DOI: 10.54083/ResBio/5.1.2023/11-15

Res. Bio., 2023, 5(1):11-15

Research Biotica

e-ISSN: 2582-6743
March, 2023

Article ID: RB152

Review Article

Emerging Importance of Sustainable Feed Ingredients as a Substitution of Traditional Fish Meal in Fish Feed Production: An Essential Step for Sustainable Aquaculture

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Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Debbarma *et al*., 2023. Emerging Importance of Sustainable Feed Ingredients as a Substitution of Traditional Fish Meal in Fish Feed Production: An Essential Step for Sustainable Aquaculture. *Research Biotica* 5(1): 11-15.

Abstract

Recently, in the agricultural allied industry, aquaculture has had the fastest growth. For this, the aquafeeds played a major role in fish culture. Fishmeal is a crucial ingredient in the manufacture of commercial fish diets, yet, securing a consistent supply of conventional fishmeal might be challenging. Feed ingredients have an impact on both fish as well on the environment, as it is required to evaluate different feed materials, whether it is an alternative for traditional fish meal or not but it should be effective on growth as well as having less impact on the environment. A good source of proteins for aquafeeds as an alternative to traditional fishmeal can be replaced by plant-based (Soybean meal, vegetable oil, *etc.*), animal-based (Earthworm meal, blood meal, *etc.*), insect-based (Black soldier fly meal, maggot meal, *etc.*) and low-value trash fishes (Families includes Carangidae, Engraulidae, Leiognathidae *etc.*) as sustainable candidates which are higher in protein content, bioactive compounds, better digestibility with fiber, low heavy metals, low feed conversion ratio and cost-effective for fish feed production. This review paper will look at the potential use of sustainable fish feed ingredients for the production of aquaculture feed.

Keywords: Animal based meal, Insect based meal, Low value fishes, Plant-based meal, Traditional fishmeal

Introduction

Now, the main subject is the difficulty of providing farmed fish with diets that are both nutrient-dense and financially and ecologically efficient (Glencross *et al*., 2020). According to Naylor *et al*. (2021), in recent decagon, scientists have concentrated their efforts on identifying the critical nutritional needs of significant cultured fish, notably trout, salmon, carp, sea bass, *etc*. The researcher's labors put the base for the replacement of fish based meal and fish based oil with other sustainable feed ingredients based on plant or animal sources (Hardy and Barrows, 2003). Scientists are trying to formulate a diet with a lower dependency on fish meal that can improve the growth of fish and feed performance as well (Olsen and Hasan, 2012). On the other hand, in highly carnivorous cultured fishes, it is currently impracticable to effectively replace fish by products in the diets that have been designed. The use of plant- or animal-based nutrients or debris of fishes can be good substitute sustainable feed materials for aqua to lessen dependency on conventional feedstuffs and oil from fish in diets (Hua *et al.*, 2019).

The fish diets alternative must be of higher quality as well as higher nutritional value with essential omega-3 fatty acids, higher protein content, sufficient essential amino acids, digestibility, and acceptability which can be met by the animal, insect, and plant-based meals and oils such as poultry based by-product meal, meat, and bone based meal, blood based meal, housefly maggot meal, krill meal, silkworm pupae meal, earthworm meal, linseed meal, soybean based meal, rapeseed based meal, microbial based oil, sunflower based meal, and low-value fish based meal can partially swap traditional fish based meal devoid of any undesirable effect on growth of fish, amino acid composition and retention. Furthermore, plant-based diets furnish rainbow trout with overall appropriate mineral composition. (Antony *et al.*, 2018).

Article History

RECEIVED on 20th October 2022 RECEIVED in revised form 04th February 2023 ACCEPTED in final form 11th February 2023

Therefore, this review tends to focus on the research on the importance of plant, animal, insect, and low-value fish-based meals as a substitution for traditional fish meal in feed formulation for sustainable aquaculture.

Animal-based Meal

Poultry by Product Meal (PBM)

According to a study by Bureau *et al*. (1999), rainbow trout's efficiency to digest poultry based by-product meal has drastically enhanced. When fishmeal is replaced with poultry based by-products on the basis of accessible amino acids, about half the protein in commercial Hybrid striped bass diets can be provided adequately (Rawles *et al*., 2006). In their study, Shapawi *et al*. (2007) found that humpback grouper diets can successfully swap good quality terrestrial PBM for far more than half of the protein contained in marine fish based meal. Yet, decreased food digestion and a dearth of critical amino acids may make it difficult to completely replace fish meals with PBM.

Meat and Bone Meal

Ai *et al*. (2006) found that MBM protein could displace almost 45% overall of FM protein in the diets of giant yellow croakers without hampering notably slowing growth. Moreover, Bureau *et al*. (2000) came to the conclusion that using meat and bone based meal in rainbow trout diets has promising prospect. According to Lee *et al*. (2012), fish fed with the diet of total 60% fish meal experience higher weight gain as well as enhancing growth rate than fish fed with total 10% meat and bone based meal alternative. Their study concluded that dietary substitution of fish meal with MBM can be made upto 20%.

Blood Meal

According to Agbebi *et al*. (2009) revealed that *Clarias gariepinus* fingerlings provided with a diet containing 25% overall blood based meal were the most productive in terms of ultimate growth aspects, survival, and overall fish productivity. Their findings demonstrate that blood based meal can entirely substitute fish meal without having a negative impact on fish growth, survival, or effective conversion of feed in *C. gariepinus* fingerlings.

Rainbow trout diets can be made with more than 20% overall with blood based meal powder substituted for herring meal without experiencing a extensive reduction in growth, according to Luzier *et al*. (1995). Also, there was no evidence that the diets' palatability was impacted by the blood based meal powder. The amount of phosphorus in the feed and effluent water was reduced by 38% overall and 47%, respectively, when dietary fish meal was substituted with more than 20% with blood based meal powder.

Krill Meal

Regardless of dietary intake, krill meal-based diets resulted in greater final weights, enhancing and providing adequate amount of protein and lipid for growth aspects, as well as conversion of feed in higher fish production (Torrecillas *et al.,* 2021). Furthermore, according to their research, krill meal enhance on growth of fish as well in the proper function of liver of European sea bass fingerlings which fed with diets incorporated with fish feedstuff meals and oil. According to Hansen *et al.* (2010), study proves that traditional fish based meal could be successfully replaced with partially deshelled krill meal as an alternative source of protein for Atlantic salmon.

Earthworm Meal

In a study by Nandeesha *et al.* (1988), it was discovered that fish grew better when their diet included 5% sardine oil and earthworm meal, which was partially substituted for fishmeal in their experiment. According to findings by Mohanta *et al.* (2016), rohu advanced fry could be raised on a pelleted earthworm diet.

Insect-based Meal

Black Soldier Fry Meal (BSFM)

According to Fisher *et al*. (2020), insects can be utilized in the fish feed production is one of the most sustainable and economically friendly options. In his study, confirms that BSF meal is a more nutrient-dense source of protein than other sources in standard fish meal diets for young freshwater Atlantic salmon fingerlings. Insect meal produced from BSF, according to Belghit *et al*. (2019), is a nutritionally suitable another source of protein for Atlantic salmon. Cummins Jr. *et al*. (2017) also deduced from their investigations that increasing inclusion levels in diets for Pacific white shrimp may be feasible with prudent alterations to diet formulations that incorporate BSF meal. Furthermore, according to Kroeckel *et al*. (2012), it offers a source of high-quality protein in general, with the amino acid content being especially valuable. Utilizing localized greenhouse wastes, BSF meal may be continuously produced year-round and may be a reasonable replacement for fish meal as a source of protein.

Housefly Maggot Meal (HMM)

In their study, Ogunji *et al.* (2008) found that maggot meal may entirely replace fishmeal in the formulation of diet for Tilapia (*Oreochromis niloticus*) juveniles and can satisfy this species' physiological needs. Maggot meal is capable as a alternative fully in place of traditional fish meal in the feed production of Nile tilapia (Ajani *et al.,* 2004). According to research findings by Ogunji *et al.* (2008), feeding *O. niloticus* fingerling diets containing maggot meal did not cause any sort of physiological arousal and can be used as a viable protein source replacement in the diets of tilapia fingerlings.

Silkworm Pupae Meal (SWP Meal)

The meal made from silkworm pupae is a highly rich source of proteins, lipids, and minerals, therefore it could potentially be utilised as an alternative dietary supplement in fish feed, (Karthick Raja *et al.,* 2019). Due to their distinct composition and lower cost, SWP meal may be one of the greatest alternatives to fish meal for lowering production costs without significantly affecting the growth performance of farmed fish species.

Low-Value Trash Fishes

India is a country where marine fishery consists of several species; especially during trawler operations numerous species of by-catch fish were captured. Mostly catch fishes were sometimes regarded as trash fish, because of poor demand in market contrasted to the expensive catch of shrimp as well as table size important species fish (Chandrapal, 2005). The low-value fishes in international, as well as national markets, can be main species in capture aquaculture due to their soaring value in nutrition for the fishes like turbot, lizard, puffer, threadfin breams, flatheads, *etc*. are the key contributors are suitable candidate for novel feed formulations (Dineshbabu *et al.,* 2012). According to Mahesh *et al.* (2014), multispecies of low-value trash fishes belonging to several numbers of genera, families, and orders were reported in numerous low value trash fishes in different landings centre in catching period, which includes fishes from Perciformes (74 species), Clupeiformes (13 species), Pleuronectiformes, Siluriformes, Tetraodontiformes (4 species each), Anguilliformes and Lophiiformes (3 species each). The family includes Carangidae (14 species), Engraulidae and Leiognathidae (8 species each), Synodontidae (6 species), Sciaenidae (5 species), Nemipteridae, Scombridae (4 species) *etc*. contributed to the trash fishes during bycatch. Fishmeal produced from fish trashes has a higher content of bones which containing higher amount of calcium and phosphorus contrasted to regular conventional fishmeal (Olsen and Hasan, 2012).

Plant-based Meal

Duckweed Meal

Duckweed diets containing higher levels of protein and fine amount lipid content. It has also can replace 10% of traditional fish meal protein by duckweed (*Lemna minor*) in the feed diet of silver barb (*Borbodes gonionotus*) gives better growth than the regular diet made from traditional fish meal (Noor *et al.*, 2000). Irabor *et al.* (2022) as well remarked that 40% duckweed based meal incorporation in a fish diet showed significantly enhances fish fingerling growth in *C. gariepinus* compared to the traditional meal-based control diet.

Soybean Meal

According to a study by Kaushik *et al.* (1995), switching from fish meal to soy protein concentrate (partially 33-100% replacement) had no impact on growth or nutritional uptake. Also, fish provided meals based on soybean protein significantly lower blood plasma cholesterol levels than fish fed diets that were traditionally based on fish meal. An investigation by Zhou *et al.* (2005) found that fingerling cobia showed that up to 40% of the protein in fishmeal may be substituted with defatted soybean meal without negatively affecting growth. When soybean meal was substituted for 20% of the fishmeal protein, the feed conversion ratio (FCR) was seen to be the lowest and the protein efficiency ratio (PER) to be the highest.

Rapeseed Meal (RM)

Dossou *et al*. (2018) discovered in their study that, rapeseed based meals can successfully substitute protein more than 50% of traditional fish meal protein without adverse effects on fish growth, diet nutrient utilization, as well as non-specific immune reaction to osmotic damage of red sea bream fingerlings. Bu *et al*. (2018) also from their study proves that overall 17% of traditional fish meal could be substitute by rapeseed based meal for the diet of *P. ussuriensis.*

Linseed Meal

El-Saidy and Gaber (2001) suggest the alternative of traditional fish meal protein maximum 75% with linseed based meal protein in the feed diets of Nile tilapia fingerlings. Their study also discovered that comparatively than regular feed with incorporated overall 75% of linseed based meal protein gives the higher protein contents in fishes.

Sunflower Meal

A positive protein substitution was observed in fish meal substituted with 25% sunflower based meal in the feed of *Oreochromis niloticus*. Lozano *et al*. (2007) found from their research that, the sunflower based meal can replace up to 14-15% of traditional fish meal from a cost-effective point of sight with no effect on growth of fish. Mérida *et al*. (2010) also demonstrated that sunflower based meals can provide up to 30% replacement of protein in fish feed diets of sea bream fingerlings with no lacking on fish growth, liver, gut, as well as amino acid profile of fish muscle after fed.

Production Costs

The studies shows that the trash fish-based diet formulation has a lower cost than commercial diet production, whereas the plant based formulation is little bit more expensive. With better growth as well immunological performance indicate that alternative feed formulations both plant based and trash fish-based diet formulation can be a suitable candidate for replacement of traditional fish meal in commercial aquaculture. A slight variation in the food conversion ratio can optimize the costs of feed and make more cost-effective formulations more acceptable because feed expenses are the principal budget aspect in the production system.

Present Challenges and Future Perspective

A high-quality feed has an important factor *i.e.*, feed efficiency in fisheries feed fed management that can decrease the amount of feed used for better fish growth with fewer feed consumed. Fast increasing in population resulted in rising food demand and as a result more demands on fisheries sector for increasing the production with limited resources. The growing fisheries sector with higher production has resulted in environmental pollution due to excess used of fish feeds, discarding unwanted species, overfishing *etc*. Among them, fisheries waste is a major problem worldwide, especially in Asian countries. A high quality feed which should not affect the environment but also be economically sustainable for cost-effective fish feed production was the future challenge.

Conclusion

Providing of nutritionally rich feed is one of the most essential steps in any aquaculture system. Even though fish meal and fish oil acts as an excellent protein source and lipid source respectively, their high economic value and unsustainable way of production has raised concern regarding environmental deterioration. Therefore, finding sustainable feed ingredients with efficient management can ensure food and energy security in addition to environmental pollution improvement as an example the proper utilization of low value fishes, animal, plant and insect based meals can enhance growth without adverse effects on the environment.

Acknowledgement

The authors are thankful to the Vice Chancellor, Central Agricultural University, Imphal, Manipur and Dean, College of Fisheries, CAU, Lembucherra, Tripura for providing support.

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