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Review paper

Recent Studies Toward the Development of Practical Diets for Shrimp and Their Nutritional Requirements

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A B S T R A C T

Shrimp is a very important source of protein which is patronized by almost half of the world's population, and hence a very important specie in aquaculture. There is the need for increase in shrimp production worldwide to meet consumer demands has become a necessity. However, shrimp production is hampered by high cost of commercial feeds. Increase in prices of fish oil and fish meal has led to calls for their substitute. This calls for substitute has resulted in researchers studying the nutritional requirement of shrimp. The rationale for this article is to review the literature available on recent studies toward the development of practical diets for shrimps focusing on the nutrients required by different species qualitatively as well as quantitatively. This review highlights on nutrient requirements with respect to growth and feed utilization. Digestibility of nutrients used in shrimp diets is also accounted for in this article.

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1. Introduction

Aquaculture is one of the fastest growing food sectors in the world (Rahman *et al.* 2015) and one of the prime food producing segments subsequently to agriculture. Shrimp farming is an aquaculture business for the cultivation of marine shrimps or prawns for human consumption, and is now considered as a major economic and food production sector as it is an increasingly important source of protein available for human consumption (Lakshmi *et al.* 2013). Shrimp aquaculture has been growing rapidly with the growth of aquaculture for decades (Kim *et al.* 2015). Among the various branches of aquaculture, shrimp culture has expanded rapidly across the world because of faster growth rate of shrimps, short culture period, high export value, and demand in the market (Rahman *et al.* 2015).

Despite the significance of shrimp aquaculture to the global aquaculture production, it faces a lot of challenges including high cost of feed. Shrimp nutrition is extremely important to make a shrimp farm profitable because the cost of the diet exceeds 50% of the variable production cost of a commercial enterprise (Jatobá *et al.* 2014).

The purpose of this study is therefore to present an update of the nutrient requirements of shrimp.

2. Nutrient Requirements

Because of the large number of species of shrimp being cultured, there seems to be a little or limited information with respect to the nutritional requirement of shrimp although researchers over the past decades have studied extensively on the qualitative as well as quantitative nutrients required by shrimps. In addition to this, is the different requirement by different age groups of shrimps. This section takes a look at the various nutrient requirements of different shrimp species.

2.1. Protein

Protein is the most expensive nutrient in practical diets for shrimp culture of which fish meal (FM) is the most commonly used protein source in the commercial feeds (Oujifard *et al.* 2012). In 2008, shrimp consumed 27.2% of FM used in aquafeeds, making it the largest consumers of FM (Tacon *et al.* 2011). Proteins are large, complex molecules made up of various amino acids that are

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essential components in the structure and functioning of all living organisms (Sales and Janssens 2005).

Some studies have been conducted to evaluate the effects of different protein levels and sources on shrimp (Bulbul *et al.* 2014; Oujifard *et al.* 2012). For instance, Gauquelin *et al.* in 2007 fed *Litopenaeus stylirostris* (21 g initial weight) six experimental diets with protein ranging from 25% to 58% crude protein (CP) for 50 days. The study revealed that as protein levels increased, weight gain (WG) increased (from 21 to 30 g) and survival rate was averaged as 80%. On the average 1 kJ shrimp^{-1} day^{-1} or 47 kJ kg live weight^{-1} day (22 kJ/kg Q4 0.8 day^{-1}), was recorded. In addition, as dietary protein content increased, there was an increase in ammonia production with an O:N ratio indicating that protein was increasingly used as an energy substrate as CP increased.

In an 8-week feeding trial of juvenile white leg shrimp, *Litopenaeus vannamei* (Boone 1931), Shahkar *et al.* (2014) recorded that the optimal dietary protein level could be 33.4% based on the broken-line analysis of WG for maximum growth performance. Shrimp (1.3 g initial weight) was fed with varying levels of CP at 25%, 30%, 35%, 40%, and 45% in triplicate groups. Growth performance was enhanced linearly and quadratically with an average waste excretion. They therefore recommended that the dietary protein requirement could range between 25% and 33.4%.

Xu and Pan (2014) conducted a study to assess the effects of dietary protein levels on growth, immune, and antioxidant system of shrimp (*L. vannamei*). Four diets with varying protein levels (20%, 25%, 30%, and 35%) were used for the 7-week feeding trial. There was no significant difference in the total hemocyte count in the hemolymph, phagocytic activity of the hemocyte, and antibacterial activity and bacteriolytic activity in the plasma of shrimp. This study documented that the lowest total antioxidant capacity in both the plasma and the hepatopancreas, as well as the lowest reduced glutathione/oxidized glutathione (GSH/GSSG) ratio in the plasma was recorded in shrimp fed with 20% dietary protein. Furthermore, except for the suboptimal growth performance of shrimp in the treatment with 20% dietary protein level, reducing dietary protein level from 35% to 25% would not compromise growth, feed conversion ratio, and physiological status of immune response and antioxidant capability.

In addition, Jatobá *et al.* (2014) evaluated the performance and dietary cost for the marine shrimp, (*L. vannamei*) using diets with different protein levels. The diets were formulated to contain four varying CP contents of 24.3%, 30.3%, 32.9%, and 36.7%. After 49 days, the highest final WG was recorded in shrimp fed diet with 32.9% CP. This same group recorded the lowest dietary cost.

It is evident that feeding shrimp with diets containing 25%–33% CP will not retard growth performance and feed utilization. However, owing to the numerous species factors such as the age and size of species under consideration, water temperature and salinity as well as culture duration must be taken into consideration.

3. Alternative Sources of Protein Q5

3.1. Alternate protein sources

High digestibility, excellent amino acid and fatty acid profile of FM, makes it an important protein source in shrimp feed and aquaculture feed at large. However, the limited availability and rising costs of dietary FM have resulted in the increasing use of plant proteins and other animal proteins in shrimp and fish feeds (Katya *et al.* 2016; Tacon and Metian 2008). Ideally, these alternative ingredients should have good availability and satisfactory nutritional quality for the species to feed, and also to be economically practical (Goytortúa-Bores *et al.* 2006). Many plant, animal byproducts, and microbial protein sources have already been assessed as possible replacements for FM in feed of shrimp.

3.1.1. Plant protein sources

Because of their low price, availability, and consistence in nutrient composition, plant proteins are normally considered as suitable alternative to FM in shrimp feeds. Over the past decades, aquaculture nutritionists have examined the efficacy of using different plant protein sources in shrimp feeds in place of fish oil. Some of the plant proteins used in shrimp feed are shown in Table 1

Macias-Sancho *et al.* in 2014 assessed the extent to which FM could be partially or fully replaced by *Arthrospira* (*Spirulina platensis*) in diets for *L. vannamei*. In their study, five isonitrogenous diets (~35% protein) were formulated to assess the extent to which FM could be replaced with *S. platensis*. FM was replaced by *S. platensis* at 0%, 25%, 50%, 75%, and 100% and fed to white shrimp (*L. vannamei*) for 50 days with the aim of evaluating the effects on the growth and immunological parameters. The results at the end of the 50 days trial indicated that fish fed diets with 100% *Arthrospira platensis* performed poorer than all other replacement levels. There was a significant difference among the groups with respect to

Table 1. Plant protein sources used in shrimp feed

Plant protein sources	Shrimp species	Observation	Reference
SBMs	Kuruma shrimp, *Marsupenaeus japonicus*	After 56 days feeding trial, *M. japonicus* (1.75 g mean initial body weight), replacing fish oil with soybean meal enhances growth	Bulbul *et al.* 2015 Q15
	Juvenile white shrimp, *Litopenaeus vannamei*	After an 8-week feeding trial, it was evident that 20% fish meal could be replaced with extruded soybean meal without compromising growth	Yang *et al.* 2015
	Indian prawn shrimp, *Fenneropenaeus indicus*	After 90 days trial, it is evident that 50% fish meal could be replaced with fermented soybean meal to enhance growth and production, and maximize cost	Sharawya *et al.* 2016 Q16
	Speckled shrimp, *Metapenaeus monoceros*	Replacing fish meal with soybean meal up to 40% has no negative effects on growth of shrimp	Rahman *et al.* 2010
CM	Kuruma shrimp, *Marsupenaeus japonicus*	After feeding *M. japonicus* (0.19 g) for 60 days, the report showed that fish meal can be replaced with 20% Canola meal without compromising growth	Bulbul *et al.* 2014
Peanut meal	Pacific white shrimp, *Litopenaeus vannamei*	42 days feeding trial, fish meal can be substituted with 140 g/kg pea nut meal diets for *L. vannamei*	Liu *et al.* 2011
Rice meal	*Litopenaeus vannamei*	50 days; five isonitrogenous diets (~35% protein), 75% of fishmeal could be replaced by *A. platensis*	Macias-Sancho *et al.* 2014
	Pacific white shrimp, *Litopenaeus vannamei* (Boone)	60 days feeding trial, rice protein can replace fish meal up to 50% in diets for *L. vannamei* without compromising growth	Oujifard *et al.* 2013
Sunflower oil cake	Tiger shrimp, *Penaeus monodon*	Sunflower cake can be incorporated into diet of *P. monodon* up to 5% by replacing 20% of fishmeal without affecting growth	Dayal *et al.* 2011

CM = canola meal; SBM = soybean meal.

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