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ALTERNATIVE PLANT PROTEINS UTILIZATION FOR SUSTAINABLE FISH FARMING: A REVIEW

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Abstract
The spontenous growth of aquaculture in Nigeria, a major contributor to food security and economic growth currently faces challenges due to over-reliance on fishmeal. Fishmeal is a critical protein source in aquaculture feeds valued for its high-quality amino acid profile and digestibility in fish species. However, its limited supply due to dwindling wild fish stocks and competing demands poses sustainability challenges. Plant based protein sources are valuable alternatives to fishmeal, which has become scarce and expensive in recent times. These plant based protein sources have succeeded in revolutionizing the aqua feed industry. Based on this review, it is crystal clear that the utilization of plant protein of different origins such as seed cakes, leafmeals, leguminous seedmeals and root tuber meals in fish feed formulations have however been limited by the presence of anti-nutritional factors inspite of their nutritional values, high protein quality and (amino acid composition) and low cost attributes. It has been established that these anti-nutritional factors in feeds negate growth and other physiological activities in cultured animals, fish inclusive. However, plant protein sources are better utilized through adoption of processing techniques suitable for the plant components being utilized in fish feed formulation as reflected in the review conducted. This review explores the potentials of utilization of alternative plant proteins to enhance sustainable fish farming in Nigeria towards supporting the countries target of increasing fish production in order to meet the rising demands while preserving the fresh water and marine ecosystem.

Keywords: Farming. Fish, Plant, Protein, Sustainable.

Introduction

Aquaculture has sustained global growth presently and is expected to fill the gap in aquatic food products (Okechi, 2004). The development and improvement of fisheries resources and revitalization of the ecosystems is dependent on agricultural activities as the only considerable alternative (Okechi, 2004). Aquaculture also helps to boost rural income through aquaculture entrepreneurships and it can also close income gaps within the nation (Hamid, 2014). According to the National Agricultural Policy Report 2016-2020 the demand and supply gaps in Nigeria's fish sector is widening with a demand of 2.7 million tons supply of 0.8million tons and a deficit / supply gap of 1.9million tons due to fall off in ocean catch and weakness in aquaculture yields, which has been attributed to high cost of fish feed. Both factors have become a major constraint on the growth of the fish industry.

According to Dasuki (2014) as aquaculture becomes more intensive for most farmers in Africa, Nigeria inclusive, Nigeria depends largely on imported feeds. In Nigeria an estimated 4000 tons of quality fish feed are imported yearly thereby contributing greatly to the high cost of fish production translating to the commodity being expensive for the growing population of low income people living in Sub-Saharan Africa (Eneanya, 2021).

Fish feed accounts for at least 60% of the total cost of fish production thus to a large extent determines the viability of the profitability of the fish farming enterprise (Fowler, 2006) in : Dasuki (2014). The growth and nutritional status of fish depends on the quality and quantity of dietary protein in its meal. Fish are unable to synthesize indispensible or essential amino acids (EAAs) as such it remains inadequate but required for growth and tissue development (Wilson *et al.,* 1989). Fishmeal compared

with other commercially used protein sources has high biological value (complete essential (EAA) amino acid profile). It is highly palatable, contains high digestible energy, rich in *lysine* and *methionine*, rich in mineral and vitamins and perhaps unidentified growth factors required to meet the nutritional requirements of most fish species (Lovell, 1981; Helfrich and Craig, 2002; Eyo, 2003).

However, this best conventional protein source (fishmeal) in fish diets has become expensive and scarce. It has been reported that annual global fishmeal output, which has been on the decline for the past 15 years is not expected to increase (Hamid, 2014). The limited supply of fishmeal from all available resources is unable to meet the increasing demand of fish feed industry and growers (Radhakrishnan *et al.*, 2016). Therefore, fish scientists have intensified efforts towards discovering alternatives to fishmeal with the aim of reducing the high cost of fish feed manufacturing. Plant protein from plant sources seems to be the most appropriate alternative to fishmeal (FM) for preparation of fish feed in view of their low cost, ready availability and good nutritional quality/complete amino acid profile (Mahboob, 2014).

Therefore, plant protein utilization in fish feeds has expanded considerably in recent years to meet the demands for feeds and sustain the development of global aquaculture production (Tacon and Merian, 2015). Numerous feeding trials have tested the inclusion of novel unconventional or under-utilized plant species.

Extent of Plant Protein Utilization

The extent of plant protein utilization depends on availability; acceptability by fish, ease of processing, and nutritive value. However, high inclusion levels of plant proteins in fish diets have in some cases resulted in reduced growth and poor feed efficiency, probably the result of improper

balance of essential nutrients, such as low protein contents, amino acids and minerals, presence of toxic substances or anti-nutritional factors or decreased palatability and pellet water stability value (Gohl, 1981; Devendra, 1985; Lim and Dominy, 1989; Oresegun and Alegbeleye 2001; Ibiyo and Oluwasegun, 2004). Generally, protein of plant origin are limiting in sulfur containing amino acids cystine and methionine.

The use of plant derived materials such as legume seeds, different types of oil seed cake, leaf meals, leaf protein concentrates, wild plants and root tuber meals as fish feed ingredients is limited by the presence of a wide variety of anti-nutritional substances, important among which are: protease inhibitors, phytates, glucosinolates, saponins, tannins, lectins, oligosaccharides and non-starch polysaccharides, phytoestrogens, alkaloids, antigenic compounds, gossypols, cyanogens, mimosine, cyclopropenoid fatty acids, canavanine, antivitamins and phorbol esters (Francis *et al.,* 2001). Francis (2002) indicated that additional research needs to be carried out to better utilize the potentials of plant-derived materials in aquaculture feeds. Considerable work has been conducted to evaluate the nutritive value of soybean meal as a substitute to fishmeal.

Soybean meal actually appeared to be better utilized by most fish farmers due to its nutritional quality (*lysine* and *tryptophan)* and initial lower cost compared to fish meal as well as its availability compared to other plant protein sources. However, the recent high cost of soybeans has shifted the attention of researchers and feed compounders into searching for alternative cheaper sources of plant protein (Viola *et al*., 1982). The high demand for soybean as source of food by man has led to its astronomic hike in price and thus, it has become an expensive component of animal feed. Recently, the analysis of inclusion of

wild plant materials attracted attention because they contain significant amount of essential nutrients that can be used for both human consumption and formulation of animal feeds. The proximate composition of some wild plants of Nigerian origin showed that they could be adequately utilized in the formulation of animal feeds provided the level of their toxic components are known (Eromosele and Eromosele, 1993). It is against this backdrop that this review titled: Alternative Plant Proteins Utilization for Sustainable Fish Farming: A Review was conducted.

Plant Protein Sources

Winged Bean

Fagbenro (1999) used autoclaved or roasted winged (40% CP) bean in the diets of African cat fish at inclusion rate of 50% to replace fish up to 80% level. The results indicate that the fish performance was not significantly different from control.

Jack bean (*Canavalia ensiformis*)

Alegbeleye *et al.* (2001) evaluated the use of Jack bean (*Canavalia ensiformis*) meal as an ingredient in feed formulation for *Clarias gariepinus* (Burchell, 1822) fingerlings at 10%, 15%, 30%, 45% and 60% levels of replacement for full fat soybean meal (FFSM) for a 56 day period on iso-nitrogenous and iso-calorific basis. Results indicated that feed consumption was higher in control (full fat soybean meal) compared to the test diets. The percentage survival rate and mean weight gains were observed to be higher in the control than the test diets. Feed Conversion Ratio (FCR) was highest in diet containing 60% inclusion level of jack bean meal where fish consumed more feed to produce unit increase in weight thereby rendering the feed uneconomical. The findings also revealed that the performance of the fish fed 15% and 30% inclusion level of Jack bean meal compared favourably with the control; however higher fish mortality was recorded in the control.

This trend which is deleterious to performance was attributed to the high dietary levels of toxins and anti-nutrients present in the leguminous seed. The presence of L-Canavanine (a thermostaple amino acid and arginine antagonist) with high inclusion levels of JBM was suggested to have been responsible for the poor feed utilization and poor survival rate observed.

Bambara groundnut (*Vigna subterranean verde L.*)

A lot of investigative work has been conducted with regards to substituting plant protein sources for fishmeal in fish diets with Bambara groundnuts. Banyigyi *et al.* (2001) used heat treated (oven toasted) Bambara groundnut (*Vigna subterranean verde L.*) meal to feed *Clarias gariepinus* juveniles to determine its effect on growth and feed utilization. Three (3) of the BGM were oven toasted for 15, 30 and 45 minutes, the fourth meal was traditionally toasted while the fifth was raw BGM meal. The result of the study indicated high digestibility of experimental diets which suggests that Bambara groundnut meal have the potential of replacing or competing with soybean in fish feed formulation. Banyigyi *et al*. (2001) suggested that extension of the duration of heat processing of bambara nut or employment of feed processing methods such as boiling or fermentation may enhance better growth and feed utilization. The result also indicated that there was no significant difference ($P > 0.05$) in the growth performance and feed utilization of *Clarias gariepinus* fed Bambara heat treated diet. The fish fed diet containing oven toasted BGM for minutes recorded highest percentage weight gain, FCE and PER. This was attributed to the deactivation of growth inhibiting substances in the meal.

Cotton seed meal and cotton seed cake

The growth of tilapia was improved when 25% of fishmeal was replaced by cotton seed meal. The growth rate was

however lower than the control when tested at 100% inclusion level (Jackson *et al*., 1982). In contrast Ofojekwu and Ejike (1984) reported a much lower weight gain and feed efficiency of *Oreochromis niloticus* fed cotton seed cake diet compared to the tilapia fed fishmeal control diet. It was further reported that low gossypol cottonseed meal (0.03%) was a good protein source for *S. mossambicus*. Falaye (1992) also reported that cotton seed meal yielded good results when fed up to 100% intilapia diets. Although cotton seed cake is an important protein source for animals, its use in commercial aquaculture feeds is very limited due to the presence of gossypol and the low level of available lysine (Alcestes and Jory, 2000). Thus it was further stressed that the level of cottonseed meal that can be incorporated in fish diets depends mainly on the gossypol content of the meal.

Rapeseed meal

The use of rapeseed meal has been documented (Jackson *et al.*,1982). Rapeseed meal is comparable in protein quality to soybean meal but has higher crude fibre content.

The use of rapeseed meal has been limited due to the anti-nutritional factors such as tannin, phytic acid, glucosinolates and enzyme myrosinase. However, great improvements have been made in processing techniques to inactivate or remove the myrosinase and glucosinolates. Jackson *et al.* (1982) reported good growth performance of *Oreochromis mossambicus* fed diets in which 50% of fishmeal was substituted by low glucosinolate rapeseed meal. Decreased growth rate was observed at higher levels of substitution.

Sunflower seed meal

Sunflower seed meal has been reported to contain a variety of endogenous anti nutritional factors such as protease inhibitor,

an arginase inhibitor and the polyphenolic tannin chlorogenic acid (Tacon *et al*., 1984). It has also been reported to have relatively high crude fibre content, which reduces the pelleting quality of the feed if included at high levels. According to Alcestes and Jory, (2000) inspite of these limitations, sunflower seed meal has been reported to be a good protein source for *Oreochromis mossambicus* even at 69.6% inclusion levels of the diet.

Sesame cake

Ofojekwu and Kigbu (2002) investigated the effects of substituting fish meal with sesame cake in fish feed diet to determine the effect on growth and feed utilization as well as body composition of the Nile tilapia (*Oreochromis niloticus*). The results in terms of best growth and food utilization were obtained from 10% sesame cake meal and 40% fishmeal. It was further indicated that up to 20% sesame cake can be used with 30% fishmeal in the diet of juvenile *Oreochromis niloticus* without any adverse effect on the overall performance. However significant growth depression was associated with high levels of sesame cake inclusion in the diet as observed in the diet with 50% sesame cake and 0% fishmeal which gave the poorest growth rate in fish. The poor performance was attributed to the high fibre content and phytic acid present in the sesame cake.

Rubberseed cake

The use of rubberseed cake (*Hevea brasiliensis*) in fish feed formulation has been investigated by Alegbeleye *et al*. (2004). In the study the seed with 36% crude protein was used to replace groundnut cake in the diets of Nile tilapia (*Oreochromis niloticus*). The findings revealed that fish fed with 30% inclusion level of rubberseed meal gave the best results with the highest specific growth rate (S.G.R.) 1.73; feed conversion ratio (FCR) 1.69 and protein efficiency ratio (PER) 1.97 which were statistically significant (P>0.05) compared to the other

diets. The results further indicated that 60% inclusion level of rubberseed meal gave the poorest results suggesting that equal replacement levels of groundnut cake and rubberseed meal was optimum as protein dietary source for growth performance and efficiency of feed utilization for Nile tilapia (*Oreochromis niloticus*).

Delonix regia

Balogun *et al.* (2004) replaced dietary protein with *Delonix regia* at different levels and fish showed appreciable performance and efficient feed utilization on completion of the feeding trial experiment.

Castor Oil Seed (*Ricinus Communis L.)*

The use of castor oil seed has also been reported. Agboola (2004) used diets containing graded levels of boiled castor oil seed (*Ricinus communis* L.) meal (CSM) as feed for *Clarais gariepinus* and *Oreochromis niloticus*. The seeds were processed at different time intervals (20, 35, 50 and 65 minutes). The raw seed served as control. The digestibility study indicated that the processed CS meals were highly digested by both species. This was attributed to reduction of the effects of anti-nutrients by heat treatment. However, based on the values of mean weight gains Specific Growth Rate (SGR), Feed Conversion Ratio (FCR), Protein Efficiency Ratio (PER), Net Protein Utilization (NPU) and digestibility, *Oreochromis niloticus* was able to utilize and convert CS meal better than *Clarias gariepinus* due to its vegetarian nature which enables it to produce enzyme (cellulase) for cellulose digestion. The poor performance of fish fed raw CS meal (control) could be attributed to high concentration of ricin which is a limiting factor to the use of castor oil seed in animal feed formulation.

Lablab bean meal (*Lablab purpureus*)

Adeparusi and Eleyinmi (2004) evaluated the effect of processed Lablab bean (*Lablab purpureus*) meal supplementation on

the digestibility and growth response of Common carp (*Cyrinus carpio*). Soybean was substituted for Raw Lablab (RLB) and processed Lablab (PLB) bean meals on iso-nitrogenous basis. The processed Lablab bean meal included Toasted Lablab (TLB) meal; Fermented Lablab (FLB) meal and Cooked Lablab (CLB) meal. The results indicated that fishes fed on the control (no Lablab) and cooked lablab bean diets had the highest specific growth rate and feed conversion ratio. The CP digestibility values obtained in the study (85.4% – 86.6%) compared favourably with earlier reports of Adeparusi and Jimoh (2002) on protein digestibility of Nile tilapia (*Oreochromis niloticus*) fed on toasted lima bean diets (84.8%). The result thus shows that heat processing (cooking and toasting) can significantly improve the digestibility of LB beans. The low digestibility recorded in fish fed on RLB based diets could be due to the presence of anti-nutrients such as tannin, phytates and trypsin inhibitors. It also suggested that the presence of cyanogenic glucosides could decrease palatability.

***Senna occidentalis* (Linn) seed**

The uses of *Senna occidentalis* (Linn) seed diet have also been documented in the search for alternative cheaper and unconventional sources of plant protein in fish diet. Umar (2006) studied the growth performance and feed utilization of *Oreochromis niloticus* fed different levels of Senna occidentalis seed. The results indicated that parboiled Senna seeds could serve as a good alternative source of protein in fish feed formulation. The growth indices indicated that diet containing 25% parboiled Senna diet was the best. The diet also had the highest carcass crude protein content.

***Bauhania monandra* Seed**

Balogun (2011) evaluated the sustainability of soaked Bauhinia monandra (kutz) seed meal diet as alternative protein source for *Clarias ganepinus* (Teugels)

during a 12 weeks feeding trial on iso-nitrogenous and isocaloristic basis. The experimental diets were formulated to contain soaked Bauhinia seedmeal (SBBM) at 25%, 50% and 75% inclusion levels with the 100% fish meal and 100% copens diet as control diets and reference. The results indicated that Bauhinia monandra seed meal could replace up to 25% of fishmeal component in the diets of African Catfish without having deleterious effects on growth performance and efficient feed utilization of fish.

However, Balogun reported that higher inclusion levels of *Bauhinia* seed meal decreased growth performance and feed utilization of fish fed on the experimental diets.

detoxified *Jatropa curcas* kernel meal

Solomon *et al.* (2016) investigated the potentials of detoxified *Jatropa curcas* kernel meal as a replacement for fishmeal in the diet of *Clarias ganepinus* fingerlings and reported that the fish *C.ganepinus* tolerated the inclusion of detoxified *Jatropa kernel* meal up to 13% without negative effects and nutrients utilization.

Conclusion

The potentials of utilization of several plant based protein sources as fish feed has been reviewed and conclusively it was eminent that plant protein sources are currently the sole promising alternative to fishmeal in fish feed formulation, with due consideration to their relatively cheaper cost, ready availability and good protein and high amino acid quality. The use of these non-fish protein sources as fish feed ingredients in the aquaculture sector is crucially important to help pull-down the present high cost of fish production, which has invariably made fish expensive and unaffordable at the table of the low income class in Nigeria and Africa by extension. However, the impediment to the efficient utilization of plant based protein sources in fish as a result of the presence of

one or more endogenous anti-nutrients need to be adequately addressed through processing. This is necessary in order to ensure efficient feed utilization and good growth performances in fish feed plant based protein sources.

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