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Review

Practical supplementation of shrimp and fish feeds with crystalline amino acids

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ABSTRACT

In 2011, aquaculture accounted for almost 64 million MT of fish, crustaceans and mollusks (FAO, 2012). Fish meal has historically been the protein source of choice in aquatic feeds, but global supplies have reached a plateau making it less available and more expensive. As a consequence, the use of cheaper proteins made from processed plant proteins, byproducts from agriculture, fisheries or the slaughtering of terrestrial production animals was popularized within the aquaculture feed industry. Although these alternative ingredients may contain a crude protein (CP) content comparable to fish meal, they may be less digestible and deficient in one or more of the ten essential amino acids (EAAs). This has required the adoption of more modern formulation approaches which take into account nutrient availability, especially in regard to EAAs. EAA requirements have been established for a number of species of fish and shrimp. Methionine (Met) followed by lysine (Lys) are the first limiting amino acids in plant and rendered animal byproducts. Formulating for EAAs by simply increasing the dietary inclusion levels of the feedstuffs that contain intact sources of the targeted EAAs can lead to overformulated feeds with excessive levels of CP and other nutrients. A more rational approach is to supplement the diet with crystalline amino acids (CAAs). A first step to the application of a nutrient-based formulation approach is knowledge of the digestible EAA content of the ingredients available for use in the formula. It is highly desirable to formulate on a CP, EAA and energy digestibility basis in line with current formulation practices of most modern feed companies. Further expansion of current EAA digestibility values across ingredients and farmed aquatic species will further enable nutrient based formulation. By formulating on an EAA basis across farmed aquatic species, nutritionists have realized least cost formulation opportunities with the use of CAAs which are now available throughout the world at accessible prices. The CAAs mostly used by the animal feed industry, in order of usage, are the following: DL-methionine or Met analogs, L-lysine, L-threonine, L-tryptophan, L-isoleucine and L-valine. Met and Lys are the most currently used due to their wide availability and importance as most limiting EAAs in plant protein ingredients, such as soy and corn based meals. There is a relatively wide variation in the dietary Met and Lys requirement values for farmed fish and shrimp. This is due to differences in species requirements, culture systems, developmental stage and composition of experimental diets. The dietary Met requirements for fish and shrimp range from 0.5 to 1.5% and from 0.7 to 0.9% of the diet, respectively (NRC, 2011). The dietary Lys requirements range from 1.2% to 3.3% of the diet for cultured fish and from 1.6 to 2.1% of the diet for cultured shrimp. Appropriate dietary Met and Lys levels improve the use of other EAAs because they have the ability to reduce the oxidation rate of other amino acids.

The present review discusses bioavailability, requirements and sources of EAAs and practical considerations for their application in aquaculture feeds. The appropriate supplementation of crystalline amino acids in feeds for fish and shrimp represents an opportunity to reduce formulation costs in the face of the volatile commodity market of protein ingredients and the short supply of fish meal. Competitiveness in the aquatic animal feed industry today depends upon application of modern and environmentally-sound formulation techniques based on nutrient value and supplementation with crystalline EAA to meet animal nutrient requirements.

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Contents

1. Introduction

In 2011, almost 64 million MT of fish, crustaceans and mollusks were harvested from aquatic farms worldwide. More than 75% of this production was achieved through the use of industrially-manufactured feeds. This contrasts markedly with aquaculture in the 1980s when production was dominated by extensive practices, low-trophic level fish and filter-feeding species (FAO, 2012). Today, due to an increasing global consumer demand, fish and shrimp are farm-raised to reach the market up to twice as fast while allowing yields as much as 10 times higher than in the early days of aquaculture.

Much of the development of modern aquaculture was achieved through improvements in farm management, genetics, disease control and a better understanding of nutrient requirements of farmed animals, ingredient processing and feed manufacturing. In the recent past, it was not uncommon to find under- or overformulated feeds. Today, commercial diets need to be fine-tuned to meet species' nutrient requirements targeting specific stages of development, culture system and farm production levels.

Aquatic feeds for farmed fish and shrimp are made from raw materials similar to those used in the feeding of livestock animals. The major difference is the need for protein-rich ingredients since the dietary concentration of crude protein (CP) in aquatic feeds is generally higher compared to feeds for terrestrial animals. A large number of protein ingredients can be used to manufacture aquatic feeds, but historically fish meal has been the protein source of choice. The reason is due to its nutrient value, especially in regard to the high levels of digestible CP and the balanced essential amino acid (EAA) profile that approximate fish and crustacean requirements. However, with the rapid growth of aquaculture, global fish meal supplies have reached a plateau. As a consequence, it has become less available and more expensive to use as a major protein component in aquatic feeds.

Hence, there has been a compelling need to increase the dietary use of alternative protein sources. Logical choices for fish meal replacement have included byproducts from agriculture, fisheries or the slaughtering of terrestrial production animals (for example: soybean meal, canola meal, corn gluten meal, meat and bone meal, soybean or pea protein concentrates, poultry by-product meal, feather meal, blood meal, and fisheries by-catch and processing waste meals). Some of these ingredients can contain CP levels comparable to fish meal, but values usually range from 40 to 75% (as is basis).

Prior to arrival at feed mills, these raw materials need to be processed by drying and grinding, by the application of chemicals to extract part of the nutritional components, or by cooking or fermentation. The way ingredients are processed, their origin and nature determine the amount of protein available and their resulting amino acid composition. Not all the protein in an ingredient is available for a certain species of fish and shrimp. The digestibility and amino acid profile are what ultimately determine the nutritional and economic value of a protein.

Therefore, selection of a protein ingredient also involves knowing its amino acid profile and bioavailability. Having all essential amino acids (EAAs) present at balanced and biologically available levels that meet the targeted species nutrient requirements is the most desirable condition. However, this is often not the case since most alternative ingredients commonly used in fish and shrimp diets are deficient in one or more of the ten EAAs. Methionine (Met) followed by lysine (Lys) are the first limiting amino acids in plant and rendered animal byproducts. Traditionally, fish meal and other marine proteins have been used to assure adequate Lys, Met and other EAA levels in feeds. However, attempting to drive up Met and Lys levels through the use of fish meal or other marine protein sources is usually too costly today due to price and market constraints. A common approach is to supplement the deficient amino acids with synthetic sources.

Commercial feeds for aquatic animals are typically high in protein with many formulations containing excessive amounts of dietary crude protein (CP). The use of the ideal protein concept in formulating EAA requirements is gaining popularity especially in reducing the dietary CP content and supplying EAA requirements through synthetic amino acids. The present article discusses different formulation approaches to meet EAA requirements of fish and shrimp through supplementation of crystalline amino acids.

2. Formulating for essential amino acids (EAAs)

Hundreds of studies have been carried out on protein and amino acid nutrition involving a very large number of fish and the most commercially-relevant shrimp species. A review chapter on protein and amino acid nutrition in fish and shrimp was compiled as part of the recently published National Research Council review entitled Nutrient Requirements of Fish and Shrimp (NRC, 2011). The chapter provides a review of the nutritional biochemistry of proteins and amino acids. Essential amino acids are discussed in the framework of factors which can affect utilization efficiencies. Literature on quantitative amino acid requirements of many commercially important fish and shrimp species is briefly summarized in Table 1. The chapter discusses methodological approaches and challenges associated with defining essential amino acid requirements and applying them to practical diet formulation in fish and shrimp.

EAA requirements established for fish and shrimp are derived from studies carried out with purified or semi-purified diets made from high-quality ingredients. These diets contain low levels of anti-nutritional factors (ANFs), avoiding negative effects on the digestibility and absorption of the tested EAAs, and the proteins used have high levels of digestibility. These experimental feeds are often designed to meet the exact animal nutrient requirements.

In a real scenario, commercially available ingredients have significant amounts of ANFs and digestibility of the proteins is highly variable. In feed mills, nutrient losses can also occur during feed manufacturing and further losses can occur due to improper storage of feed at the farm level. For this reason, a safety margin of 5% or more above the animal EAA requirements should be set to accommodate these conditions. Yet no universal safety margin can be proposed for all situations due to the wide variation in ingredient composition and culture conditions (e.g., water quality, feed management, stocking density). Any excess

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