Fish Nutrition: Plant Source as an Alternative

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Abstract: **The aquaculture sector is potentially the world's most important fish food provider for human consumption. Fish nutrition plays a major role in aquaculture as it influences the growth of stock for production. Fishmeal, which is the most conventional protein source, is a very expensive protein source in fish feed production. The increasing cost of fishmeal is due to the decrease in marine supplies and increase in demand from various other sectors of feed industry. Therefore aquaculture is looking for alternative suitable protein sources, which could replace this limited resource. This has resulted on the ongoing search for suitable alternatives that are befitting without compromise. Plant protein has been the only easy alternative that is readily available and is also lower in cost when compared to fish meal. This review focuses on five major plant protein source namely soybean, rapeseed, sesame seed, cotton seed and sunflower which have been suggested by several researchers and have the needed potentials in terms of protein content and can be used to supplement if not replace the role of fish meal in fish nutrition so as to reduce the cost of feed and also boost the income of farmers.**

Keywords: **Aquaculture, Fish nutrition, Fish feed, Fish meal, Plant protein.**

I. INTRODUCTION

World capture fisheries have reached a plateau at approximately 94 million tonnes (FAO, 2007). According to (khan *et al*., 2013), the most recent estimates suggest that 52% of marine stocks are fully exploited. With around three quarters of the world's capture fisheries fully or overexploited, aquaculture is seen as the main source for future growth of fish production. Global aquaculture has made a considerable contribution towards bridging the gap between supply and demand (Huntington and Hasan, 2009; FAO, 2009; Ajani *et al*., 2011). Aquaculture is a form of agriculture that involves the propagation, cultivation, and marketing of aquatic animals and plants in a controlled environment (FAO, 1988). It also define aquaculture as farming of aquatic organisms including fish, mollusks, crustaceans, and aquatic plants where farming implies some form of intervention in the rearing process and individual or corporate ownership of the stock being cultivated (FAO, 2014). Although various types of technologies have been examined to improve fish growth and performance, productivity largely depends on interactions among nutrition and feeding environment (Small *et al*., 2016). Over the years, aquaculture feeds have undergone major changes that have greatly increased performance of farmed fish and contributed to increased aquaculture production worldwide. Although aquaculture has ancient origins, development of intensive aquaculture production where fish are fed nutritionally complete feeds was hampered by lack of knowledge of specific dietary requirements of fish. Feeds were formulated empirically rather than by rational formulation. This situation changed when a nutritionally complete, semi-purified diet for fish was developed (Halver, 1957). Good nutrition in animal production systems is essential to economically produce a healthy, high quality product. In fish farming, nutrition is critical because feed represents 40-50% of the production costs (Craig and Helfrich 2002; Jamu and Ayinla 2003). According to (Fagbenro *et al*., 2005), feeding cost is the highest single cost item of most fish farm operations, accounting for about 60% of the total cost of fish production. Fish nutrition has advanced dramatically in recent years with the development of new, balanced commercial diets that promote optimal fish growth and health. The development of new species-specific diet formulations supports the aquaculture (fish farming) industry as it expands to satisfy increasing demand for affordable, safe, and high-quality fish and seafood products (Steven and Louis, 2009). Rapid growth in fish, as in man, is ensured by a balanced diet. In aquaculture, this hinges on proper feed and feeding techniques. According to (Shahzadi *et al*., 2006; FAO 2008), sustainability of aquaculture depends on supplementary feed source and management. According to (Eroldogan *et al*., 2006; Priestley *et al*., 2006), insufficient feeding lead to poor growth and high fish mortalities which make losses in the aquaculture business. The farmer's dilemma therefore is whether to supplement the natural food or to completely control the diet of the fish. Be it a supplemental feed or a complete diet, the feed preferences, feeding habits and nutrient requirements of the cultured fish, the feed development techniques based on basic nutrition concepts have to be known before a feeding scheme can be successful.

II. COMPOSITION OF FISH FEED

Fish feeds like other animal feeds can be partitioned into six major compounds, (1) moisture, (2) protein, (3) fat, (4) ash, (5) crude fibre and the (6) nitrogen free extract (NFE). Fish feeds are mostly characterized by their protein and fat levels. The protein in the feed is primarily needed for the build-up of (muscle) tissues and the fat is a major source of energy and

for accretion of fat tissue (Ali *et al*., 2005; Udo and William, 2018). The amount of carbohydrates in fish feeds are usually low, since fish and particularly carnivorous fish, have a low capacity to digest carbohydrates. As a consequence, the energy in the diet has to be derived from fat and fat has a higher energy density than carbohydrates. For that reason, fish feeds are more concentrated and have thus also a higher protein level (up to about 40 – 45%) and energy density than feeds for terrestrial farm animals. The digestible protein /digestible energy ratio is an important characteristic of a fish feed, and as a rule of thumb, this ratio in the fish feed should be more or less similar to the ratio of protein / energy of the growing fish itself. This way, a maximal retention of dietary protein, an expensive ingredient of (fish) feed, is achieved (NRC, 1993; Kaushlik, 1995; Halver and Hardy, 2002; Tacon *et al*., 2008; Udo and Umoren, 2011).

Protein Sources for Fish Feed

According to (Sayed *et al*., 2020), Proteins may come from animal or plant sources. Feedstuffs of animal origin have high protein content ranging from 34 to 82%. Proteins from animal sources contribute a mixture of amino acids different from that of proteins from plant sources. Some examples of animal protein sources are: (1) fish meal - most common protein source; (2) shrimp meal; (3) squid meal; (4) poultry by-products; (5) meat and bone meal. Fish meal is an excellent protein source in fish feed due to it's balanced amino acid profile and high digestibility. Traditionally, fish meal is the main dietary protein source in fish feed formulation, especially for carnivorous fish species such as salmon and eel. In general, fish feed contains 5 to 50% of fish meal (Dersjant, 2002; Huntington and Hasan, 2009). The rapid development of aquaculture results in the high demand and the shortage of supply for fish meal. Besides being limited in supply, fish meal is relatively an expensive ingredient used in fish feed production. The high cost and competing demand for fish meal in fish diet has made the search for alternative ingredient very expedient. Finding an alternative protein source has become a major focus of research from the view point of producing a stable supply of commercial fish feed at a reduced price (Zamal *et al*., 2009; Ajani *et al*., 2016). Farmers and feed stuff producers value fish meal mainly because of it high protein content and health enhancing nutrient. These characteristics are however not only found in fish meal, but to different degree also in vegetable/plant based products. Plant ingredient which contain high protein content such as oil seeds, are alternative protein sources for fish meal. These ingredients are readily available worldwide with a low cost. However, plant proteins in general are low in some essential amino acid and containing anti-nutritional factors. Therefore the levels of raw or under processed plant materials containing high protein content and it high digestibility of crude protein and low anti-nutritional component are potential alternative protein sources for replace of fish meal in fish diet (Davies *et al*., 1990; Belal, 1999; Nyirenda *et al*., 2000; Dersjant, 2002; Zamal *et al*., 2008; Koumi *et al*., 2009). The common plant protein sources are legumes and oil-bearing seeds. Legumes are potentially valuable as aquaculture feed source in the tropics because of their abundance. Their leaves are also rich in protein and minerals. Oil-bearing seeds and oil cakes which are by-products of the vegetable and oil industry are also plant protein sources. They are high in protein and low in carbohydrate. Terms used with these types of feedstuffs are cake or oilcake and meal or oil meal (Refstie and Storebakken 2001; Tacon *et al*., 2008; khan *et al*., 2013). Some examples of plant sources are: (1) Soybean meal (2) Rapeseed meal (3) Sunflower meal (4) Cottonseed meal (5) Sesame meal.

III. EXAMPLES OF SOME PLANT BASED PROTEIN SOURCE ARE DISCUSSED BELOW

Soybean meal as a protein source for fish feed

Soybean (*Glycine max* (L.) Merr) is one of the important oilseed crop and grown all over the world. It contained maximum amount of protein and other important essentials vitamins that play important role in our daily life (Hartman *et. al.*, 2011). Soybean is a legume that grows in tropical, subtropical, and temperate climates. Soybean grains contain about 40% protein, 20% oil, an optimal supply of essential amino acids and nutrients, and a high calorie value [Singh *et. al.*, 2008]. It is one of the important sources of oil and protein in the world and it is commonly used in both human and animal diets. The soybean seeds contain high quantity of protein and its amino acid composition is approximate to composition of animal proteins, therefore is often used as replacement component of animal protein (Onwueme and Sinha, 1991; Ariyo 1995; Thompson *et al*., 2006; Biswas *et al*., 2007; Hernandez *et al*., 2007; Abdel-Tawwab *et al*., 2010). Studies have shown that soybean is considered to be one of the most suitable and economical candidate for replacing fish meal in commercial fish feeds production. It is been identified as having the best amino acid profile of all protein rich plant feed stuffs for meeting the essential amino acid requirements of fish(Chou *et al*., 2004; Lim *et al*., 2004; Hernandez *et al*., 2007; Pham *et al*., 2007; Lim and Lee, 2008). From (O'keefe, 2003; Jahan *et al*., 2007), Soybean meal is the by-product of the extraction of soybean oil. Soybean meal is usually classified for marketing by its crude protein content. High-protein types are obtained from dehulled seeds and contain 47-49% protein and 3% crude fibre (as fed basis). Other types of soybean meal include the hulls or part of the hulls and contain less than 47% protein and more than 6% crude fibre. In solvent-extracted soybean meals, the oil content is typically lower than 2% while it exceeds 3% in mechanically-extracted meals (Kim *et al*., 2008; Cromwell, 2012; Nenad *et al*., 2012). The table bellows shows the basic nutrient composition of soybean.

Table 1. Basic nutrients in soybean seeds

Nutrient	Soybean meal % of DM
Moisture	10.4
Crude protein	48.6

Crude ash	6.0
Crude fat	1.1
Crude fiber	3.8
N-free-extractive	30.1

Source: (Van Eys *et al.*, 2004; ENV/JM/MONO (2001)15; Ari *et al*., 2012; Etiosa *et al*., 2017)

Rapeseed meal as a protein source for fish feed

Canola and rapeseed are names used to describe the plants *Brassica napus.* The primary product of canola/rapeseed is its oil content, but canola meal is also a valuable protein resource for use in animal nutrition. Some research have been directed into the assessment of the nutritional value of rapeseed meal for a range of animals (Yigit and Olmez 2009; Enami, 2011). According to (Burel *et al*., 2000; Shafaeipour *et al*., 2008; Enami and Safafar 2010), Rapeseed meal, called canola meal in North America, Australia and some other countries, is the by-product of the extraction of oil from rapeseed. Rapeseed meal is often included in the diets of several species of livestock because of its high protein content (35-44% of DM). Rapeseed meal is the major plant protein source which is alternative source for fish meal replacement in fish diets. In comparison to fish meal, rapeseed meal is limiting in lysine and few other essential amino acids but have high level of methionine and cysteine. Rapeseed meal is used as a source of protein for many fish species (Cheng and Hardy, 2002; Burel and Kaushik, 2008). The main issue of rapeseed meal for fish feeding is its high fiber content, which limits its nutritional value for carnivorous fish species. However, as rapeseed meal is included at rates much lower than 50%, the fiber content is unlikely to exceed 8% of the diet and to impair growth performance. The combination of rapeseed meal and soybean meal is often a good solution to replace fish meal. The use of plant protein to replace fish meal in fish diets reduces the price of the diet (Glencross *et al*., 2005; Drew *et al*., 2007; Gatlin *et al*., 2007). Rapeseeds contain 40-45% oil and yield about 55-60% oil meal when fully extracted by crushing followed by solvent extraction. The main steps of this process are seed cleaning, seed pre-conditioning, rolling and flaking, seed cooking and pressing to mechanically remove a portion of the oil, solvent extraction (hexane) of the press-cake to remove the remainder of the oil, desolventizing and toasting. Temperature is one of the main factors affecting the quality of rapeseed meal. Solvent-extracted rapeseed meal should not contain more than 2-3% oil (Leming and lember, 2005; Newkirk, 2009; Jatta, 2014).The table bellows shows the basic nutrient composition of rapeseed.

Table 2. Basic nutrients in rapeseeds

Nutrients	Rapeseed meal% in DM
Moisture	9.2
Crude protein	39.0
Crude ash	7.2
Crude fat	1.2
Crude fiber	13.2
N-free-extractive	30.2

Source: (Abdul *et al*., 1999; Yigit and Olmez 2009; Rajeev and Athithan, 2015)

Sesame Seed Meal as A Protein Source in Fish Feed Production

Sesame, benne, beni, beniseed, benneseed, are the common names of the plant. Sesame (*Sesamum indicum* L.) is a tropical and subtropical plant cultivated for its seeds. Sesame seed is an important source of oil and composed of about 47.8-52.2% oil, 26.9-25.8% protein and 4.7-5.6% ash. In the sesame oil industry, sesame seed is used as the raw material for oil extraction, either using organic solvents or by mechanical pressing. The sesame seed meal is a by-product after oil extraction. The extraction of oil has led to increased protein content of defatted sesame seed meal (Onsaard *et al*., 2010; Dernekbaşı *et al*., 2017). According to (Hasan *et al*., 1997; Mukhodadhyay, 2001; Rama Roa *et al*., 2008; Jimoh and Aroyehun, 2011; Jahanbakhshi et al., 2012; Onsaard, 2012), This meal, can be used as a protein source ingredient in the food industry and in fish feed of species such as Clarias gariepinus, Cyprinus carpio, amongs others. Farming, harvesting and oil extraction of sesame seed is wide-spread throughout the world. These products have more appropriate nutritional quality as compared to other oil seeds proteins including soybean and other traditional cereal seeds. And their potential as a source of nutritional protein in animal foods is well known (Kaneko *et al*. 2002; Lee *et al*., 2005; Emadi *et al*., 2014). Sesame meal can be used as an alternative protein source in feeding diets of carnivorous fish at least in a half rate of fish meal protein (without amino acid supplementary) without any reduction in growth rate of rainbow trout fingerlings (Fagbenro *et al*., 2010; Nang Thu *et al*., 2010; Jimoh and Aroyehun, 2011). The table bellows shows the basic nutrient composition of sesame meal.

Table 3. Basic nutrients in sesame meal

Nutrients	Sesame meal% DM
Moisture	9.0
Crude protein	34.9
Crude ash	10.9
Crude fat	11.6
Crude fiber	16.5
N-free-extractive	17.1

Source: (Akande *et al*., 2010; Barbiker, 2012; Onsaard *et al*., 2913).

Cotton Seed Meal as A Protein Source in Fish Feed Production

Cotton (*Gossypium spp*) is a multipurpose crop cultivated for its highly valuable textile fibre and rich protein value of its seed. Cottonseed meal is the by-product of oil extraction from cotton seeds (Jiang *et al*., 2012). Cottonseed meal is a plant

protein source that is abundant in most parts of the world, relatively high in protein, and generally less expensive per unit of protein than soybean meal. It is highly palatable and readily digested by most aquatic animals, though generally not as digestible as soybean meal. It is used in aquaculture feeds (Mbahinzireki *et al*., 2001; El-Saidy and Gaber, 2003; Li and Robinson, 2006; Agbo *et al*., 2011). Several methods are used to extract cottonseed oil, resulting in different types of cottonseed meal. This situation is slightly different from that of other major oilseeds such as soybean and sunflower, where one process is usually dominant. As a result, there is a wide range of cottonseed meals differing in their protein, fibre and oil content (Heuze *et al*., 2019). Cottonseed meal is a potential source of protein for fish. As a highly palatable ingredient, it has often been assessed in order to replace fish meal and other various proteins in fish diets (Li and Robinson, 2006; Robinson and Li, 2008; Gaber *et al*., 2012). The table bellows shows the basic nutrient composition of Cotton seed meal.

Table 4. Basic nutrients in Cotton seed meal

Nutrients	Cotton seed meal %DM
Moisture	6.0
Crude protein	45.3
Crude ash	1.4
Crude fat	5.7
Crude fiber	11.9
N-free-extractive	29.7

Source: (Barros *et al*., 2002; Elangovan *et al*., 2003 Heuze *et al*., 2019).

Sunflower Meal as A Protein Source in Fish Feed Production

Sunflower (*Helianthus annuus L.*) is one of the most important oilseed crops in the world. Sunflower meal is a byproduct of sunflower oil production - it is the protein-rich residue that remains in the form of seeds after the oil has been extracted. The sunflower oil industry produces millions of tons of this material, and it has attracted some attention as a possible substitute for fishmeal in aquaculture feeds(Mohammad and Hossain, 2018). Comparison of the biochemical makeup of sunflower meal with fishmeal suggests some potential as a plant-based substitute for declining supplies of increasingly expensive and environmentally unsustainable fishmeal (Mehta, 2009; Brown *et al*., 2014). Total protein content and specific amino acid profiles of the two are comparable, although sunflower meal has relatively lower levels of lysine and threonine than fishmeal. Trials of the palatability, digestibility, and nutrient utilization of sunflower meal -based aquaculture diets have produced generally encouraging results (Maina *et al*., 2007 and Dayal *et al*., 2011). Sunflower meal contains a high level of crude protein - 27.8–37.4%, which varies with seed quality and processing. The potential of sunflower meal for replacement of animal and plant protein sources such as fishmeal and soybean meal is based in part on competitive nutritional value and relatively lower prices (Munguti *et al*., 2006 and Hossain *et al*., 2018).The table bellows shows the basic nutrient composition of Cotton seed meal.

Table 5. Basic nutrients in Sunflower meal

Nutrients	Sunflower meal %DM
Moisture	9.4
Crude protein	34.4
Crude ash	5.6
Crude fat	18.3
Crude fiber	13.2
N-free-extractive	19.1

Source: (Arroyo *et al*., 2005; Fagbeno *et al*., 2010 Hossain *et al*., 2018)

IV. CONCLUSION

Nutrition plays a critical role in intensive aquaculture as it influences not only the production cost but also fish growth, health and waste production (Gatlin, 2002). Cost effective diets are essential for successful fish farming. The profitability and success of compound feed production depends on the cost, availability and digestibility of the feed ingredients to be used. The conventional feed ingredients for fish are mainly from plant and animal products especially by-products of processing plants. These products are also used as human food (SRAC, 2010). Therefore there is a need to search for lesser known materials suitable for fish feed. Legumes are less expensive sources of protein that have been identified to be capable of reducing the cost of fish feed when combined as complementary ingredients to meet the nutritional requirement of fish. The protein component of the aquaculture diet is the single most expensive portion and important dietary nutrient. Fish meal remains the major dietary protein source ranging between 20-60% of the fish feed but escalating cost, uncertainty in availability and lesser quantity has necessitated the use of other animal and plant protein sources to reduce the feed cost without compromising growth. Therefore, efforts are now being directed in different parts of the world to find alternate protein sources of good quality, which ideally are less expensive and readily available as substitutes for the expensive fish meal component in the practical diets. In this respect due to low cost and market availability soybean, rapeseed, sesame, cotton seed and sunflower among others, has been identified universally as most attractive vegetable protein source for animal feeds. From the above enumerations we can see that the plants examined have great potentials and could be a good protein source in fish feed production (Muhammad *et al*., 2003). More so, they are readily available and also at a very cheap rate when compared to protein source from animal. Farmers and fish feed producers should be enlightened on these protein source alternatives so as to boost fish feed production as well as increase aquaculture intensity to meet with the current demand. This way, farmers can also in turn realize more profit and more sustainability of the venture.

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