

Feed Ingredients and Feeds for Channel Catfish

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In the southeastern United States, channel catfish are generally cultured in earthen ponds at relatively high densities. The intensive culture system requires that the fish be fed a nutritionally complete diet that provides nutrients and energy at or above the required levels for optimum growth and feed efficiency. This is mainly because the amount of natural food in the pond is relatively small compared to the total nutrient requirements of the fish, except in early stages of life (fry and small fingerlings).

Feed represents the largest variable cost in catfish production. While the need for more economical feeds is clear, it is imperative that catfish feeds are formulated to be cost-effective, not just less costly. This can be achieved by carefully selecting and blending various traditional and alternative feedstuffs that are suitable for use in catfish feeds. It is important that using less expensive alternative feedstuffs not degrade the nutritional and physical quality of the feed, fish growth, processed yield, and product quality. In this publication we examine various feed ingredients that are or could be used in catfish feeds, as well as feed formulation guidelines and various types of feeds.

Feed ingredients

Commercial catfish feeds are a mixture of feedstuffs and vitamin and mineral supplements that provide adequate amounts of essential nutrients and digestible energy. To be suitable, dietary ingredients must be highly digestible, easily handled in the manufacturing process, able to withstand the rigors of the manufacturing process, available on a consistent basis, economical, and contain sufficient nutrients. Although all feedstuffs contain energy, protein, and other nutrients, they are usually

classified as either protein or energy feedstuffs. In animal feeds, those containing 20 percent protein or more are generally referred as protein feedstuffs, and those containing less than 20 percent protein are energy feedstuffs. Protein feedstuffs are further divided by the source, either animal or plant. There are many feedstuffs that may be nutritionally suitable for use in catfish feeds, but relatively few are readily available on a timely basis and at reasonable cost. Although we will consider all types of feedstuffs, we will focus mostly on protein feedstuffs, as protein is the most costly fraction of catfish feeds.

Protein feedstuffs

The primary protein sources used in catfish feeds are oilseed meals, such as soybean meal and cottonseed meal; peanut meal and canola meal also can be used. Compared to animal proteins, most plant proteins, except for soybean meal, are deficient in lysine, the most limiting essential amino acid in catfish feeds. Also, certain plant proteins contain antinutritional factors and toxins (see SRAC Publication No. 5002, *Mycotoxins in Aquaculture Feeds*). Some antinutrients, such as trypsin inhibitor, are inactivated by heat during extrusion, but others, such as phytate, are unaffected by heat treatment. Other processing methods may be used to reduce levels of some antinutrients. Although there are exceptions, animal proteins are generally considered to be of higher quality than plant proteins, primarily because they typically contain more indispensable amino acids and do not contain antinutritional factors (see SRAC Publication No. 5003, *Principles of Fish Nutrition*). Animal proteins that have been used in catfish feeds include fish meal, meat and bone meal, blood meal, meat and bone/blood meal blend, poultry by-product meal, and catfish offal meal. These animal proteins, especially fish

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meal, are more expensive than plant proteins. Although there have been conflicting reports, properly balanced diets with all-plant proteins can provide satisfactory growth of catfish raised in ponds from advanced fingerlings to market size.

Soybean meal, dehulled, solvent-extracted, is obtained by grinding the flakes remaining after removing most of the oil from dehulled soybeans by a solvent-extraction process. It contains about 48 percent high-quality protein and is the predominant protein source in catfish feeds. Soybean meal has the best amino acid profile of all common plant protein sources and is highly palatable and digestible to catfish. Antinutritional factors, such as trypsin inhibitor, are destroyed or reduced to insignificant levels with heat that is applied during the extraction process. Levels of soybean meal up to 50 percent have been used in commercial catfish feeds without detrimental effects. In recent years, its use has been reduced somewhat because of increasing cost.

Cottonseed meal, solvent-extracted, is obtained by finely grinding the flakes that remain after removing most of the oil from cottonseed by a solvent-extraction process. It generally contains about 41 percent protein, but must not contain less than 36 percent. It is highly palatable to channel catfish. Cottonseed meal contains free gossypol and cyclopropenoic acids, which can be toxic at high levels; however, in commonly available cottonseed meal these compounds are generally well below toxic levels. Cottonseed meal has generally been used in catfish feeds at a level of 10 to 15 percent, but levels up to 30 percent with lysine supplements can be used to replace part of the soybean meal in catfish feeds.

Distillers dried grains with solubles (DDGS) is the product obtained after removing ethyl alcohol by distillation from the yeast fermentation of grain or grain mixture. The predominant product in the U.S. is the DDGS from corn. The product contains approximately 27 percent protein and is highly palatable to catfish. Because oil is of higher value, some of the DDGS is solvent-extracted to remove part of the oil for human consumption and biodiesel production. Studies have shown that levels of DDGS up to 40 percent, with lysine supplement, can be used in catfish feeds without affecting fish growth. However, DDGS from yellow corn contains a relatively high level of yellow pigments (mainly lutein and zeaxanthin), which may be deposited in the catfish product and make it unacceptable to the typical consumer. A level of 10 to 20 percent may be used as long as the yellow pigments in the finished diet do not exceed about 7 ppm.

Peanut meal, mechanical- or solvent-extracted, is a ground product of shelled peanuts composed of the kernels and hulls (fiber) or oil left in the ordinary course

of mechanical or solvent extraction. It contains about 45 to 47 percent protein and must not contain more than 7 percent crude fiber. Peanut meal is highly palatable to catfish and has no known antinutritional factors, but it is prone to become contaminated with mold, which produces aflatoxins. It is seldom used because of its sporadic availability.

Canola meal, solvent-extracted, consists of the meal obtained after removing most of the oil (by mechanical or solvent extraction) from the whole canola seeds. Canola refers to varieties of rapeseed specially bred to contain much lower levels of the toxic glucosinolates and erucic acid. Canola meal contains about 38 percent protein. Up to 25 percent canola meal can be used to replace part of the soybean meal in feed. It is rarely used in catfish feeds because it often is not cost-effective and is in limited supply.

Fish meal is the clean, dried, ground tissues of undecomposed whole fish or fish cuttings. Sometimes part of the oil has been extracted. Fish meal generally refers to products from marine sources, and the most common fish meal used in the U.S. is menhaden meal. Fish meal contains 60 to 80 percent protein of excellent quality that is highly palatable to catfish. It is also rich in energy, essential fatty acids, and minerals. It has been used at levels of up to 60 percent in catfish fry feeds, up to 15 percent in fingerling feeds, and up to 12 percent in food fish feeds. Because of its high cost, little, if any, fish meal is used in commercial catfish feeds except for fry feeds.

Porcine meat and bone meal is the rendered product from pork processing, exclusive of any blood, hair, hoof, hide trimmings, manure, or stomach contents (except in amounts as may occur unavoidably in good processing practices). It contains approximately 52 percent crude protein. Its protein quality is inferior to whole fish meal because it contains less lysine. Although it is a good source of minerals, its high ash content may limit its use because of possible mineral imbalance. The maximum level of meat and bone meal recommended for catfish feeds is 15 percent of diet.

Porcine meat and bone/blood meal blend is a mixture of meat and bone meal and blood meal from pork processing. The two ingredients are mixed to mimic the nutritional profile of menhaden fish meal (at least in regard to lysine). The blended product provides 60 to 65 percent protein (an excellent protein source for catfish feeds) and is generally used as a replacement for fish meal.

Poultry by-product meal consists of the ground, rendered, clean parts of the carcass of slaughtered poultry, such as necks, feet, undeveloped eggs, and intestines. It does not include feathers, except in such amounts as might occur unavoidably in good processing practices.

Feed-grade poultry by-product meal contains approximately 60 percent protein and is an excellent product for use in catfish feeds. However, it is not available on a regular basis at a reasonable cost per unit of protein.

Hydrolyzed poultry feathers is the product resulting from the treatment under pressure of clean, undecomposed feathers from slaughtered poultry. It is free of additives. At least 75 percent of its crude protein must be digestible by the pepsin digestion method. It is high in protein (85 percent), but deficient in several essential amino acids, especially lysine. Hydrolyzed poultry feathers are rarely used in catfish feeds because of the low levels of essential amino acids and low palatability to catfish.

Energy feedstuffs

Energy feedstuffs used in commercial catfish feeds are primarily grains (corn and wheat) and grain by-products (corn gluten feed, corn germ meal, wheat middlings, and rice bran), animal fat, and fish oil.

Corn has traditionally been used as the main energy source in catfish feeds. Corn improves the expansion of feed pellets during extrusion, resulting in a pellet that floats. Because of recent dramatic increases in its price, less corn is being used in catfish feeds. However, a minimum of 15 percent corn should be included in the feed to ensure proper expansion and floatability of feed pellets.

Wheat is a good source of energy for catfish and a good pellet binder, but it is generally more expensive than corn and is seldom used in catfish feeds. However, wheat by-products such as wheat middlings are typically used.

Wheat middlings consist of fine particles of wheat bran, shorts, germ, flour, and some of the offal from the milling of wheat. Depending on cost, wheat middlings are generally used to replace corn and/or wheat in catfish feeds. It can be used at levels up to 25 percent of diet.

Corn gluten feed is the part of the shelled corn that remains after the extraction of the larger portion of the starch, gluten, and germ in the wet milling manufacture of corn starch or syrup. It typically contains 21 percent crude protein (it is referred to as an energy feedstuff here because it is mainly used to replace the energy feedstuffs corn and wheat middlings in catfish diets). Corn gluten feed is usually competitively priced relative to corn and wheat middlings. Catfish feeds can contain up to 30 percent corn gluten feed without detrimental effects. Unlike high-protein corn gluten meal, corn gluten feed contains a level of yellow pigments similar to that in corn grain. Corn gluten feed is less digestible than corn grain.

Corn germ meal is ground corn germ, which consists of corn germ with other parts of the corn kernel from which part of the oil has been removed. The product is obtained by the dry milling process to manufacture corn

meal, corn grits, hominy feed, and other corn products, or by the wet milling process to manufacture corn starch, syrup, etc. The product contains 18 to 20 percent protein. It has less yellow pigment than corn gluten feed and corn. It can be used in catfish feeds at levels up to about 35 percent of diet. The digestible energy of corn germ meal is lower than that of corn grain.

Rice bran is the bran layer and germ of the rice, with only such quantity of hull fragments and broken rice as is unavoidable in the regular milling of edible rice. It is high in fat, which limits its use in catfish feeds. Because of its high fat content and a potent lipase enzyme, rice bran oxidizes rapidly and becomes rancid under normal storage conditions. Rice bran can be stabilized by heat and pressure treatment to inactivate the lipase enzyme. No more than 5 percent of full-fat rice bran may be used in catfish feeds. Solvent-extracted and stabilized rice bran can be used at higher levels (up to 15 percent). It is rarely used in catfish feeds because it is not regularly available and because some feed manufacturers report that it is highly abrasive to feed processing equipment.

Fats and oils from animals or plants are highly concentrated sources of energy and contain essential fatty acids and fat-soluble vitamins. Animal fats and oils used in catfish feeds include catfish offal oil, menhaden oil, and poultry fat. Plant oils can be used, but are generally too expensive. Supplemental fat/oil is generally sprayed on the finished feed pellet at a rate of 1 to 2 percent, primarily to reduce feed dust or "fines."

Vitamin and mineral supplements

Commercial catfish feeds are supplemented with a vitamin premix that provides all vitamins in quantities necessary to meet requirements and compensate for losses caused by feed processing. Phosphorus and trace mineral supplements are commonly added in catfish feeds to ensure that mineral requirements are met.

Supplemental amino acids

The essential amino acid requirements of fish are generally met with a diet that contains a mixture of feedstuffs with complimentary amino acid profiles. If the mixture is deficient in certain amino acids, synthetic amino acids are supplemented. Catfish can efficiently utilize supplemental amino acids. Lysine and sulfur-containing amino acids (methionine and cystine) are the most limiting essential amino acids for most fish. In catfish feed formulations using commonly available feedstuffs, lysine is typically the only amino acid that needs to be supplemented in the diet. Supplemental lysine can be used up to about 0.4 percent of the diet.

Feed additives

Currently, no feed additives are used in catfish feeds except the phytase enzyme that is used by some feed mills. The enzyme breaks down the bound form of phosphorus (phytate) in the main feed ingredients, making it available to the fish. It can completely replace the inorganic phosphorus supplement if the main feed ingredients provide a minimum of 0.6 percent total phosphorus. Phytase must be applied post-extrusion because it cannot withstand the high temperature associated with the manufacture of extruded feeds.

Feed formulations

Catfish feeds are generally formulated using computer programs based on specifications for including all required nutrients and energy needs and for ensuring that the diet is highly palatable and digestible. Measures are also taken to ensure that the diet has high water stability and floatability and is manufactured at the least cost. To formulate least-cost feeds, the following information is needed:

- Nutrient requirements of fish
- Nutrient and energy concentrations of feed ingredients
- Nutrient and energy digestibility and availability from feed ingredients
- Price and availability of feed ingredients
- Levels of antinutrients or undesirable compounds present in the ingredients
- Nutritional and non-nutritional restrictions

In formulating least-cost catfish feeds, nutritional and non-nutritional specifications can be set to include an exact, a minimum, or a maximum amount of an ingredient or nutrient. There are several specifications that need to be considered (Tables 1 and 2), but if too many specifications are used, the program may not be capable of calculating a formula, or it will produce a formula that is not practical. To calculate a formula for catfish, it is necessary to set nutrient specifications only for protein, available lysine, and total and available phosphorus. In addition, vitamin and trace mineral premixes are added to ensure that the requirements for these nutrients are met. Regardless of the

specifications set, it is essential that the formula be double-checked to ensure that the ingredient composition is practical and that the nutritional requirements are satisfied.

Table 1. Nutrient specifications for least-cost formulation of a 28 percent protein feed.

Nutrient	Minimum	Maximum
Crude protein (%)	28	28
Crude fat (%)	–	6
Crude fiber (%)	–	7
Available lysine ¹ (%)	1.43	–
Available methionine and cystine ² (%)	0.65	–
Available phosphorus (%)	0.30	0.40
Digestible energy (kcal/g)	2.6	2.8
Yellow pigments ³ (ppm)	–	7

¹ Minimum available lysine should be 5.1 percent of the dietary protein.

² Minimum methionine and cystine should be 2.3 percent of the dietary protein.

³ Lutein and zeaxanthin.

Table 2. Ingredient specifications for least-cost formulation of a fingerling or food fish feed.

Nutrient	Minimum	Maximum
Soybean meal, dehulled, solvent extracted (%)	20	–
Corn grain (%)	15	–
Cottonseed meal, solvent-extracted (%)	–	25
Wheat middlings (%)	–	25
Corn gluten feed or corn germ meal (%)	–	30
Distillers dried grain with solubles ¹ (%)	–	20
Rice bran, solvent-extracted (%)	–	15
Animal protein feedstuff ² (%)	–	15
Supplemental fat ³	1.5	3
Mono- or dicalcium phosphate (%)	Meet requirement for phosphorus	
Vitamin premix	Meet all vitamin requirements	
Trace mineral premix	Meet all trace mineral requirements	
Phytase enzyme ⁴ (FTU ⁵ /kg)	500	500

¹ Yellow pigment levels can vary greatly among different sources, and dietary yellow pigments should be monitored if distillers dried grains with solubles are used.

² Animal proteins used in catfish fingerling feeds include menhaden fish meal, poultry by-product meal, porcine meat and bone meal, and porcine meat and bone/blood meal blend.

³ Sprayed on the finished feed to reduce feed dust.

⁴ Can be used to completely replace mono- or dicalcium phosphate supplement. Total phosphorus should be maintained at 0.6 percent or above if phytase is used.

⁵ FTU = phytase unit.

Types of feeds

Several types of feeds are available for commercial catfish production. They vary in nutrient and ingredient compositions, forms, and pellet sizes, depending on fish ages, sizes, and stages of culture. Fry and fingerling feeds contain higher protein than food fish feeds because small fish have a higher protein requirement than large fish.

Fry feeds

In the hatchery, catfish fry (once the yolk sac is absorbed) are typically fed a trout or salmon starter diet containing about 50 percent protein supplied mainly by marine fish meal. Once stocked into the nursery ponds, they are fed finely ground feed powder (Fig. 1) from catfish fingerling or food fish diets. During this early stage of life catfish fry depend mainly on natural foods (large zooplankton, insect larvae, and small insects) for normal growth and survival. Fry feeds are used as supplements until they reach a size of 3 to 5 cm.

Fingerling feeds

Small fingerlings are fed small floating pellets (3 mm in diameter) containing 32 to 36 percent protein (Fig. 1). A typical fingerling feed contains soybean meal, cottonseed meal, animal proteins (such as porcine meat and



Figure 1. Various types of catfish feeds. Top left, fry feed (powder); top right, fingerling feed (3 mm in diameter, floating); bottom left, food fish feed (5 mm, floating); bottom right, slow-sinking feed (4 mm).

bone meal, meat and bone/blood meal blend, or poultry by-product meal), corn, wheat middlings, animal fat/fish oil, and vitamin and mineral supplements.

Food fish feeds

Channel catfish grown from advanced fingerlings to market size are typically fed a 28 or 32 percent protein floating diet approximately 5 mm in diameter (Fig. 1). Evidence

Table 3. Examples of ingredient compositions for catfish fingerling and food fish feeds

Ingredient	36% protein fingerling	32% protein food fish ¹	32% protein food fish	32% protein food fish	28% protein food fish	28% protein food fish	28% protein food fish
Soybean meal (48% ²)	51.05	44.10	33.25	30.60	32.90	25.35	22.30
Cottonseed meal (41% ²)	10.00	10.00	25.00	25.00	10.00	20.00	20.00
Porcine meat & bone meal ³ (52% ²)	10.00	5.00	–	–	5.00	–	–
Corn grain	20.00	20.00	18.21	15.00	25.00	20.00	15.00
Wheat middlings	5.50	18.20	–	10.82	24.32	11.08	24.10
Corn gluten feed ⁴	–	–	20.00	–	–	20.00	–
DDGS ⁵ (27% ²)	–	–	–	15.00	–	–	15.00
Dicalcium phosphate	0.25	0.50	1.00	1.00	0.50	1.00	1.00
Lysine HCl	–	–	0.34	0.38	0.08	0.37	0.40
Vitamin mix ⁶	Included	Included	Included	Included	Included	Included	Included
Trace mineral mix ⁶	Included	Included	Included	Included	Included	Included	Included
Animal fat/oil ⁷	3.00	2.00	2.00	2.00	2.00	2.00	2.00

¹ Can also be used to feed fingerlings.

² Crude protein.

³ Can be replaced by poultry by-product on an equal protein basis.

⁴ Can be replaced by corn germ meal on an equal protein basis.

⁵ Distillers dried grains with solubles. Yellow pigment levels should be closely monitored.

⁶ Meets requirements for all vitamin and trace minerals.

⁷ Catfish oil, menhaden oil, poultry fat, or a mixture of these oils or fats is used post-pelleting to control feed dust.

shows that a properly balanced 28 percent protein diet can provide the same level of growth as a 32 percent protein diet with little impact on processed yield and body nutrient composition. Because of the high cost of animal proteins, food fish diets are made up of all plant feed-stuffs. Traditional high-cost ingredients such as soybean meal and corn are being replaced partially by alternative ingredients such as cottonseed meal, corn gluten feed, corn germ meal, and DDGS.

Brood fish feeds

Channel catfish brooders are usually fed a 32 percent protein food fish feed or 36 percent protein fingerling

feed. Some producers prefer feeding a slow-sinking feed because brood fish may be hesitant to feed at the surface.

Overwintering feeds

During the winter, when water temperatures are above 50 °F (10 °C), catfish should be fed a slow-sinking feed containing 28 or 32 percent protein according to winter feeding schedules based on water temperatures (see SRAC Publication No. 181, *Feeding Catfish in Commercial Ponds*, for details). Slow-sinking feeds (by extrusion) are typically fed during the winter because it is thought that catfish may be reluctant to feed at the surface during cold weather.

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