Vol. 24, No. 16 Research Report September 2015

A Brief Overview of Catfish Nutrition

Edwin H. Robinson and Menghe H. Li

Introduction

Modern catfish feeds are based on data derived from extensive nutritional research that allowed formulation of feeds containing a balance of energy and nutrients necessary for optimum growth. This report briefly examines catfish feeds in respect to energy and nutrient requirements essential to maximize growth and optimize the composition of gain. In addition, selected references are provided for those who require a more detailed examination of catfish nutrition.

Energy

All animals require energy for growth, reproduction, and health, regardless of whether they live on land or in water or whether they are cold-blooded or warm-blooded. While their dietary requirements, food sources, and efficiency of energy utilization may differ, their energy needs are ultimately met from energy released during metabolism of carbohydrates, proteins (amino acids), and fats and oils. Quantitatively, energy is the most important dietary component because feed intake in animals with free access to feed is largely regulated by dietary energy concentration. Therefore, feeding standards for many animals are based on energy needs.

Since catfish typically do not have free access to feed, feed intake may be more a function of feed allowance than of the dietary energy concentration, except perhaps when fish are fed to satiety. Although catfish feed intake may not be strictly regulated by dietary energy concentration, dietary energy balance in relation to protein is important, primarily because nonprotein energy deficiency in the diet will result in the more expensive protein being utilized for energy. Also, if dietary energy is excessively high, food intake may decline, resulting in a reduced intake of essential nutrients. Or if too much energy is consumed, dressed yield and shelf life of frozen products may be reduced because of an increase in visceral and fillet fat.

Energy requirement is one of the most notable differences in fish nutrition compared to other livestock. For example, less energy is required for protein synthesis in

Robinson and Li are research professors at the Delta Research and Extension Center in Stoneville, Mississippi. This research report was published by the Office of Agricultural Communications, a unit of the Division of Agriculture, Forestry, and Veterinary Medicine at Mississippi State University.

MAFES
MISSISSIPPI AGRICULTURAL & FORESTRY EXPERIMENT STATION • George M. Hopper, Director
Mississippi State University • Mark E. Keenum, President • Gregory A. Bohach, Vice President

fish. Maintenance energy requirements are lower for fish than for warm-blooded animals because fish do not have to maintain a constant body temperature, and they expend less energy to maintain their spatial position. Energy losses in metabolic waste are lower in fish because most nitrogenous waste is excreted as ammonia instead of urea or uric acid. In addition, the increase in energy cost associated with the assimilation of ingested food (i.e., heat increment) is less in fish.

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 energy amount. Energy requirements reported for catfish, which have generally been expressed as a ratio of digestible energy to crude protein (DE/P), range from 7.4–12 kcal per gram. Based on current knowledge, a DE/P ratio of 8.5–9.5 kcal per gram appears to be optimum for use in commercial catfish feeds.

Because fish evolved in an aqueous environment where food items typically contained high protein and fat levels and little carbohydrate, they appear to have evolved to utilize protein and fats more efficiently for energy than carbohydrates. However, herbivorous and omnivorous fish typically utilize carbohydrate for energy fairly well. For example, the digestibility coefficient for channel catfish for carbohydrate in cooked corn was 70% and that for purified cornstarch was 66%.

The fact catfish can utilize carbohydrate relatively well is fortunate, not only because it is an inexpensive energy source, but also because starch is necessary to make a floating feed. Also, fats and oils, which are the most concentrated and most highly digestible energy sources for catfish, must be used sparingly because high levels can be detrimental to fish growth and product quality. Therefore, the predominant energy source in commercial catfish feeds is from carbohydrates contained in grains (primarily corn) and grain milling by-products.

Protein and Amino Acids

Animals require a continual protein supply throughout life for maintenance and growth. Actually, they do not have a requirement for protein, as such, but rather require the amino acids that compose proteins and nitrogen for other nitrogenous compound synthesis. Yet, we still refer to a "protein requirement" when describing catfish nutrient needs. This is because the most economical method of providing amino acids and nitrogen in the quantity and quality needed is to feed protein feedstuff mixture in the diet in the proper amounts and proportions.

Ingested proteins are broken down to release amino acids used for tissue protein synthesis or, if in excess, utilized for energy. Feeding excess protein is undesirable not only because it is expensive, but also because it adds to the physiological burden of excreting the extra nitrogen, which in turn adds to the pond nitrogen budget. Catfish feeds should be balanced in regard to protein and energy with ample energy supplied from nonprotein sources (i.e., starch and fat).

Nutritionally, amino acids may be classified as either indispensable (must be supplied in the diet) or dispensable (can be synthesized by the animal and not required in diet). Most simple-stomach animals, including catfish, require the same 10 indispensable amino acids (Table 1). It is critical that all 10 indispensable amino acids are provided in the proper amounts and proportions. If a single indispensable amino acid is missing, growth will not occur. In practice, an amino acid will not be completely missing, but if a specific feed mix is improperly balanced, the concentration of one or more indispensable amino acids could be lower than required by the animal.

A single amino acid deficiency will decrease growth. That is, the animal will grow only to the point at which the supply of the deficient amino acid is exhausted. The deficient amino acid limiting growth is referred to as the "limiting" amino acid in that specific feed mix. Using the feedstuffs typically found in catfish feeds, lysine is considered the first limiting amino acid. Generally, if catfish feeds are formulated from commonly used feedstuffs to meet the dietary lysine requirement, all other indispensable amino acids are present in adequate amounts.

Amino acid requirements are best met by feeding a feedstuff mixture because different proteins contain amino acids in varying amounts and proportions. Supplemental amino acids may be added to correct an imbalance if necessary. In practice, lysine is typically the only supplemental amino acid needed in commercial catfish feeds.

The optimum dietary protein level to include in commercial catfish feeds depends on several factors, but when producers use high-quality feedstuffs, feeds that contain as little as 24% protein provide for fast growth and high feed efficiency. However, there may be a problem using low-protein feeds for catfish, because dietary energy levels are too high relative to the protein levels. As protein is decreased, the dietary energy-to-protein ratio increases, resulting in increased fish fattiness. Even though dietary protein can be reduced to 24% without negatively affecting weight gain and feed efficiency, feeds containing less than 28% protein generally result in increased fattiness, which may lead to a reduction in dressed yield.

Over the last 20 years or so, we have conducted numerous studies—including comparisons of 28% and 32% protein feeds prepared from various feedstuffs—and there have been absolutely no differences in weight gain or feed efficiency. In some studies, we observed a slight increase in body fat and a reduction in dressed yield in fish fed a 28% protein feed. On average, we found that fish fed 28% protein diet had about 0.5% lower carcass and fillet yield. Based on these studies and studies conducted at other research facilities, we recommend using a 28% protein feed with protein being supplied primarily from high-quality oilseed meals. If feed is severely restricted, a higher protein feed may be beneficial, but with typical feeding rates that allow about 100 pounds per acre per day, there is no need for high-protein feeds.

Carbohydrates and Lipids

Carbohydrates are in a group of compounds that include sugars, starches, celluloses, and other closely related substances among the most abundant organic compounds found in nature. They are the primary energy form stored in seeds, roots, and tubers, making up 60% to 70% of the dry weight of most grains. For catfish and other simple-stomached animals, carbohydrates can be broadly divided into an indigestible fraction (fiber) and a digestible fraction (sugars and starches). Ability to utilize sugars and starches as an energy source differs among fish species. Most fresh- and warmwater fish, including catfish, can utilize higher dietary starch levels more efficiently than coldwater fish. This ability may be attributed to the fact warmwater fish have a much higher intestinal amylase concentration—necessary for starch utilization—than coldwater species. Digestibility values for catfish for carbohydrates in cooked corn range from 62−78%.

There is actually no dietary requirement for carbohydrate for catfish because they, as other animals, are capable of synthesizing carbohydrates from lipids and proteins. Even so, catfish feeds inherently contain fairly large amounts of grain or grain by-products that are rich in starch. Starch is important in catfish feeds because it is an inexpensive energy source that can help prevent the more expensive protein from being used for energy. Catfish readily use protein for energy if other nonprotein energy sources are not included in the diet. Starch is also important in feed manufacture for binding ingredients and allowing for extruded feed-pellet expansion so they are water-stable and will float on the water surface. A typical catfish feed contains 35–40% or more digestible carbohydrates, plus an additional 3–7% crude fiber. Dietary fiber should be maintained at as low a level as practical to minimize indigestible material passing into the culture water via the feces.

Lipids (fats and oils) are a highly digestible concentrated energy source. For example, fish oil contains more than twice the energy found in an equivalent amount of carbohydrates and protein and is 97% digestible to catfish. In addition to supplying energy, lipids are a source of essential fatty acids (EFAs) that cannot be synthesized by the animal and thus must be provided in the diet. EFAs are classified based on their chemical structure and are designated as either n-3 (omega-3) or n-6 (omega-6) fatty acids. Even though there may be exceptions, fish generally appear to require n-3 fatty acids. Catfish EFA requirements appear to be met by 0.5–0.75% highly unsaturated n-3 fatty acids. EFAs can be supplied by marine fish oil such as menhaden oil. Natural food organisms found in the pond may also be a good EFA source, but their contribution to the EFA requirement has not been quantified. However, we do know that the highly unsaturated n-3 fatty acid concentration found in zooplankton exceeds the EFA requirements of small catfish fingerlings that prey on these organisms. Lipids also serve as a vehicle for fat-soluble vitamin absorption and are precursors for steroid hormones and other compounds. They may also affect the flavor of edible tissue and help maintain neutral buoyancy of fish.

Since catfish appear to have the ability to synthesize most fatty acids, nutritionally there may be no “best” dietary lipid concentration except that needed to provide EFAs. But since lipid is a concentrated energy source that can spare the more expensive protein, additional lipid should be included in catfish diets. However, too much dietary lipid may result in excessive fat deposition in the body cavity and tissues. This problem may adversely affect processed yield, product quality, and storage of processed products. Also, weight gain and feed efficiency are depressed when catfish are fed diets containing 15% or more lipids. This is not an issue in practice because 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 lipids aids in feed dust (“fines”) reduction. Both animal fats and fish and vegetable oils have been used in commercial catfish feeds. A mixture of menhaden fish oil and catfish oil is often used.

Table 1. Nutrients recommended for catfish feeds.

Nutrient	Recommended level[1]	Comments
Protein (%)	Grow out: 26–32 Small fingerings: 32–35 Fry: 40–50	Will vary depending on fish size, water temperature, dietary energy level, and daily feed allowance.
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 the methionine requirement. Tyrosine can replace about 50% of the 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)	8.5–9.5	Use carbohydrate and lipid (fats or oils) as energy to spare protein for growth. Fats are more highly digestible to catfish than are carbohydrates.
Lipid (%)	4–6	A 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 grains and 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-α-tocopheryl acetate is used for improved stability.
K	4.4 ppm	K is required, but level for catfish are 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 is generally used.
Nicotinic acid	None	This vitamin is required, but feed contains adequate nicotinic acid without a supplement.
Biotin	None	Biotin is required, but feed contains adequate amounts without a supplement.
Folic acid	2.2 ppm	
B-12	0.01 ppm	B-12 is required, but the amount is not known. It is synthesized in the intestine of catfish.
Choline	None	Choline is required in low-methionine diets. It is abundant in most feedstuffs; therefore, choline supplements do not appear to be necessary.
Inositol	None	No requirement has been demonstrated.
Ascorbic acid	50[2] ppm	The 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. There is a 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 phosphorus source in catfish feeds. Phytase enzymes may be used to replace supplemental phosphorus sources.
Magnesium	None	No supplement is needed. It is abundant in feedstuffs.
Sodium, potassium, and chloride	None	No supplement is necessary. It is abundant in feedstuffs.
Sulfur	None	No supplement is needed. It is abundant in feedstuffs.
Cobalt[3]	0.05 ppm	Cobalt carbonate is used to ensure adequacy.
Iodine[3]	2.4 ppm	Calcium iodate is used to ensure adequacy.
Zinc	200 ppm	Phytic acid in feed reduces availability. Zinc oxide is generally used.
Selenium	0.1 ppm	Maximum allowable by FDA is 0.1 ppm. Sodium selenite is used.
Manganese[3]	25 ppm	Phytic acid in feed reduces availability. Manganese oxide is used.
Iron[3]	30 ppm	Ferrous sulfate and ferrous carbonate are used.
Copper[3]	5 ppm	Copper sulfate is used.

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

Vitamins and Minerals

Vitamins are highly diverse in chemical structure and physiological function. They are generally defined as organic compounds required in small amounts in the diet for normal growth, health, and reproduction by one or more animal species. If catfish are fed purified diets under controlled laboratory conditions, characteristic vitamin deficiency signs can be induced when the diet is deficient in a particular vitamin. However, vitamin deficiencies are rarely encountered in natural fish populations or in cultured catfish. This is because vitamins are present in natural food sources, and some vitamins can be synthesized in the intestine. In the case of cultured fish, many vitamins are inherent in feedstuffs used in commercial fish feeds.

To ensure there are sufficient vitamins to meet the requirements, feed manufacturers add vitamin supplements. Although microorganisms in the intestines of certain animals can synthesize some vitamins in quantities sufficient to meet metabolic needs, it is important to note that catfish intestinal microflora are generally not as extensive as the bacteria found in some land animals. Therefore, the intestinal-synthesized vitamin contribution to the catfish diet is likely rather small. Further, vitamins present in feedstuffs usually have been disregarded during feed formulation because the bioavailability of most vitamins to catfish is not known. This being said, we have conducted several studies with catfish that indicate vitamins inherent in feedstuffs contribute significantly to the vitamin nutrition of catfish.

In addition, natural food (large zooplankton) present in commercial catfish ponds contains vitamins (some in relatively high concentrations) that can meet most, if not all, vitamin requirements for catfish fry and small fingerlings. However, large fingerling and food-sized fish do not readily consume zooplankton, so the tiny invertebrates contribute little, if any, to the vitamin nutrition of catfish.

Qualitative and quantitative vitamin requirements for catfish have been fairly well defined (Table 1). Initially, catfish vitamin requirements were typically determined with small, rapidly growing fish under laboratory conditions. These values were considered to be sufficient to meet pond-raised fish needs. However, vitamin requirements are affected by numerous factors, including stresses encountered in the culture environment.

To address these issues, we conducted several studies on pond-raised catfish grown from large fingerlings to market size. In these studies, we fed fish a commercial-type diet with and without supplemental vitamins or with and without specific vitamins to provide insights into practical vitamin requirements. Results indicated the concentrations of certain vitamins can be reduced, and some vitamins can be removed from the vitamin premix without affecting fish performance.

Fourteen minerals are essential for catfish to maintain normal metabolism and skeletal structure, as well as to maintain an osmotic balance between body fluids and their environment. The requirement for most minerals is met by elements inherent in feedstuffs and/or by supplements added to the feed. However, catfish can absorb certain minerals from the water. For example, a calcium supplement is not necessary when the culture water contains an adequate amount of this mineral. However, catfish require 0.45% calcium in the diet when raised in calcium-free water. In practice, a calcium supplement is not needed because most pond water contains ample calcium, and commercial catfish feeds generally contain a relatively high calcium concentration from feedstuffs. In most animal feeds, the dietary calcium-to-phosphorus ratio is an important consideration. However, this ratio apparently is not critical for catfish because calcium is regulated at the gills.

Other minerals that do not need to be supplemented include sodium, potassium, chloride, magnesium, and sulfur. These minerals are either absorbed from culture water or are abundant in feedstuffs typically used in catfish feeds.

As with calcium, catfish require a relatively high phosphorus level (0.35%). However, catfish do not obtain significant phosphorus from the water. Catfish feeds are composed primarily of feedstuffs of plant origin, some of which contain high phosphorus concentrations. But catfish can utilize only about one-third of the plant phosphorus. Phosphorus is bound to a compound found in plants (phytate), and catfish do not have the enzyme (phytase) necessary to utilize this phosphorus form. Fishmeal and animal by-products contain high phosphorus concentrations. Catfish can utilize about 50–70% of this phosphorus, but commercial feeds typically contain low amounts of these feedstuffs. Therefore, catfish feeds are typically supplemented with dicalcium or defluorinated phosphates to ensure adequate concentrations of this nutrient.

Commercially available phytase that releases the phytate-bound phosphorus, making it available for use by catfish, can be used instead of a phosphorus supplement. Research with catfish has shown that phytase enzymes are effective, and phytase has been successfully used in some commercial catfish feeds for several years. One advantage of using phytase enzymes is that there is a significant reduction in fecal phosphorus. The recommended rate is 500 phytase units per kilogram of feed in a feed containing at least 0.6% total phosphorus from feedstuffs. In addition to a phosphorus additive, catfish feeds also are supplemented with a trace mineral premix that provides minerals required in small quantities (Table 1).

Selected Readings

Robinson, E. H., M. H. Li, and B. B. Manning. 2001. A practical guide to nutrition, feeds, and feeding of catfish (second revision). Mississippi Agricultural and Forestry Experiment Station Bulletin 1113.

Li, M. H., B. B. Manning, and E. H. Robinson. 2004. Summary of phytase studies for channel catfish. Mississippi Agricultural and Forestry Experiment Station Research Report Vol. 23, No. 13.

Robinson, E. H., and M. H. Li. 2005. A summary of catfish nutrition research conducted under a cooperative agreement between MAFES and Delta Western Research Center. Mississippi Agricultural and Forestry Experiment Station Bulletin 1144.

Robinson, E. H., and M. H. Li. 2007. Catfish protein nutrition: revised. Mississippi Agricultural and Forestry Experiment Station Bulletin 1159.

Robinson, E. H., and M. H. Li. 2007. Catfish feeds and feeding. Mississippi Agricultural and Forestry Experiment Station Bulletin 1163.

Robinson, E. H., and M. H. Li. 2007. Effects of fish size and feeding frequency on catfish production. Mississippi Agricultural and Forestry Experiment Station Research Report Vol. 24, No. 2.

Li, M. H., and E. H. Robinson. 2008. Feeding catfish in commercial ponds. Southern Regional Aquaculture Center Publication No. 181.

Robinson, E. H., and M. H. Li. 2011. Reducing catfish feed cost. Mississippi Agricultural and Forestry Experiment Station Research Report Vol. 24, No. 10.

Robinson, E. H. and M. H. Li. 2012. Composition and formulation of channel catfish feeds. Mississippi Agricultural and Forestry Experiment Station Bulletin No. 1200.

Li, M. H., and E. H. Robinson. 2012. Summary of nutrition and feeding studies for pond-raised hybrid catfish. Mississippi Agricultural and Forestry Experiment Station Research Report Vol. 24, No. 12.

Li, M. H., and E. H. Robinson. 2013. Feed ingredients and feeds for channel catfish. Southern Regional Aquaculture Center Publication No. 1806.

Robinson, E. H., and M. H. Li. 2013. Comparative quality of feedstuffs for catfish feeds. Mississippi Agricultural and Forestry Experiment Station Bulletin 1205.

Robinson, E. H., and M. H. Li. 2014. Plant-based catfish feeds. Mississippi Agricultural and Forestry Experiment Station Research Report Vol. 24, No. 14.