UF IFAS Extension UNIVERSITY of FLORIDA

FA144

The Concept of Ideal Protein in Formulation of Aquaculture Feeds[1]

Richard D. Miles and Frank A. Chapman[2]

Aquaculture feeds characteristically contain a higher percent of protein than feeds used in agriculture for poultry, swine, and beef. A typical commercial production diet formulated for tilapia or catfish contains approximately 32–40% protein, while one formulated for trout or salmon contains as much as 44–50% protein, on a dry weight basis. A commercial grower diet formulated for most terrestrial animals rarely exceeds 20% in total protein, and even for carnivorous species such as cats, the total protein rarely exceeds 38%. The use of higher protein levels in fish feeds is accepted because fish require less energy for maintenance of normal body functions than warm blooded animals such as poultry, swine, cattle, horses, and other terrestrial animals. Also, several species such as salmon and trout derive their energy from protein and fats more efficiently than from carbohydrates; similar to cats.

Protein is typically the most costly nutrient in a formulated feed. Feed costs are usually the major operational expense in most aquaculture operations, typically ranging from 30% to 50% of the variable operating costs. Protein in the majority of formulated fish diets (worldwide) depends greatly on fishmeal, which is more costly than high quality, plant-based protein sources, such as soy protein.

Nitrogen in wastewater from aquaculture effluents is often considered a pollutant. In freshwater systems, nitrogen is sometimes a limiting nutrient, so adding it stimulates plant and algal growth. A majority of the excess nitrogen in either tank or pond culture systems originates as ammonia excreted by fish. The ammonia, as a waste product, is formed during the breakdown of proteins and excess amino acids not incorporated into tissue by the fish.

The Concept of Ideal Protein

The *ideal protein* can be defined as one that provides the exact balance of amino acids needed for optimum performance and maximum growth (e.g., size, carcass weight, yield, and body composition). Formulating a feed based on an ideal protein is an effective way of using less protein in the diet to meet amino acid requirements. Maximizing the effective use of protein and minimizing the amount needed in feeds can substantially reduce production costs, increase farm profitability, and reduce harvest of wildfish used for fishmeal. Nitrogen pollution arising from fish production can also be reduced by applying the concept of ideal protein to the formulation of fish feed, just as it is already being applied successfully to feeds for poultry and swine.

Fish do not have a specific protein requirement but rather a definite requirement for essential amino acids that comprise proteins. In other words, it is essential amino acids in dietary protein that a fish requires and not the protein per se. When protein is digested, the amino acids comprising it are released and absorbed into the body as either individual amino acids or shorter chains of amino acids, the di- and tri-peptides. There are about 20 known amino acids used as

1. This document is FA144, one of a series of the Department of Fisheries and Aquatic Sciences; UF/IFAS Extension. Original publication date March 2007. Reviewed April 2017. Visit the EDIS website at http://edis.ifas.ufl.edu.

2. Richard D. Miles, professor, Department of Animal Sciences; and Frank A. Chapman, associate professor and Extension aquaculture specialist, Department of Fisheries and Aquatic Sciences; UF/IFAS Extension, Gainesville, FL, 32611.

building blocks for the proteins in all living organisms. Ten amino acids are essential, and they must be incorporated into diets because fish either cannot synthesize them or can synthesize them at a rate that is inadequate for cellular demand. The other amino acids are classified as dispensable or dietary non-essentials because fish can synthesize them at a rate that meets cellular demand for protein synthesis. Both essential and non-essential amino acids are *required* by body cells whenever proteins are being synthesized.

If a fish feed contained a protein composed of the exact amount of each essential amino acid required by a particular fish species (i.e., mostly for deposition of lean body tissue), then this, theoretically, would be the perfect or ideal protein. The use of this ideal protein means that there will be no amino acid deficiency or excess. Furthermore, changes in the feed's amino acid composition would be made in a way that did not alter the relative ratios of amino acids. In other words, the ideal protein concept is built on the principle that amino acids are required and supplied in specific proportions to each other. Growing fish fed such a diet would use very few (if any) amino acids for energy. The amino acids would be used efficiently for maintenance, health, and synthesis of new structural proteins (i.e., lean fillets), which will result in maximum feed efficiency and growth.

The ideal protein concept in feed formulation requires that the essential amino acid requirements of the fish be met using digestible amino acids rather than total amino acids because fish, like other animals, are not 100% efficient in utilizing what they consume.

Lysine: the Reference Amino Acid

When discussing the ideal protein concept, each of the amino acids in the feed is related to the requirement for lysine (Table 1). Lysine is one of the ten essential amino acids. Using lysine as a reference, the target concentrations for each of the other essential amino acids are expressed as a percentage of lysine, which is set at 100% (Table 1). For instance, in Table 1 the lysine requirement is 1.43% of a feed that contains 3,000 kilocalories of digestible energy per kilogram. The arginine requirement is 84% of the lysine requirement or 1.20% of the feed. Thus, it becomes obvious that once the lysine requirement is established for each fish species of commercial interest, specific feeds for a particular species are easily formulated.

There are several reasons for selecting lysine as the reference amino acid. First, lysine has only one major function in the animal body and that is for protein tissue deposition, therefore, its requirement is not influenced by other metabolic roles. Second, depending on the fish species and type of ingredients, lysine is usually the most or second most limiting amino acid; thus more is known about the requirements for lysine than other amino acids. Third, the analysis of lysine in feed is usually accomplished without analytical complications.

Using Ideal Proteins in Aquaculture Feeds: Feeding Excess Protein Is Not Acceptable

Feeds which are typically formulated with an excess of protein are usually due to one of two reasons: either the protein is not very digestible so more has to be added to meet amino acid requirements, or excess protein is added because specific essential amino acid requirements are not known. The excess protein provides a large *margin of safety* so that there will be less chance that essential amino acids are limiting in the diet. It is not economical or necessary to increase the total protein content of a feed to a point where excessive amounts of many amino acids are included in an attempt to meet the requirement for one or more of the essential amino acids that are shortest in supply. A diet should be formulated based on digestible amino acid values of feed ingredients and an ideal protein.

The excess nitrogen excreted as ammonia by fish may have a negative impact on the environment because it is a major contributor to water pollution. Because every species of fish and the individual proteins within each species has its own unique amino acid composition, the ideal situation would be to formulate a low protein feed that would minimize nitrogen excretion and at the same time meet all requirements for essential amino acids. Today, in other species such as poultry and swine, this is done routinely since synthetic essential amino acids (e.g., methionine, lysine, threonine) are commercially available, and these animals utilize these synthetic amino acids efficiently.

Reducing the amount of total protein in fish feeds can increase profitability and minimize nitrogen pollution. Selecting proteins with high digestibility and formulating feeds with the appropriate balance of amino acids can easily accomplish this. The use of nutrient-dense feeds can also decrease costs and minimize nitrogenous waste from aquaculture facilities. A nutrient-dense feed will supply a significant amount of a particular nutrient or nutrients relative to the amount of energy occupying space in a feed pellet. Both of these approaches are being successfully implemented for poultry and swine, with significant

improvements in feed conversion ratios and reductions in nitrogenous waste.

Summary

Aquaculture is a dynamic industry that continues to provide consumers with a reasonably priced, high quality protein. The impact that any aquaculture system has on the environment, is today, and will continue to be, in the forefront when environmental issues are discussed. A better understanding of the dietary nutrient requirements of cultured fish species and a continual search for accessible, highly digestible proteins to replace expensive fishmeal is essential. This approach coupled with applying the ideal protein concept in the formulation of fish feeds can greatly ameliorate nitrogen pollution arising from fish production systems and increase profitability. The catfish and trout farms, which account for the vast majority of the food-fish produced in the United States, already have greatly reduced their use of fishmeal in feeds, to a total of around 5% in catfish diets, and a total of 20% in trout diets.

Table 1. Ideal protein amino acid profile and percentage of amino acid in a channel catfish feed.

Amino Acid	Essential Amino Acid Profile (Expressed as a % of Lysine)	% Amino Acid in Feed (Energy base is 3000 kcal DE/kg feed)[1]
Lysine	100	1.43
Phenylalanine + Tyrosine[2]	98	1.40
Arginine	84	1.20
Leucine	68	0.98
Valine	59	0.84
Isoleucine	51	0.73
Methionine + Cystine[3]	45	0.64
Threonine	39	0.56
Histidine	29	0.42
Tryptophan	10	0.14

[1] Values taken from NRC, 1993 (National Research Council, 1993. Nutrient Requirements of Fish. Washington, DC: National Academy of Sciences.)
[2] Phenylalanine in cellular metabolism is used to synthesize tyrosine.
[3] Methionine in cellular metabolism is used to synthesize cystine.