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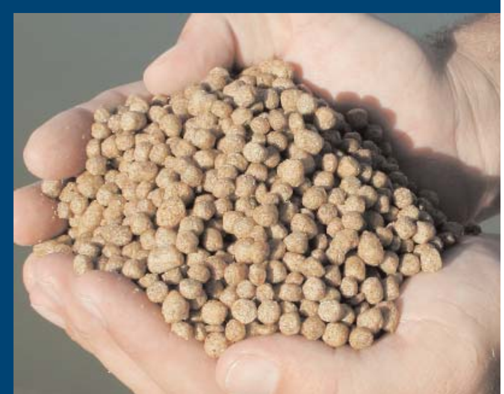
A Summary of Catfish Nutrition Research Conducted Under a Cooperative Agreement Between MAFES and Delta Western Research Center



Experiment Station
Vance H. Watson, Director

Mississippi Agricultural & Forestry Experiment Station
J. Charles Lee, President • Mississippi State University • Vance H. Watson, Vice President

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Catfish Nutrition Research

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Edwin Robinson
Research Professor
Delta Research and Extension Center

Menghe Li
Research Professor
Delta Research and Extension Center

We thank those in MAFES and at Delta Western that had the foresight to enter into a cooperative research agreement. Without the combined resources available through the agreement, we would not have been able to accomplish a third of what we have. Also, thanks to the research associates, technicians, and other scientists that contributed to this work, because without them the research could not have been done. Bulletin 1144 was published by the Office of Agricultural Communications, a unit of the Division of Agriculture, Forestry, and Veterinary Medicine at Mississippi State University.

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PREFACE

This bulletin is a summary of 15 years of catfish nutrition research conducted under a cooperative agreement between the Mississippi Agricultural and Forestry Experiment Station (MAFES) and Delta Western Research Center (DWRC). It was prepared in response to requests by the catfish industry. It is intended to serve as a source of nutritional information that will be useful to catfish farmers, researchers, and students. The bulletin is arranged in a manner that is easily read. For example, we did not include data tables or references in the text so they do not distract from our main points, but the data and references are easily accessible in appendices to those wishing to use them.

Lester Myers, Jr., (left) president of Delta Western Feed Mill, is pictured with Vance Watson, director of the Mississippi Agricultural and Forestry Experiment Station and vice-president of the Mississippi State University Division of Agriculture, Forestry and Veterinary Medicine. Myers, who is also a catfish producer, provided the foresight and leadership that lead to the establishment of the Delta Western Research Center in 1990 to complement the catfish research program at the Delta Research and Extension Center.

Introduction

For the last 15 years, most nutrition and feeding information developed for catfish has resulted from work conducted under a cooperative agreement between the Mississippi Agricultural and Forestry Experiment Station (MAFES) and Delta Western Research Center (DWRC). Extensive production research has been conducted on the nutrition and feeding of catfish, and as a result their practical nutrient requirements and feeding characteristics are well documented. Those data, along with basic nutritional data derived from earlier studies conducted at various sites, have served as a basis for the formulation of efficient, economical diets and for the development of feeding strategies — both of which have been instrumental to the success of the catfish industry. Today's catfish producer feeds a nutritionally complete diet that provides all known nutrients at required levels and the energy necessary for their utilization in a water-stable, readily digestible form.

The studies summarized here were conducted jointly by MAFES (via the Thad Cochran National Warmwater Aquaculture Center) and DWRC. Various topics related to catfish nutrition and feeding are discussed briefly, conclusions made, and recommendations given. Data are presented in the appendices for in-depth review by the reader.

Bill McClain (left), research technician (7 years); Derrick Cotton, research technician (5 years); Tommy Jobe, research technician (1 year); Jan Swindell, research technician (2 years); and Dwayne Holifield, research manager (8 years). Not pictured: Otis White, Sr., research technician (3 years); Allen Milton, research technician (1 year); and Ed Robinson, research coordinator MAFES/DWRC.

MAFES nutrition group at the National Warmwater Aquaculture Center: Sandra Phillips (left), fishery technician (10 years); Danny Oberle, research associate III (9 years); Menghe Li, research professor (14 years); Leighton Janes, research associate I (2 years); and Cliff Smith, fishery technician (8 years). Not pictured: Ed Robinson, research professor (21 years).

CATFISH NUTRITION RESEARCH METHODS

The research reported in this bulletin was primarily conducted in ponds, but some data were derived from control laboratory studies. Conducting laboratory growth studies gives the researcher control of all but the variable being studied. Thus, if differences occur among treatments, one can reasonably assume that they were caused by the variable introduced into the diet or environment. Laboratory studies are much less expensive than pond studies, but since they are typically conducted with small fingerlings for relatively short periods of time (8–12 weeks), the data are generally considered preliminary. However, if treatment differences are not seen in a laboratory, it is highly unlikely that differences will be seen in a pond study. This is because of the higher experimental variability inherent in pond studies. The laboratory studies reported here were conducted using well-established procedures for feeding studies with catfish. Generally, small fingerlings (4–6 grams) were raised in glass aquaria (4–5 aquaria per treatment) in a flowing-water, temperature-controlled system for 8–12 weeks. Fish were typically fed the experimental diets once or twice daily to satiation. Water quality parameters were maintained at levels optimum for catfish growth.

Practical catfish research must be conducted to closely reflect commercial culture practices. However, it must be based on proper experimental design so that the appropriate statistical method can be applied and valid conclusions can be drawn. Because of the relative high experimental variability observed among ponds, several replicate ponds are required for each treatment. This adds significantly to the already high cost of conducting pond research. Pond studies reported here were conducted in small (0.1- to 1-acre) research ponds using management practices that reflect those used in the industry. Most of the studies were conducted for a single growing season, but some were multiyear studies. Additional details on the experimental design of specific studies are described in the footnotes of various tables in Appendix I.

Nutrient Characteristics of Farm-Raised Catfish

Previous reports on the nutrient profile of catfish show that it is highly nutritious, being high in protein, low in fat and cholesterol, and a good source of certain vitamins and minerals. We revisited this issue because several changes in the diet that have been implemented since the last report may affect nutrient composition of catfish. These include an increase in the digestible energy (DE) to crude protein ratio (DE/P) of the diet, a decrease in the concentration of marine fish meal, and a reduction or elimination of certain vitamins and minerals in premixes typically used by the catfish feed industry. Also, feeding rates have continued to increase, which may affect tissue nutrient content. In addition to muscle tissue, liver nutrient concentrations were determined. Liver data can be used in conjunction with data from muscle tissue to provide baseline nutritional information that may be useful in assessing the nutritional status of catfish.

Proximate composition of muscle averaged over three seasons (fall, winter, spring) was fairly typical of food-sized channel catfish. On an average, 100 grams of raw tissue contained 16.3 grams of crude protein, 5.4 grams of crude fat, 77.3 grams of moisture, and 1.1 grams of ashes (Appendix I, Table 1). Crude fat was somewhat lower than the 6.9 grams per 100 grams of raw tissue previously reported. We typically observe significant variation in the fat content of individual catfish. This may be related to genetic variation, diet composition, or feed intake. When fat data were corrected for fish size, fish sampled in the fall contained a higher level of fat compared with fish sampled in the spring or winter. No other seasonal changes in proximate composition were observed. Mean energy value for muscle tissue from our study was 118 kcal per 100 grams of raw tissue (Appendix I, Table 1), which was lower than previously reported. The lower energy value observed in the present study appears to be related to the lower level of fat contained within muscle tissue.

The major fatty acids in fillets, accounting for about 75% of the total, were 16:0, 18:0, 18:1, and 18:2 n-6 (Appendix I, Table 2). Saturated fatty acids accounted for 23.8% of total fat, monoenoic fatty acids 43.8%, dienoic fatty acids 15.3%, and trienoic fatty acids 4.1%. Muscle tissue contained 3.7% n-3 (omega-3) fatty acids (omega-3) and 21.5% n-6 (omega-6) fatty acids. These values are within the range generally found in catfish muscle tissue, but their concentrations are dramatically influenced by diet. For example, feeding a source high in n-3 fatty acids (marine fish oil) results in a significant increase in n-3 fatty acids deposited in the tissue.

The major fatty acids found in the liver were the same as those found in muscle. The primary differences between liver and muscle fatty acids were that dienoic fatty acids were markedly lower, and both n-3 and n-6 highly unsaturated fatty acids were higher in liver. There were some seasonal differences in both liver and muscle fatty acids. For example, n-3 fatty acids were higher in the winter and spring than in early fall. It may be that n-3 fatty acids were conserved for proper physical and metabolic functions. In addition, during the winter and spring, catfish are fed sparingly and may consume natural food organisms that are rich in these fatty acids.

Vitamin concentrations (Appendix I, Table 3) of muscle tissue were similar to values previously reported. There were some seasonal variations in tissue concentrations of pantothenic acid and choline. Concentrations of vitamins in liver tissue were generally higher than in muscle except for thiamin and choline (Appendix I, Table 4). These values were similar to values of pond-raised channel catfish fed a diet containing supplemental vitamins at recommended levels.

Mineral concentrations in muscle (Appendix I, Table 5) were similar to values previously reported. No appreciable seasonal variation was observed in mineral concentrations. Pond-raised channel catfish are a good source of phosphorus, potassium, and selenium.

Conclusions

1. *Muscle nutrient profile shows that channel catfish are highly nutritious — high in protein, low in fat, and a good source of certain vitamins and minerals.*
2. *Liver nutritional profile may be useful in assessing the nutritional status of the fish.*
3. *Changes that have been implemented in commercial catfish diets during the last few years, such as an increase in the DE:P ratio, a decrease in marine fish meal, and a reduction in the concentrations of supplemental vitamins and minerals, have not appreciably affected the nutrient composition of the fish.*

Dietary Components

Energy

Quantitatively, energy is the most important component of the diet, because feed intake in animals that are fed *ad libitum* is largely regulated by dietary energy concentration. Since catfish are not typically fed *ad libitum*, feed intake may be more of a function of feed allowance than of the dietary energy concentration, except when the fish are fed to satiety. Although catfish feed intake may not be strictly regulated by the dietary energy concentration, balance of dietary energy in relation to dietary nutrient content is important when formulating catfish feeds. This is true primarily because a deficiency of nonprotein energy in the diet will result in the more expensive protein being utilized for energy.

Absolute energy requirements for catfish are not known. Estimates of the requirement have been determined by measuring weight gain or protein gain of catfish fed diets containing a known amount of energy. Energy requirements reported for catfish, which have generally been expressed as a ratio of DE to crude protein (DE/P), range from 7.4 to 12 kcal per gram. Work reported in this bulletin (Appendix I, Tables 6–13) support previous data in that a DE/P ratio of 8.5–9.5 kcal per gram is adequate for use in commercial catfish feeds.

Conclusions

1. *A 28% protein feed should contain 1,080–1,200 kcal DE per pound, and a 32% protein feed should contain 1,235–1,380 kcal DE per pound.*
2. *Increasing the energy of catfish diets above the optimum range may increase fat deposition or, if the dietary energy is too low, growth rate will be reduced.*

Protein and Amino Acids

Protein comprises about 70% of the dry weight of fish muscle. A continual supply of protein is needed throughout life to supply amino acids and nonspecific nitrogen for maintenance and growth. It is difficult to set a specific level of dietary protein that is optimum for all situations, because several factors affect the dietary protein requirement of catfish. These include water temperature, feed allowance, fish size, amount of nonprotein energy in the diet, protein quality, natural food available, and management practices. Further, the optimum dietary protein level is driven by economics as much as rate of gain. Thus, to maximize profits, the optimum dietary protein level should be changed as fish and feed prices change. In the past, catfish producers have typically fed the same level of dietary protein regardless of cost factors because there were no other choices. Currently, lower-protein feeds containing a reduced concentration of animal protein are available that provide for rapid and more economical gain.

In regard to dietary protein, a catfish producer typically equates protein quantity to feed quality when evaluating feeds — generally considering a higher-protein feed to be superior. In reality, when evaluating feed quality, the actual percentage of dietary protein is not as critical as the concentrations and proportions of amino acids provided in the protein. To insure that catfish feeds are of high quality, the nutritionist considers several factors, including the amino acid composition of various feedstuffs and their digestibility, along with the proper balance of protein and energy. The most economical method to achieve the proper balance between protein quantity and quality is to use a mixture of complementary protein feedstuffs and (if needed) supplemental amino acids. For example, the nutritional value of distillers' grains and cottonseed, peanut, and canola meals is improved by adding feedstuffs high in lysine (blood meal, fish meal) or by adding supplemental lysine.

Since dietary protein is the most expensive component of a catfish feed, our research has concentrated on the protein nutrition of catfish. Studies summarized here (Appendix I, Tables 6–36) examine the following issues: optimum protein requirement and protein quality on growth and processed yield, protein sources, effect of feeding rate and stocking density on the protein requirement, finishing diets, use of supplemental amino acids in practical diets, dietary protein and disease resistance, and effect of fish strain on protein requirements.

In evaluating the studies on dietary protein presented in Appendix I (Tables 6–36), several points need to be discussed. Catfish do not require as much dietary protein for maximum growth as has typically been thought. We examined dietary protein levels from 10–40% in various studies and found no differences in weight gain and feed conversion in fish fed diets containing as low as 24% protein. In addition, we found that fish fed 16–20% dietary protein had 80–90% of the growth of fish fed a 32% protein diet. However, as dietary protein decreased, the DE/P ratio increased beyond the recommended range, resulting in an increase in visceral and fillet fat. This effect is quite dramatic in diets containing very low levels of dietary protein. Fish fed 16% dietary protein grew well but had about twice as much body fat as similar-sized fish raised on a 32% protein diet. The primary problem with increased fattiness is that too much fat may reduce processed yield. There are many factors other than diet that affect processed yield, but in general, fish that are fed 26% or less dietary protein will have reduced processed yield. The data are not as consistent with fish fed a 28% diet since some studies show a reduction in processed yield and some do not. Overall, there are minimal differences in processed yield of fish fed a 28% or 32% protein diet, but the difference may be significant to catfish processors. Diets containing 35% protein or more may result in a decrease in fattiness compared with fish fed a 28% or 32% diet. This approach to reduce fattiness and increase processed yield may not be economical for the catfish producer, but if the producer is paid a premium for higher processed yield, it may be a more attractive proposition.

Catfish do not require animal protein for grow out (Appendix I, Tables 14–16). All-plant diets based on soybean meal, wheat, and corn can be formulated to meet the amino acid requirements for grow out of catfish. It should also be noted that all-plant diets require additional supplemental phosphorus and the use of a mineral premix. The advantages of using all-plant diets include lower feed cost, milder flavor, and less body fat because of a reduction in dietary energy.

Cottonseed meal, canola meal, and distillers' grains can be used to replace part or all of the soybean meal (Appendix I, Tables 17–21). If the inclusion rate is higher than 20–25% of the diet, then the diet may need to be supplemented with lysine. The use of these ingredients will depend on their cost per unit of protein. Also, corn gluten feed can be used to replace up to 50% of the corn (Appendix I, Table 22). This will help reduce fattiness because of the decrease in dietary energy resulting from replacing corn with corn gluten feed. Levels of the yellow pigment xanthophyll in corn gluten feed are generally similar to xanthophyll levels in corn grain; thus, it does not result in yellow coloration in catfish fillets.

Fish meal can be replaced by poultry by-product meal, meat and bone/blood meal, catfish offal meal, hydrolyzed feather meal plus lysine, or a combination of these protein sources (Appendix I, Tables 23–25). Care must be used to ensure that these products are of high quality, because processing methods can have a significant effect on their quality. Although these products are good sources of protein for catfish, their use depends on cost and availability. Further, since the perception of using beef products to feed catfish may be detrimental to marketing catfish products (because of its implication of "mad cow" disease), we do not recommend the use of beef by-products in catfish feeds.

Generally, low-protein diets are effective when fish are fed to satiation, but higher-protein diets are required when feed is restricted. It appears that a 28% protein diet provides for good growth at feeding rates of 80 pounds per acre per day or more (Appendix I, Tables 26a–28). Also, a 28% protein diet can be fed throughout the growing season. We find no advantage to begin feeding in early spring with a higher-protein diet and then reducing dietary protein as feeding activity increases if fish are fed all they will eat daily. However, if feeding is restricted to every other day or every third day, higher-protein diets are recommended.

Finishing catfish on high-protein diets to reduce body fat does not appear to be an effective strategy (Appendix I, Table 29). That is, there is no difference in body fat of fish fed a 28% protein diet for most of the growing season and then fed a high-protein diet for 30–90 days before harvest compared with fish fed the 28% protein diet for the entire growing season. There were also no differences in fish fed a 28% or 32% protein diet for 150 days compared with fish finished for 30 or 60 days on 35% or 38% protein diets. Basically there were no advantages to using high-protein finishing diets.

Adding supplemental amino acids to low-protein diets to simulate a higher-protein diet does not improve growth. For example, adding the limiting amino acids lysine and methionine to a 24% protein diet to simulate the levels of these amino acids found in a 32% protein diet does not improve performance (Appendix I, Table 30). This is because the diet contained the proper levels of essential amino acids as expressed as a percentage of the protein. That is, diets that contain adequate levels of amino acids are not improved by adding additional amino acids. However, if the diet had been deficient either in lysine or methionine, a growth response would have been observed when the diet was supplemented with those amino acids.

Higher-protein diets (32–35%) may increase net production and weight gain when feeding every other day compared with feeding daily (Appendix I, Table 31a, b), but this practice may or may not be economical. Regardless of diet, feeding every other day improves feed efficiency and reduces aeration time, but weight, carcass yield, and fillet yield are reduced compared with fish fed daily.

There were no differences in fish production using a 28% or 32% protein diet when fish were stocked at 6,000, 12,000, or 18,000 per acre (Appendix I, Table 32a). Further, production increased with stocking density, but the fish were smaller. Over two growing seasons, fish weight was 2, 1.5, and 1.4 pounds for fish stocked at 6,000, 12,000, or 18,000 per acre, respectively. Feed efficiency also decreased at the higher stocking densities. Fish fed the 28% protein diet were slightly fatter than those fed the 32% protein diet, but there was no effect on processed yield (Appendix I, Table 32b).

Low-protein diets are generally recommended for stockers and food fish, but not for small fingerlings. However, there were no differences in production of fingerling catfish (23 pounds per 1,000 initial weight) stocked at 100,000 per acre and raised to 100 pounds per 1,000 using either a 28%, 32% or 41% diet (Appendix I, Table 33). It would appear that high-protein diets offer no advantage for fingerlings from about 4 inches in length and larger.

Protein requirements did not differ among catfish strains [Mississippi normal, USDA102, USDA103 (now, NWAC103), and Norris] (Appendix I, Tables 34–36). Thus, it appears that for commonly used catfish strains, dietary protein requirements are similar.

Neither the level of dietary protein nor the source of dietary protein affected the response of catfish exposed to *Edwardsiella ictaluri*, the bacterium causing enteric septicemia of catfish (ESC) (Appendix I, Table 23). Fish fed diets containing 28%, 32%, or 36% protein without animal protein or with fish meal, meat and bone/blood meal, or a combination of the two sources did not differ in survival after challenge with the bacterium. All diets were formulated to meet all nutritional requirements of catfish; thus, no difference would be expected unless dietary protein was a factor. Basically, this illustrates that the nutrients needed for immune response and growth can be supplied by various feedstuffs.

Conclusions

1. *Catfish grow as well on low-protein diets (24–28%) as they do on 32–35% protein diets, but fattiness may increase and processed yield may decrease as dietary protein is reduced.*
2. *Animal protein is not required in the diet for food fish grow out; a properly balanced all-plant diet can provide the nutrients needed for rapid growth of catfish.*
3. *Various mixtures of feedstuffs can replace soybean meal, and fish meal can be replaced by other animal proteins or soybean meal.*
4. *Supplementing low-protein diets with lysine and methionine to mimic a higher-protein diet does not improve catfish growth.*
5. *Feeding every other day to satiation improves feed efficiency and reduces aeration time, but weight gain and processed yield are reduced compared with feeding daily.*
6. *Diets containing 32–35% protein appear to be beneficial when feeding every other day.*
7. *Increasing dietary protein from 28% to 32% did not affect fish production as stocking rate increased up to 18,000 fish per acre when fish were fed once daily to satiation.*
8. *As stocking densities increased (6,000, 12,000 and 18,000 per acre), fish average weight was reduced, and fewer fish were of harvestable size.*
9. *Commonly used catfish strains have similar dietary protein requirements.*
10. *Increasing dietary protein does not improve immunity of catfish to* Edwardsiella ictaluri.

Lipids

Lipids (fats and oils) are a highly digestible source of concentrated energy and play several important roles. These roles include supplying essential fatty acids (omega-3 fatty acids), serving as a vehicle for absorption of fat-soluble vitamins, and serving as precursors for steroid hormones and other compounds. The type and amount of lipid used in catfish diets are based on essential fatty acid requirements, economics, constraints of feed manufacture, and quality of fish flesh desired. Lipid levels in commercial feeds for food-sized catfish rarely exceed 5–6%. About 3–4% of the lipid is inherent in the feed ingredients, with the remaining 1–2% being sprayed onto the finished pellets. Spraying feed pellets with lipid increases dietary energy and aids in the reduction of feed dust ("fines"). A variety of vegetable and animal lipids have been used in commercial catfish feeds. These were recommended over marine fish oils because high levels of fish oil may impart "fishy" flavors to the catfish flesh. Our research has shown that menhaden fish oil, catfish oil, or beef tallow can be used in catfish feeds (Appendix I, Tables 37a, b–38). However, dietary menhaden oil levels of 2% or more reduced survival of catfish exposed to the bacterial pathogen *Edwardsiella ictaluri*. The negative effects of menhaden oil on bacterial resistance are likely caused by the immuno-suppressive effect of highly unsaturated n-3 fatty acids. Catfish fed menhaden oil had higher levels of omega-3 fatty acids in edible tissue than those fed other lipids.

Conclusions

1. *A small amount of lipid is needed to provide essential fatty acids.*
2. *Catfish feeds should not contain more than 5–6% lipid.*
3. *Plant and animal lipids can be used, but marine fish oils should be limited to no more than 2% of the diet.*

Vitamins

Vitamins are organic compounds that are required in small amounts in the diet for normal growth, health, metabolism, and reproduction. Some vitamins may be synthesized in the body in quantities sufficient to meet metabolic needs, and thus are not required in the diet. Catfish feeds are generally supplemented with a vitamin premix that contains all essential vitamins in sufficient quantities to meet dietary requirements and to compensate for losses during feed processing and storage. We conducted several studies on various aspects of vitamin nutrition of catfish both in laboratory and pond studies (Appendix I, Tables 39a–53b). Our primary interest was in practical vitamin requirements — that is, the amount of each vitamin needed under commercial culture conditions. We also evaluated various forms of vitamin C in regard to stability, biological activity, and disease resistance. Further, we investigated the stability of B-complex vitamins during feed processing.

Studies conducted in ponds in which catfish were fed diets containing a complete vitamin premix, one-half of the recommended vitamins, one-fourth of the recommended vitamins, or no supplemental vitamins showed that fish grew as well on diets containing no supplemental vitamins as those fed a full complement of vitamins (Appendix I, Tables 39a, b, 40a, b). This does not mean that catfish do not require vitamins, but that they were able to utilize vitamins inherent in feedstuffs and/or natural pond organisms. Feedstuffs commonly used in catfish feeds contain considerable quantities of most vitamins except for vitamin C. Certain organisms found in pond water are rich in vitamin C and other vitamins. However, the availability of vitamins from these sources to catfish is not known. For example, we do not know the percentage of a particular vitamin (for most vitamins) in a feedstuff that is actually utilized (digested and assimilated) by catfish. Also, the abundance of natural organisms will vary from pond to pond, making it difficult to quantify their contribution to the vitamin nutrition of catfish. Our data indicate that catfish are getting ample vitamins from feed ingredients and natural food organisms, but since these sources may be highly variable in vitamin content and we are unable to quantify their contribution, catfish feeds must continue to be supplemented with vitamins. However, this information along with other data allows for modifications in recommended catfish vitamin supplements (Appendix II, Table 2).

There is a series of vitamins that are grouped as B-complex vitamins, which are essential to catfish. B-complex vitamins are fairly widespread in natural feedstuffs. We conducted several experiments in ponds to determine practical levels of these vitamins for catfish (Appendix I, Tables 41–44b). Basically, the data demonstrated that catfish were able to meet their requirements for these vitamins from feedstuffs or natural food organisms found in pond water. Although we recommend supplementing catfish feeds with B-complex vitamins, we were able to demonstrate that a choline supplement is unnecessary, and that the level of certain other B-complex vitamins could be reduced in the vitamin supplement used for catfish. Additionally, the data indicate that B-complex vitamins are highly stable during feed processing (Appendix I, Table 45). This means that large excesses are not needed in the diet to compensate for losses during feed processing.

Vitamin C is an essential vitamin for catfish, which is of particular interest because it is easily destroyed by oxidation, and it has implications in immune function. Because vitamin C is easily destroyed during feed manufacture and storage, it is often coated or chemically bound to improve stability. Typically, products include fat- or ethylcellulose-coated vitamin C and a vitamin C that has been phosphorylated (chemically bound to phosphorus). We conducted several studies to examine the stability of various forms of vitamin C and their biological activity (Appendix I, Tables 46–51). Basically, all the products tested were biological active, and there were no differences in the stability of fat-coated or ethylcellulose-coated products during extrusion or storage. About 50% of the coated products were destroyed during extrusion. After 90 days of storage in polyethylene bags at 77°F, 20–40% of the vitamin C originally added to the feed was retained. Earlier research conducted in our laboratory (not shown in tables) demonstrated that phosphorylated vitamin C was highly stable (70–80%) during extrusion processing of catfish feeds, and it was biologically available to catfish. Also, higher ascorbate tissue levels were observed when using the phosphorylated vitamin C.

Megadose levels of vitamin C (1,000 ppm or more) were used in catfish feeds because it was thought that these high levels improved immune response and thus survival, particularly to ESC. Our earlier research and research presented in Appendix I, Tables 52–53b, showed that megadose levels of vitamin C were no more effective than lower levels of vitamin C in preventing mortality from ESC. Catfish feeds typically contain vitamin C supplements that provide around 100 ppm of vitamin C in the final feed. This level is more than ample for immune response. The data also showed that if fish are stressed, mortality increases upon exposure to the bacterium that causes ESC.

Conclusions

1. *Commonly used feedstuffs are a relatively good source of vitamins except for vitamin C.*
2. *Catfish can meet their vitamin requirements from vitamins inherent in feedstuffs and from natural foods. However, because of the variability of vitamins from these sources, catfish feeds should be supplemented with a vitamin premix.*
3. *Vitamin C is easily destroyed during feed manufacturing, so an excess must be added to account for losses or a stable form of the vitamin must be used.*
4. *Megadoses of vitamin C are not beneficial to catfish.*
5. *B-complex vitamins are highly stable during feed manufacture.*

Minerals

Minerals are inorganic elements that are required by catfish for metabolism, skeletal structure, and osmotic balance between body fluids and their environment. Some minerals can be absorbed from the water; these dissolved minerals in the water can complicate mineral nutrition studies with fish. Catfish feeds are typically supplemented with a trace mineral premix that contains all essential trace minerals and with dicalcium phosphate as a source of phosphorus.

Our research with minerals for catfish included work with zinc, but it focused primarily on phosphorus requirements, phosphorus sources, and the use of phytase enzymes to release the phosphorus bound in feedstuffs (Appendix I, Tables 54–63). Zinc bioavailability was of interest because a form of zinc bound to a protein had been shown to be more highly available than zinc sulfate (typically used as zinc source in catfish feeds). We could not show that the proteinated zinc products were more available than zinc sulfate (Appendix I, Tables 54–55). Thus, there appears to be no justification to use the higher-priced proteinated products in catfish feeds.

Phosphorus is particularly important in catfish feeds because fish require a relatively large quantity of the mineral. There is considerable phosphorus in certain feedstuffs, particularly animal proteins that contain bone. However, digestibility trials indicate that only about 50% of animal phosphorus is available to catfish. Most plant proteins contain rather low levels of phosphorus, but there are exceptions. Cottonseed meal, for example, contains a relatively high amount of phosphorus. However, about two-thirds of phosphorus in feedstuffs of plant origin is in the form of phytate — a bound form of phosphorus that is unavailable to fish. Phytate phosphorus can be made available by the use of phytase enzymes that release the bound phosphorus.

Our work with phosphorus initially concentrated on practical requirements and sources (Appendix I, Tables 56–59b). The phosphorus requirement for pond-raised catfish is about 0.3% of the diet as available phosphorus. The primary source of phosphorus used in catfish feeds has typically been dicalcium phosphate. However, defluorinated phosphate can also be used (Appendix I, Tables 56–58). Solubility of phosphorus sources in a solution of neutral ammonium citrate (NAC) provides an indication of its availability to animals; compounds with a higher NAC solubility value are more highly available. We compared dicalcium phosphate with defluorinated phosphates that had low, medium, or high NAC solubility and found no differences in either product for growth of catfish (Appendix I, Tables 56–58). We also compared inorganic with organic phosphorus sources (such as fish meal, soybean meal, cottonseed meal, etc.) and found that inorganic forms were more highly available to catfish (Appendix I, Tables 59a, b). Phosphorus from animal sources was more available than that from plant sources (roughly 45% vs. 33%).

Using phytase enzymes to release bound phosphorus in feedstuffs would allow for the use of otherwise unused phosphorus and eliminate the need for adding inorganic phosphorus supplements to catfish feeds. This would also limit the amount of unused phosphorus entering the pond. We conducted several studies that showed phytase could be used in catfish feeds to replace supplemental phosphorus and reduce fecal phosphorus (Appendix I, Tables 60–63). However, phytase must be applied after extrusion, because the enzyme is destroyed during extrusion. It can be sprayed onto the finished pellet, but the results have been unsatisfactory. That is, the amount of phytase retained in the finished pellet has been highly variable. When the feed is screened to remove fines, some of the phytase comes out with the fines. Thus, it is difficult to meet the target level. More recent work on the application of phytase shows that it can be sprayed on the feed pellets after screening (just before load out) with satisfactory results.

Conclusions

1. *Catfish feeds should contain about 0.3% available phosphorus.*
2. *About one-half of the phosphorus found in animal sources is available to catfish; about one-third of the phosphorus found in plant sources is available.*
3. *Phytase enzymes effectively release the phosphorus bound in plants to make it available to catfish, so it can replace inorganic phosphorus supplements used in catfish feeds.*
4. *Phytase does not withstand the rigors of feed manufacture and comes out with the fines during screening; therefore, it must be applied after pelleting and screening.*

Natural Foods

Because of the high level of nutrients introduced by feeding, commercial catfish ponds are fertile and normally contain large numbers of organisms, including phytoplankton, zooplankton, other crustaceans, and insects. Many of these organisms are high in protein and other essential nutrients and may contribute to the diet of pond-raised catfish (Appendix I, Table 64). The contribution of natural food organisms to the nutrition of farm-raised catfish is unclear, but their major contributions are likely to be nutrients that are required in trace amounts. For example, natural foods may contribute vitamins, minerals, or essential fatty acids. There is some indirect evidence for this. When raised in the laboratory under controlled conditions, a catfish can be induced to have a deficiency of a specific vitamin if it is fed a purified diet devoid of that vitamin. However, the same deficiency could not be induced in a pond-raised catfish fed a practical diet lacking the vitamin in question. Thus, the vitamin requirement can be met either from vitamins naturally occurring in feedstuffs, natural food organisms, or from a combination of the two. Likewise, we have been unable to induce signs of mineral or essential fatty acid deficiencies in pond-raised catfish fed diets containing no supplement.

Conclusions

1. *Natural food items found in pond waters may contribute micronutrients (vitamins, minerals, essential fatty acids) to the diet of fry and small fingerling catfish.*
2. *Because of the variability of natural foods among ponds, one cannot rely on these sources alone to meet the catfish's dietary requirements.*

Feed-Borne Mycotoxins

Feed-borne mycotoxins are produced by molds growing on feed ingredients and include aflatoxin, fumonisin and moniliformin, ochratoxin A, T-2, and others. Several studies were conducted to evaluate the effects of these toxins on catfish (Appendix I, Tables 65–70). Basically, if these toxins are present at sufficient levels, they can reduce growth and decrease survival of catfish. For example, when fed to catfish, fumonsin reduced growth and survival at 40 ppm; ochratoxin A reduced growth at 2 ppm and survival at 8 ppm; T-2 toxin reduced growth at 0.62 ppm and survival at 2.5 ppm; and T-2 toxin and ochratoxin A decreased survival of catfish challenged with *Edwardsiella ictaluri*. Catfish can tolerate very high levels of aflatoxins without adverse effects. Fortunately, these toxins, if present in catfish feeds, are typically at levels well below those required to cause adverse effects.

Conclusion

1. *Various feed-borne toxins may be found in catfish feedstuffs, but they are typically found at levels below those detrimental to catfish.*

Feed Additives

A feed additive could be anything added to a feed, but for our discussion we define an additive as a compound not typically added to a catfish feed that is used to improve health or growth. There are numerous products that are purported to enhance the health and/or growth of animals when added to the diet, including bacteria, yeast, and enzymes. Bacteria and yeast products are promoted to stimulate the growth of beneficial bacteria in the intestine, thereby assisting in "healthy" intestinal tract maintenance. This would theoretically improve digestibility and the overall well-being of the animal. Digestive enzymes are also used to improve digestibility. We tested the efficacy of some of these products for catfish and found no benefits of adding such products to the diet (Appendix I, Tables 71–74). Bacteria and yeast products work by improving the microflora in the intestine. Since the catfish intestinal microflora is relatively sparsely inhabited compared with those of livestock, the feed additives may not be as beneficial to catfish.

Conclusion

1. *Various yeast, bacteria, or enzyme additives used in animal feeds do not appear to be beneficial to catfish when added to the diet.*

Feeding

Feeding catfish is far from an exact science in that it is highly subjective, and feeding practices differ among catfish producers. There does not appear to be one "best" method for feeding catfish in all situations, particularly considering that numerous factors (most of which cannot be controlled) affect feeding. The feeding trials reported herein were designed to provide insight into various aspects of feeding catfish, including how feeding affects digestibility, weight gain, feed conversion, and body composition (Appendix I, Tables 75–82b). We also investigated the potential nutritional value of natural food items (zooplankton) typically found in pond water, which may provide essential nutrients for fry and small fingerlings (Appendix I, Table 64). Some general information on feeding rate, feed conversion, and fish size are given in Appendix II, Tables 6–7.

Studies demonstrate that digestibility is not significantly affected by feeding rate (Appendix I, Table 75). There were no differences in digestibility coefficients for fish fed to approximately 70%, 85%, or 100% of satiation. These data dispel the idea that feeding catfish at high rates results in the feed passing through fish essentially undigested. Part of this misconception is due to the appearance of fecal material from catfish fed a commercial feed. That is, the fecal material is similar in color to the feed, and small particles of corn grain (from corn that may have passed through a small hole in a hammer mill screen) can sometimes be seen. Another reason for this idea is that when feeding fish in large, commercial ponds, feed conversion often increases when fish are fed all they will eat. However, the reason for this is not due to a decrease in feed efficiency or because of poor digestibility. In fact, feed efficiency is improved as feeding rate increases (Appendix I, Tables 76a; 77–78). At low feeding rates, feed efficiency is actually decreased because a larger proportion of the feed is used to maintain the fish and not for growth. Thus, the primary reason that an increase in feed conversion is observed on commercial catfish farms when fish are fed to satiation is overfeeding. Feeding to satiation is highly subjective, and it is hard to judge when to cut off feed. This uncertainty often results in overfeeding.

Several factors affect fattiness in animals. One less obvious factor is that body fat is affected by the time it takes a fish to reach a certain weight. The faster a fish grows to the desired weight, the more body fat it will have (Appendix I, Tables 76a, b). Thus, catfish grown to market size at a slower rate will contain less fat. But, it is unlikely that such an approach to catfish culture would be economical because faster growth is generally more efficient, and fish reach a market size quicker.

There may be no single best method to feed catfish in all situations, but feeding catfish daily to satiation results in a higher weight gain and thus more total production (Appendix I, Tables 79–80b). Catfish demonstrate compensatory growth but are unable to make up for the decrease in growth due to days skipped during the growing season. Catfish weighing about 0.75 pound consumed more feed on the day fed when they were fed every other day (50% more) or every third day (60% more) compared with fish fed daily. However, they were unable to consume enough feed to compensate for gain lost due to not feeding.

Feeding once weekly to satiation can maintain the body weight of advanced fingerling and larger-sized catfish (Appendix I, Table 81). Normally, catfish should be fed daily, but under unusual circumstances it may be desirable to feed fish a restricted ration or even a maintenance ration. Maintenance feeding means that all feed eaten by the fish is used to maintain the animal with no gain or loss of weight. Since fish of various sizes are typically present in a given pond at the same time, it is better to feed all they will eat on days fed to allow the smaller, less aggressive fish to feed. If economics permit, fish should be fed more frequently than once weekly to improve the overall condition of the fish.

The value in feeding more than once daily or at a specific time during the day has been debated, but based on our data there appears to be little advantage in feeding food-sized catfish twice daily or at a certain time of the day (Appendix I, Tables 82a, b). Although feeding at night in our study did not cause problems, we would not recommend night feeding because of the possibility of an increased oxygen demand due to digestion of food. It appears satisfactory to feed fish for grow out once daily to satiation starting in the morning as dissolved oxygen levels are increasing.

Conclusions

1. *Digestibility is not significantly affected by feeding rate.*
2. *The faster a catfish reaches market weight, the fatter the fish.*
3. *Feeding catfish daily to satiation results in higher weight gain.*
4. *Feeding catfish once weekly to satiation will maintain body weight.*
5. *Feeding food fish more than once daily does not provide an advantage.*

CATFISH STRAIN EVALUATION

We conducted studies concerning the protein requirements of various catfish strains (discussed in the protein section). In addition, we compared the NWAC103 strain to the channel x blue catfish hybrids (Appendix I, Tables 83a, b). The hybrid outperformed the NWAC103 strain in most of the parameters measured. The hybrid grew better, converted feed more efficiently, and had increased survival, more fillet protein, less fillet fat, and higher carcass and nugget yield. Part of the difference may have been because the hybrid was larger at stocking (70 vs. 55 pounds per 1,000 for the NWAC103 strain). However, it does appear that the hybrid is a better overall fish than the NWAC103. However, the hybrid is difficult to produce in large numbers.

Conclusions

1. *NWAC103 strain grows faster than other commonly used strains of channel catfish because it eats more feed.*
2. *Channel x blue hybrid catfish appear to outperform the NWAC103 strain of channel catfish.*

STOCKING DENSITY

Our studies on stocking density and fish size were primarily conducted to evaluate the effect of stocking density and fish size on dietary protein requirements — not just stocking density. Thus, the data are scattered throughout the various tables. We conducted our experiments using various stocking rates and fish sizes. Stocking rates ranged from 6,000 to 18,000 per acre, and fish size ranged from about 60 pounds per 1,000 to more than 500 pounds per 1,000. We used high stocking rates to push the system to the limit by applying high feeding rates and various nitrogen loads. Some generalizations can be made from our studies. One is that the higher the stocking density (at a given initial fish size), the smaller the fish at harvest. For example, fish weighing 60 pounds per 1,000, stocked at a rate of 6,000 fish per acre and grown for one season, averaged about 1.25 pounds at harvest. Stocked at 10,000–12,000 fish per acre, the same size of fingerling weighed an average of 0.75 pound at harvest; at 18,000 fish per acre, they averaged 0.5 pound at harvest. At the higher stocking rates, many of the fish were below market size. Second, stocking large fingerlings (150–200 pounds per 1,000) was required to grow fish to a market size at stocking rates of 10,000–12,000 per acre in a single growing season. In addition, larger fingerlings survived better than those stocked at a small size. Third, more feed was required to satiate fish as stocking density increased, which could result in a deterioration of water quality.

Conclusions

1. *As stocking rate increases, average fish size at harvest decreases.*
2. *Large fingerlings are required when stocking at high densities to reach a harvestable weight in a single growing season.*
3. *As stocking rate increased, more feed was required to satiate the fish, leading to the possibility of decreasing pond water quality.*

Feed Formulation

A summary of recommendations for ingredient and nutrient composition for catfish feeds is presented in Appendix II, Tables 1–2. Catfish feeds are of high quality and provide all the nutrients and energy required for rapid growth of catfish. There is no one best feed formulation. When properly formulated, various ingredient mixtures (based on least cost) can be used to meet the nutrient requirements of catfish (Appendix II, Tables 3–4). Information on feed conversion and feed cost, feeding rate and temperature, and feed conversion and fish size are presented for comparative purposes (Appendix II, Tables 5–7).

Conclusions

1. *Catfish feeds are of high quality and provide all known nutrients needed by the fish.*
2. *Mixtures of various feedstuffs can be balanced to provide a high-quality feed. That is, there is no one combination that must be used.*

Recommendations

Recommendations given here are to be considered as guidelines, because each farm and even each pond on the same farm is different and may require different management strategies. The bottom line is economics; to maximize profits, individual catfish producers must decide what is best for their particular situations. There are many factors to consider when making a decision on management strategies, but major concerns include fish price, feed price, and whether the producer is paid based on a live weight or processed yield. These issues were evaluated in our studies and factored into our recommendations. Again, to be clear, these recommendations are intended as general guidelines — a place to start. If they do not work for you, change to what fits your needs. The following recommendations are for growing stocker-sized fingerlings to a market size unless otherwise noted:

1. **Feed the most cost-effective feed for the management strategy used. We recommend a 28% protein feed composed of a mixture of ingredients that result in a high-quality feed at the least cost.**
2. **Feed small fingerlings (less than 25 pounds per 1,000) a 32% or 35% protein diet containing 8% animal protein.**
3. **Under normal circumstances, feed stockers and food fish once daily to satiation, not exceeding what the pond can safely "metabolize."**
4. **If fish are fed every other day or every third day, feed a 32% protein feed to satiation.**
5. **Feed fingerlings twice daily what they will consume.**
6. **If animal protein is used in the diet, beef by-products are not recommended because of the negative perception of these products due to their association with "mad cow" disease.**
7. **Stock 6,000 (150–200 pounds per 1,000) fingerlings per acre, or at least stock as large a fingerling as possible.**

Appendix I. Data from Various Studies

Common Notes and Abbreviations Used in Tables

1. Means within a column followed by different letters are statistically different ($P \leq 0.05$).
2. * = significant ($P \leq 0.05$).
3. NS = not significant ($P > 0.05$).
4. DE/P = digestible energy/crude protein ratio.
5. FCR = feed conversion ratio.
6. SD = standard deviation.
7. Fillet composition data were expressed as percentages of wet tissue.
8. Tissue vitamin data were expressed as ppm on wet-tissue basis.
9. – indicates that no value was determined.

Table 1. Proximate nutrient composition and energy value of the fillet of pond-raised channel catfish (expressed as unit per 100 g raw tissue) collected from a local processing plant at three sampling dates.

	May 12, 1998		October 13, 1998		February 17, 1999		Overall
	Mean[1]±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Protein (g)	16.6±0.7	14.1–18.0	16.5±0.5	15.5–17.7	15.8±0.9	13.8–18.7	16.3±0.4
Fat (g)	5.1±1.9	1.9–10.9	5.4±1.8	1.9–9.6	5.6±1.6	3.2–9.7	5.4±0.3
Moisture (g)	77.3±1.7	70.9–80.4	76.9±1.7	72.6–81.0	77.6±1.8	73.2–80.3	77.3±0.4
Ash (g)	1.09±0.06	0.99–1.39	1.03±0.04	0.98–1.12	1.03±0.04	0.94–1.10	1.05±0.03
Energy (kcal)[2]	117		119		118		118
Fish weight (g)	685±146	440–974	536±182	358–1,098	827±136	588–1,238	683±146
Least square means using live weight as covariate							
Protein (g)	16.6		16.5		15.8		–
Fat (g)	5.1		6.1		5.0		–
Moisture (g)	77.3		76.2		78.2		–
Ash (g)	1.09		1.04		1.02		–

[1] Mean of each sampling date represents 50 fish.
[2] Energy was calculated by using 4.27 kcal/g protein and 9.02 kcal/g fat.

Table 2. Fatty acid composition (mean[1]±SD) of the fillet of pond-raised channel catfish (expressed as percentage of total fat) collected from a local processing plant at three sampling dates.

Fatty acid[2]	May 12, 1998	October 13, 1998	February 17, 1999	Overall
14:0	1.00±0.11	1.00±0.05	0.90±0.09	0.97±0.06
16:0	15.85±0.66	16.80±0.65	16.12±0.39	16.26±0.49
16:1	2.63±0.23	3.08±0.18	2.56±0.17	2.75±0.28
18:0	6.51±0.18	5.95±0.65	6.62±0.27	6.36±0.36
18:1	37.10±3.55	44.38±3.17	36.64±3.06	39.37±4.34
18:2 n-6	14.54±0.33	12.17±0.38	13.97±0.31	13.56±1.24
18:3 n-6	0.46±0.05	0.39±0.06	0.87±0.13	0.57±0.26
18:3 n-3	1.13±0.09	0.81±0.13	0.81±0.15	0.92±0.19
20:1	1.35±0.39	1.47±0.10	1.35±0.09	1.39±0.07
20:2 n-6	1.79±0.53	1.67±0.47	1.81±0.47	1.76±0.07
20:3 n-9	0.48±0.05	0.71±0.14	0.81±0.14	0.67±0.17
20:3 n-6	1.90±0.19	1.46±0.17	2.46±0.32	1.94±0.50
20:4 n-6	2.51±0.56	1.36±0.29	3.18±0.49	2.35±0.92
20:5 n-3	0.58±0.07	0.00	0.44±0.14	0.34±0.29
22:5 n-6	1.39±0.20	0.96±0.29	1.76±0.27	1.37±0.40
22:5 n-3	0.55±0.12	0.17±0.24	0.54±0.30	0.42±0.22
22:6 n-3	2.70±0.56	1.16±0.46	2.25±0.25	2.04±0.79
Saturated	23.63±0.76	23.88±0.56	23.76±0.47	23.76±0.12
Monoenes	41.08±4.00	48.93±3.33	41.25±3.23	43.75±4.48
Dienes	16.33±0.64	13.84±0.16	15.75±0.49	15.31±1.30
Trienes	3.97±0.20	3.37±0.33	4.86±0.49	4.07±0.75
n-3	4.96±0.72	2.16±0.63	4.11±0.56	3.74±1.44
n-6	22.60±1.19	18.02±0.86	23.76±1.08	21.46±3.04
n-3 HUFA[3]	3.82±0.73	1.35±0.65	3.31±0.63	2.83±1.31
n-6 HUFA	3.91±0.75	2.33±0.55	4.77±0.74	3.67±1.24

[1] Mean of each sample date represents five composite samples with 10 fish per sample.
[2] Fatty acids are typically designated by the use of three numbers: the first indicates the number of carbon atoms; the second, the number of double bonds; and the third, the position of the first double bond.
[3] Highly unsaturated fatty acids include fatty acids with a minimum of 20 carbons and four double bonds.

Table 3. Concentrations (mean[1]±SD) of selected vitamins in the fillet of pond-raised channel catfish (expressed as µg per g of wet tissue) collected from a local processing plant at three sampling dates.

Vitamin	May 12, 1998	October 13, 1998	February 17, 1999	Overall
Thiamin	2.3±0.5	1.8±0.1	1.5±0.5	1.9±0.4
Riboflavin	1.4±0.3	1.2±0.1	1.5±0.2	1.4±0.2
Pyridoxine	1.3±0.2	1.8±0.1	1.1±0.1	1.2±0.1
Folic acid	0.24±0.01	0.14±0.01	0.08±0.03	0.15±0.08
Niacin	15.9±2.4	12.3±1.4	12.4±2.5	13.5±2.1
Pantothenic acid	4.8±0.8	16.5±1.3	8.9±2.2	10.1±5.9
Choline	369±123	665±84	800±48	611±220
Ascorbic acid	4.5±1.1	4.31±0.31	2.9±0.2	2.5±2.2

[1] Mean of each sampling date represents five composite samples with 10 fish per sample.

Table 4. Concentrations (mean[1]±SD) of selected vitamins in the liver of pond-raised channel catfish (expressed as µg per g of wet tissue) collected from a local processing plant at three sampling dates.

Vitamin	May 12, 1998	October 13, 1998	February 17, 1999	Overall
Thiamin	0.49±0.20	0.54±0.06	0.38±0.05	0.47±0.08
Riboflavin	12.2±0.8	12.7±0.8	11.8±0.6	12.2±0.4
Pyridoxine	4.2±0.1	4.4±0.01	3.5±0.4	4.0±0.5
Folic acid	0.63±0.04	0.54±0.14	1.7±0.6	0.96±0.65
Niacin	98.4±10.4	97.8±6.8	60.8±3.4	85.7±21.5
Pantothenic acid	19.6±2.2	24.0±2.2	22.4±1.5	22.0±2.23
Choline	595±96	548±229	668±223	604±60
Ascorbic acid	57.8±8.7	41.1±7.5	12.1±2.9	37.0±23.1

[1] Mean of each sampling date represents five composite samples with 10 fish per sample.

Table 5. Concentrations (mean[1]±SD) of selected minerals in the fillet of pond-raised channel catfish (expressed as µg per g of wet tissue) collected from a local processing plant at three sampling dates.

Mineral	May 12, 1998	October 13, 1998	February 17, 1999	Overall
Potassium	3,711±53	3,388±148	3,508±171	3,536±163
Phosphorus	1,761±77	1,688±98	1,888±114	1,799±101
Sodium	372±41	431±24	410±17	404±30
Magnesium	219±10	246±11	205±9.2	224±21
Calcium	80±22	92±27	100±30	91±10
Zinc	6.5±0.3	5.9±0.2	5.2±0.2	5.9±0.6
Iron	5.3±0.7	5.2±0.5	4.5±0.4	5.0±0.5
Selenium	0.11±0.01	0.13±0.01	0.10±0.02	0.11±0.01
Copper	< 0.3	< 0.3	< 0.3	< 0.3
Manganese	< 1.1	< 1.1	< 1.1	< 1.1
Cobalt	< 1.1	< 1.1	< 1.1	< 1.1

[1] Mean of each sampling date represents three composite samples with 16-17 fish per sample.

Table 6. Means of performance and body composition data for channel catfish fed practical diets containing various levels of crude protein for 12 weeks in aquaria.

Dietary protein	DE/P ratio	Feed consumption	Weight gain[1]	FCR	Survival	Fillet moisture	Fillet protein	Fillet fat	Fillet ash
%	*kcal/g*	*g/fish*	*g/fish*	*feed/gain*	%	%	%	%	%
24	8.5	99.0	59.6 b	1.67 a	100.0	79.2 ab	15.7 a	4.1 c	1.00
24	11.4	97.4	64.0 b	1.53 b	100.0	78.2 b	14.6 ab	6.0 a	0.90
28	8.5	99.6	62.8 b	1.59 ab	99.0	79.8 a	14.9 ab	4.1 c	0.87
28	9.9	96.6	75.3 a	1.28 c	100.0	79.5 ab	14.3 ab	4.9 b	0.90
32	8.5	97.2	75.9 a	1.28 c	99.0	78.7 ab	15.3 ab	4.7 bc	0.90

[1] Mean initial weight was 5.2 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 7. Means of weight gain, processing yield, and fillet composition data for channel catfish fed diets containing various concentrations of crude protein for one growing season in ponds.

Dietary	DE/P	Weight	Carcass	Visceral	Fillet composition		
protein	ratio	gain[1]	yield	fat	Fat	Protein	Moisture
%	*kcal/g*	*lb/fish*	%	%	%	%	%
26	10.8	0.98	63.3 a	2.7	5.6	15.8 b	77.3
28	10.1	0.96	63.5 a	3.0	5.2	16.4 ab	76.8
32	9.1	0.93	62.4 ab	2.9	5.4	16.6 a	76.5
35	8.4	0.93	61.8 b	2.9	5.2	16.9 a	76.4

[1] Data were based on a sample of 500 fish per pond. Mean initial weight was 500 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.

Table 8. Means of performance, processing yield, and fillet composition data for channel catfish fed diets containing various concentrations of crude protein for one growing season in ponds.

Dietary	DE/P	Feed	Weight	FCR	Survival	Carcass	Visceral	Fillet composition			
protein	ratio	consumption	gain[1]			yield	fat	Protein	Fat	Moisture	Ash
%	*kcal/g*	*lb/fish*	*lb/fish*	*feed/gain*	%	%	%	%	%	%	%
16	16.2	0.93 ab	0.62 b	1.49 a	96.6	55.1	5.2 a	15.7 c	8.2 a	74.4 b	1.10 b
20	13.1	0.95 ab	0.65 b	1.46 ab	97.6	55.7	4.5 b	15.6 c	7.8 a	75.0 ab	1.15 ab
24	11.3	1.01 a	0.72 a	1.40 bc	91.0	56.2	3.8 c	16.1 bc	5.8 b	76.4 a	1.21 a
28	9.7	0.98 a	0.73 a	1.35 cd	96.0	56.5	3.2 d	17.2 ab	5.2 bc	76.1 ab	1.21 a
32	8.9	0.88 b	0.68 ab	1.30 d	92.5	57.0	3.1 d	18.2 a	4.4 c	76.1 ab	1.12 b

[1] Mean initial weight was 60 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.

Table 9. Means of performance, processing yield, and fillet composition data for channel catfish fed diets with various crude protein concentrations and quality once daily to satiation for one growing season in ponds.

Dietary protein[1]	Feed consumption	Weight gain[2]	FCR	Survival	Visceral fat	Carcass yield	Fillet yield	Fillet moisture	Fillet protein	Fillet fat
	lb/fish	*lb/fish*	*feed/gain*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
28% control[3]	1.50 ab	0.96 a	1.56 c	98.4	4.19 d	65.6 a	35.7 a	75.4	16.9 a	6.9 c
28% w/o suppl.[4]	1.59 a	0.90 a	1.77 b	93.0	5.41 c	66.2 a	36.4 a	74.9	15.8 b	8.4 b
18% w/o AP[5]	1.58 a	0.91 a	1.75 b	96.2	4.53 d	64.1 b	34.0 b	74.5	16.1 b	8.6 b
10% w/o suppl.[6]	1.20 c	0.54 c	2.21 a	93.7	6.99 a	59.5 d	28.3 d	74.5	15.1 c	9.3 ab
10%[7]	1.37 bc	0.62 b	2.21 a	96.8	6.10 b	61.2 c	30.7 c	73.7	14.9 c	10.3 a

[1] The DE/P ratios were 9.9, 9.5, 14, 25, and 25 kcal/g protein for 28% protein control, 28% protein without supplement, 18% protein, 10% protein without supplement, and 10% protein diets, respectively.
[2] Mean initial weight was 141 pounds per 1,000 fish. Fish were stocked at 7,000 fish per acre and fed to apparent satiation once daily.
[3] Nutritionally complete diet.
[4] Without supplemental vitamins, minerals, or fat.
[5] With supplemental lysine, vitamins, and minerals, but without animal protein.
[6] Without animal protein, soybean meal, or supplemental vitamins and minerals
[7] With supplemental lysine, vitamins, and minerals, but without animal protein or soybean meal.

Table 10. Means of performance, processing yield, and fillet composition data for channel catfish fed diets containing various concentrations of crude protein for one growing season in ponds.

Dietary protein	DE/P ratio	Feed consumption	Weight gain[1]	FCR	Survival	Carcass yield	Fillet yield	Visceral fat	Fillet composition: Protein	Fat	Moisture
%	*kcal/g*	*lb/fish*	*lb/fish*	*feed/gain*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
24	11.7	1.43	0.79	1.81 a	96.6	59.6	35.3 b	3.2 a	17.1	5.4 a	76.1
28	10.2	1.44	0.84	1.70 c	96.3	60.3	36.1 ab	3.1 a	16.9	5.2 ab	76.3
28-pl[2]	10.2	1.40	0.78	1.80 a	94.3	60.1	35.6 b	3.0 a	17.3	5.1 abc	76.1
32	9.0	1.39	0.79	1.77 ab	96.7	60.4	35.8 ab	3.1 a	17.0	4.6 bc	77.0
36	8.1	1.45	0.84	1.73 bc	94.9	60.5	36.6 a	2.7 b	17.4	4.4 c	77.0

[1] Mean initial weight was 60 pounds per 1,000 fish. Fish were stocked at 7,500 fish per acre and fed to apparent satiation once daily.
[2] 28% protein, all-plant diet.

Table 11. Means of performance, processing yield, and fillet composition data for channel catfish fed a 28% or 32% protein diet for one growing season in ponds.

Dietary protein	DE/P ratio	Feed consumption	Weight gain[1]	FCR	Carcass yield	Visceral fat	Fillet composition: Protein	Fat	Moisture
%	*kcal/g*	*lb/fish*	*lb/fish*	*feed/gain*	*%*	*%*	*%*	*%*	*%*
28	10.0	1.24	1.03	1.27	60.6	2.9	15.2	6.6 a	76.1 b
32	8.7	1.27	0.92	1.37	61.3	3.0	14.7	5.1 b	78.9 a

[1] Mean initial weight was 77 pounds per 1,000 fish. Fish were stocked at 6,000 fish per acre and fed to apparent satiation once daily.

Table 12. Means of performance, processing yield, and fillet composition data for channel catfish fed a 28% or 32% protein diet for one growing season in ponds.

Dietary protein	DE/P ratio	Feed consumption	Weight gain[1]	FCR	Carcass yield	Visceral fat	Fillet composition: Protein	Fat	Moisture
%	*kcal/g*	*lb/fish*	*lb/fish*	*feed/gain*	*%*	*%*	*%*	*%*	*%*
28	10.2	1.00 a	0.75 a	1.35	61.8	3.1	17.6	7.6	74.2
32	9.1	0.83 b	0.61 b	1.34	62.2	3.4	17.1	6.1	75.1

[1] Mean initial weight was 80 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.

Table 13. Means of performance, processing yield, and fillet composition data for channel catfish fed diets containing various concentrations of crude protein for two growing seasons in ponds.

Dietary protein	DE/P ratio	Feed consumption	Weight gain[1]	FCR	Survival	Carcass yield	Fillet yield	Visceral fat	Fillet composition Protein	Fat	Moisture
%	kcal/g	lb/fish	lb/fish	feed/gain	%	%	%	%	%	%	%
26	10.9	3.97	2.01	1.97	97.2	63.3	37.6	2.7 ab	18.0	8.0	73.2
28	10.2	4.20	2.10	2.00	97.9	63.1	37.7	2.9 a	17.9	8.2	73.1
28-pl[2]	10.2	4.13	1.95	2.12	96.9	63.5	37.8	2.5 b	18.0	7.5	73.5
32	9.0	3.99	1.97	2.03	99.3	63.7	38.1	2.8 a	18.4	7.8	72.8

[1] Mean initial weight was 60 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.
[2] 28% protein, all-plant diet.

Table 14. Means of performance, carcass yield, and fillet composition data for channel catfish fed diets with or without animal protein for one growing season in ponds.

Diet[1]	Feed consumption	Weight gain[2]	FCR	Carcass yield	Visceral fat	Fillet composition Protein	Fat	Moisture
	lb/fish	lb/fish		%	%	%	%	%
Animal protein[3]	2.18	1.28	1.71	61.1	4.1 a	17.3	5.5	75.6
No animal protein	2.09	1.20	1.73	60.7	3.2 b	17.0	4.7	76.4

[1] The diet with or without animal protein had DE/P ratios of 9.1 and 8.8 kcal/g protein, respectively.
[2] Mean initial weight was 400 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.
[3] Animal protein included 4% menhaden meal and 4% meat and bone/blood meal.

Table 15. Means of performance, carcass yield, and fillet composition data for channel catfish fed diets[1] containing different levels of total protein and animal protein for one growing season in ponds.

Dietary protein	Animal protein[1,2]	Feed consumption	Weight gain[3]	FCR	Survival	Carcass yield	Visceral fat	Fillet composition Protein	Fat	Moisture	Ash
%	%	lb/fish	lb/fish	feed/gain	%	%	%	%	%	%	%
Individual Treatment Means											
28	0	1.13	0.74	1.54	89.9	54.0	4.1	15.5	6.1 b	76.8	1.00
32	0	1.12	0.72	1.55	95.6	54.3	3.5	14.9	7.6 ab	75.6	0.96
28	8	1.15	0.78	1.47	93.7	53.2	4.0	14.7	8.6 a	74.6	1.01
32	8	1.05	0.74	1.43	95.0	53.7	2.6	15.6	6.3 b	76.4	0.99
Pooled Means											
28		1.14	0.76	1.50	91.8	53.6	4.0 a	15.1	7.4	75.7	1.00
32		1.08	0.73	1.49	95.3	54.0	3.1 b	15.3	7.0	76.0	0.97
	0	1.13	0.73	1.55	92.8	54.2	3.8	15.2	6.9	76.2	0.98
	8	1.10	0.76	1.45	94.4	53.5	3.3	15.2	7.5	75.5	1.00
Analysis of Variance											
Dietary protein (DP)		NS	NS	NS	NS	NS	*	NS	NS	NS	NS
Animal protein (AP)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DP x AP		NS	NS	NS	NS	NS	NS	NS	*	NS	NS

[1] The 28% and 32% protein diets with or without animal protein had DE/P ratios of 10.1, 10.2, 9.1, and 9.0 kcal/g protein, respectively.
[2] Animal protein included 4% menhaden meal and 4% meat and bone/blood meal.
[3] Mean initial weight was 58 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.

Table 16. Means of performance, carcass yield, and fillet composition data for channel catfish fed diets[1] containing different levels of total protein and animal protein for one growing season in ponds.

Dietary protein	Animal protein[1,2]	Feed consumption	Weight gain[3]	FCR	Survival	Carcass yield	Visceral fat	Fillet composition: Protein	Fat	Moisture	Ash
%	*%*	*lb/fish*	*lb/fish*	*feed/gain*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Individual Treatment Means											
26	0	1.20	0.84	1.42	95.0	55.8	3.3	16.4	7.6	74.3	1.11
26	2	1.31	0.84	1.54	97.9	54.9	3.5	16.0	7.0	75.8	1.10
26	4	1.33	0.89	1.51	99.0	55.3	3.5	15.8	6.8	75.0	1.11
26	6	1.31	0.85	1.54	96.1	55.6	3.9	16.9	7.2	74.3	1.05
28	0	1.30	0.86	1.52	97.2	56.0	3.3	15.7	6.2	76.1	1.12
28	2	1.27	0.85	1.49	97.7	56.9	3.2	16.6	6.8	75.0	1.10
28	4	1.31	0.90	1.46	96.0	56.6	3.5	17.0	6.5	75.3	1.11
28	6	1.28	0.88	1.46	98.8	55.8	3.5	17.4	6.4	74.8	1.10
32	0	1.34	0.87	1.53	97.0	56.2	3.0	17.2	6.1	75.6	1.13
32	2	1.43	0.96	1.48	97.4	56.1	2.8	16.3	5.5	76.6	1.12
32	4	1.32	0.89	1.49	98.8	56.9	2.9	17.6	6.7	74.4	1.11
32	6	1.30	0.85	1.53	99.3	56.1	2.9	17.4	5.1	75.9	1.06
Pooled Means											
26		1.29	0.86	1.50	97.0	55.4 b	3.6 a	16.3	7.1 a	74.8	1.09
28		1.29	0.87	1.48	97.4	56.3 a	3.4 a	16.7	6.5 ab	75.3	1.11
32		1.35	0.89	1.51	98.1	56.3 a	2.9 b	17.2	5.8 b	75.6	1.11
	0	1.28	0.86	1.49	96.4	56.0	3.2	16.4	6.6	75.3	1.12
	2	1.34	0.89	1.50	97.7	56.0	3.2	16.3	6.4	75.8	1.11
	4	1.32	0.89	1.48	97.9	56.3	3.3	16.8	6.7	74.9	1.11
	6	1.29	0.86	1.51	98.0	55.8	3.4	17.2	6.2	75.0	1.07
Analysis of Variance											
Dietary protein (DP)		NS	NS	NS	NS	*	*	NS	*	NS	NS
Animal protein (AP)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DP x AP		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] The 26%, 28%, and 32% protein diets with or without animal protein had a DE/P ratio of 10.9, 10.2, and 9.0 kcal/g protein, respectively.
[2] Meat and bone/blood meal.
[3] Mean initial weight was 152 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.

Table 17. Means of performance data of fingerling channel catfish fed diets[1] in which soybean meal was replaced with cottonseed meal and lysine for 12 weeks in aquaria.

Percent soybean meal replaced	Weight gain[2]	FCR	Survival
	%	*feed/gain*	*%*
0 (control)	396 ab	1.72 bc	95
25	437 a	1.63 c	100
50	396 ab	1.72 bc	99
100	326 c	1.98 a	99
50 + lysine	421 ab	1.69 bc	100
100 + lysine	387 b	1.77 bc	98

[1] Diets contained 32% protein with DE/P ratios of 8.4–8.8 kcal/g protein.
[2] Mean initial weight was 7.2 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed at 4% of fish body weight per day divided into two equal feedings.

Table 18. Means of performance, processing yield, and fillet composition data for channel catfish fed diets[1] in which soybean meal was replaced with cottonseed meal and lysine for one growing season in net pens suspended in ponds.

Pct. soybean meal replaced	Weight gain[2]	FCR	Survival	Carcass yield	Fillet yield	Fillet moisture	Fillet protein	Fillet fat	Fillet ash
	lb/fish	*feed/gain*	%	%	%	%	%	%	%
0 (control)	0.60 b	1.61 bc	97	61.7 ab	39.6 abc	76.1	15.9 ab	6.3 ab	1.1
50	0.66 a	1.53 cd	96	61.4 ab	39.8 ab	76.5	15.4 b	6.5 a	1.2
100	0.50 c	1.84 a	96	61.0 b	38.8 c	76.3	15.3 b	6.9 a	1.1
50 + lysine	0.66 a	1.46 d	95	62.3 a	40.4 a	76.5	16.4 a	5.8 b	1.2
100 + lysine	0.58 b	1.66 b	97	61.1 b	39.0 bc	76.6	16.4 a	5.5 c	1.1

[1] Diets contained 32% protein with DE/P ratios of 8.4–8.8 kcal/g protein.
[2] Mean initial weight was 119 pounds per 1,000 fish. Fish were stocked at 40 fish per cage and fed to apparent satiation once daily.

Table 19. Means of performance data of male channel catfish fed diets[1] containing different levels of cottonseed meal for two growing seasons in ponds.

Cottonseed meal	Feed fed	Weight gain[2]	FCR	Survival	Testis weight	Initial sperm motility	24-hour sperm motility
%	*lb/acre*	*lb/fish*	*feed/gain*	%	*% BW*	%	%
0	17,420	2.80 a	4.2	96 a	0.47	59 b	61
25	17,330	2.40 ab	4.2	88 ab	0.47	53 b	51
37.5	19,200	1.81 b	5.9	86 b	0.61	65 ab	67
52	17,060	2.01 b	6.1	92 ab	0.61	73 a	71

[1] The diets contained 32% protein with free gossypol levels of 0, 200, 300, and 400 ppm, respectively.
[2] Mean initial weight was 2.73 pounds per fish. Fish were stocked at 1,200 fish per acre and fed to apparent satiation once daily.

Table 20. Means of performance, processing yield, and fillet composition data for channel catfish fed diets[1] containing 0% or 25% canola meal for one growing season in ponds.

Canola meal	Feed consumption	Weight gain[2]	FCR	Survival	Visceral fat	Carcass yield	Fillet moisture	Fillet protein	Fillet fat	Fillet ash
%	*lb/fish*	*lb/fish*	*feed/gain*	%	%	%	%	%	%	%
0	1.45	0.89	1.63	95.9	3.04	60.0	75.4	16.2	6.8	1.2
25	1.33	0.85	1.57	94.2	3.04	57.5	76.9	16.4	6.2	1.1

[1] The diets contained 32% protein with a DE/P ratio of 8.8 kcal/g protein.
[2] Mean initial weight was 250 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.

Table 21. Means of performance, processing yield, and fillet composition data for channel catfish fed diets[1] containing 0% or 22.5% distillers' grains with solubles for one growing season in ponds.

Distillers' grains	Feed consumption	Weight gain[2]	FCR	Survival	Visceral fat	Carcass yield	Fillet moisture	Fillet protein	Fillet fat	Fillet ash
%	*lb/fish*	*lb/fish*	*feed/gain*	%	%	%	%	%	%	%
0	1.83	1.11	1.65	97.6	3.9 b	61.3	76.3	16.9	5.4	1.1
22.5	1.71	1.15	1.49	97.8	4.8 a	61.2	74.2	16.8	6.6	1.2

[1] The diets contained 32% protein with a DE/P ratio of 8.8 kcal/g protein.
[2] Mean initial weight was 350 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.

Table 22. Means of performance, processing yield, and fillet composition data for channel catfish fed diets[1] containing 0%, 25%, or 50% corn gluten feed for one growing season in ponds.

Corn gluten feed	Feed consumption	Weight gain[2]	FCR	Survival	Visceral fat	Carcass yield	Fillet moisture	Fillet protein	Fillet fat
%	*lb/fish*	*lb/fish*	*feed/gain*	*%*	*%*	*%*	*%*	*%*	*%*
0	1.80	1.07	1.68	99.0	4.0 a	56.8 b	73.6 b	18.1	8.1 a
25	2.00	1.17	1.72	99.1	3.3 b	57.5 a	75.5 ab	16.7	7.0 ab
50	1.77	1.01	1.75	98.8	2.9 b	57.8 a	76.3 a	17.0	5.7 b

[1] The diets contained 32% protein with a DE/P ratio of 8.8–9.0 kcal/g protein.
[2] Mean initial weight was 126 pounds per 1,000 fish. Fish were stocked at 7,500 fish per acre and fed to apparent satiation once daily.

Table 23. Means of performance data and survival 4 weeks after challenge with *Edwardsiella ictaluri* for channel catfish fed practical diets containing various levels of total protein and animal protein for 9 weeks in aquaria.

Dietary protein	Animal protein source[1]	DE/P ratio	Feed consumption	Weight gain[2]	FCR	Survival prechallenge	Survival postchallenge
%		*kcal/g*	*g/fish*	*g/fish*	*gain/feed*	*%*	*%*
32	None[3]	8.8	55.7	49.0 ab	1.14 abc	99.0	51.5
32	6% MFM	9.0	54.5	48.7 ab	1.12 bc	100.0	53.0
32	12% MFM	9.1	55.7	52.1 a	1.07 c	100.0	44.0
32	6% MBB	8.8	52.5	43.5 c	1.21 a	100.0	45.0
32	12% MBB	8.8	54.5	46.3 bc	1.18 ab	99.0	64.8
28	6% MFM + 6% MBB	10.1	54.2	46.7 bc	1.16 ab	100.0	45.0
32	6% MFM + 6% MBB	9.0	53.8	48.5 ab	1.11 bc	100.0	41.0
36	6% MFM + 6% MBB	8.2	56.5	50.0 ab	1.13bc	99.0	54.0

[1] MFM = menhaden fish meal; MBB = meat and bone/blood meal.
[2] Mean initial weight was 6.6 g per fish. Fish were fed to apparent satiation twice daily.
[3] All-plant protein diet (no animal protein used).

Table 24. Mean performance, visceral fat, and fillet composition data for channel catfish fed practical diets[1] containing 5% of each animal protein source for 9 weeks in aquaria.

Protein source	Feed consumption	Weight gain[2]	FCR	Visceral fat	Fillet protein	Fillet fat	Fillet moisture	Fillet ash
	g/fish	*g/fish*	*feed/gain*	*%*	*%*	*%*	*%*	*%*
Menhaden fish meal	76.4	56.7	1.35	3.52	16.6	5.8	75.7	1.18
Meat and bone/blood meal	72.6	51.3	1.43	3.28	16.4	5.9	75.8	1.17
Catfish by-product meal	75.5	52.9	1.43	3.40	16.7	6.4	74.9	1.21
Poultry by-product meal	76.7	55.9	1.37	3.69	16.3	6.4	75.6	1.17
Hydrolyzed feather meal + lysine	74.3	51.6	1.45	3.64	16.4	6.3	75.6	1.17

[1] Diets contained 32% protein with DE/P ratios of 8.8–9.0 kcal/g protein.
[2] Mean initial weight was 6.4 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 25. Means of performance, carcass yield, and fillet composition data for channel catfish fed a 32% protein diet containing 8% menhaden fish meal or 8% meat and bone/blood meal for one growing season in ponds.

Diet	Weight gain[1]	FCR	Survival	Carcass yield	Visceral fat	Fillet composition			
						Protein	Fat	Moisture	Ash
	lb/fish		*%*	*%*	*%*	*%*	*%*	*%*	*%*
Menhaden fish meal	0.61	1.33	99.9	62.2	3.4	17.0	6.2	75.1	1.2
Meat and bone/blood meal	0.59	1.36	100.0	61.9	3.4	16.0	5.8	75.8	1.2

[1] Mean initial weight was 100 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.

Table 26-a. Means of performance data for channel catfish fed once daily to apparent satiation or at a rate of ≤ 80 pounds per acre per day with diets[1] containing various levels of crude protein for one growing season in ponds.

Dietary protein	Feeding rate	Feed consumption	Weight gain[2]	FCR	Survival	Aeration time
%	*lb/acre*	*lb/fish*	*lb/fish*	*feed/gain*	*%*	*hours*
Individual Treatment Means						
28	≤ 80	1.34	1.01	1.33	95.2	801
28	Satiation	1.79	1.16	1.55	98.3	966
32	≤ 80	1.40	1.01	1.39	97.9	756
32	Satiation	1.83	1.13	1.62	97.4	897
36	≤ 80	1.41	1.00	1.42	96.6	813
36	Satiation	1.78	1.18	1.51	95.5	922
40	≤ 80	1.38	1.04	1.33	95.1	912
40	Satiation	1.75	1.09	1.61	95.2	879
Pooled Means						
28		1.57	1.08	1.44	96.7	884
32		1.61	1.07	1.50	97.6	826
36		1.60	1.09	1.47	96.1	868
40		1.57	1.07	1.47	95.1	896
	≤ 80	1.38 y	1.02 y	1.37 y	96.2	820 y
	Satiation	1.79 x	1.14 x	1.57 x	96.6	916 x
Analysis of Variance						
Dietary protein (DP)		NS	NS	NS	NS	NS
Feeding rate (FR)		*	*	*	NS	*
DP x FR		NS	NS	NS	NS	NS

[1] The 28%, 32%, 36%, and 40% protein diets had DE/P ratios of 10.3, 9.2, 8.3, and 7.6 kcal/g protein, respectively.
[2] Mean initial weight was 141 pounds per 1,000 fish. Fish were stocked at 7,000 fish per acre and fed once daily.

Table 26-b. Means of processing yield and fillet composition data for channel catfish fed once daily to satiation or at a rate of ≤ 80 pounds per acre per day with diets containing various levels of crude protein for one growing season in ponds.

Dietary protein	Feeding rate	Visceral fat	Carcass yield	Fillet yield	Fillet moisture	Fillet protein	Fillet fat
%	*lb/acre*	*%*	*%*	*%*	*%*	*%*	*%*
Individual Treatment Means							
28	≤ 80	3.33	65.9	35.9	75.6	17.1	6.26
28	Satiation	3.53	66.2	36.5	76.2	16.5	6.38
32	≤ 80	3.33	66.2	36.5	76.5	17.1	5.43
32	Satiation	3.60	67.0	37.4	75.1	16.8	7.11
36	≤ 80	2.99	66.6	37.4	77.0	16.6	5.43
36	Satiation	3.28	67.0	37.4	75.5	17.2	6.47
40	≤ 80	3.00	67.0	37.6	76.1	17.6	5.46
40	Satiation	3.48	67.1	37.6	75.6	17.2	6.40
Pooled Means							
28		3.43 ab	66.0 b	36.2 b	75.9	16.8	6.32
32		3.46 a	66.6 a	36.9 b	75.8	17.0	6.27
36		3.14 c	66.8 a	37.4 a	76.2	16.9	5.95
40		3.24 bc	67.0 a	37.6 a	75.9	17.4	5.93
	≤ 80	3.17 y	66.4	36.8	76.3 x	17.1	5.65 y
	Satiation	3.47 x	66.8	37.2	75.6 y	16.9	6.59 x
Analysis of Variance							
Dietary protein (DP)		*	*	*	NS	NS	NS
Feeding rate (FR)		*	NS	NS	*	NS	*
DP x FR		NS	NS	NS	NS	NS	NS

Table 27. Means of performance, carcass yield, and fillet composition data for channel catfish fed diets[1] containing 28% or 32% crude protein at different feeding rates for two growing seasons in ponds.

Dietary protein	Feeding rate	Feed consumption	Weight gain[2]	FCR	Survival	Carcass yield	Visceral fat	Fillet composition: Protein	Fat	Moisture	Ash
%	*lb/acre*	*lb/fish*	*lb/fish*	*feed/gain*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Individual Treatment Means											
28	≤ 80	2.21	1.41	1.57	89.5	55.6	3.0	16.2	3.8	78.0	1.13
28	≤ 100	2.77	1.58	1.76	81.8	55.2	3.3	15.5	5.0	77.7	1.13
28	≤ 120	3.05	1.71	1.78	84.4	55.1	3.4	15.9	5.2	77.4	1.14
28	Satiation	3.07	1.84	1.68	89.9	55.9	4.4	15.5	5.3	77.7	1.11
32	≤ 80	2.43	1.40	1.74	84.3	56.4	2.5	15.8	3.6	78.9	1.16
32	≤ 100	2.67	1.52	1.76	87.4	55.6	2.9	16.2	4.1	78.1	1.12
32	≤ 120	3.04	1.76	1.73	84.7	56.6	3.6	16.0	5.0	77.5	1.13
32	Satiation	3.21	1.81	1.79	86.5	56.7	3.8	16.0	5.2	77.2	1.15
Pooled Means											
28		2.77	1.63	1.70	86.4	55.4 y	3.5 x	15.8	4.8	77.7	1.13
32		2.83	1.62	1.75	85.7	56.3 x	3.2 y	15.8	4.5	77.9	1.14
	≤ 80	2.32 c	1.40 c	1.65	86.9	56.0	2.7 d	16.0	3.7 b	78.4	1.15
	≤ 100	2.72 b	1.54 bc	1.76	84.6	55.4	3.1 c	15.8	4.5 a	77.9	1.12
	≤ 120	3.05 a	1.73 ab	1.75	84.6	55.8	3.5 b	15.7	5.1 a	77.4	1.13
	Satiation	3.14 a	1.82 a	1.73	88.2	56.3	4.1 a	15.7	5.2 a	77.5	1.13
Analysis of Variance											
Dietary protein (DP)		NS	NS	NS	NS	*	*	NS	NS	NS	NS
Feeding rate (FR)		*	*	NS	NS	NS	*	NS	*	NS	NS
DP x FR		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] The 28% and 32% protein diets had DE/P ratios of 10.2 and 9 kcal/g protein, respectively.
[2] Mean initial weight was 58 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed once daily.

Table 28. Means of performance, processing yield, and fillet composition data for channel catfish fed diets[1] containing various concentrations of crude protein at two feeding rates (apparent satiation or ≤120 lb/acre/day) for one growing season in ponds.

Dietary protein	Feeding rate	Feed consumption	Weight gain[2]	FCR	Survival	Carcass yield	Visceral fat	Fillet composition: Protein	Fat	Moisture	Ash
%	*lb/acre*	*lb/fish*	*lb/fish*	*feed/gain*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Individual Treatment Means											
24	≤ 120	2.04	1.13	1.80	92.7	58.3	3.2	17.7	7.4	73.6	1.17
24	Satiation	2.12	1.17	1.81	94.9	58.9	2.9	17.6	7.3	73.8	1.17
28	≤ 120	1.97	1.11	1.78	99.8	60.1	2.3	17.5	6.7	74.6	1.28
28	Satiation	2.05	1.16	1.76	96.7	59.7	2.4	17.9	5.9	75.1	1.19
32	≤ 120	2.07	1.20	1.73	97.6	60.3	2.2	18.4	5.4	74.7	1.29
32	Satiation	2.08	1.18	1.77	91.9	59.3	2.4	17.6	6.2	74.8	1.17
Pooled Means											
24		2.08	1.15	1.80	93.8	58.6 b	3.1 a	17.6	7.4 a	73.7	1.17
28		2.01	1.13	1.77	98.2	59.9 a	2.4 b	17.7	6.3 b	74.8	1.23
32		2.08	1.19	1.75	94.8	59.8 a	2.3 b	18.0	5.9 b	74.8	1.23
	≤ 120	2.02	1.14	1.77	96.7	59.6	2.6	17.8	6.5	74.3	1.24
	Satiation	2.08	1.17	1.78	94.5	59.3	2.6	17.7	6.5	74.6	1.17
Analysis of Variance											
Dietary protein (DP)		NS	NS	NS	NS	*	*	NS	*	NS	NS
Feeding rate (FR)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DP x FR		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] The 24%, 28%, and 32% protein diets had DE/P ratios of 11.7, 10.2, and 9.0 kcal/g protein, respectively.
[2] Mean initial weight was 820 pounds per 1,000 fish. The fish were stocked at 7,000 fish per acre and fed once daily.

Table 29. Means of performance, processing yield, and fillet composition data for channel catfish fed diets[1] containing different levels of crude protein for varying periods of time in ponds.

Dietary protein	Days fed	Feed consumption	Weight gain[2]	FCR	Survival	Visceral fat	Carcass yield	Fillet moisture	Fillet protein	Fillet fat
%		lb/fish	lb/fish	feed/gain	%	%	%	%	%	%
32	150	1.27	0.92	1.37	92.7	2.98	61.3 ab	78.9 a	14.7	5.1 b
28	150	1.25	0.95	1.27	91.7	2.86	60.6 b	76.1 b	15.2	6.6 a
28	90									
38	60	1.29	0.96	1.37	96.4	2.75	62.0 a	77.4 ab	16.3	4.4 b
28	90									
35	60	1.29	0.99	1.33	90.0	2.85	62.0 a	77.3 ab	15.7	5.0 b
28	120									
38	30	1.27	0.96	1.37	93.2	3.10	62.0 a	77.6 ab	15.4	5.4 ab
28	120									
35	30	1.27	0.99	1.33	92.4	2.75	61.9 a	77.5 ab	15.7	4.8 b

[1] The 28%, 32%, 35%, and 38% protein diets had DE/P ratios of 10.4, 10.1, 8.3, and 7.6 kcal/g protein, respectively.
[2] Mean initial weight was 77 pounds per 1,000 fish. Fish were stocked at 6,000 fish per acre and fed to apparent satiation once daily.

Table 30. Means of performance and body composition data for channel catfish fed practical diets[1] containing various levels of crude protein and supplemental lysine (Lys) and methionine (Met) for 12 weeks in aquaria.

Dietary protein	Supplemental amino acid	Feed consumption	Weight gain[2]	FCR	Survival	Fillet moisture	Fillet protein	Fillet fat	Fillet ash
%		g/fish	g/fish	feed/gain	%	%	%	%	%
Individual Treatment Means									
24	None	85.9	60.6	1.43	100.0	78.8	16.3	3.5	1.12
24	Lys	88.0	61.3	1.45	99.0	78.8	16.3	3.7	1.14
24	Met	84.9	57.1	1.49	100.0	79.0	16.0	3.8	1.12
24	Lys + Met	86.6	60.0	1.45	100.0	78.6	16.6	3.4	1.14
28	None	88.4	63.9	1.39	100.0	78.4	17.2	3.2	1.14
28	Lys	89.0	63.8	1.41	100.0	78.0	17.4	3.3	1.16
28	Met	90.8	63.5	1.43	100.0	78.6	17.4	2.8	1.15
28	Lys + Met	89.5	64.7	1.39	100.0	77.6	17.8	3.5	1.10
Pooled Means									
24		86.4 y	59.8 y	1.45	99.8	78.8 x	16.3 y	3.6 x	1.13
28		89.4 x	64.0 x	1.41	100.0	78.2 y	17.4 x	3.2 y	1.14
	None	87.2	62.3	1.41	100.0	78.6	16.7	3.3	1.13
	Lys	88.5	62.6	1.43	99.5	78.4	16.9	3.5	1.15
	Met	87.8	60.3	1.47	100.0	78.8	16.7	3.3	1.14
	Lys + Met	88.1	62.3	1.43	100.0	78.1	17.2	3.4	1.12
Analysis of Variance									
Supplemental amino acid (SAA)		*	*	NS	NS	*	*	*	NS
Dietary protein (DP)		NS	NS	NS	NS	NS	NS	NS	NS
SAA x DP		NS	NS	NS	NS	NS	NS	NS	NS

[1] The 24% and 28% protein diets had DE/P ratios of 11.4 and 10.0 kcal/g protein, respectively.
[2] Mean initial weight was 10 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation once daily.

Table 31-a. Means of performance data for channel catfish fed once daily or once every other day (EOD) to satiation with different protein diets[1] for one growing season in ponds.

Dietary protein	Feeding regimen	Amount of feed fed	Net production	Feed consumption	Weight gain[2]	FCR	Survival[2]	Aeration time	Market-sized fish[3]
%		*lb/acre*	*lb/acre*	*lb/fish*	*lb/fish*	*feed/gain*	%	*hour*	%
Individual Treatment Means									
28	Daily	10,303 a	3,563	2.58	0.89	2.89	91.0	830	34.7
28	EOD	5,641 c	2,290	1.43	0.58	2.47	91.3	683	16.7
32	Daily	8,622 b	3,396	2.39	0.94	2.54	84.5	860	40.0
32	EOD	5,015 c	2,283	1.44	0.66	2.19	82.5	743	22.5
35	Daily	8,223 b	3,251	1.94	0.76	2.53	91.4	799	31.5
35	EOD	5,867 c	2,470	1.57	0.66	2.38	86.8	794	14.7
Pooled Means									
28			2,926	2.01	0.73	2.68 u	91.1	756	25.7 b
32			2,839	1.92	0.80	2.37 v	83.5	801	31.3 a
35			2,861	1.75	0.71	2.46 v	89.1	796	23.1 b
	Daily		3,403 x	2.30 x	0.86 x	2.66 x	88.9	829 x	35.4 x
	EOD		2,348 y	1.48 y	0.63 y	2.35 y	86.9	740 y	18.0 y
Analysis of Variance									
Dietary protein (DP)		*	NS	NS	NS	*	NS	NS	*
Feeding regimen (FR)		*	*	*	*	*	NS	*	*
DP x FR		*	NS	NS	NS	NS	NS	NS	NS

[1] Commercial feeds.
[2] Initial weight was 205 pounds per 1,000 fish. Fish were stocked at 4,500 fish per acre and fed to apparent satiation. Weight gain and survival were estimated based on a 500-fish random sample per pond.
[3] Fish of 1.25 pounds and above were considered market-sized.

Table 31-b. Means of visceral fat, processing yield, and body composition data for channel catfish fed once daily or once every other day (EOD) to satiation with different protein diets for one growing season in ponds.

Dietary protein	Feeding regimen	Visceral fat	Carcass yield	Fillet yield	Fillet moisture	Fillet protein	Fillet fat
%		%	%	%	%	%	%
Individual Treatment Means							
28	Daily	4.26	65.6	36.2	75.5	16.6	7.08
28	EOD	2.75	64.7	35.4	78.6	16.0	4.58
32	Daily	4.04	66.3	36.5	75.7	16.7	6.68
32	EOD	2.50	65.1	36.1	77.9	16.2	4.98
35	Daily	4.22	65.7	36.6	75.8	16.3	6.79
35	EOD	2.65	64.7	35.0	78.3	16.4	4.49
Pooled Means							
28		3.51	65.2	35.8	77.1	16.3	5.83
32		3.27	65.7	36.3	76.8	16.5	5.83
35		3.44	65.2	35.8	77.1	16.3	5.64
	Daily	4.17 x	65.9 x	36.4 x	75.7 y	16.6	6.85 x
	EOD	2.63 y	64.8 y	35.5 y	78.3 x	16.2	4.69 y
Analysis of Variance							
Dietary protein (DP)		NS	NS	NS	NS	NS	NS
Feeding regimen (FR)		*	*	*	*	NS	*
DP x FR		NS	NS	NS	NS	NS	NS

Table 32-a. Means of performance data for channel catfish stocked at three densities and fed a 28% or 32% protein diet[1] for two growing seasons in ponds.

Stocking density	Dietary protein	Net production	Feed consumption	Weight gain[2]	FCR	Survival
fish/acre	*%*	*lb/acre*	*lb/fish*	*lb/fish*	*feed/gain*	*%*
Individual Treatment Means						
6,000	28	11,835	3.67	2.02	1.84	97.5
6,000	32	12,390	3.61	2.09	1.74	98.7
12,000	28	17,875	2.74	2.51	1.82	98.3
12,000	32	17,580	2.80	1.49	1.88	98.0
18,000	28	23,860	2.86	1.43	1.99	92.6
18,000	32	23,508	2.80	1.42	1.97	91.8
Pooled Means						
6,000		12,113 c	3.64 a	2.05 a	1.79 b	98.1 a
12,000		17,719 b	2.77 b	1.50 b	1.85 b	98.2 a
18,000		23,684 a	2.83 b	1.43 b	1.98 a	92.2 b
	28	17,851	3.09	1.65	1.88	96.1
	32	17,826	3.07	1.67	1.86	96.2
Analysis of Variance						
Stocking density (SD)		*	*	*	*	*
Dietary protein (DP)		NS	NS	NS	NS	NS
SD x DP		NS	NS	NS	NS	NS

[1] The 28% and 32% protein diets had DE/P ratios of 10.4 and 9.3 kcal/g protein, respectively.
[2] Mean initial weight was 107 pounds per 1,000 fish. Fish were fed to apparent satiation once daily.

Table 32-b. Means of processing yield and fillet composition data for channel catfish stocked at three densities and fed a 28% or 32% protein diet for two growing seasons in ponds.

Stocking density	Dietary protein	Visceral fat	Carcass yield	Fillet yield	Fillet moisture	Fillet protein	Fillet fat	Fillet ash
fish/acre	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Individual Treatment Means								
6,000	28	3.00	67.1	37.2	75.4	17.5	6.02	1.22
6,000	32	2.86	67.5	38.2	76.9	17.4	4.79	1.19
12,000	28	2.87	67.8	37.9	77.2	16.8	4.74	1.17
12,000	32	2.54	67.4	37.6	77.4	16.4	4.78	1.19
18,000	28	3.08	66.8	37.4	76.0	16.7	5.76	1.20
18,000	32	2.64	67.0	37.8	76.9	17.2	5.03	1.22
Pooled Means								
6,000		2.93	67.3	37.7	76.1	17.4	5.41	1.20
12,000		2.71	67.6	37.7	77.3	16.6	4.76	1.18
18,000		2.86	66.9	37.6	76.4	16.9	5.40	1.21
	28	2.98 x	67.2	37.5	76.2	17.0	5.51 x	1.20
	32	2.68 y	67.3	37.9	77.1	17.0	4.87 y	1.20
Analysis of Variance								
Stocking density (SD)		NS	NS	NS	NS	NS	NS	NS
Dietary protein (DP)		*	NS	NS	NS	NS	*	NS
SD x DP		NS	NS	NS	NS	NS	NS	NS

Table 33. Means of performance data for channel catfish fingerlings fed diets containing 28%, 32%, or 41% crude protein for one growing season in ponds.

Dietary protein	Fingerlings produced[1]	Gross production[1]	Final weight[2]	Amount of feed fed	Estimated survival[1]	Estimated FCR[1]
%		lb/acre	lb/1,000	lb/acre	%	
28	77,878	8,006	104	14,391	77.9	2.58
32	76,505	8,114	107	14,398	76.5	2.54
41	74,466	7,859	107	14,132	74.5	2.60

[1] Values were based on the number and weight of fish harvested. Each pond was seined three times, and fish that remained in the pond were considered to be negligible.
[2] Mean initial weight was 23 pounds per 1,000 fish. Fish were stocked at a rate of 100,000 fish per acre and fed to apparent satiation once daily.

Table 34. Means of performance and fillet composition data of different channel catfish strains fed practical diets[1] containing various levels of crude protein for 8 weeks in aquaria.

Strain	Dietary protein	Feed consumption	Weight gain[2]	FCR	Survival	Fillet moisture	Fillet protein	Fillet fat	Fillet ash
	%	g/fish	g/fish	feed/gain	%	%	%	%	%
Individual Treatment Means									
USDA102	25	94.9	42.4	2.25 b	100.0	78.3	17.3	3.3	1.12
USDA102	35	104.9	64.3	1.65 c	100.0	77.4	17.9	3.8	1.11
USDA102	45	100.9	48.0	2.11 b	100.0	78.1	17.7	3.0	1.09
USDA103	25	100.4	59.8	1.69 c	99.0	77.8	17.1	3.9	1.09
USDA103	35	115.9	87.8	1.32 d	100.0	77.7	17.1	4.0	1.06
USDA103	45	114.0	67.2	1.70 c	100.0	78.6	16.8	3.3	1.01
MN[3]	25	83.0	32.2	2.60 a	98.0	79.7	16.4	2.4	1.14
MN	35	101.5	59.6	1.71 c	100.0	78.4	17.5	2.8	1.11
MN	45	96.5	46.8	2.10 b	100.0	79.0	17.4	2.3	1.07
Pooled Means									
USDA102		100.3 v	51.6 v	2.00	100.0	77.9 v	17.6	3.3 u	1.10 u
USDA103		110.1 u	71.6 u	1.57	99.7	78.1 v	17.0	3.8 u	1.05 v
MN		93.6 w	46.2 w	2.14	99.3	79.0 u	17.1	2.5 v	1.11 u
	25	92.7 z	44.8 z	2.18	99.0	78.6 x	16.9	3.2 xy	1.12 x
	35	107.4 x	70.6 x	1.56	100.0	77.8 y	17.6	3.6 x	1.09 x
	45	103.8 y	54.0 y	1.97	100.0	78.6 x	17.3	2.9 y	1.06 y
Analysis of Variance									
Strain (ST)		*	*	*	NS	*	NS	*	*
Dietary protein (DP)		*	*	*	NS	*	NS	*	*
ST x DP		NS	NS	*	NS	NS	NS	NS	NS

[1] The 25%, 35%, and 45% protein diets had DE/P ratios of 10.0, 8.1, and 6.8 kcal/g protein, respectively.
[2] Mean initial weight was 15.1 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.
[3] Mississippi “normal” strain.

Table 35. Means of performance, processing yield, and fillet composition data of USDA103 and Mississippi "normal" (MN) strains of channel catfish fed diets containing three levels of crude protein for one growing season in ponds.

Fish strain	Dietary protein[1]	Feed consumption	Weight gain[2]	FCR	Survival	Visceral fat[1]	Carcass yield	Fillet yield	Fillet moisture	Fillet protein	Fillet fat
	%	*lb/fish*	*lb/fish*	*feed/gain*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Individual Treatment Means											
USDA103	26	1.46	0.88	1.66	95.6	2.95	61.9	36.0	73.0	18.4	7.1
MN	26	1.31	0.78	1.67	96.3	3.44	60.3	36.1	74.2	18.2	6.9
USDA103	28	1.47	0.90	1.65	98.6	2.59	62.4	36.4	72.9	18.1	7.8
MN	28	1.28	0.84	1.53	92.0	3.41	60.7	36.1	73.6	18.7	6.4
USDA103	32	1.47	0.90	1.65	96.1	2.46	63.5	37.3	73.0	17.8	8.0
MN	32	1.36	0.84	1.61	96.4	3.18	60.9	36.5	74.5	18.0	6.1
Pooled Means											
USDA103		1.47 a	0.89 a	1.65	96.8	2.67 b	62.6 a	36.5	73.0 b	18.1	7.6 a
MN		1.32 b	0.82 b	1.60	94.9	3.34 a	60.6 b	36.2	74.1 a	18.3	6.5 b
	26	1.39	0.83	1.67	96.0	3.19 x	61.1 x	36.1 x	73.6	18.3	7.0
	28	1.38	0.87	1.59	95.3	3.00 xy	61.5 x	36.2 xy	73.3	18.4	7.1
	32	1.41	0.87	1.63	96.3	2.82 y	62.2 y	36.9 y	73.8	17.9	7.1
Analysis of Variance											
Strain (ST)		*	*	NS	NS	*	*	NS	*	NS	*
Dietary protein (DP)		NS	NS	NS	NS	*	*	*	NS	NS	NS
ST x DP		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] The 26%, 28%, and 32% protein diets had DE/P ratios of 10.8, 10.2, and 9.2 kcal/g protein, respectively.
[2] Mean initial weight was 32.5 and 47.3 g per fish for USDA103 and MN strains, respectively. Fish were stocked at 7,500 fish per acre and fed to apparent satiation once daily.

Table 36. Means of performance and fillet composition data of USDA103 and Norris strains of channel catfish fed practical diets[1] containing 28% or 32% protein twice daily to satiation or about ⅔ of satiation for 10 weeks in aquaria.

Fish strain	Feeding rate[2]	Dietary protein	Feed consumption	Weight gain[3]	FCR	Survival	Fillet moisture	Fillet protein	Fillet fat
		%	*g/fish*	*%*	*feed/gain*	*%*	*%*	*%*	*%*
Individual Treatment Means									
Norris	S	28	43.0	827	1.75	99.0	77.9	16.2	4.6
Norris	S	32	46.1	869	1.74	98.0	78.1	17.0	3.6
Norris	R	28	25.6	625	1.38	99.0	78.2	16.3	4.1
Norris	R	32	26.7	652	1.35	98.0	78.2	16.4	4.1
NWAC103	S	28	100.8	1,637	1.29	99.0	77.7	16.7	4.7
NWAC103	S	32	98.2	1,530	1.33	98.0	77.2	17.6	3.9
NWAC103	R	28	50.2	913	1.16	100.0	78.8	16.8	3.1
NWAC103	R	32	49.7	938	1.15	100.0	78.3	17.2	3.2
Pooled Means									
Norris			35.3	742	1.53	98.5	78.1	16.5	4.1
NWAC103			74.8	1,254	1.23	99.3	78.0	17.1	3.7
	S		72.0	1,215	1.49	98.5	77.7	16.9	4.2
	R		38.1	781	1.25	99.3	78.4	16.7	3.6
		28	54.9	1,000	1.36	99.3	78.1	16.5	4.1
		32	55.2	998	1.36	98.5	77.9	17.0	3.7
Analysis of Variance									
Strain (ST)			*	*	*	NS	NS	NS	NS
Feeding rate (FR)			*	*	*	NS	NS	NS	NS
Dietary protein (DP)			NS	NS	NS	NS	NS	*	NS
ST x FR			*	*	*	NS	NS	NS	NS
ST x DP			*	NS	NS	NS	NS	NS	NS
FR x DP			NS	NS	NS	NS	NS	NS	*
ST x FR x DP			NS	NS	NS	NS	NS	NS	NS

[1] The 28% and 32% protein diets had DE/P ratios of 9.8 and 8.8 kcal/g protein, respectively.
[2] S = satiation; R = restricted to about ⅔ satiation.
[3] Mean initial weight was 3.0 and 4.7 g per fish for Norris and NWAC103 strains, respectively. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 37-a. Means of performance data and postchallenge (with *Edwardsiella ictaluri*) mortality and antibody titer for channel catfish fed practical diets containing 32% crude protein supplemented with 2% different animal fat sources for 8 weeks in aquaria.

Supplemental lipid	Weight gain[1]	FCR	Prechallenge survival	Postchallenge mortality[2]	Antibody titer
	g/fish	*feed/gain*	*%*	*%*	*log_2*
Experiment 1					
Catfish offal oil	10.0	1.43	98.0	60.3	–
Beef tallow	9.7	1.52	97.9	63.6	–
Menhaden oil	9.0	1.56	97.6	73.1	–
Experiment 2					
Catfish offal oil	14.6	1.82 ab	99.4	80.9	9.1
Beef tallow	13.2	2.04 b	100.0	85.2	8.4
Menhaden oil	14.9	1.72 a	100.0	95.3	8.8
Analysis of Variance Using the Two Experiments as Blocks					
Catfish offal oil	11.9	1.64	98.9	69.5 b	–
Beef tallow	11.4	1.64	98.9	73.2 ab	–
Menhaden oil	11.6	1.64	98.9	82.9 a	–

[1] Mean initial weights of fish were 2.7 g and 4.1 g for experiments 1 and 2, respectively. Fish were stocked at 50 fish (Experiment 1) and 40 (Experiment 2) per 30-gallon aquaria and fed to apparent satiation twice daily.

Table 37-b. Selected fatty acid composition of liver polar lipids for channel catfish fed practical diets supplemented with different animal fat sources.

Fatty acid[1]	Supplemental fat source		
	Catfish offal oil	Beef tallow	Menhaden oil
16:0	16.62	16.95	17.25
18:0	11.08	10.36	11.30
18:1	22.04	22.89	21.66
18:2 (n-6)	6.14	6.25	5.60
18:3 (n-6)	0.42 a	0.40 a	0.26 b
18:3 (n-3)	0.08	0.07	0.10
20:3 (n-9)	1.78 a	1.72 a	0.99 b
20:3 (n-6)	5.63 a	5.60 a	3.19 b
20:4 (n-6)	8.11 a	7.21 b	3.38 c
20:5 (n-3)	0.62 b	0.63 b	2.86 a
22:5 (n-6)	4.33 a	3.78 a	0.78 b
22:5 (n-3)	0.71 b	0.78 b	1.51 a
22:6 (n-3)	10.13 b	9.40 b	17.21 a
n-3 HUFA[2]	11.47 b	10.81 b	21.57 a
n-6 HUFA	19.58 a	18.21 b	9.03 c
n-3/n-6 HUFA ratio	0.59 b	0.59 b	2.39 a

[1] Fatty acids are typically designated by the use of three numbers: the first indicates the number of carbon atoms; the second, the number of double bonds; and the third, the position of the first double bond.
[2] Highly unsaturated fatty acids with 20 carbons or longer and four or more double bonds.

Table 38. Levels of n-3 highly unsaturated fatty acids (20:5 n-3 and 22:6 n-3) in fillets of channel catfish fed diets containing catfish offal oil and alkaline-refined (deodorized) menhaden oil for one growing season in ponds.

Fish oil source	Supplemental level	Fillet fat	20:5 n-3 + 22:6 n-3
	%	*% of wet tissue*	*% of oil*
Catfish offal oil	2	7.80	2.07 b
Catfish offal oil	4	8.12	3.09 b
Menhaden oil	2	6.87	6.38 a
Menhaden oil	4	7.22	6.67 a

Table 39-a. Means of performance data for channel catfish fed diets containing various levels of vitamins for one growing season in ponds.

Supplemental vitamin	Feed consumption	Weight gain[1]	FCR	Survival	Hematocrit
	lb/fish	*lb/fish*	*feed/gain*	*%*	*%*
Control	0.87 b	0.69 b	1.27	92.7	27.3
No vitamin mix	0.87 b	0.63 b	1.33	93.8	26.2
½ vitamins mix	1.01 a	0.80 a	1.27	94.3	27.7

[1] Mean initial weight was 72 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.

Table 39-b. Mean liver vitamin concentrations for channel catfish fed diets containing various levels of vitamins for one growing season in ponds.

Supplemental	Liver vitamin (ppm)							
vitamin	Thiamin	Riboflavin	Pyridoxine	Niacin	Pantothenic acid	Folic acid	Ascorbate	Alpha-tocopherol
Control	0.78	7.4 b	3.8	51.1 ab	12.8	0.79	84.5 a	112.6 a
No vitamin mix	0.69	7.6 ab	3.9	49.0 b	16.1	0.58	11.8 c	13.3 c
½ vitamin mix	0.71	7.9 a	3.7	56.8 a	14.9	0.55	59.3 b	72.4 b

Table 40-a. Means of performance data for channel catfish fed diets containing various levels of vitamins for one growing season in ponds.

Supplemental vitamin	Feed consumption	Weight gain[1]	FCR	Survival	Hematocrit
	lb/fish	*lb/fish*	*feed/gain*	*%*	*%*
Control	1.66	0.98	1.65	98.8	29.9
No vitamin mix	1.50	0.98	1.52	98.5	25.2
½ vitamin mix	1.77	1.03	1.71	96.7	31.7
½ B-vitamins	1.87	0.96	1.95	95.5	30.2
¼ vitamin mix	1.92	1.08	1.78	96.2	30.8

[1] Mean initial weight was 261 pounds per 1,000 fish. The fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.

Table 40-b. Mean liver vitamin concentrations for channel catfish fed diets containing various levels of vitamins for one growing season in ponds.

Supplemental	Liver vitamin (ppm)						
vitamin	Riboflavin	Pyridoxine	Niacin	Pantothenic acid	Folic acid	B-12	Ascorbate
Control	5.9	4.6	56.9	12.8	0.59	0.13	28.9 b
No vitamin mix	4.4	3.6	54.7	10.6	0.70	0.12	5.5 c
½ vitamin mix	6.1	4.5	63.8	14.7	0.40	0.14	34.5 b
½ B-vitamins	4.5	4.1	58.5	12.2	0.71	0.14	52.8 a
¼ vitamin mix	5.2	4.0	64.2	11.4	0.64	0.13	13.1 c

Table 41. Means of performance and liver vitamin data for channel catfish fed diets containing various levels of riboflavin and niacin in ponds.

Supplemental vitamin	Feed consumption	Weight gain[1]	FCR	Survival	Liver riboflavin		Liver niacin	
					October	February	October	February
	lb/fish	*lb/fish*	*feed/gain*	*%*	*ppm*	*ppm*	*ppm*	*ppm*
Control	1.07	0.72	1.56	73.0	2.53	2.70	123.3 a	71.2 b
No riboflavin	1.02	0.69	1.56	68.7	2.62	3.21	–	–
6.6 ppm riboflavin	1.06	0.74	1.49	73.7	1.93	3.33	–	–
No niacin	0.97	0.66	1.53	73.2	–	–	109.5 b	75.5 ab
44 ppm niacin	1.02	0.68	1.57	73.1	–	–	129.2 a	83.0 a

[1] Mean initial weight was 73 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre, fed to apparent satiation once daily during the growing season, and fed according to winter feeding recommendations during the winter.

Table 42. Means of performance and liver vitamin data for channel catfish fed diets containing various levels of thiamin and pyridoxine in ponds.

Supplemental vitamin	Feed consumption	Weight gain[1]	FCR	Survival	Liver thiamin		Liver pyridoxine	
					October	February	October	February
	lb/fish	*lb/fish*	*feed/gain*	*%*	*ppm*	*ppm*	*ppm*	*ppm*
Control	1.12	0.70	1.61	86.9 ab	5.51	3.40 a	4.3	12.88
No thiamin	1.17	0.73	1.60	91.2 ab	4.82	1.87 b	–	–
2.2 ppm thiamin	1.13	0.69	1.64	83.3 b	3.90	2.11 b	–	–
No pyridoxine	1.14	0.73	1.58	92.1 a	–	–	4.2	13.25
2.3 ppm pyridoxine	1.18	0.73	1.64	90.3 ab	–	–	3.3	13.05

[1] Mean initial weight was 60 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre, fed to apparent satiation once daily during the growing season, and fed according to winter feeding recommendations during the winter.

Table 43. Means of performance and liver vitamin data for channel catfish fed diets containing various levels of pantothenic acid in ponds.

Supplemental vitamin	Feed consumption	Weight gain[1]	FCR	Survival	Liver pantothenic acid	
					October	February
	lb/fish	*lb/fish*	*feed/gain*	*%*	*ppm*	*ppm*
Control	1.18	0.62	1.90	87.4	35.89	26.56
No pantothenic acid	1.24	0.62	2.01	89.3	32.29	28.44
4.4 ppm pantothenic acid	1.24	0.62	2.01	88.5	28.47	27.66
8.8 ppm pantothenic acid	1.16	0.61	1.88	91.5	28.12	31.24

[1] Mean initial weight was 40 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre, fed to apparent satiation once daily during the growing season, and fed according to winter feeding recommendations during the winter.

Table 44-a. Means of performance data for channel catfish fed diets containing various levels of B-vitamins in ponds.

Supplemental vitamin	Feed consumption	Weight gain[1]	FCR	Survival	Hematocrit
	lb/fish	*lb/fish*	*feed/gain*	*%*	*%*
Control[2]	1.16 b	0.66	1.76	95.7	33.1
No pantothenic acid	1.25 ab	0.69	1.83	88.3	32.9
No pyridoxine	1.25 ab	0.68	1.87	88.0	33.4
No thiamin	1.20 b	0.67	1.81	91.6	33.8
No riboflavin	1.22 b	0.68	1.78	92.1	33.6
No niacin	1.37 a	0.76	1.79	87.2	35.9
500 ppm added choline	1.16 b	0.66	1.78	93.3	33.9

[1] Mean initial weight was 57 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre, fed to apparent satiation once daily during the growing season, and fed according to winter feeding recommendations during the winter.
[2] The vitamin premix used in the control diet did not contain supplemental choline.

Table 44-b. Mean liver vitamin concentrations for channel catfish fed diets containing various levels of vitamins in ponds.

Supplemental vitamin	Pantothenic acid		Pyridoxine		Thiamin		Riboflavin		Niacin		Choline	
	Oct.	Feb.	Oct.	Feb.	Oct.	Feb.	Oct.	Feb.	Oct.	Feb.	Oct.	Feb.
	ppm	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*
Control	13.1 a	12.3 a	1.78	1.19	1.18	3.50 a	11.7 b	10.3	79.6	48.7	1,197	1,443 b
No pantothenic acid	8.4 b	5.5 b	–	–	–	–	–	–	–	–	–	–
No pyridoxine	–	–	1.63	1.15	–	–	–	–	–	–	–	–
No thiamin	–	–	–	–	0.73	2.15 b	–	–	–	–	–	–
No riboflavin	–	–	–	–	–	–	12.8 a	10.0	–	–	–	–
No niacin	–	–	–	–	–	–			82.7	45.7	–	–
500 ppm added choline	–	–	–	–	–	–	–	–	–	–	1,258	1,744 a

Table 45. Mean retention of selected B-complex vitamins in extruded catfish feeds.[1]

Vitamin	Retention (%)
Thiamin mononitrate	65.1
Riboflavin	100.0
Pyrodoxine	70.3
Niacin	96.3
Pantothenic acid	100.0

[1] The feed was manufactured at the following conditions: conditioning chamber — temperature - 275°F, pressure - 1 bar; extruder barrel — temperature - 320°F, pressure - 35 bar; drying—temperature - 250-275°F, time - 30 minutes.

Table 46. Means of performance data and liver ascorbate concentrations for channel catfish fed chemically defined diets containing graded levels of vitamin C supplied by L-ascorbyl-2-polyphosphate (AsPP) for 12 weeks in aquaria.

Dietary vitamin C[1]	Weight gain[2]	FCR	Survival	Liver ascorbate
ppm	%	*feed/gain*	%	*ppm*
0	725 b	1.85 a	91 b	0.0 c
15	1,098 a	1.28 b	100 a	4.3 c
30	1,023 a	1.31 b	96 ab	9.8 bc
45	1,066 a	1.29 b	100 a	16.5 bc
60	1,133 a	1.29 b	99 ab	18.2 bc
75	1,285 a	1.18 b	100 a	26.6 ab
90	1,177 a	1.25 b	98 ab	40.5 a

[1] Ascorbic acid equivalent concentration.
[2] Mean initial weight was 5–6 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 47. Means of performance data and tissue ascorbate concentrations for channel catfish fed chemically defined diets containing graded levels of vitamin C supplied by fat-coated (FC) or ethylcellulose-coated (EC) vitamin C for 12 weeks in aquaria.

Dietary vitamin C[1]	Source	Weight gain[2]	FCR	Survival	Liver ascorbate	Kidney ascorbate
ppm		%	*feed/gain*	%	*ppm*	*ppm*
0	–	244 b	3.88 a	79 b	0 e	3.0 f
30	FC	846 a	1.57 b	84 ab	13.3 de	20.1 ef
60	FC	984 a	1.37 b	99 a	40.6 bc	50.3 d
100	FC	945 a	1.49 b	85 ab	55.4 b	73.6 c
330	FC	899 a	1.50 b	98 a	154.1 a	172.5 a
30	EC	1,021 a	1.28 b	100 a	11.2 de	15.8 ef
60	EC	914 a	1.46 b	97 a	23.4 d	37.4 de
100	EC	1,073 a	1.32 b	92 ab	42.1 bc	51.9 cd
330	EC	1,099 a	1.26 b	98 a	171.9 a	131.8 b

[1] Ascorbic acid equivalent concentration
[2] Mean initial weight was 5–6 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 48. Means of performance data and tissue ascorbate concentrations for channel catfish fed chemically defined diets containing graded levels of vitamin C supplied by fat-coated (FC) and ethylcellulose-coated (EC) vitamin C for 12 weeks in aquaria.

Dietary vitamin C[1]	Source	Weight gain[2]	FCR	Survival	Liver ascorbate	Kidney ascorbate
ppm		*%*	*feed/gain*	*%*	*ppm*	*ppm*
0	–	456 b	3.22 a	96 ab	0.0 d	0.0 d
30	FC	1,362 a	1.55 b	99 ab	11.1 c	16.1 c
60	FC	1,475 a	1.42 b	94 b	27.7 b	42.8 b
100	FC	1,616 a	1.36 b	100 a	43.5 a	60.4 a
30	EC	1,497 a	1.42 b	98 ab	10.8 c	15.4 c
60	EC	1,446 a	1.42 b	95 ab	25.9 b	45.8 b
100	EC	1,688 a	1.34 b	98 ab	40.2 a	66.7 a

[1] Ascorbic acid equivalent concentration.
[2] Mean initial weight was 5-6 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 49. Means and ranges (in parenthesis) of concentrations and retention of vitamin C supplied by fat-coated (FC) and ethylcellulose-coated (EC) vitamin C in catfish feeds during extrusion in feed manufacturing.[1]

Vitamin C source	Number of runs	Concentration	Retention
		ppm	*%*
FC	3	70 (50–85)	47 (34–57)
FC	10	102 (69–179)	68 (45–119)
FC	1	80 (50–125)	57 (36–89)
EC	6	160 (122–128)	48 (37–75)

[1] The initial concentrations of FC and EC vitamin C were 150 and 320 ppm, respectively.

Table 50. Concentrations (ppm) and retention (%, in parenthesis) of vitamin C supplied by fat-coated vitamin C in extrusion-processed catfish feeds during storage in polyethylene bags at 77°F.

Sample number	Pct. dry matter	Day 0 [1]	14	28	35	42	49	56	63	94
1	85	74.7	7.3 (10)	0.0 (0)	–	–	–	–	–	–
2	85	72.6	4.7 (6)	0.0 (0)	–	–	–	–	–	–
3	90	55.0	27.0 (49)	12.4 (22)	–	–	–	–	–	–
4	90	76.2	50.0 (65)	19.0 (25)	–	–	–	–	–	–
5	94	178.5	107.1 (60)	84.5 (47)	87.1 (49)	71.8 (40)	65.1 (36)	64.9 (34)	60.2 (34)	32.1 (18)
6	96	128.4	115.0 (90)	80.4 (62)	93.3 (73)	91.1 (71)	81.3 (63)	85.4 (66)	89.2 (69)	53.0 (41)

[1] Vitamin C concentrations of finished feeds that were manufactured through the extrusion and drying process.

Table 51. Means and ranges of concentrations and retention of vitamin C supplied by ethylcellulose-coated vitamin C in extrusion-processed catfish feeds during storage in polyethylene bags at 77°F.

	Day 0	7	14	21	28	35	56	63	77	91
Mean	1,630	1,378	1,167	952	782	694	491	442	405	334
Minimum	1,629	1,373	1,162	923	777	691	488	411	401	324
Maximum	1,646	1,383	1,173	972	783	696	497	483	412	347
Retention	–	84	71	58	48	42	30	27	25	20

Table 52. Means of performance data, tissue ascorbate concentrations, and postchallenge (with *Edwardsiella ictaluri*) mortality for channel catfish fed practical diets containing graded levels of vitamin C supplied by L-ascorbyl-2-polyphosphate for 8 weeks in aquaria.

Dietary vitamin C[1]	Weight gain[2]	FCR	Survival	Liver ascorbate	Kidney ascorbate	Challenge mortality
ppm	*g/fish*	*feed/gain*	*%*	*ppm*	*ppm*	*%*
Experiment 1						
82	15.5	1.64	96.0	163	160	62.4
314	16.2	1.69	96.5	273	231	70.1
465	14.4	1.79	96.5	313	249	65.3
1,132	16.1	1.52	99.0	383	230	71.4
2,071	16.6	1.47	96.8	443	266	66.6
Regression						
Linear	NS	NS	NS	*	*	NS
Quadratic	NS	NS	NS	*	*	NS
Experiment 2						
0	7.2	2.04	97.2	0	0	78.1
26	10.3	1.43	97.6	47	54	64.0
54	10.0	1.43	96.8	72	104	69.2
109	10.0	1.43	98.0	151	183	60.3
968	10.1	1.43	98.0	369	249	64.9
2,059	10.2	1.39	98.0	415	270	69.9
Regression						
Linear	*	*	NS	*	*	NS
Quadratic	*	*	NS	*	*	NS

[1] Ascorbic acid equivalent concentration.
[2] Mean initial weight was 10.5 and 2.7 g per fish for Experiments 1 and 2, respectively. Fish were stocked at 40 fish per 30-gallon aquarium and fed to apparent satiation twice daily. Postchallenge mortality was observed for 21 days.

Table 53-a. Means of performance data for channel catfish fed practical diets containing graded levels of vitamin C supplied by L-ascorbyl-2-polyphosphate for 8 weeks in aquaria.

Dietary vitamin C[1]	Feed consumption	Weight gain[2]	FCR	Survival
ppm	*g/fish*	*g/fish*	*feed/gain*	*%*
3	45.3	30.9 b	1.47 a	89.5
53	48.1	41.0 a	1.17 b	88.5
148	48.6	41.9 a	1.19 b	84.0
256	47.9	39.1 a	1.27 b	86.5

[1] Ascorbic acid equivalent concentration.
[2] Mean initial weight was 6.5 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily. Postchallenge mortality was observed for 21 days.

Table 53-b. Mean serum cortisol, serum and liver ascorbate concentrations, and postchallenge (with *Edwardsiella ictaluri*) mortality and antibody level for channel catfish fed practical diets containing graded levels of vitamin C supplied by L-ascorbyl-2-polyphosphate for 8 weeks in aquaria.

Dietary vitamin C	Stress[1]	Serum cortisol	Serum ascorbate	Liver ascorbate	Mortality[2]	Antibody level[3]
ppm		*µg/ml*	*ppm*	*ppm*	*%*	
3	None	19.2	0.2	11.0	55.7	0.44
53	None	21.4	9.4	59.0	21.4	0.49
148	None	28.3	12.7	192.6	34.3	0.46
256	None	21.1	17.9	222.0	56.5	0.53
3	Stressed	40.4	0.3	11.3	84.4	0.49
53	Stressed	42.0	8.6	84.3	71.9	0.46
148	Stressed	41.7	9.9	204.8	65.5	0.45
256	Stressed	40.6	17.2	316.1	70.1	0.54
Pooled Means						
3		29.8	0.3 c	11.2 d	70.1 a	0.47
53		31.7	9.0 b	71.7 c	46.7 b	0.48
148		35.0	11.3 b	198.7 b	49.9 b	0.46
256		30.9	17.6 a	269.1 a	63.3 ab	0.54
	None	22.5 y	10.1	121.2	42.0 y	0.48
	Stressed	41.2 x	9.0	154.1	73.0 x	0.49
Analysis of Variance						
Vitamin C (VC)		NS	*	*	*	NS
Stress (ST)		*	NS	NS	*	NS
VC x ST		NS	NS	NS	NS	NS

[1] Fish were stressed by confinement (by placing them into a 1.5 gallon plastic pail containing 0.5 gallon of water with air supply) for 2 hours.
[2] Postchallenge mortality was observed for 21 days.
[3] Optical density.

Table 54. Means of performance data and bone ash and zinc concentrations for channel catfish fed practical diets containing zinc sulfate ($ZnSO_4$) and zinc methionine (ZnMet) for 12 weeks in aquaria.

Zinc source	Zinc added	Feed consumption	Weight gain[1]	FCR	Survival	Bone ash	Bone zinc
	ppm	*g/fish*	*g/fish*	*feed/gain*	*%*	*%*	*ppm*
None	0	67.2	51.3	1.27 abc	96.0	54.3	56.2 e
$ZnSO_4$	15	68.6	53.6	1.25 abc	96.0	54.2	83.8 d
$ZnSO_4$	30	71.0	56.2	1.23 bc	95.0	54.8	108.3 c
$ZnSO_4$	90	66.1	48.3	1.33 a	95.0	54.6	202.5 a
ZnMet	15	66.4	50.4	1.29 abc	96.0	54.4	89.2 d
ZnMet	30	66.0	48.6	1.32 ab	96.0	54.3	107.0 c
ZnMet	90	68.8	55.2	1.22 c	95.0	55.0	189.9 b

[1] Mean initial weight was 1.6 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 55. Means of performance data and bone ash and zinc concentrations for channel catfish fed practical diets containing zinc sulfate ($ZnSO_4$) and zinc proteinate (ZnPr) for 10 weeks in aquaria.

Zinc source	Zinc added	Feed consumption	Weight gain[1]	FCR	Survival	Bone ash	Bone zinc
	ppm	*g/fish*	*g/fish*	*feed/gain*	*%*	*%*	*ppm*
None	0	23.7	14.6	1.65	99	52.6	84.2
$ZnSO_4$	200	23.4	13.7	1.76	100	51.4	327.4
ZnPr	45	23.5	14.0	1.69	100	52.0	123.1

[1] Mean initial weight was 2.7 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 56. Means of performance and bone ash and phosphorus data for channel catfish fed diets containing various sources and levels of phosphorus for one growing season in ponds.

Phosphorus source[1]	Available phosphorus	Feed consumption	Weight gain[2]	FCR	Survival	Bone ash	Bone phosphorus
	%	*lb/fish*	*lb/fish*	*feed/gain*	%	%	%
Experiment 1							
None	0.26	1.39	0.87	1.60	96.2	55.0 b	9.9 b
DCP	0.34	1.35	0.84	1.61	97.2	55.7 ab	10.3 a
DCP	0.41	1.42	0.84	1.67	98.3	56.5 a	10.6 a
Experiment 2							
None	0.20	1.84	1.05 b	1.76	94.6	49.0 c	9.0 c
DCP	0.27	1.85	1.12 ab	1.67	93.5	52.9 b	9.7 b
DCP	0.35	1.97	1.22 a	1.62	93.1	55.8 a	10.1 a
Experiment 3							
DCP	0.40	1.30	0.90	1.45	93.7	57.4	10.5
DFP	0.40	1.28	0.90	1.43	93.3	56.9	10.3

[1] DCP = dicalcium phosphate; DFP = defluorinated phosphate.
[2] Mean initial weight was 300, 51, and 137 pounds per 1,000 fish for Experiments 1, 2, and 3, respectively. Fish were stocked at 10,000 fish per acre and fed to apparent satiation once daily.

Table 57. Means of performance, bone ash, and bone phosphorus data for channel catfish fed chemically defined diets containing various forms and levels of total phosphorus for 12 weeks in aquaria.

Phosphorus source[1]	Dietary phosphorus	Feed consumption	Weight gain[2]	FCR	Survival	Bone ash	Bone phosphorus
%	%	*g/fish*	*g/fish*	*feed/gain*	%	%	%
Individual Treatment Means							
DCP	0.2	49.1	33.3 g	1.48	99.0	28.9	5.34
DCP	0.3	67.9	51.2 e	1.34	99.0	38.4	6.99
DCP	0.4	73.4	59.9 d	1.23	99.0	43.6	7.83
DCP	0.8	84.8	81.5 a	1.04	100.0	54.9	10.15
HDFP	0.2	51.2	38.1 f	1.35	99.0	33.6	6.18
HDFP	0.3	71.0	60.1 d	1.18	100.0	44.3	8.18
HDFP	0.4	75.9	67.0 c	1.14	100.0	48.9	8.89
HDFP	0.8	85.9	85.0 a	1.01	99.0	57.1	10.51
MDFP	0.2	50.7	36.5 fg	1.39	96.0	30.8	5.51
MDFP	0.3	68.1	53.0 e	1.29	99.0	39.7	7.36
MDFP	0.4	73.8	63.2 cd	1.17	100.0	47.5	8.86
MDFP	0.8	82.9	76.4 b	1.08	98.0	52.7	9.85
Pooled Means							
DCP		67.8 u	55.6	1.27 t	99.3	41.4 v	7.58 v
HDFP		72.2 t	63.9	1.16 u	99.5	45.9 t	8.44 t
MDFP		68.9 u	57.3	1.23 t	98.3	42.9 u	7.90 u
	0.2	50.3 z	36.0	1.41 w	98.0	31.1 z	5.67 z
	0.3	69.0 y	54.7	1.27 x	99.3	40.8 y	7.51 y
	0.4	74.4 x	63.4	1.18 y	99.7	46.7 x	8.53 x
	0.8	84.5 w	81.0	1.05 z	99.0	54.9 w	10.17 w
Analysis of Variance							
Phosphorus source (PS)		*	*	*	NS	*	*
Dietary phosphorus (DP)		*	*	*	NS	*	*
PS x DP		NS	*	NS	NS	NS	NS

[1] DCP = dicalcium phosphate with solubility of 90.7% in neutral ammonium citrate (NAC); HDFP = defluorinated phosphate with high NAC solubility (85.4%); MDFP = defluorinated phosphate with medium NAC solubility (62.7%).
[2] Mean initial weight was 4.8 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 58. Means of performance, bone ash, and bone phosphorus data for channel catfish fed chemically defined diets containing various forms and levels of phosphorus for 12 weeks in aquaria.

Phosphorus source[1]	Dietary phosphorus	Feed consumption	Weight gain[2]	FCR	Survival	Bone ash	Bone phosphorus
%	%	*g/fish*	*g/fish*	*feed/gain*	%	%	%
DCP	0.49	66.9 b	40.8 b	1.65	99.0	49.2	8.86
HDFP	0.49	73.2 a	46.9 a	1.57	98.0	52.1	9.37
MDFP	0.49	66.2 b	40.6 b	1.64	99.0	52.5	9.49
LDFP	0.49	67.1 b	43.2 ab	1.56	98.0	49.5	8.53

[1] DCP = dicalcium phosphate with solubility of 90.7% in neutral ammonium citrate (NAC); HDFP = defluorinated phosphate with high NAC solubility (85.4%); MDFP = defluorinated phosphate with medium NAC solubility (62.7%); LDFP = defluorinated phosphate with low NAC solubility (44.6%).
[2] Mean initial weight was 3.8 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 59-a. Means of performance, bone ash, and bone phosphorus data for channel catfish fed diets containing various forms and levels of phosphorus for 12 weeks in aquaria.

Dietary ingredient	Feed consumption	Weight gain[1]	FCR	Survival	Bone ash	Bone phosphorus
	g/fish	*g/fish*	*feed/gain*	%	%	%
Sodium phosphate (monobasic)[2]	98.1 a	85.7 a	1.15 c	100.0 a	56.6 a	10.3 a
Dicalcium phosphate	88.5 b	70.4 b	1.26 c	99.0 a	52.2 b	9.6 b
Soybean meal	87.2 b	41.7 d	2.20 a	89.0 b	32.1 c	5.8 c
Cottonseed meal	68.5 d	37.0 de	1.86 b	99.0 a	25.6 d	4.8 d
Wheat middlings	68.6 d	32.4 e	2.15 a	97.0 a	22.9 d	4.3 d
Menhaden fish meal	84.0 c	64.1 c	1.31 c	100.0 a	54.0 ab	9.9 ab
Meat and bone/blood meal	89.0 b	72.1 b	1.24 c	100.0 a	54.6 ab	9.9 ab

[1] Mean initial weight was 3.8 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.
[2] The chemically defined, basal diet contained 32% protein, 2.9 kcal DE, and 0.45% total phosphorus supplied by monobasic sodium phosphate. The test materials were used in the test diets to replace sodium phosphate and chemically defined ingredients to contain the same levels of protein, DE, and total phosphorus.

Table 59-b. Percentages of phosphorus availability from common feed ingredients for channel catfish based on weight gain, bone ash, or bone phosphorus of fish fed diets containing various phosphorus sources compared with fish fed a diet containing monosodium phosphate.

Ingredient	Relative phosphorus availability based on		
	Weight gain	Bone ash	Bone phosphorus
	%	%	%
Monosodium phosphate	100	100	100
Dicalcium phosphate	82	92	93
Soybean meal	49	55	56
Cottonseed meal	43	45	47
Wheat middlings	38	40	41
Menhaden fish meal	75	95	96
Meat and bone/blood meal	84	96	96

Table 60. Means of performance, bone ash, bone phosphorus, and fecal phosphorus data for channel catfish fed practical diets containing different concentrations of fungal phytase for 11 weeks in aquaria.

Fungal phytase	Feed consumption	Weight gain[1]	FCR	Survival	Bone ash	Bone phosphorus	Fecal phosphorus[2]
FTU/kg	*g/fish*	*g/fish*	*feed/gain*	%	%	%	%
0	101.8 b	51.4 b	1.99 a	100.0	51.8 b	9.7 b	1.4
500	110.6 a	59.1 b	1.89 ab	100.0	57.7 ab	10.8 ab	1.4
1,000	113.1 a	63.4 a	1.79 b	100.0	55.1 ab	10.3 ab	0.9
2,000	111.9 a	59.2 a	1.90 ab	99.0	58.6 a	10.9 a	0.9
4,000	113.3 a	60.7 a	1.87 ab	100.0	56.2 ab	10.6 ab	0.5

[1] Mean initial weight was 6.5 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.
[2] Statistical analysis was not conducted for fecal phosphorus because a single pooled sample per treatment was analyzed.

Table 61. Means of performance, bone ash, bone phosphorus, and fecal phosphorus data for channel catfish fed practical diets containing various concentrations of fungal phytase for 12 weeks in aquaria.

Fungal phytase	Dicalcium phosphate	Feed consumption	Weight gain[1]	FCR	Survival	Bone ash	Bone phosphorus	Fecal phosphorus
(FTU/kg)	%	*g/fish*	*g/fish*	*feed/gain*	%	%	%	%
0	0	117.1 b	46.5 b	2.53 a	98.0	42.0 c	7.4 c	0.78 a
250	0	133.9 a	65.0 a	2.07 bc	97.0	53.6 ab	9.6 a	0.28 b
500	0	131.7 a	65.6 a	2.01 c	96.7	53.9 ab	9.8 a	0.22 b
750	0	131.0 a	61.1 a	2.19 bc	97.0	54.2 a	9.9 a	0.12 b
0	1	128.5 a	55.2 ab	2.35 ab	93.8	51.7 b	9.1 b	0.96 a

[1] Mean initial weight was 6.8 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 62. Means of performance and bone ash and phosphorus data for channel catfish fed diets containing different concentrations of fungal phytase for one growing season in ponds.

Dicalcium phosphate	Fungal phytase	Feed consumption	Weight gain[1]	FCR	Survival	Bone ash	Bone phosphorus
%	*FTU/lb*	*lb/fish*	*lb/fish*	*feed/gain*	%	%	%
0	113	1.44	0.97	1.48	82.5	55.5	9.53
0	226	1.41	0.97	1.46	88.0	56.8	9.90
0.75	0	1.40	1.00	1.41	80.8	56.6	9.79

[1] Mean initial weight was 52 pounds per 1,000 fish. Fish were stocked at 7,500 fish per acre and fed to apparent satiation once daily.

Table 63. Means of performance and bone ash and phosphorus data for channel catfish fed diets containing different concentrations of fungal phytase for one growing season in ponds.

Dietary phytase	Feed consumption	Weight gain[1]	FCR	Survival	Bone ash	Bone phosphorus
FTU/lb	*lb/fish*	*lb/fish*	*feed/gain*	%	%	%
0	1.66 b	0.89 b	1.87	96.0	52.5 b	8.63 b
226	1.79 a	1.03 a	1.75	96.9	55.1 a	9.15 a

[1] Mean initial weight was 152 pounds per 1,000 fish. Fish were stocked at 7,000 fish per acre and fed to apparent satiation once daily.

Table 64. Nutrient composition (dry matter basis) of zooplankton collected during the summer from commercial catfish ponds in the Mississippi Delta.

Nutrient	Concentration	Nutrient	Concentration	Nutrient	Concentration
Proximate nutrients (%)		**Fatty acids [1] (% fat)**		**Vitamins**	
Dry matter	7.7	14:0	1.3	D	111 IU/lb
Crude protein	72.5	16:0	16.4	E	115 ppm
Crude fat	6.2	16:1	2.9	Thiamin	3.4 ppm
Crude fiber	10.7	18:0	7.1	Riboflavin	100 ppm
Nitrogen-free extract	8.1	18:1	6.2	Pyrodoxine	2.5 ppm
Ash	2.6	18:2 n-6	4.1	B-12	2.2 ppm
		18:3 n-3	6.3	Folic acid	1.2 ppm
Amino acids (% protein)		20:4 n-6	5.9	Niacin	141 ppm
Arginine	7.1	20:5 n-3	12.0	Pantothenic acid	20 ppm
Histidine	3.0	22:5 n-6	4.3	Biotin	1.5 ppm
Isoleucine	4.1	22:5 n-3	1.5	Inositol	1,565 ppm
Leucine	7.3	22:6 n-3	13.9	C	164 ppm
Lysine	6.8	Total n-3 HUFA[2]	28.4		
Methionine	2.3	Total n-6 HUFA	11.1	**Minerals**	
Cystine	1.1	n-3/n-6 HUFA ratio	2.6	Phosphorus	0.93 %
Phenylalanine	3.9			Calcium	0.39 %
Tyrosine	6.1			Sodium	0.15 %
Threonine	4.5			Potassium	0.38 %
Tryptophan	0.9			Sulfur	0.72 %
Valine	4.6			Magnesium	0.12 %
Alanine	8.0			Iron	622 ppm
Aspartic acid	7.9			Manganese	113 ppm
Glutamic acid	12.3			Zinc	76 ppm
Glycine	4.8			Copper	16 ppm
Proline	4.3				
Serine	4.1				

[1] Fatty acids are typically designated by the use of three numbers: the first indicates the number of carbon atoms; the second, the number of double bonds; and the third, the position of the first double bond.
[2] Highly unsaturated fatty acids with 20 carbons or longer and four or more double bonds.

Table 65. Means of performance and hematocrit data for channel catfish fed practical diets containing various levels of fumonisins supplied by corn inoculated with *Fusarium moniliforme* for 12 weeks in aquaria.

Dietary fumonisin FB_1	Feed consumption	Weight gain[1]	FCR	Survival	Hematocrit
ppm	*g/fish*	*g/fish*	*feed/gain*	%	%
0.7	71.2 ab	49.6 a	1.43 bc	97.5 a	35.4 a
2.5	70.3 ab	49.8 a	1.41 c	97.6 a	35.7 a
5.0	73.6 ab	51.2 a	1.45 bc	92.6 a	35.0 a
10.0	69.7 ab	48.1 a	1.45 bc	93.8 a	35.5 a
20.0	75.4 a	49.9 a	1.52 b	77.5 b	33.6 a
40.0	66.9 b	36.2 b	1.85 a	73.8 b	32.3 a
80.0	–	14.8 c	–	90.0 a	27.6 b
240.0	–	4.5 d	–	73.8 b	25.8 b

[1] Mean initial weight was 6.8 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 66. Means of performance and hematocrit data for channel catfish fed diets containing various levels of ochratoxin A supplied by corn inoculated with *Aspergillus ochraceus* for 8 weeks in aquaria.

Dietary ochratoxin A	Weight gain[1] Week 2	Week 4	Week 6	Week 8	FCR	Survival	Hematocrit
ppm	*g/fish*	*g/fish*	*g/fish*	*g/fish*	*feed/gain*	%	%
0	7.92 a	17.18 a	30.83 a	47.01 a	1.30 c	100 a	36.9 a
0.5	7.71 a	16.88 a	29.52 a	45.60 ab	1.30 c	99 a	38.3 a
1.0	7.12 b	16.62 a	29.19 a	43.83 b	1.30 c	100 a	36.9 a
2.0	4.87 c	11.72 b	20.92 b	30.36 c	1.45 c	100 a	37.8 a
4.0	3.03 d	6.76 c	11.84 c	15.74 d	1.85 b	100 a	35.7 a
8.0	2.24 e	3.68 d	4.48 d	4.91 e	4.54 a	80 b	29.9 b

[1] Mean initial weight was 6.1 g per fish. Fish were stocked at 30 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 67. Means of performance and hematocrit data for channel catfish fed diets containing various levels of crystalline T-2 toxin for 8 weeks in aquaria.

Dietary T-2 toxin	Weight gain[1] Week 2	Week 4	Week 6	Week 8	FCR	Survival	Hematocrit
ppm	*g/fish*	*g/fish*	*g/fish*	*g/fish*	*feed/gain*	%	%
0	11.0 a	20.6 a	29.1 a	42.8 a	1.21 b	100.0 a	31.6 a
0.625	9.4 b	16.9 b	25.5 b	38.6 b	1.20 b	100.0 a	32.6 a
1.25	5.7 c	10.8 c	16.2 c	24.8 c	1.21 b	98.8 a	26.8 b
2.5	2.1 d	3.7 d	5.9 d	7.7 d	1.91 b	78.8 b	21.2 c
5.0	0.4 e	0.5 e	0.8 e	1.1 e	8.86 a	80.0 b	19.3 c

[1] Mean initial weight was 8.9 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 68. Means of performance and postchallenge (with *Edwardsiella ictaluri*) mortality data for channel catfish fed diets containing various levels of T-2 toxin and ochratoxin A for 6 weeks in aquaria.

Mycotoxin	Dietary level	Weight gain[1]	FCR	Survival	Challenge mortality
	ppm	*g/fish*	*feed/gain*	%	%
Control	0	23.5 a	1.10 c	97.8	68.3 c
T-2 toxin	1.0	22.0 b	1.11 c	99.4	84.1 b
T-2 toxin	2.0	8.0 e	2.19 a	97.5	99.3 a
Ochratoxin A	2.0	16.6 c	1.17 c	98.8	80.3 bc
Ochratoxin A	4.0	12.4 d	1.37 b	92.5	80.5 b

[1] Mean initial weight was 6.4 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 69. Means of performance and hematocrit data for channel catfish fed practical diets containing naturally occurring aflatoxins from moldy corn for 12 weeks in aquaria.

Diet	Feed consumption	Weight gain[1]	FCR	Survival	Hematocrit
	g/fish	*g/fish*	*feed/gain*	%	%
20% clean corn	125.9	68.2	1.85	97	35.4
40% clean corn	131.6	74.4	1.79	99	34.3
20% moldy corn	124.2	70.3	1.79	100	34.9
40% moldy corn	127.3	66.2	1.92	98	35.4

[1] Mean initial weight was 7.1 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 70. Means of performance and hematocrit data for channel catfish fed diets containing naturally occurring aflatoxins from moldy corn for one growing season in ponds.

Diet	Weight gain[1]	Net production	FCR	Survival	Hematocrit
	lb/fish	*lb/acre*	*feed/gain*	%	%
50% clean corn	0.81	5,904	1.64	85.7	39.8
50% moldy corn	0.80	6,124	1.61	90.1	37.5
25% clean corn + 25% moldy corn	0.80	5,686	1.72	81.6	38.2

[1] Mean initial weight was 110 pounds per 1,000 fish. Fish were stocked at 7,500 fish per acre and fed to apparent satiation once daily.

Table 71. Means of performance data for channel catfish fed chemically defined diets with or without *Streptococcus* bacterial concentrate for 6 weeks in aquaria.

Diet and feeding period	Weight gain[1]	FCR	Survival
	g/fish	*feed/gain*	%
Control (no bacteria added)	17.8	1.6	96
Control + 20 ppm bacteria for 2 weeks, then control + 10 ppm bacteria for 4 weeks	16.2	1.7	96
Control + 40 ppm bacteria for 2 weeks, then control + 10 ppm bacteria for 4 weeks	15.3	1.8	92

[1] Mean initial weight was 12 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 72. Means of performance and fillet composition data for channel catfish fed practical diets with or without live yeast *Saccharomyces* for 10 weeks in aquaria.

Live yeast	Weight gain[1]	FCR	Survival	Fillet protein	Fillet fat	Fillet moisture	Fillet ash
% of diet	*g/fish*	*feed/gain*	%	%	%	%	%
0	31.1	1.5	90	17.2	2.1	79.3	1.1
0.25	25.6	1.7	91	17.6	2.0	78.8	1.1
0.50	30.9	1.5	94	17.6	1.9	78.7	1.1

[1] Mean initial weight was 5 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 73. Means of performance and fillet composition data for channel catfish fed practical diets with various levels of fiber, energy, and yeast *Saccharomyces* culture for 10 weeks in aquaria.

Diet	Weight gain[1]	FCR	Survival	Fillet protein	Fillet fat	Fillet moisture	Fillet ash
	g/fish	*feed/gain*	%	%	%	%	%
Control (4% fiber, 2.86 kcal DE/g)	31.7a	1.42 b	87.5 a	17.6	2.2 a	78.0	1.2
Control + 0.50% yeast culture[2]	30.1ab	1.53 ab	78.3 b	17.6	2.1 a	77.9	1.3
High fiber diet (11% fiber, 2.86 kcal DE/g)	26.7 b	1.58 ab	78.3 b	17.6	2.1 a	77.8	1.3
High fiber diet + 0.50% yeast culture	29.3 ab	1.42 b	88.3 a	17.8	2.3 a	77.7	1.3
High fiber, low energy diet (12% fiber, 2.27 kcal DE/g)	23.9 c	1.67 a	93.8 a	17.7	1.0 b	79.0	1.3
High fiber, low energy diet + 0.50% yeast culture	23.3 c	1.69 a	86.2 a	17.7	1.0 b	78.8	1.3

[1] Mean initial weight was 4.7 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.
[2] Yeast culture contained yeast cells, vitamins, enzymes, and flavor.

Table 74. Mean performance data for channel catfish fed practical diets with various concentrations of digestive enzymes for 10 weeks in aquaria.

Digestive enzymes	Weight gain[1]	FCR	Survival
% of diet	*g/fish*	*feed/gain*	%
0	15.6	1.6	100
0.05	15.6	1.6	99
0.1	15.0	1.6	100

[1] Mean initial weight was 4.8 per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation twice daily.

Table 75. Mean apparent digestibility coefficients for dry matter, protein, fat, and energy for channel catfish fed at 70%, 85%, or 100% of apparent satiation in fiberglass tanks.

Satiation	Apparent digestibility coefficients			
	Dry matter	Protein	Fat	Energy
	%	%	%	%
70	59.5	81.9	82.4	61.6
85	56.6	81.1	81.2	59.7
100	57.1	80.0	84.7	59.8

Table 76-a. Means of performance data for channel catfish fed a commercial fingerling diet for 66 to 112 days in aquaria.

Designed feeding rate	Actual feeding rate[1]	Duration of feeding	Feed consumption	Weight gain[2]	FCR	Survival
% satiation	*% satiation*	*days*	*g/fish*	*g/fish*	*feed/gain*	*%*
50	61	112	77.9	57.1	1.36 a	99
75	78	91	79.9	59.5	1.34 ab	98
100	100	66	78.5	60.4	1.30 b	100

[1] Fish in the satiation group (100% satiation) were fed as much as they would eat within 30 minutes, and remaining feed pellets were removed and counted to determine the amount of uneaten feed. Fish in the restricted-feeding groups were fed based on 50% or 75% of the percentage of body weight fed to the satiation group. Actual feeding rate = (amount of feed consumed per fish by each of the restricted-feeding group)/(amount of feed consumed per fish by the satiation group) x 100.
[2] Mean initial weight was 6.3 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed once daily.

Table 76-b. Means of visceral fat and fillet composition data for channel catfish fed a commercial fingerling diet for 66 to 112 days in aquaria.

Designed feeding rate	Actual feeding rate	Duration of feeding	Visceral fat	Fillet fat	Fillet protein	Fillet moisture
% satiation	*% satiation*	*days*	*%*	*%*	*%*	*%*
50	61	112	2.47 b	2.53 c	18.3 a	78.1 a
75	78	91	3.30 a	3.05 b	17.6 b	77.8 a
100	100	66	3.49 a	4.03 a	17.6 b	77.2 b

Table 77. Means of performance data for channel catfish fed a commercial 36% protein diet for 2 weeks in aquaria.

Designed feeding rate[1]	Actual feeding rate[2]	Feed consumption	Weight gain[3]	FCR	Survival
% BW	*% BW*	*g/fish*	*g/fish*	*feed/gain*	*%*
0.5	0.52	3.2 g	-2.8 g	–	100
1.0	0.99	6.4 f	1.0 f	6.67 a	100
1.5	1.43	9.5 e	4.3 e	2.22 b	100
2.0	1.82	12.6 d	7.0 d	1.79 c	100
2.5	2.20	15.4 c	9.5 c	1.62 cd	100
3.0	2.44	17.7 b	11.8 b	1.50 de	100
Satiation	2.99	22.7 a	16.8 a	1.36 e	100
Regression					
Linear		–	*	*	–
Quadratic		–	NS	*	–

[1] As percent of initial body weight (BW).
[2] Average actual feeding rate = (amount of feed consumed)/((initial body weight + final body weight)/2) x 100.
[3] Mean initial weight was 45.6 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation once daily.

Table 78. Means of performance data for channel catfish fed a commercial 36% protein diet for 4 weeks in aquaria.

Designed feeding rate[1]	Realized feeding rate[2]	Feed consumption	Weight gain[3]	FCR	Survival
% BW	*% BW*	*g/fish*	*g/fish*	*feed/gain*	*%*
1.0	1.25	14.3 f	7.9 f	1.81 a	100
1.5	1.70	21.6 e	16.1 e	1.34 b	100
2.0	2.14	28.9 d	21.5 d	1.35 b	100
2.5	2.45	35.2 c	28.2 c	1.25 c	100
3.0	2.77	43.1 b	36.9 b	1.17 c	100
Satiation	3.69	69.4 a	59.3 a	1.17 c	100
Regression					
Linear		–	*	*	–
Quadratic		–	*	*	–

[1] As percent of initial body weight (BW).
[2] Average realized feeding rate = (amount of feed consumed)/((initial body weight + final body weight)/2) x 100.
[3] Mean initial weight was 37.3 g per fish. Fish were stocked at 15 fish per 30-gallon aquarium and fed to apparent satiation once daily.

Table 79. Means of performance and visceral fat data for channel catfish fed at various feeding schedules for 12 weeks in aquaria.

Treatment	Days fed/ days not fed	Total days fed	Feed consumption	Weight gain[1]	FCR	Survival	Visceral fat
			g/fish	*g/fish*	*feed/gain*	*%*	*%*
1	7/0	82	94.6	67.4	1.42	100.0	3.05
2	6/1	71	76.0	58.5	1.33	98.0	2.67
3	4/1	66	68.2	47.6	1.44	96.0	2.53
4	5/2	60	58.1	45.8	1.28	99.0	2.22
5	7/3	58	66.5	46.9	1.42	100.0	2.17
6	4/3	48	44.8	32.4	1.38	97.0	1.95
Regression							
Linear			*	*	NS	NS	*
Quadratic			NS	NS	NS	NS	NS

[1] Mean initial weight was 14.4 g per fish. Fish were stocked at 20 fish per 30-gallon aquarium and fed to apparent satiation on days fed.

Table 80-a. Means of performance and carcass yield data for channel catfish fed at different schedules for one growing season in ponds.

Treatment	Days fed/ days not fed	Total days fed	Feed fed	Net production[1]	FCR	Mortality[2]	Visceral fat	Carcass yield
			lb/acre	*lb/acre*	*feed/gain*	*%*	*%*	*%*
1	7/0	159	15,152	8,028	1.89	3.2	3.3	64.3
2	6/1	138	13,955	7,762	1.80	3.5	3.1	63.8
3	4/1	129	13,626	7,519	1.81	4.1	3.0	63.8
4	5/2	117	13,004	7,471	1.74	3.7	2.8	63.6
5	7/3	114	12,544	7,297	1.72	2.7	2.7	63.2
6	4/3	95	9,977	5,773	1.73	2.4	2.4	63.1
Regression								
Linear			*	*	*	NS	*	*
Quadratic			*	*	NS	NS	NS	NS

[1] Mean initial weight was 97 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation on days fed.
[2] Mortality was based on the number of fish observed and removed from the pond.

Table 80-b. Means of proximate analysis data of fillet samples for channel catfish fed at different schedules for one growing season.					
Treatment	**Days fed/ days not fed**	**Total days fed**	**Fillet moisture**	**Fillet protein**	**Fillet fat**
			%	%	%
1	7/0	159	75.6	17.0	6.31
2	6/1	138	75.8	16.7	6.46
3	4/1	129	76.6	16.7	5.54
4	5/2	117	76.0	17.0	6.06
5	7/3	114	76.9	16.7	5.43
6	4/3	95	77.2	16.6	4.98
Regression					
Linear			*	NS	*
Quadratic			NS	NS	NS

Table 81. Means of performance and condition factor data for channel catfish fed one, two, or three times weekly for one growing season in ponds.						
Initial fish size[1]	**Feeding regimen**	**Amount of feed fed**	**Weight gain**	**FCR**	**Survival**	**Condition factor[2]**
	no./week	*lb/fish*	*lb/fish*	*feed/gain*	%	
Small	1	0.22	0.08	2.76 ab	72.3	0.90
Small	2	0.40	0.20	2.09 c	76.6	0.92
Small	3	0.87	0.29	3.02 a	65.6	0.96
Large	1	0.46	0.21	2.16 bc	84.8	0.85
Large	2	0.69	0.26	2.67 ab	78.8	0.90
Large	3	1.48	0.63	2.45 bc	79.4	1.01
Pooled means						
Small		0.50 v	0.19 v	2.62	71.5 v	0.93
Large		0.88 u	0.37 u	2.43	81.0 u	0.92
	1	0.34 y	0.15 y	2.46	78.5	0.87 y
	2	0.54 y	0.23 y	2.38	77.7	0.91 xy
	3	1.17 x	0.46 x	2.74	72.5	0.99 x
Analysis of Variance						
Fish size (FS)		*	*	NS	*	NS
Feeding regimen (FR)		*	*	NS	NS	*
FS x FR		NS	NS	*	NS	NS

[1] Mean initial weight of small and large fish was 86 and 549 pounds per 1,000 fish, respectively. Fish were stocked at 6,000 fish per acre and fed to apparent satiation on days fed.
[2] Condition factor = $100 \times BW/TL^3$, where BW is fish body weight (g) and TL is fish total length (cm).

Table 82-a. Means of performance data for channel catfish fed once daily in the morning or afternoon, or twice daily in both morning and afternoon for two growing seasons in ponds.							
Feeding time and frequency[1]	**Amount of feed fed in year 1**	**Amount of feed fed in year 2**	**Total amount of feed fed**	**Weight gain[2] in year 1**	**Net production**	**Weight gain[3]**	**FCR**
	lb/acre	*lb/acre*	*lb/acre*	*lb/fish*	*lb/acre*	*lb/fish*	*feed/gain*
A.M.	10,532	18,032	28,564	1.06	12,607	2.46	2.19 b
P.M.	10,663	18,063	28,727	1.02	11,896	2.42	2.40 a
A.M. & P.M.	11,541	18,920	30,461	1.05	12,042	2.27	2.31 a

[1] A.M. = 8:00–10:00 a.m., and P.M. = 3:00–5:00 p.m.
[2] Based on mean weight of 300 fish randomly sampled from each pond.
[3] Based on the mean weight of 500 fish randomly sampled from each pond. Mean initial weight was 49 pounds per 1,000 fish. Fish were stocked at 10,000 fish per acre and fed to apparent satiation daily during the growing season.

Table 82-b. Means of processing yield and fillet composition data for channel catfish fed once daily in the morning or afternoon, or twice daily in both morning and afternoon for two growing seasons in ponds.

Feeding time and frequency	Visceral fat	Carcass yield	Fillet yield	Fillet protein	Fillet fat	Fillet moisture
	%	%	%	%	%	%
A.M.	3.83	68.1 ab	40.0 ab	16.3	11.9	70.6
P.M.	3.52	67.9 b	39.5 b	16.5	11.1	71.1
A.M. and P.M.	3.51	68.6 a	40.5 a	16.4	11.2	71.3

Table 83-a. Mean performance data of NWAC103 channel catfish and channel x blue catfish hybrids fed a commercial feed for one growing season in ponds.

Catfish genotype	Amount of feed fed	Net production	Estimated feed consumption[1]	Estimated weight gain[1, 2]	FCR	Estimated survival[1]
	lb/acre	*lb/acre*	*lb/fish*	*lb/fish*	*feed/gain*	%
NWAC103	9,603 b	4,693 b	1.85 b	0.93 b	1.99 a	85.4 b
Hybrid	12,494 a	6,777 a	2.23 a	1.22 a	1.84 b	93.8 a

[1] Estimate based on weight of a 500-fish sample per pond.
[2] Mean initial weight was 55 pounds per 1,000 fish for NWAC103 strain of channel catfish and 70 pounds per 1,000 fish for channel x blue catfish hybrids. Fish were stocked at 6,000 fish per acre and fed to apparent satiation once daily.

Table 83-b. Mean processing yield and fillet proximate data of NWAC103 channel catfish and channel x blue catfish hybrids fed a commercial feed for one growing season in ponds.

Catfish genotype	Visceral fat	Carcass yield	Fillet yield	Nugget yield	Fillet moisture	Fillet protein	Fillet fat	Fillet ash
	%	%	%	%	%	%	%	%
NWAC103	3.40 b	68.4 b	38.6	9.6 b	72.6 b	17.0 b	9.37 a	1.17
Hybrid	5.42 a	69.9 a	38.4	10.6 a	74.1 a	18.1 a	7.30 b	1.12

Appendix II. Recommendations on Ingredients and Nutrients in Catfish Feeds and Information on Feed Conversions

Table 1. Feed ingredients that may be used in commercial catfish feeds.[1]

Feed ingredient	Selected characteristics (%)						Comments
	Dry matter	Crude protein	Crude fat	Crude fiber	Lys	Met + Cys	
Protein Supplements							
Soybean meal (dehulled, solvent-extracted)	89.3	48	1	3	3.2	1.5	Major protein source used. A high-quality ingredient. Contains antinutritional factors that are destroyed by heating. Palatable to catfish.
Cottonseed meal (direct solvent-extracted)	90.4	41	2.1	11.3	1.76	1.1	Used sparingly. About 10–15% is generally used. Higher levels can be used if supplemented with lysine. Highly palatable to catfish. Contains free gossypol, which can be toxic to catfish at high levels. Deficient in lysine; lysine availability reduced by binding to free gossypol.
Peanut meal (mechanically-extracted)	91.8	45	5	12	1.55	1.1	Deficient in lysine. Levels restricted to about 15-20% without lysine supplementation.
Fish meal[2] (Menhaden)	92	62	10.2	1	4.7	2.4	Good source of indispensable amino acids, phosphorus, and digestible energy. May also provide essential fatty acids. Highly palatable to catfish. Grow-out feeds for catfish generally contain 2–4% fish meal.
Meat and bone meal[3]	92.6	50	8.5	2.8	2.6	1.0	Good source of calcium and phosphorus. High in ash, which limits its use somewhat because of possibility of mineral imbalances. Maximum level recommended for catfish feeds is 15%.
Blood meal[3]	91	85	1	1	6.9	1.6	Flash or spray-dried blood meal have been used. Excellent source of lysine but is deficient in methionine. Up to 5% can be used as lysine supplement. Generally used in combination with meat meals.
Catfish offal meal	90	58	11	–	4.19	1.9	Prepared from catfish processing waste. Good source of calcium, phosphorus, and energy. Its use depends on availability.
Poultry by-product meal	94	58	14	2.5	2.57	2.04	Prepared from ground, rendered or clean parts of the carcass of slaughtered poultry. It is marginal in lysine. Its use depends on availability and cost.
Hydrolyzed feather meal	93	85	2.5	1.5	1.05	3.55	Prepared by the high-pressure treatment of clean, undecomposed feathers from slaughtered poultry. It is high in methionine and cystine but severely deficient in lysine; therefore, it is rarely used in catfish feeds.
Canola meal	91	38	3.8	11.1	2.3	1.2	Prepared from a special rapeseed that is low in glucosinolates and erucic acid, toxic compounds to animals. Slightly deficient in lysine. It is palatable to catfish and can be used at levels up to about 35% in catfish feeds without detrimental effects.
Distiller's grains	91	29	8.4	7.8	0.81	0.98	Prepared from residuals after removal of the alcohol by distillation from the yeast fermentation of cereal grains. Deficient in lysine. It is palatable to catfish and can be used at levels up to about 35% in catfish feeds without lysine supplementation.
Full-fat soybeans	90	38	18	5	2.4	1.1	Rarely used in catfish feeds, primarily because of high fat content. A limited amount can be used as long as total fat level in feed does not exceed about 6%.
(Continued)							

[1] Adapted from Robinson, E. H. 1990. Feed, feed processing, and feeding of catfish. Technical Bulletin, Takeda, Inc.
[2] Other fish meals may be used.
[3] Meat and bone meal and blood meal from ruminant animals are not recommended because of the perception of "mad cow" disease.

Table 1 (continued). Feed ingredients that may be used in commercial catfish feeds.							
Feed ingredient	Selected characteristics (%)						Comments
	Dry matter	Crude protein	Crude fat	Crude fiber	Lys	Met + Cys	
Energy supplements							
Corn grain[4] (yellow)	88	8.9	3.5	2.9	0.22	0.3	Abundant and relatively inexpensive source of energy. Cooking improves energy digestibility. Aids in pelleting and improves floatability of feed.
Wheat grain	88	13.5	1.9	3	0.4	0.6	Generally used sparingly in catfish feeds because corn is less expensive. Is used at rate of 3–4% to improve binding of feed pellet.
Wheat middlings	89	17.7	3.6	7	0.6	0.3	Used at levels up to 15–30% in some catfish feeds. Improves pellet binding. Nutritional value to catfish as good or better than corn and wheat grain.
Rice bran	91	13.5	12.5	13	0.5	0.3	Used at low levels (3–5%) because of high fat and fiber levels.
Corn gluten feed	88	21	2.0	10	0.6	1.0	It is the part of corn remaining after the extraction of most of the starch and gluten by the process of wet milling of corn starch to produce ethanol and syrup. Up to 50% can be used in catfish feeds without detrimental effects.
Catfish oil	–	–	100	–	–	–	Fat extracted from processing waste. About 1–2% is sprayed on top of finished feed. Good energy source and used to reduce feed dust.
Fish oil	–	–	100	–	–	–	Good source of essential fatty acids and energy. Also used to reduce feed dust by spraying on finished feed pellet. Used at a rate of < 2%. Higher levels may reduce survival of fish exposed to ESC.
Fat	99.5	–	99.4	–	–	–	Generally highly digestible. May not supply essential fatty acids. Spray on top of finished feed at rate of 1–2% to reduce feed dust.
Vitamin Supplements							
Vitamin premix	–	–	–	–	–	–	Meet recommendations given in Appendix II, Table 2.
Mineral Supplements							
Mineral premix	–	–	–	–	–	–	Meet recommendations given in Appendix II, Table 2.
Dicalcium or defluorinated phosphates	–	–	–	–	–	–	Used as a phosphorus source at a rate of 1–1.5%. Phosphorus from these sources is about 80% available to catfish.
Pellet Binders[5]	–	–	–	–	–	–	Generally natural binders in grains are sufficient for extruded feeds. Some feed manufacturers add about 2–2.5% processed milo as a binder in extruded feeds. Various binders have been used in pelleted (sinking) feeds, including lignosulfonates, bentonites, and processed milo.

[4] Corn screenings and corn gain are often used interchangeably.
[5] If processed milo is used as a binder, it has nutritive value of milo grain.

Table 2. Nutrients recommended for catfish grow-out feeds.		
Nutrient	**Recommended level[1]**	**Comments**
Protein (%)	26–32	Will vary depending on fish size, water temperature, dietary energy level, and daily feed allowance. Feeding diets containing less than 32% protein may reduce processing yield.
Essential amino acids (% of protein)		
Arginine	4.3	Generally, if lysine and sulfur-containing amino acid requirements are met other amino acids will be adequate with feedstuffs commonly used in catfish feeds. Cystine can replace about 60% of methionine requirement. Tyrosine can replace about 50% of phenylalanine requirement. Synthetic amino acids can be used to supplement deficient proteins.
Histidine	1.5	
Isoleucine	2.6	
Leucine	3.5	
Lysine	5.1	
Methionine	2.3	
Phenylalanine	5.0	
Threonine	2.0	
Tryptophan	0.5	
Valine	3.0	
Digestible energy (kcal/g protein)	8.5–10	Use carbohydrate and lipid (fats or oils) as energy to spare protein for growth.
Lipid (%)	4–6	Mixture of animal, vegetable, and fish oils may be used. High levels of marine fish oil may impart a “fishy” flavor to the fish. Supplemental fat or oil should be sprayed on pellet surface.
Carbohydrate (%)	25–35	Floating feeds require at least 25% grain. Use grain by-products for good expansion and bonding. Crude fiber should be maintained below 7%.
Vitamins		
A	1,000 IU/lb	Acetate ester is used to improve stability during feed processing.
D_3	500 IU/lb	D-activated animal sterol used as source of D_3.
E	30 ppm	DL-alpha-tocopheryl acetate is used for improved stability.
K	4.4 ppm	Required, but level for catfish not known. Menadione sodium bisulfite is used to ensure adequacy.
Thiamin	2.5 ppm	Thiamin mononitrate is generally used.
Riboflavin	6 ppm	
Pyridoxine	5 ppm	Pyridoxine HCl is generally used.
Pantothenic acid	15 ppm	Calcium d-pantothenate generally used.
Nicotinic acid	None	Required, but feed contains adequate nicotinic acid without adding a supplement
Biotin	None	Required, but feed contains adequate biotin without adding a supplement.
Folic acid	2.2 ppm	
B-12	0.01 ppm	Required, but amount not known. It is synthesized in intestine of catfish.
Choline	None	Required in low-methionine diets. It is abundant in most feedstuffs; therefore, choline supplements do not appear to be necessary.
Inositol	None	No requirement demonstrated.
Ascorbic acid[2]	50 ppm	Phosphorylated form is stable during feed processing and storage. Metabolized forms will lose 40–60% of activity during processing.
Minerals		
Calcium	None	Catfish usually absorb sufficient calcium from water to meet their needs. Requirement of 0.45% for fish reared in calcium-free water.
Phosphorus, available	0.3–0.35%	About 33% of plant phosphorus and about 50–70% of animal phosphorus is available to catfish. Dicalcium or defluorinated phosphates are generally used as a phosphate source in catfish feeds.
Magnesium	None	No supplement needed; abundant in feedstuffs.
Sodium, potassium, and chloride	None	No supplement necessary; abundant in feedstuffs.
Sulfur	None	No supplement needed.
Cobalt[3]	0.05 ppm	Cobalt carbonate used to insure adequacy.
Iodine[3]	2.4 ppm	Calcium iodate used to insure adequacy.
Zinc	200 ppm	Phytic acid in feed reduces its availability. Zinc oxide is generally used.
Selenium	0.1 ppm	Maximum allowable by FDA is 0.1 mg/kg. Sodium selenite used.
Manganese[3]	25 ppm	Phytic acid in feed reduces its availability. Manganese oxide used.
Iron[3]	30 ppm	Ferrous sulfate and ferrous carbonate used.
Copper[3]	5 ppm	Copper sulfate used.

[1] Recommendations are for advanced fingerlings to market size (1–2 pounds).
[2] Amount in finished feed.
[3] A supplement may not be needed when the diet contains 4% or above animal protein.

Table 3. Restrictions for least-cost formulation of a 28% protein feed for catfish.			
Item	**Restriction**	**Amount**	**Unit**
Crude protein	Minimum	28.0	%
Crude fiber	Maximum	7.0	%
Lipid	Maximum	6.0	%
Available phosphorus	Minimum	0.30	%
Available phosphorus	Maximum	0.40	%
Digestible energy	Minimum	2.8	kcal/g
Digestible energy	Maximum	3.0	kcal/g
Available lysine	Minimum	1.43	%
Available methionine	Minimum	0.26	%
Available methionine + cystine	Minimum	0.65	%
Grain or grain by-products	Minimum	25.0	%
Cottonseed meal[1]	Maximum	15.0	%
Whole fish meal	Maximum	3.0	%
Non-fish animal protein[2]	Maximum	3.0	%
Xanthophylls	Maximum	11.0	ppm
Vitamin premix[3]	Include		
Trace mineral premix[3]	Include		

[1] Higher levels may be used if supplemental lysine is used.
[2] Beef products are not recommended because of its implication of "mad cow" disease.
[3] Meet dietary allowances for catfish given in Appendix II, Table 2.

Table 4. Examples of feed formulations that can be used to culture catfish.							
Ingredient	**Percent of feed**						
	Fry feed	**Fingerling feed**	**Food fish feed**				
	(50%)[1]	**(35%)**	**(32%)**	**(32%)**	**(28%)**	**(28%)**	**(26%)**
Soybean meal (48%)[1]	–	44.2	41.6	47.0	30.1	35.4	28.3
Cottonseed meal (41%)	–	10.0	10.0	10.0	10.0	10.0	5.0
Menhaden meal (61%)	74.2	8.0	4.0	–	4.0	–	4.0
Corn grain	–	27.6	32.1	30.3	33.6	31.9	35.3
Wheat middlings	20.4	7.5	10.0	10.0	20.0	20.0	25.0
Dicalcium phosphate	–	0.5	0.6	1.0	0.6	1.0	0.7
Catfish vitamin mix[2]	Include	Include	Include	Include	Include	Include	Include
Catfish mineral mix[2]	Include	Include	Include	Include	Include	Include	Include
Fat/oil[3]	5.0	2.0	1.5	1.5	1.5	1.5	1.5

[1] Values in the parentheses represent percentage protein.
[2] Commercial mix that meets or exceeds all requirements for channel catfish.
[3] Sprayed on finished feed pellet to reduce feed dust ("fines").

Table 5. Feed cost in cents per pound of catfish produced at different feed conversion ratios and feed prices.

FCR (feed/gain)		Feed cost (¢ per lb of fish produced)					
	Feed price ($/ton):	200	225	250	275	300	325
	Feed price (¢/lb):	10.0	11.3	12.5	13.8	15.0	16.3
1.3		13	15	16	18	20	21
1.4		14	16	18	19	21	23
1.5		15	17	19	21	23	24
1.6		16	18	20	22	24	26
1.7		17	19	21	23	26	28
1.8		18	20	23	25	27	29
1.9		19	21	24	26	29	31
2.0		20	23	25	28	30	33
2.1		21	24	26	29	32	34
2.2		22	25	28	30	33	36
2.3		23	26	29	32	35	37
2.4		24	27	30	33	36	39
2.5		25	28	31	34	38	41
2.6		26	29	33	36	39	42
2.7		27	30	34	37	41	44
2.8		28	32	35	39	42	46
2.9		29	33	36	40	44	47
3.0		30	34	38	41	45	49
3.5		35	39	44	48	53	57
4.0		40	45	50	55	60	65

Table 6. Example of feeding rate for catfish grown from advanced fingerlings to market size and fed once daily to satiation from May to October in ponds stocked at a rate of 10,000 fish per acre in a single-batch system in the Mississippi Delta.

Date	Water temperature (°F)		Fish size	Feeding rate
	7:00 a.m.	4:00 p.m.	(lb/1,000 fish)	(% body weight)
May 1	68	73	110	2.1
May 15	72	79	136	3.4
June 1	70	77	180	2.9
June 15	81	86	244	3.2
July 1	81	88	316	2.7
July 15	82	88	388	2.4
August 1	82	90	513	1.8
August 15	81	86	628	2.0
September 1	77	86	739	1.5
September 15	77	86	841	1.3
October 1	68	72	1,019	1.1

Table 7. Average feed consumption and feed conversion ratio for different sizes of catfish grown in 1-acre earthen ponds at the Thad Cochran National Warmwater Aquaculture Center.

Initial fish weight	Final fish weight	Feed consumption	FCR[1,2]
lb/fish	*lb/fish*	*lb/fish*	*feed/gain*
0.06	0.45	0.72	1.74
0.06	0.55	0.88	1.77
0.35	1.23	1.57	2.04
0.86	2.61	3.42	2.53
2.5	5.00	6.10	2.68

[1] Feed conversion ratio is corrected for mortalities.
[2] A study conducted at the Delta Western Research Center in Indianola, Mississippi, in earthen ponds indicated that catfish grown from about 2.5–3 pounds to 5–6 pounds had a FCR of 3.5–4.

Appendix III. Selected References

Journal Articles

Robinson, E.H., M.H. Li, and B.B. Manning. In press. Low-quality diets for grow out of channel catfish *Ictalurus punctatus*. Journal of Applied Aquaculture.

Manning, B.B., M.H. Li, and E.H. Robinson. In press. Aflatoxins from moldy corn cause no reductions in channel catfish (*Ictalurus punctatus*) performance. Journal of World Aquaculture Society.

Li, M.H., B.B. Manning, D.F. Oberle, and E.H. Robinson. In press. Effects of daily feeding time and frequency on channel catfish *Ictalurus punctatus* production in earthen ponds. Journal of Applied Aquaculture.

Li, M.H., E.H. Robinson, and B.G. Bosworth. Submitted. Effect of periodic feed deprivation on growth, feed efficiency, processing yield, and body composition of channel catfish *Ictalurus punctatus*. Journal of World Aquaculture Society.

Bosworth, B.G., J.T. Silverstein, W.R. Wolters, M.H. Li, and E.H. Robinson. Submitted. Family, strain, gender, and dietary protein effects on production and processing traits of Norris and NWAC103 strains of channel catfish *Ictalurus punctatus*. Aquaculture Research.

Manning, B.B., J.S. Terhune, M.H. Li, E.H. Robinson, D.J. Wise, and G.E. Rottinghaus. 2005. Exposure to feed-borne mycotoxins T-2 toxin or ochratoxin A causes increased mortality of channel catfish challenged with *Edwardsiella ictaluri*. Journal of Aquatic Animal Health17:147–152.

Li, M.H., E.H. Robinson, B.B. Manning, and D.F. Oberle. 2005. Effects of maintenance feeding regimens on weight gain, feed efficiency, and body condition of pond-raised channel catfish. North American Journal of Aquaculture 67:129–132.

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Robinson, E.H., M.H. Li, B.B. Manning, C.C. Mischke, and B.G. Bosworth. 2004. Effects of high protein diets on channel catfish *Ictalurus punctatus* production, composition of gain, processing yield, and water quality. Journal of the World Aquaculture Society 35:463–472.

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Li, M.H., D.J. Wise, B.B. Manning, and E.H. Robinson. 2003. Effect of dietary total protein and animal protein on growth and feed efficiency of channel catfish *Ictalurus punctatus* and their response to *Edwardsiella ictaluri* challenge. Journal of the World Aquaculture Society 34:223–228.

Jackson, L.S., E.H. Robinson, M.H. Li, W.R. Wolters, and D.A. McKee. 2003. Restricted and satiate feeding of two genetically isolated strains of juvenile channel catfish *Ictalurus punctatus* reared on 28% and 32% protein diets. Journal of the World Aquaculture Society 34:478–486.

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