage of weight lost in cleaning channel catfish depends largely on size of fish and the cleaning system. Small fish lose a higher percentage than do larger fish (Table 38). If fish average about 1 pound and are to be fully dressed, they lose about 50% of their live weight. When fins and "collar bone" are left, loss is about 40%. Machines to skin channel catfish have been in operation for several years.

Table 38. *Live weight, dressed weight, and percentage weight lost for various sizes and 2 dressing procedures of channel catfish.*

No. fish	Average weight (oz.)	Total weight (oz.)	Cleaned weight (oz.)	% of weight lost
13	5.5	718	400	44.3
133	7.2	962	471	51.0
133	8.0	1042	480	53.9
200	7.7	1709	867	49.2
317	11.2	3028	1600	47.2
22[1]	14.4	316	192	39.3
56[1]	12.7	710	436	38.6

[1]Head, pectoral, pelvic, and dorsal fins removed with skin and tail fin left. All others completely cleaned.

Aroma and flavor of channel catfish and experimentally flavoring the fish

Recent studies show that flavor of channel catfish depends primarily on pond conditions; ponds with noticeable off-odors produce muddy-flavored fish. Purging those fish in tanks reduces off-flavors. In addition, catfish kept in tanks and fed specified rations such as turkey livers carry the flavors of the feed. The long-range objective of our work on fish flavor was to recommend, from the consumers' viewpoint, preferred methods for producing, processing, and handling catfish in retail markets, homes, and restaurants (Maligalig *et al.,* 1973).

Channel catfish were seined from our experimental ponds and identified throughout the experiment by the following code:

Group code	*Pond no.*	*Aroma and flavor*
A	4	Acceptable
B	6	Muddy
C	7	Acceptable

Immediately after being seined, fish were dressed and individually wrapped in heavy-duty aluminum foil, then labeled and transported to the University's Food Flavor Laboratory. Samples were held refrigerated, frozen in a walk-in freezer (–15 to 5°F), or frozen in liquid nitrogen spray.

To allow inherent aromas and flavors to be perceptible, each fish sample was steamed over boiling, deionized water in a covered aluminum pan. Fish cooked from the frozen state were steamed 5 to 10 minutes longer than were thawed fish.

Tasters experienced in the flavor-profile method examined 1 hot fish at a time and 2 fish from a given group per session. Panelists independently recorded aroma and flavor findings and discussed them to define the descriptive vocabulary (Table 39).

Fish taken directly from pond 6 had muddy aroma and flavor. To eliminate off-flavors, tainted fish were held without feed in an aerated tank having a continuous flow of well water. Purging was accomplished in 18 days; 11 days of treatment helped, but it did not entirely eliminate earthy flavor.

We therefore periodically took samples from the pond to analyze. Sometimes fish seined from pond 6 had earthy and muddy flavors. Analyses of algae present showed an abundance of the algae *Anabaena*, *Ceratium*, and *Pediastrum*, all known *to* emit characteristic odors and tastes. *Anabaena* produces grassy, nasturtium-like odors when growth is moderate and a septic odor when growth is abundant. *Pediastrum* produces a green, grassy odor, and a pronounced fishy odor is associated with *Ceratium*. Abundant growth of these algae undoubtedly contributed to the earthy and muddy flavors in the fish.

Fish taken from ponds 4 and 7 had no off-flavors, although those slow-frozen from the same catch developed earthy and lemony off-flavors after a month or more of storage. Slow freezing combined with refrigerator-freezer storage (–15 to 50°F) seemingly caused undesirable flavor changes. The fish were inedible after 5 days of refrigeration.

Samples cooked from the frozen state after 11 days of freezer storage tasted more like freshly caught, purged fish than did samples from the same lot cooked after 3 days of refrigeration.

Thawing method also seemed important. Fish frozen and stored in a home-type freezer exhibited slightly poorer flavor when cooked from the frozen rather than from the thawed state.

After 2 weeks of freezer storage, the fish lost fresh character of the fishy note. Total flavor decreased progressively, being almost nil at week 6. Panelists noted various degrees of "old" fishy character in fish stored 10 weeks. The 20-week-old samples were described as "stale" and "old fishy."

Different sites of the same cooked fish had slight flavor differences. Anterior portions (belly and top) were similar, but differed from the tail portions, which usually had more total flavor. Dorsal and ventral sides of the tail had similar flavor.

Large fish samples often seemed to have stronger intensities of "less desirable" flavor.

Some fish were held without feed in aerated metal tanks for 3 months at 70°F. Frozen turkey liver, thawed overnight under refrigeration, was fed to fish in 1 tank and a 25% protein floating feed to those in another tank.

Panel examinations of the boiled turkey livers and floating feed led to these observations: Livers had some liver, gizzard, and poultry character and tasted bitter; the floating-feed aroma had a cereal or grain identity.

Turkey liver notes were present in the flavor of fish fed turkey livers for 19 days; they were more pronounced in the flavor of fish fed the liver for 33 days. Fish given the prepared feed also exhibited properties of the feed in their flavor after 33 days of feeding.

The next series of experiments (Maligalig *et al.*, 1975a) were designed to demonstrate the effect of 3 concentrations of the flavorants 2-pentanone (methyl propyl ketone) and dimethyl sulfide (DMS) and 3 exposure times on their flavor-imparting capacities of channel catfish. Both flavorants met the following criteria: 1) Odor differed from channel catfish odor with intensity differences detectable by panel members; 2) polar characteristics differed; 3) retention times on chromatographic column differed from retention times of volatile constituents of channel catfish; and 4) they were fluid at room temperature.

Live channel catfish were retained in aerated, 20-gallon glass aquaria containing concentrations of 25, 62.5, or 125 parts per million (ppm) by weight of odor-imparting chemicals; they were exposed 10, 20, or 30 minutes. (Two teaspoonsful of the flavorant in 20 gallons would provide approximately 25 ppm.)

Four fish were used for each flavoring treatment: 2 cooked for sensory evaluation and 1 raw and 1 cooked for each gas-liquid chromatographic (GLC) analysis. Fish were dressed and prepared for anal-

Table 39. *Aroma and flavor of cooked channel catfish.*[1]

Days in tank	Fish group	Days of storage		Observations	
		Frozen	Refrig.	Aroma	Flavor
11	B	-	3	earthy	fishy, earthy
11	A	-	3	earthy	meaty, earthy
11	C	-	3	green	fishy, lemon, sweet, meaty
11	B	4	1	fishy, green	earthy
11	A	4	1	fishy, (pond water)	slightly earthy
11	C	4	1	fishy, green, meaty	meaty, chicken-like
18	B	-	-	fishy	flat, just misses earthy
18	A	-	-	fishy	fishy flat (fleeting earthy aromatic)
21	A	7	-	fishy, green	flat, slightly earthy
21	B	8	1	fishy, green	meaty, earthy
21	A	8	1	fishy, green	just barely earthy, almost lemony, sweetish
32	B	-	-	green	earthy, odd flavor
32	A	-	-	fishy, green, rubbery	earthy, rubbery
32	C	-	-	fishy, rubbery	fishy, fatty, odd flavor
39	B	-	1	fishy, green	earthy, lemony
39	A	-	1	fishy, green	earthy
39	C	-	1	fishy	fishy
63	B	-	1	fishy, green	bland, fishy, just barely earthy

[1]All fish of age group I (avg. wt., 107 grams), seined from KSU experimental ponds.

yses immediately after being removed from the aquaria. Four untreated fish (controls) were dressed and prepared for flavor and GLC analyses. Aqueous tissue extracts for GLC analysis were prepared after fish flesh had been removed from the bones, prepared into a slurry by adding water, and homogenized.

The results of these experiments indicated that live channel catfish held in solutions at 25, 62.5, and 125 ppm of 2 pentanone or dimethyl sulfide quickly absorbed the chemicals (Fig. 12). Pentanone concentration in cooked fish was correlated with flavor score and with concentration in raw fish, although cooked fish had 48-67% less 2-pentanone than raw fish did. Fish apparently lost 50% of the pentanone during cooking through volatization or interactions with other compounds.

Flavor scores for treated fish indicated that intensities of acquired flavors were proportional to flavorant concentrations.

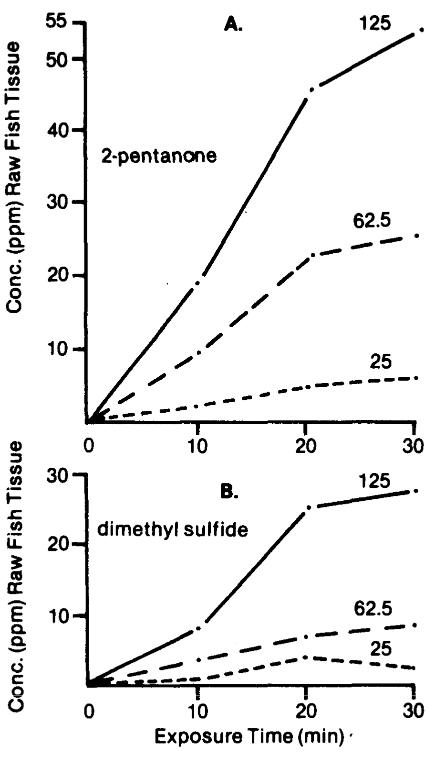


Figure 12. *Effect of exposure time on flavorant concentration in raw tissues of fish exposed to solutions containing 25, 62.5, or 125 ppm of (A) 2-pentanone or (B) dimethyl sulfide.*

Live channel catfish absorbed 2-pentanone or DMS within 10 minutes after being exposed to either solution. Such rapid absorption indicated that these catfish absorb compounds through the gills. The rapid rate that live channel catfish absorb flavors from their environment, as shown by our experiments, emphasizes that rigid control measures are needed in the catfish industry to prevent off -flavors.

Further studies were conducted (Maligalig *et al.*, 1975b) to determine how rapidly live channel catfish can eliminate flavorants during storage and when purged. Live channel catfish treated with 2-pentanone or DMS for 30 minutes at a concentration of 125 ppm were either dressed for storage at 5°C or were placed into 150-gallon tanks with running dechlorinated tap water.

Concentration of 2-pentanone in dressed fish refrigerated 1, 2, or 3 days changed little, although concentration in cooked fish varied less than in raw fish. Concentration and flavor intensity of DMS were lower in fish refrigerated 3 days than in fish refrigerated 1 or 2 days, but differences were not significant statistically.

Purging reduced pentanone in raw fish 2.1 ppm per hour; DMS, 1 ppm per hour (Fig. 13). These studies indicated experimental flavors are easier to produce in channel catfish than to get rid of.

Because the preliminary studies indicated the feasibility of "preflavoring" channel catfish, a study (Clithero, 1975) was undertaken to assess the flavor effects and retention of a preflavoring treatment of channel catfish. The preflavorant was Griffith's Natural Concentrated Liquid Smoke Flavor—a hardwood smoke mixture, stable to refrigeration and freezing, that will readily mix with water.

Live fish were preflavored by holding them for 30 minutes in an aerated, 20-gallon aquarium filled with dechlorinated tap water and 125 ppm, 10 g.; 250 ppm, 19 g.; or 500 ppm, 38 g. of the liquid smoke. After exposure, fish were dressed.

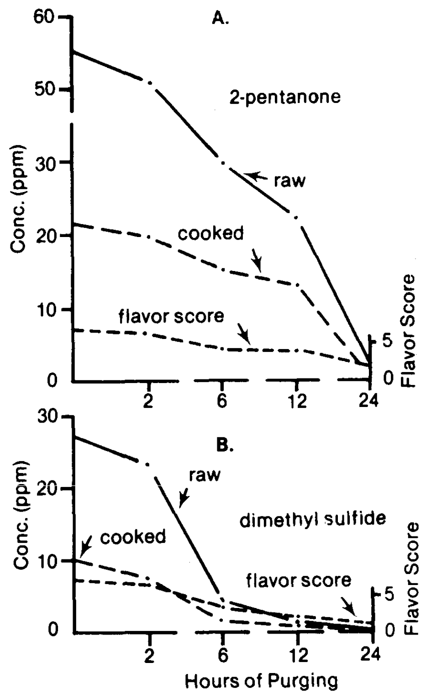


Figure 13. *Effect of purging on flavor score and concentration of (A) 2-pentatone and of (B) dimethyl sulfide in raw and in cooked fish.*

Some were placed in refrigerated storage for 0-1 day, considered market fresh; some for 3 days. Some fish were kept in frozen storage for 2, 6, 8, or 10 weeks. For frozen fish, untreated fish (controls) also were stored.

A 4-member, trained taste panel used the flavor-profile method of examining the fish. Interpreting their findings emphasizes 2 flavor factors: fish quality and smoky character. Preflavored fish refrigerated 3 days before steaming did not show any striking aroma and flavor differences from day-old fish. That indicated the smoky flavoring endured throughout the storage period and did not change in quality.

In frozen fish cooked by steaming, smoky character endured throughout the 8 to 10 weeks' storage period. Control fish developed off-fish flavor described as "old." With one exception, any possible off-fish or offnotes were covered by the smoky flavoring. A "seasoned" quality was first described at 6 weeks; apparently the flavor of reflavored, steamed fish was enhanced, or made fuller, by the smoke flavoring. The smoky character in aroma and flavor endured and remained intact.

In the aroma, the smoky-note intensity was in the same range for the 3 preflavoring concentrations, and in the flavor smoky character was approximately the same for all levels: slight. Smoky was reported in the aftertaste, when the smoky note in flavor had been found at the 500-ppm level.

The smoky flavor endured throughout the storage periods and survived the cooking methods, maintaining (with a few exceptions) its true identity. It apparently masked, although that was not intended, undesirable aromas and flavors that developed during prolonged frozen storage. Preflavored fish had more total or fuller flavor than did untreated fish.

Other preflavorants used successfully were garlic, onions, and even vanilla.

Smoking channel catfish

A gourmet food item can be produced by smoking channel catfish, as here described. Remove the viscera and head of fish weighing 10 to 14 ounces—do not remove the skin. (If larger fish are used they should be split into pieces.) Marinate the eviscerated fish overnight (refrigerated) in a solution of 1 pound of brown sugar and 1/2 pound of salt dissolved in 1 gallon of water. Then place the fish on racks in an old refrigerator—one having metal, not plastic, lining. Also, place an aluminum container (or 2 containers) filled with your favorite baked beans on the shelves. Insert a meat thermometer through the wall of the refrigerator toward the top; the hole left when the electric cord was removed remains as an outlet for the smoke.

Place a gallon can of small, moist fruitwood twigs (we prefer apple) on an electric hotplate in the bottom of the refrigerator. When the temperature on the meat thermometer reaches 180°F, turn off the electricity to the hotplate and plug the smoke-outlet hole to help retain the heat. Within 2 1/2 to 3 hours the fish will be cooked. The skin will retain some of the moisture, and the meat can readily be removed from the skin and bones.

The smoked fish, potato chips, baked beans, and your favorite beverage provide a delicious treat. Uneaten fish and beans can be frozen in heavy foil and eaten at a later date.

SUMMARY AND RECOMMENDATIONS

1. Do not feed fish unless you plan to feed them regularly and plan to continue feeding until you harvest them. You must have an adequate water supply. Because not all fish are recovered by seining, ponds should have an adequate drain pipe.

2. Feed fines or crumbles to fish less than 4 inches long, then feed pellets 3/16-inch in diameter and 3/8-inch long. Any feed mill with mixing and pelleting equipment can prepare the pellets. Request a firm, durable pellet.

3. Stocking 1,000 fingerlings 5 to 6 inches long per surface acre of water is recommended for rapid growth of the fish. Do not stock more than 2,000 fingerlings per surface-acre if you plan to raise the fish to 1 pound or more. Fry stocked at 3 to 5 pounds per acre can be expected to grow well if given supplemental rations. Depending on water volume, channel catfish can be reared at rates to 2,000 pounds per surface-acre per year, provided water temperature is 70°F or higher.

4. The Kansas Fish and Game Commission will not provide fish for a feeding program, but channel catfish can be purchased from private sources.

5. In Kansas, if fish are purchased and fed in waters originating on the owner's property, they can be harvested and sold without a permit. For other areas, write to your state fish and game organization for a copy of the laws and regulations on feeding and selling fishes.

6. Feed when water temperature is above 60 or 65°F. Better feed conversions and faster growth are obtained at 70 to 80°F than at 65 or 70°F.

7. Fish should be fed at the same time each day (6 days per week) and at about the same location in the water, but no deeper than 3 or 4 feet. Fish can be trained within a few days to come to a certain location in the pond to be fed. We recommend that daily, 6 days a week, fingerlings 4 to 10 inches long be given feed equal to 3% of their total weight and fish 10 inches long (up to 1 pound) at 2% or less of their total weight. Fry should be fed twice daily, 7 days a week, at 5% daily. Amount (not percentage) is increased every 2 weeks as fish increase in size. Do not expect to see the fish feed if you give them sinking pellets. However, you may see around the feeding areas swirls in the water made by the larger fish in search of the pellets.

8. Any results approximating 1 1/2 to 2 pounds of feed per pound of gain should be considered excellent. As fish become larger, rates of feed conversion become less efficient.

9. Fish require nutrients for growth. A well-balanced formula is one consisting of sufficient nutrients for energy and adequate amounts of amino acids from protein sources, vitamins, and minerals. Such a formula should insure that fish will grow rapidly and remain healthy, when combined with a good fish-management program.

10. Growth and conversion obtained by feeding fish pellets have been as good as those obtained by feeding chopped packing-house wastes. Pellets are much easier to feed. Fresh ingredients should be included in the preparation of rations.

11. Do not feed manures or animal products that may be contaminated. Good feed and water produce good fish. To assure consumers an excellent product, producers must take special care in feeding and handling fish. Properly reared fish make a nutritious, delicious, healthful food.

12. Fish are especially sensitive to careless handling. Crowding, squeezing, bruising, and lack of oxygen should be avoided. Diseases and parasites thrive best on injured fish.

13. The Kansas Commercial Fish Growers Association, organized to develop potentials of commercial fisheries in Kansas, welcomes new members.

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Table of Conversion Units

1 acre-foot	=	1 acre of water surface area and 1 foot deep.
	=	43,560 cubic feet.
	=	2,718,144 pounds of water.
	=	326,000 gallons of water.
1 cubic foot	=	7.5 gallons.
	=	62.4 pounds of water.
	=	28,354.6 grams of water.
1 gallon	=	8.34 pounds of water.
	=	3,800 grams of water.
	=	3,800 cubic centimeters.
1 quart	=	950 cubic centimeters.
	=	950 grams of water.
1 pound	=	453.6 (or 454) grams.
	=	16 ounces.
1 ounce	=	28.35 grams.

1 ppm (parts per million) requires
- 2.7 pounds per acre-foot.
- 0.0038 gram per gallon.
- 0.0284 gram per cubic foot.
- 0.0000623 pound per cubic foot.

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