E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2020; 8(6): 19-23

www.fisheriesjournal.com
Received: 12-09-2020
Accepted: 16-10-2020

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Feed resources and policy options on feed for aquaculture production in Africa: A review

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Abstract
Africa is well endowed with diverse feed resources that can be utilized in aquaculture production in Africa. Some of the feed resources, currently being used have been described in this article, including their merits and demerits, whilst others are yet to be identified, evaluated and used. The aquaculture sector in Africa is bedeviled with lack of and high cost of aqua-feeds, which places a limitation on aquaculture production in Africa. With feed accounting for about 60 to 90 percent of the total cost of production, the need to identify and evaluate feed resources has become very urgent. Policy making and implementation can play a great role in addressing the challenges in the aqua-feed sector. As such. various policy options for the development of the feed sector to boost aquaculture production in Africa have also been outlined.

Keywords: Feed resources, aquaculture, policy options, fisheries, Africa and fish

1. Introduction
The amount of fish caught in the wild is declining as a result of overexploitation of fisheries resources and pollution of the seas and oceans in Africa. On the other hand, the population in Africa keeps increasing. It has been estimated that the current population of 1.25 billion people in Africa would double to about 2.5 billion by 2050 [1]. This development is creating increased demand for fish, which currently outstrips fish supply in Africa. In many instances, fish constitutes the key means by which the protein requirements of Africans, especially the poor ones are met. Aquaculture production is therefore, important, as it contributes in addressing nutritional deficiencies, food insecurity and poverty in Africa. Aquaculture, if well developed, could serve as the bridge in meeting the demand gaps of fish in Africa. According to the Food and Agriculture Organization (FAO) of the United Nations [2], a total of 2,196,000 tonnes of fish was produced in Africa in 2018. When this figure is compared with that of 1995 output from aquaculture, a record compound annual growth rate of 15.55 percent was recorded [3, 4]. Currently, good progress is being made in aquaculture production in selected countries such as Egypt, Nigeria, Kenya, Ghana, Malawi, Zambia and Uganda. To sustain this development and increase aquaculture production in Africa, cheaper and readily available feed resources need to be identified, evaluated and used. Feed accounts for about 60 to 90 percent of the total cost of aquaculture production [5, 6]. As such, cheaper sources of feed would lower the cost of aquaculture production, leading to cheaper fish for the consumer and higher profit margins for the aquaculture farmer.
Some of the feed ingredients used in manufacturing aqua-feeds are imported, which is a drain on the foreign exchange reserves of central governments in Africa. The continued use of fish meal and fish oil for aquaculture production is also becoming increasingly prohibitive as human beings also use it for food. This development makes the need to identify and evaluate non-conventional feed resources even more urgent. Africa is well endowed with diverse feed resources which can be used in aquaculture production. More studies should therefore, be carried out on available feed resources, so that the most promising ones among them, in terms of their nutrient composition, digestibility and nutritive value can be identified and recommended for use by aquaculture farmers in Africa. In this article, an attempt is made to describe these feed resources, including their merits and demerits, when used for aquaculture production. Furthermore, policy options that can be pursued to effectively utilize the available feed resources in Africa to boost aquaculture production on the continent have also be offered.

2. Feed resources for aquaculture production in Africa

Various systems of aquaculture production have been used to produce fish, sea weeds, shrimps and crustaceans. The most predominant ones among them are cages and ponds. Also, the key fish species used in aquaculture are tilapia and catfish, of which several species and strains exist. These fish species are fed various types of feeds using several of these feed ingredients and diets.

2.1 Fish Meal and Fish Oil

Fish meal is extensively used as a source of protein in the diets fed to aquatic species. It is readily available in coastal and riverine countries and regions of Africa. However, in recent times as a result of increased demand for fish, fish meal is becoming expensive as a feed ingredient for aquaculture production. Notwithstanding its current limitation, fish meal has a high digestibility and nutritive value. The price of fish meal is relatively high because of the competition its usage has with humans. As such, several studies have been carried out to substitute fish meal in the diets of aquatic species with plant protein sources such as soybean, bambara nut, cashew nut, etc. Fish oil is also used in some aqua-feeds but can easily render the feed rancid, if incorporated at high levels. It is a source of fatty acids to the fish and makes the diet more palatable when incorporated at low levels.

2.2 Commercially Compounded Aqua Feeds

Commercial aqua feeds are available in some major cities and towns in Africa but the price can be exorbitant to aquaculture farmers. Aquaculture farmers in the hinterlands of Africa have difficulty accessing commercial aqua-feeds because of the transportation cost involved, which increases its price. The quality of some of commercial aqua-feeds is relatively superior but some unscrupulous aqua feed manufacturers lower the quality of their products to increase their profit margins. It is therefore essential that feed quality control measures are put in place to check such malpractices.

2.3 Soybean Meal

Soybean meal is increasingly being used in aqua-feeds to replace fish meal as a source of protein to aquatic species. It is cheaper compared to fish meal. Soybean can be grown in most parts of Africa and therefore this feed ingredient is readily available. Its amino acid profile is less superior to fish meal and therefore it may require some strategic supplementation to enhance its value as a source of protein to aquatic species.

2.4 Agriculture and Agro-Industrial Products

Agriculture and agro-industrial products such as groundnut cake, sunflower meal, bambara nut meal, cotton seed meal, sesame meal, palm kernel, linseed cake, cashew nut meal and copra cake are readily available in most parts of Africa. They are relatively cheaper but less than optimal when used as a source of protein in the diets of aquatic species. Some of them contain anti-nutritional factors, which must be ameliorated, when being used in aqua-feeds. Depending on the extraction method employed, some of these feed ingredients can contain high amount of oil, which can readily render the feed rancid. Their merit as a feed ingredient is that they have no competition with humans. They require supplementation with artificially manufactured amino acids to nutritionally balance the diets. Da and colleagues [7] evaluated the efficacy of locally available feed resources for Tra Catfish (*Pangasianodon hypophthalmus*) cultured in cages and discovered that fish meal protein could be replaced with protein from locally available plant and animal feed ingredients such as groundnut cakes, soybean meal, shrimp head meal, golden apple snail meal among others. In another study, Enyidi and co-workers [8] assessed the growth performance of African Catfish (*Clarias gariepinus*) after the fish meal had been substituted in the diet with Bambara nut (*Voandzeia subterranean*) meal and Soybean (*Glycine max*) meal. These authors observed that bambara nut meal can partly substitute fish meal and completely replace soybean in the diets of African Catfish. The substitution rate of these plant protein sources was 60 percent of the total diets.

Iheanacho and collaborators [9] studied the use of discarded cashew nut (*Anacardium occidentale*) meal as a replacement of soybean (*Glycine max*) in the diet of juvenile African catfish (*Clarias gariepinus*) and reported that the former could replace the latter up to 50 percent in the diet with improved growth performance and better hematological profile of the catfish used.

2.5 Yeast

Yeasts such as *Saccharomyces, Cerevisiae, Candida utilis and Kluyveromyces marxianus* have favorable amino acid composition and can serve as an excellent source of protein in the diets of fish. Yeast is readily available and can be derived from lignocellulose biomass found all over Africa. It is also cheaper than fish meal.

2.6 Yucca

The incorporation of Yucca (*Yucca Schidigera*) in the diets of fishes has been found to reduce total ammonia nitrogen of the water in aquaculture ponds and thereby enhances water quality [10]. Reham, Mounes and Ahmed [11] had earlier confirmed this finding that Yucca Schidigera extract could significantly reduce ammonia and nitrate levels in the water used to rear Nile Tilapia (*Oreochromis niloticus*) and thereby enhance the quality of water in the pond. Furthermore, these research workers discovered that the Yucca extract has a tissue protective effect on Nile tilapia.

2.7 Insects

Africa has various kinds of insects such as housefly, maggots, locusts, crickets, termites, beetles, black soldier fly (BSF) and cockroaches that can be used in aqua-feeds as a source of protein. Adeoye and co-workers [12] evaluated the use of black soldier fly (*Hermetia Illucens*) larval meal in the diet of African Catfish (*Clarias gariepinus*) and reported that fish meal could be replaced by BSF up to 50 percent of the diet without affecting the growth performance, nutrient utilization, survival and welfare of C. gariepinus fingerlings. Similar finding had earlier been recorded by Anvo *et al.* [13] when *Cirina butyrospermi* caterpillar meal was fed at 50 percent of the total diet to *Clarias gariepinus* fingerlings.

The usage of insects in aquaculture production, however, has aesthetic problems with some fish consumers. Another problem with insects is that some of them contain toxins in their exoskeletons. As such, when fed at high levels, it can adversely affect aquatic species.

2.8 Poultry Manure and Poultry Meal

Poultry manure from an integrated poultry-aquaculture production system has been successfully practiced in Africa. The manure from the poultry serves as a source of protein to

the fish. Bok and Jongbloed [14] fed poultry manure at a rate of 30 to 428 kg dry manure/ha per day to Sharp tooth Catfish, Clarias gariepinus in South Africa and discovered that poultry manure application led to rapid fish growth and high yields with no negative effects on the quality of water used. These authors further noted that the effectiveness of poultry manure as a source of feed to aquatic species is dependent on the type of fish being reared, the total stocking rate and the proportion of the different types of fish raised. Poultry meal is also rich in protein and can be fed to aquatic species with superior outcomes [15].

2.9 Blood Meal

Blood meal is an excellent source protein to aquatic species. Makinde and Sonaiya [16] assessed the potential of two vegetable-carried blood meals as sources of protein in the diets of juvenile African Catfish and concluded that they can serve as alternatives to imported commercial fish feed. However, it should be hygienically treated so that it does not become the source of pathogens when used as aqua-feeds. The blood meal can be found in all parts of Africa and therefore is readily available.

2.10 Abattoir Waste

Countless livestock animals and poultry are slaughtered daily in Africa and their waste can be treated and used as a source of proteins and minerals in the diets of aquatic species. Like blood meal, abattoir waste is excellent medium for the growth of pathogenic organisms. As such, as a feed ingredient for fish, it requires careful treatment before use [17].

2.11 Cereal Grains and by-Products

Cereal grains such as maize and sorghum as well as rice milling by-products and wheat bran can be fed to aquatic species with excellent outcomes. For example, in Egypt yellow maize is incorporated up to 35 percent in aqua-feeds and rice bran is added to the diets of aquatic species at between 10 and 25 percent [6]. When used in aqua-feeds, these cereal grains and by-products serve as a source of carbohydrates and glucose to the aquatic species.

2.12 Molasses

Molasses is a rich source of nitrogen and can be used as a source of protein to aquatic species. It is a by-product of alcohol distillation and be found in most parts of Africa. It is also relatively cheap as a feed ingredient in the diets of fish.

2.13 Fertilizers

Fertilizers such as NPK can be fed to aquatic species, with remarkably excellent outcomes [18]. It is rich in nitrogen, phosphorus and potassium. The proportion of these minerals is however dependent on how it was manufactured. Fertilizers are, however not cheap in Africa.

2.14 Cocoa Pod Husk Meal

Cocoa pod husk is a waste product after the extraction of the cocoa beans from the pod. It is readily available in cocoa growing countries in Africa and Latin America. It is a good source of energy but is less digestible as a result of its high fiber content. However, it can be incorporated in the diets of aquatic species at lower levels. When used as a feed ingredient, cocoa pod husk meal can significantly lower the cost of aquaculture production, since it can be obtained at little or no cost to the aquaculture farmer. Cocoa has anti-nutritional factors such as theobromine, which limit the use of cocoa pod husk meals at higher levels in the diets of aquatic species. However, the adverse effects of these anti-nutritional factors can be reduced or eliminated through fermentation [19] Despite its limitation, Ashade and colleagues [20] discovered that maize can be replaced 100 percent with cocoa pod husk (CPH) in the diets of *Oreochromis niloticus* as a source of energy with no adverse effect on survival, weight gain and feed conversion ratio.

2.15 Vitamin and Mineral Feed Ingredients

Artificially manufactured vitamins and minerals and those from raw sources can be incorporated in the diets of aquatic species to balance the rations. The incorporation of these feed ingredients results in better performance of aquatic species. However, a greater proportion of the artificial minerals are imported into Africa with hard-earned foreign currencies.

2.16 Leguminous Grains

Leguminous grains such as cowpea, bambara groundnut, chick pea, pigeon pea, groundnuts, etc. are used as a component of aqua-feeds, mainly as a source of protein to aquatic species. A good number of these grains can partially or fully replace fish meal in aqua-feeds. They are readily available and cheaper in Africa than fish meal and should be used in aqua-feeds when available. Some of the leguminous grains have anti-nutritional factors such as tannins, which can be rendered harmless through subjection to heat.

2.17 Coffee Pulp

Coffee pulp is a by-product from coffee and is available in all coffee growing countries in Africa. It has a rich energy source. Coffee pulp has little or no monetary value and therefore can potentially reduce the cost of feed when incorporated in the diets of aquatic species. Like cocoa pod husk, it has a high fiber content which reduces its level of digestibility. However, its low cost merits its inclusion in aqua-feeds when available.

2.18 Snail Meal

Snails are abundant in the forest zones of Africa. They can be collected from the wild or grown artificially in one's backyard and sold to aquaculture farmers. It has a high sodium and potassium content [21]. The shells of snails are rich in calcium but it is the flesh that is converted into a meal and fed to aquatic species. Since, humans also use it as food, its price may be exorbitant to the aquaculture farmer as an aqua-feed ingredient. However, when available at cheaper prices especially in the raining seasons, it may be a good candidate as an aqua- feed. Sogbesan and Ugwumba [21] assessed the use of garden snail as a source of protein in aquaculture in Nigeria and discovered that it could supplement fish meal in the diets of aquatic species since their nutritive values are similar.

2.19 Brewer's Spent Grains

Brewer's spent grains are by-products from the brewing industry. They are a rich source of energy and can be obtained at minimal cost. Brewer's spent grain poses a lot of environmental challenge in its safe disposal in Africa and so its use as a feedstuff in aquaculture production is an excellent way of addressing this challenge [22]. The brewing methods used determines its richness as a source of energy and protein in the diets of aquatic species. Where their energy levels are relatively low, it may require strategic supplementation with

other energy-rich cereal grains. Brewer's spent grains are less digestible. However, enzymatic hydrolysis prior to a stabilization process has been found to improve the digestibility of brewer's spent grain and increases the assimilation of nutrients contained therein by fishes [23]. The afore-mentioned research workers further reported that after enzymatic hydrolysis, brewer's spent grains can successfully replace fish meal in aqua-feed diets. Jayant *et al*. [22] also assessed the use of Brewer's spent grains (BSGs) as a feedstuff for striped catfish, *Pangasianodon hypophthalmus* fingerlings and recommended that 50 percent of dietary BSGs could effectively substitute for soybean meal. This study was undertaken in Asia and it is not unreasonable to expect similar findings in Africa, where catfish is also extensively reared.

3. Policy options for increased use of feed resources in Africa to boost aquaculture production

Policy options needed to increase the use of feed resources in Africa to boost aquaculture production are as follows: -

1. Identify and assess all feed resources that can be used in aquaculture production at the national and regional levels.
2. Determine the chemical composition, digestibility and nutritive value as well as the utilization efficiencies of feed resources in Africa for different aquatic species used in aquaculture production.
3. Equip aquaculture farmers in Africa with the knowledge and skills in compounding superior aqua-feeds using locally available feed resources.
4. Establish feed information systems that provide aquaculture farmers with real-time information on the availability and prices of aqua-feeds at the national level.
5. Provide affordable loans and credit facilities to aqua-feed input suppliers, aqua-feed manufacturers, marketers and traders to enable them provide aqua-feeds to fish farmers.
6. Establish a quality control and assurance system for aqua-feeds used in aquaculture production at the national level. To this end, it may be necessary to establish modern laboratories for evaluating aqua-feeds to ensure that what is made available to aquaculture farmers are safe, nutritionally balanced and true-to-type (i.e. the nutrient composition of the aqua-feeds is true).
7. Support from Governments and Development Partners to Aqua-feed manufacturers and associations at the national level to enable them produce cheaper and nutritious aqua-feeds.
8. Deliberate policy directives that discourage the importation of feed ingredients into Africa and rather encourage the use of cheaper, locally available and nutritious feed ingredients in compounding aqua diets to reduce the cost of aquaculture production in Africa.

4. Conclusion

This article has described the merits and demerits of some selected feed resources being currently used in aqua feed production in Africa. There are however, others that need to be identified and evaluated. It has also outlined various policy measures with respect to feed resources that can boost aquaculture production in Africa when implemented. It is our fervent hope that this article will be beneficial to aquaculture farmers, decision and policy makers in Africa.

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