

A Review of the Efficiency of Alternative Feed Sources for Cultured Catfish Species in Nigeria

Oluwagbemileke Omoyinmi[1] T.T. Bello[2]
1. Department of Agricultural Economics and Farm Management, Federal University of Agriculture, Abeokuta, Ogun state, Nigeria
2. Agricultural Education Department, Federal College of Education, PMB 2096, Abeokuta, Ogun State Nigeria
Email: gbemilekeomoyinmi@gmail.com

Abstract
The African catfish, Clarias gariepinus, is a major cultured food fish in Nigeria because of its fast growth, good feed conversion, hardiness, and high market value. However, one of the problems facing catfish production is the high cost of fish feed caused by the escalating cost of fishmeal, the main protein source in fish feeds. In Nigeria, the raw material for fish feed formulation such as under-utilized "trash" fish, groundnut cake, palm kernel cake and soybeans are becoming increasingly expensive. The sustainability of the catfish culture industry, therefore, depends on reducing the fishmeal content of fish feeds by finding alternative protein sources of good nutritional quality that are readily available and more cost effective than fishmeal.
Keywords: Cultured Catfish Species, Alternative Feed Sources
DOI: 10.7176/JBAH/13-16-03
Publication date: September 30th 2023

Introduction

Clariid catfish (comprising of *Clarias gariepinus, Heterobranchus bidorsalis, H. longifilis* and their hybrids) are the major cultured species. Other important cultured species include *Oreochromis niloticus, Tilapia zillii, Heterotis niloticus* etc. Clariid catfish production accounts for 80-90% of the total aquaculture production in the country (Williams *et al*., 2008). Miller and Atanda (2011) estimated 120,000metric tons for the production of Clariid catfish and less than 5,000metric tons for Tilapias. From these estimations, Nigeria is the largest producer of catfish in sub-Saharan Africa (Fakoya *et al*., 2009). This review provides an insight into the available alternative sources of feed for clariid catfish which could be harnessed for sustainable fish production in Nigeria.

1. Scientific name: *Oreochromis niloticus*

Common name: Tilapia
Yoruba name: Epiya

Oreochromis niloticus is a tropical fish. It exists in a variety of fresh water and brackish habitats. Its preferred temperature is 31-36°C but can survive from 12-42°C. *Oreochromis niloticus* prefers shallow water (FishBase, 2007). It is omnivorous, feeds on variety of living organisms and accepts artificial diets. This fish is highly prolific, sexual maturity begins at 5-6 months. It can live up to 10 years and reach weights of 5kg (FAO, 2007). *Oreochromis niloticus* is a very important fish in aquaculture. It is the second most intensively cultured species in the world because of its wide range of trophic and ecological adoptions. The males of this species grow faster than the females thus encouraging monoculture of the males. In order to avoid stunted growth and overcrowding because of their prolific nature, fish of 21-28days of age, are given a food containing a male hormone that changes the sex of female members to males.

2. Scientific name: *Clarias gariepinus*

Common name: Mud fish/ Catfish
Yoruba name: Abori/ Aro

Clarias gariepinus is one of the commonly cultured, indigenous species of fish in Africa. It is a omnivorous species with a propensity to be carnivorous. It is hardy and has high resistance to diseases. It can tolerate low dissolved oxygen level. The presence of an accessory breathing organ enables this species to breath air when very active or under very dry condition. This species accepts artificial diets. It can grow to a size of 150cm; maximum weight of 60kg. The flesh is soft and very delicious, making it of high demand in Nigeria (Adewolu 2017).

The African catfish (*Clarias gariepinus*) is an important food-fish in Nigeria and has remained an important candidate for research. In Ogun State, the importance of *C. gariepinus* has no less than elsewhere in Nigeria based mainly in the farmers' and consumers' preferences (Adekoya, *et al*., 2006; Olubanwo, 2011).

Catfish of the family *Claridae* comprises the most commonly cultivated fishes in Nigeria; the growth of aquaculture in Nigeria is now largely being boosted by a steady rise in catfish culture, inadequate availability of seed stocking and feed used to be major problems. Africa catfish is popular in the market and has great potentials to boost the rapidly growing Nigeria aquaculture (Omeru *et al.*, 2016).

Clarias gariepinus is generally considered to be one of the most important tropical fresh water fish species for aquaculture whose aquaculture potential have been documented (Dada and Wanah, 2003; Omeru *et al*, 2016).

Bruton (1979) pointed out that *C.gariepinus* has also high fecundity rate, grows faster, and tolerates high density and environmental extremes. It is generally considered one of the most important tropical species of the aquaculture. It has an almost Pan-African distribution ranging from East Africa to West Africa and from Algeria to Southern Africa. They also occur in Asia Minor (Isreal, Syria and South of Turkey) (Omeru *et al.*, 2016).

Clarias gariepinus at various geographical locations bears different values. It is called *Clarias lazera* in Northern and central Africa, *Clarias gariepinus* in South Africa (Viveen, *et al.,* 1985; Omeru *et al*, 2016). *Clarias gariepinus* is characterized with noted skin with fairly long dorsal aid anal fins. The dorsal fin has 61-80 soft rays and anal fin has 45-65 soft rays. They have strong pectoral fins with spines that are serrated on the outer side (Tangels, 1986; Omeru *et al.*, 2016). It possesses nasal and maxillary barbells and somewhat smallish eyes, their colouring is dark grey or black dorsally and green ventrally. Adult possess a dark longitudinal lies on either side of the head. However, this is absent in young fish the head is large, depressed and heavily boned. The mouth is large (Shoelton, 1993;Teugels 1986 ad Omeru *et al.*, 2016).

Catfish Nutrition

The nutritional value of fish is similar to those of land animals. For growth, reproduction and other normal physiological functions, they need to consume carbohydrate, protein, minerals and vitamins A deficiency of one or more of these nutrients results in a reduced rate of performance (Lovell, 1977).

The major classes of nutrients are the following:

(a) Energy source: Fats and carbohydrate
(b) Proteins
(c) Vitamins
(d) Minerals

Lovell (1979) stated that fish would eat to satisfy their metabolic energy requirements and consequently, ease feeding when their calorie needs are satisfied, be use of this phenomenon too much energy in relation to the percentage of protein in the ration can prevent fish from consuming enough protein to eat their daily need for optimum growth rates, even though the fish are allowed to eat as much as they will consume. It is therefore necessary to know the basic nutritional requirements of fish with a view to achieve efficient utilization of feed or ration.

Energy requirement of Fish

Energy is required for practically all life processes in all animals including shell and fin fish. The processes include maintenance of blood pressure, muscle tone, heat action, and transmission of nerve impulses, ions transport across membranes, reabsorption in the kidney, reproduction processes and other metabolic processes.

Madu *et al* (1984) however maintained that energy utilization would be improved without the other essential nutrients and that growth would cease. There is therefore the need to strike a balance in the carbohydrate protein ratios. According to Ivlev (1967), about 60% of the energy in fish is used for maintenance and the remaining 40% for growth. Nagai and Ikeda (1971) in their study of carbohydrate precede neither protein nor lipid as these nutrients are mobilized as energy source and rarely converted to lipid. Carbohydrate are cheaper and more readily available than protein sources (Ufodike and Matly, 1983) and would therefore be economical and beneficial to man if cheap carbohydrate food could be beneficially incorporated into fish feed without compromising growth and conversion efficiency.

Protein and amino Acids Requirement

Phillip (1969), reported proteins as large molecule of compounds consisting of multiple combinations of amino-acids joined together by peptide linkage formed from Sulphur bonds, Hydrogen bonds and Vander waals forces. According to F.A.O. (1976) all fish species require the same amino-acids which are Arginine, Histidine, Isoleucine, Lysne, Valine, Therconine, Methionine, Phenylamine and Tryptophan. These amino acids must be present in their diet since the fish species cannot synthesize them. Several factors which influence the protein requirements of fish were principally based on genetic factor. Ivlev (1967) and Phillip (1969) gave a review of factors that affect growth and food conversion co-efficiency in fish as follow;

i. Size of fish
ii. Frequency of breeding
iii. The species involved and its feeding habits
iv. Water temperature

Cruz and Llaudecia (1971) observed that the proportion of protein food needed by fish varies with species, while Fauroti and Lawal (1986) recommended 40% crude protein for *Clarias garepinus* in grow-out ponds. However, Ayinla and Akande (1988) recommended 38% crude protein for *C. lazera* brood stock in ponds. Cowey (1972) reported that the minimum protein requirement for optimum growth of many fish species is high and much of the ingested protein is used as a source of energy and that the metabolic rate of fish.

Fat Requirement of Fish
Lipids and fats both serve as source of essential fatty acids (EFA) and energy thus sparing protein as e diet component. They also act as carriers of fat soluble vitamins. Recent studies on EFA in fish suggest that their fats requirements may differ from species to species (Lagler, 1977). Apart from carbohydrates, fish can use large quantities of fat as an energy source, with consequent sparing of protein in the ration (Halver, 1972). Fats are most efficient calorie source because of the calorie density of the diet component. It has been shown that unsaturated fatty acids are the best form of fatty acids for nutritional requirement of fish.

Vitamin Requirement of Fish
Vitamins are complex organic substances usually of comparatively small molecular size. They are distributed in feed stuffs in small quantities and form a distinct entity and other major and minor food components. Vitamins are needed for normal growth, maintenance and reproduction of fishes. Thiamin, Riboflavin, folic acid, pyriodoxine, choline, ascobic acid, vitamin B12, Necotine acid, pantothenic aid are all essential vitamins required for growth of all temperate fish Ogino, (1965). Halve (1972) reported that thiamin deficient fish soon developed paralysis, while growth retardation and cataracts developed on fish deficient in riboflavin diets. Fish deficient in pyridoxines have been found to exhibit violent muscular contraction and later died.

Mineral Requirement of Fish
Minerals, like vitamin occur in most natural diets in sufficient quantities to satisfy the metabolic requirements of fish. Some mineral elements are known to be required in trace form while others are required in fairly large quantities in animals. Fishes depend partly on minerals absorbed from the surrounding water through the gills, intestine and skin while some are obtained from the diets. About twenty inorganic elements are required to maintain the structure and metabolic functions of vertebrates. Of these twenty inorganic elements, six are of importance namely: calcium, chlorine, sodium, magnesium, phosphorus and potassium while the remaining is needed in minute quantities in feed. In catfish farming, salt regulation is of special significance since fresh water fish are likely to lose ions to greatly hypotonic environment and thus suffer from hydration. The opposite is the case with salt water fish. Salt regulating mechanisms are highly developed in fish especially those that migrate from fresh water to salt water and vice versa. Conversely, fresh water requires a mineral supplement in their food. Minerals and other element can be classified according to their 3 main functions in the body.
a) Structural: calcium, phosphorus, fluorine and magnesium nine for tooth and bone formation.
b) Respiration: iron, copper and cobalt (function and formation of haemoglobin.
c) General metabolism: Sodium, potassium, calcium chlorine etc (body and cell functions).

In order to feed on a wide variety of organisms in different situations *C. gariepinus* is equipped with a wide array of anatomical adaptations for feeding under low visibility including:
1. A wide mouth capable of considerable vertical displacement for engulfing large prey or large volumes of water during filter feeding.
2. A broad band of curved teeth on the jaws and pharyngeal teeth preventing prey from escaping.
3. An abundant network of sensory organs on the body, head, lips and circumoral barbels. These barbels are extensively used for prey detection and fixation. Hecht and Applebaum (1988) found that *C. gariepinus* with barbels were 22.6% more efficient at catching prey than those without. This could indicate that tactile behaviour is important in the prey catching processes.
4. A wide, rounded caudal fin, typical for fish which ambush their prey.
5. Long gill rakers on the five branchial arches.

A short and dilatable oesophagus which opens into a distinct muscular stomach (mechanical digestion) and a simple thin walled intestine. Slow, methodical searching is the normal predatory tactic of *C. gariepinus*, with catfish grasping their prey by suction; a negative pressure (suction) being created by a sudden increase of the bucco-pharyngeal chamber. An important aspect of predation by *C. gariepinus* is their ability to switch feeding from one type of prey to another. In Lake Sibaya (South Africa), catfish ignore (or cannot catch) fish prey during daylight and feed mainly on invertebrates, which are abundant and relatively easy to catch. By contrast, at night, when fish preys become more vulnerable, they switch their feeding habits to fish prey (Bruton, 1979b). In general, fish prey provides far more energy per unit weight than other prey items. However, switching feeding habits relies on the existence of at least two alternate abundant preys.

Fish Feeds and Feeding
Feed Ingredients
No single feed ingredient can supply all the nutrients that fish need for growth. Commercial fish feeds contain a mixture of feedstuffs from animal and plant sources, vitamin and mineral premixes. (Adewolu, 2017). Nutritionists in the world are seeking for dietary protein ingredients to be used in fish feed that will maximize fish growth and

increase production within the shortest possible time and at the lowest cost of production (Adewolu, 2017). When seeking for such ingredient, the following are usually considered;

1. **The Nutrient composition of The Ingredient:** The protein content of the test ingredient should be more than 20% and must be free of impurities; these can be from plant and animal origin. These are generally known as protein supplements, examples are fish meal, soybean meal and groundnut cake. Feed ingredients containing less than 20% crude protein known as energy feedstuffs, examples are maize, rice bran and wheat offal.
2. **Availability and Price:** the ingredients must be easily available and must not be frequently used for livestock feeds or consumed by human beings, and must be affordable.
3. **Presence and Concentration of Anti-nutrients:** Anti-nutrients are usually found in plant ingredient and can negatively affect feed intake, efficiency and growth. Most anti-nutrients are easily deactivated by simple processing methods. Example of these processing methods are drying, cooking, or roasting.
4. **Absence of Contaminants:** The ingredients should be free of contaminants. Examples of these contaminants are pesticides, hydrocarbons and mercury.
5. **Digestibility:** the feed ingredient must be easily digestible and utilizable by fish.
6. Attractiveness and palatable. Examples are feed meals and animal meal.

Alternatives to Plant Protein Ingredient in Fish Feed

These are generally known as non-conventional plant feed stuff (NCPF). These are readily available nationwide and all seasons. Their potential uses in fish feed have been studied. Their levels of inclusion in fish feed vary and depend on their availability, nutrient composition, processing methods, species of fish and culture systems. The levels of inclusion are low, between 20-30% (Adewolu, 2011). The factors limiting their higher inclusion in fish diets are imbalance of amino acids, low protein content and the presence of anti-nutritional factors. Examples of plant protein feed ingredients as substitute for conventional feed ingredients in fish feed, are leaves of plants such as Groundnut cake (GNC), palm kernel cake (PKC) and soya bean meal (SBM) (Adewolu, 2011)

Leaf Meal as Protein Ingredient

Leaf meal proteins are among the unconventional sources of protein that can be used as feed ingredients in fish feed. They are usually abundant and cheap, they can thus, reduce the cost of fish feed. The inclusion of leaf meal is fast gaining global attention because of its availability, high nutrient content such as protein, minerals/vitamins and low price (Adewolu, 2011).

In Nigeria, there are large numbers of plant-based matter which are not currently used for any industrial use. Examples of such plant-based ingredients are plant leaves of sweet potato (*Ipomoea batatas*) and *Amaranthus Spinosus.* (Adewolu, 2011). The leaves of this plant have been used in the tropic as a cheap protein source in ruminant feeds.

The leaf meal has a high protein content of between 26-30% with high amino acid score. It has a good mineral profile and vitamins such as vitamin A, vitamin B_2, vitamin C and vitamin E (Adewolu, 2011). The leaves are abundant and can be harvested many times in a year. One major factor limiting the use of these leaves is the presence of anti-nutrients (Tacon, 1993). These anti-nutritional substances are the invertase and protease inhibitors (Oyenuga, 1968). These can be inactivated by various processing methods such as oven or sun-drying, boiling or steaming and grinding prior to inclusion in fish feed.

Amaranthus spinosus

This plant commonly referred to as 'Tete elegun' among the Yorubas; is found in the tropics and grows mostly on any soil and thus regarded as weed. The leaves are not edible by man or animals due to the presence of thorns on their stem. In Nigeria, this has not been used for agricultural or industrial purposes, thereby, making it to be abundant with very little or no cost implication. The chemical analysis of this plant shows that it is high in protein (30-32%) with lysine content of 5.9%. This level of lysine is equal to the amount found in soybean but more than the amount present in maize (Adeniji, *et al.,* 2007). This plant was therefore, adjudged to be a potential feed ingredient for fish feed.

Fishmeal as Feed Ingredient

Fishmeal is an excellent source of dietary protein, essential amino acids, essential fatty acids, minerals and trace elements. It also contains fat soluble and some water soluble vitamins (Tacon *et al.,* 2009). It is therefore, an ideal feed ingredient for the aquaculture industry; because it's nutritional profile is very close to the nutritional requirements of most fish species (NRC, 2011). The aquaculture industry has been the largest consumer of fishmeal for over a decade, consuming 68% of the total global fishmeal production in year 2012 (Naylor *et al.,* 2009).

Fish meal is used as the major protein source in the aqua-feed industry. However, its increased demand, coupled with its significant shortage in the global production has created sharp competition for its use by the animal feed industry (Adewolu, 2017). As a result, fish meal has become the most expensive protein ingredient in aquaculture feeds. Many developing countries have realized that, in the future, they might not be able to afford fish meal as a major protein source in aqua-feeds. The sustainability of the aquaculture industry, therefore, depends on reducing the fish meal content of fish feeds by finding alternative protein sources of good nutritional quality that are readily available and more cost effective than fishmeal (Adewolu, 2017).

Feedstuffs of animal origin are generally considered alternative protein sources because their protein content is higher and their complement of indispensible amino acids is superior to those of plant origin (Adewolu, 2017).

Alternative Animal-Protein Ingredients as Replacement for Fish Meal

Most quality feeds protein ingredient that are of animal origin are not consumed by human being. They are cheaper than their conventional counterparts. They can be included in fish diets to replace fish meal. The only problem is that some of them are unavailable at commercial quantities (Adewolu, 2017). Fishmeal has been replaced by single animal protein sources such as maggot meal (Adewolu, 2001), poultry visceral meal (Usman *et al.,* 2007), and feather meal (Hassan *et al.,* 1997).

Feather Meal

Feather meal is made from poultry feathers; it contains a high percentage of protein. However, the raw feathers contain mainly keratins that contain disulphide bonds that, without processing, are unavailable for fish. Steaming under high pressure and drying can break the disulphide bonds thus making the protein and amino acid become available (Feedipedia, 2011). These processing methods have tremendous effects on the nutritional quality of feather meal, mainly on the digestibility of protein and amino acids. The crude protein and amino acid profile are quite similar to that of fish meal, but deficient in methionine and lysine. Feather meal is a highly valuable protein source for aquaculture feed and can give significant opportunities to improve the cost effectiveness of fish feeds without losing fish performance (Adewolu, 2017).

Chicken Offal Meal

Chicken offal meal is one of the alternative sources of animal protein to reduce the level of fish meal in fish diet. In Nigeria, it is made from the intestines (excluding gizzard) of slaughter chicken (Adewolu, 2017). The traditional way of processing it is by cooking and sterilization and drying to about 10% moisture, before making it into a meal. Poultry offal obtained from healthy birds are classified as low-risk material with protein content in the range of 55-75%, ash content about 15% and fat between 15% and 30% (Feedipedia 2011). This composition depends on processing conditions and on the source of raw materials. It is generally a palatable and highly-quality feed ingredient due to its content in essential amino acids, fatty acids, vitamins and minerals. Processing poultry by-products into feed is a good way to mitigate the environmental problems caused by poultry processing (FAO, 2011).

Maggot Meal

The housefly *(Musca domestica Linnaeus 1758)* is the most common fly. The larvae (maggots) and the adult fly feed on manure and decaying organic wastes. This ability of housefly maggots to grow on a large range of substrates makes them useful in turning wastes into a valuable biomass rich in protein and fat. This is therefore, a potential solution to waste management in poultry farms. The optimal production of maggot requires warm temperatures (over 25^{o}C) and moisture. The maggots are made into meal by sun drying or oven drying. The crude protein content varies between 40 and 60%. Lipid content ranges between 9 and 25%. Pupae and older larvae contain less protein and more lipids. The amino acid profile is close to that of fishmeal but superior to that of groundnut cake and soybean meal (Aniebo *et al* 2009).

Most of these single animal protein sources were unable to completely replace fishmeal as each of them cannot match up the amino acid required (Aniebo *et al* 2009). Fish diets should include a wider range of alternative ingredients, including combinations of ingredients from animal origin (Glencross *et al.,* 2007). Feather meal, chicken offal meal, and maggot meal are potential alternative animal protein sources because of their availability, high protein contents, and low price. Protein of feather meal is low in lysine and methionine, poultry offal meal and maggot meal have higher content of these amino acid.

Earthworm

Earthworms also called night crawlers are very important animal that aerate the soil with their burrowing action which enriches the soil. Soil can have as many as 1,000,000 worms per acre. Earthworms are more than just fish bait. They are the main contributors to enriching and improving soil per plants, animals and even humans. Earthworms create tunnels in the soil by burrowing which aerates the soil to allow air water and nutrients to reach deep within the soil. Earthworms eat the soil which has organic matter such as decaying vegetation or leaves.

Plants cannot use this organic matter directly. After the organic matter digested by the earthworm is released as waste from their bodies called casting, earthworm has been found to be a good source of protein (Guererro 1983, Hilton 1983, Tacon *et al.,* 1983; Sogbesan and Ugumba 2008) and its usage as fish bait is well known in fishing (Omorinkoba *et al.,* 1985., Segun, 1987). Earthworms with an important high protein component are used to feed pigs, rabbit and as dietary supplement for fish species (Mason *et al.,* 1992). The high reproductive rate and biomass production of earthworm species make it ideally suited to worm meal production.

Factors that Affect the Protein Requirements of Fish

According to Adewolu 2017, the following are the factors affecting fish protein requirement.

1. **Fish Species**: The proportion of the protein required by fish varies from species to species. This is attributed to the food feeding habits of different fish species. Some fish are piscivorous, others are herbivorous, carnivorous or omnivorous. The carnivorous fish require higher protein in their diets than the omnivorous or herbivorous.
2. **Life Cycle:** Fish like all other animals need higher protein levels in their diets during their early life than during the later phases of growth. This is because the metabolic rate is higher in young fish than in the adults.
3. **Water Temperature:** There is a direct relationship between changes in water temperature and changes in the protein requirement. As water temperature increases, the protein requirement increases, because of accelerated fish growth. Low water temperature depresses growth rate and less protein is therefore required by fish.

Empirical Review

Peterson, Booth and Manning (2012) examined the effects of a yeast-derived protein source (NuPro) as a replacement for menhaden fish meal on weight gain, specific growth rate (SGR), food conversion ratio (FCR), whole-body composition and disease resistance in juvenile channel catfish (9.9 ± 0.2 g fish)1). NuPro replaced fish meal at six levels (0, 25, 50, 75, 100 and 125 g kg^{-1} diet). Catfish were sampled for whole-body composition and then challenged with the bacterium *Edwardsiella ictaluri*. Growth performance was negatively affected ($P < 0.01$) when NuPro was added at 125 g kg^{-1} diet. The amount of whole-body fat decreased ($P < 0.05$) when NuPro was added at 75 g kg-^{1} or more of the diet. Regardless of the amount of NuPro added, survival after challenge with *E. ictaluri* was similar among treatments. Results indicate that up to 100g kg^{-1} of NuPro can be added without negatively affecting growth performance. The yeast-derived protein source used in this study is a sustainable protein alternative that could be used as a partial replacement for fish meal in juvenile channel catfish diets.

Adewolu, Ikenweiwe and Molero in 2010 evaluated an alternative animal protein mixture as a replacement for fishmeal in diets for fingerlings of the catfish, *Clarias gariepinus*. The mixture comprised hydrolyzed feather meal, chicken offal meal, and maggot meal at a ratio of 4:3:2. Five diets (36% crude protein), containing the mixture at replacement levels of 0% (control), 25%, 50%, 75%, or 100%, were fed to triplicate groups of ten *C. gariepinus* fingerlings (3.0±0.05 g) at 3% body weight per day for 56 days in 50-l plastic tanks. The weight gain, specific growth rate, feed conversion ratio, and protein efficiency ratio of fish fed the 25-50% diets did not significantly differ ($p>0.05$) from those fed the control diet. However, in fish fed the 75-100% diets, these indicators were significantly lower. Carcass protein decreased as the level of the mixture increased. Carcass lipid of fish fed the 75-100% diets was lower than in fish fed the 0-50% diets. Results indicate that our animal protein mixture can replace up to 50% of the fish meal component in diets for *C. gariepinus* fingerlings without causing adverse effects on growth.

Conclusion and future outlook

In the last decade, a remarkable growth has taken place in aquaculture; conventional fish farming has transformed from the extensive to semi-intensive/ intensive cultured in ponds, tanks, flow-through ad recirculating systems. In 2010, aquaculture production in Nigeria reached 200,000 metric tonnes out of the total 820,000metric tonnes of fish produced. Aquaculture contributed only 24.4% of the domestic fish production. However, this production level is far below the country's estimated potential of 2.5million metric tons considering the existing vast and unexploited natural resources. Presently, Nigeria ranks second to Egypt in terms of aquaculture production in Africa but the leading producer in sub-Saharan Africa. Today, the government is actively pursuing the development of aquaculture in order to cope with the rising demand for fish and also to diversify its oil-based economy. However, catfish production is plagued with high cost of fish feed caused by the escalating cost of fishmeal, the main protein source in fish feeds. The sustainability of the catfish culture industry, therefore, depends on reducing the fishmeal content of fish feeds by finding alternative protein sources of good nutritional quality that are readily available and more cost effective than fishmeal. Although foreign feeds have a higher proportion of protein than Nigerian produced feed, which gives better results in terms of table size fish at shorter time but the cost. imported fish meals which is the protein source is very high. In general, locally produced feeds are cheaper than imported products. In Nigeria, the raw material for fish feed formulation such as under-utilized "trash" fish, groundnut cake, palm kernel cake and soybeans are becoming increasingly expensive. As a result of high cost of these materials emphasis is placed on the evaluation of the potential of some locally available but under-exploited and under-utilized materials such as tadpoles, toads, crabs, shrimps, maggot, earthworm etc. The cost of feeding fish is about 60% of the total recurrent cost of fish farming, hence if fish production is to be sustained in the country, there is a need for an alternative protein source at a cheaper rate to substitute the expensive feed meal.

Bibliography

Adekoya, B. B; Ayansanwo T.O, Idowu A.A, Kudoro O.A and Salisu eds A.A: (2006). In directory of Fish Hatcheries in Ogun State". Ogun State Agricultural Development Programme (OGADEP), Abeokuta.18pp.

Adeniji, C.A., Fakoya, K.A., and Omamohwo, V.R. (2007). Partial replacement of soybean cake with Amaranthus spinous leaf meal in the diet of nile tilapia, Oreochromis niloticus. *Pak.J.Sci Ind. Res*, 50:335-338

Adewolu M. A., Ikenweiwe N. B. and Mulero S. M. (2010). Evaluation of an animal protein mixture as a replacement for fishmeal in practical diets for fingerlings of Clarias gariepinus (Burchell, 1822). Israeli J. Aquacult. - Bamidgeh, 62 (4): 237-244

Adewolu M.A. (2001). The use of maggot meal as a protein source in the diet of *Clarias gariepinus* fingerlings. *Res. Comm. Fish.*, 1(1):11-20.

Adewolu, M.A. (2008). Potentials of sweet potato (Ipomoea batatas) leaf meal as dietary ingredient for Tilapia Zilli fingerlings. *Pakistan journal of Nutrition*. 7(3): 444 – 449.

Adewolu, M.A. Adeniji, C.A. and Akinkugbe, O.F (2017). Determination of feeding frequency for Clarias gariepinus fingerlings on fixed ration level. *International Journal of Agricultural Research*. In Press

Adewolu, M.A. and Adamson A.A. (2011) Amaranthus Spinous leaf meal as Potential Dietary Protein Source in the practical Diets for clarias gariepinus (Burchell, 1822) fingerlings. *International journal of zoological Research* 7(2): 128-137

Aniebo A.O., Erondu E.S. and Owen O.J. (2009). Proximate composition of housefly larvae (Musca domestica) meal generated from mixture of cattle blood and wheat bran. Lives. Res. Rural Dev. 20 (12).

Ayinla O.A. (1988). Nutritive and Reproductive performance of Clarias gariepinus (Burchell1822). Unpublished Ph.D thesis, University of Ibadan. Nigeria. 433p

Dada B. F. (1975). Present status and prospects for aquaculture in Nigeria. Paper presented at the symposium on aquaculture in Africa. Accra, Ghana 30th Sept, - "2nd Oct 1975.

Fakoya, K.A., Adewolu, M.A., Akintola, S.L., Jimoh, A.A., Owodehinde F.G., Whenu, O.O., (2009). Environmental threats to the development of aquaculture in Lagos State Nigeria. European Journal of Scientific research ISSN 1450-216X Vol.34 No.3 (2009), pp.337-347 © EuroJournals Publishing, Inc. 2009 http://www.eurojournals.com/ejsr.htm

FAO (2007): State of world fisheries and aquaculture.2006 Food and Agriculture Organization, Rome.

FAO, (2011). Food and Agriculture Organisation of the United nations. The State of world fisheries and aquaculture 2011. Rome, Italy.

FAO, (2016) Food and Agriculture Organisation of the United Nations. The State of the World Fisheries and Aquaculture FAO, Rome, Italy.

FAO, 2013 Food and Agriculture Organization of the United Nations, The State of the World Fisheries and Aquaculture FAO, Rome, Italy.

FAO., 1996. Chronicles of marine fishery landings (1950-1994): Trend analysis and fisheries potential. FAO Fisheries Technical Paper No. 359. Rome.

Fishbase, (2007) Froese, R., and Pauly Editors, 2007. World Web electronic publication. www.Fishbase.org.version (04/2007).

Glencross B.D., Booth M. and Allan G.L., (2007). A feed is only as good as its ingredients a review of ingredient evaluation strategies for aquaculture feeds. Aquacult. Nutr., 13:17-34, moist diets, aquacult, Asia Mag., April-June: 33-36

International Trade Centre (2002). ITC Databases: Aggregated Trade Centre.http://www.thewaveonline.com/article/?id= 13781. Accessed April 23, 2003.

Ivlev, V.S., 1966. The biological production of rivers. J.Fish.Res.Board Can., 23(11):1727–59

Lovell, R. (1979). Fish culture in the United States. Science, 200(21), 1368-1372.

Madu, C.T. and Olurebi, S.O. (1984). Dietary protein requirements of mudfish (Clarias anguillaris) fingerlings. I. The effects of varying dietary protein level on growth and food utilization. KLRI Annual Report. 46 - 49.

Miller, J.W., Atanda, T. (2011). The rise of peri-urban aquaculture in Nigeria. *International journal of agricultural sustainability* 9(1): 274-281.

National Population Commission (2006) The Nigeria Population Census 2006.

Naylor, R.L.; Hardy, R.W.; Bureau, D.P.; Chiu, A,; Elliot, M.; Farrell, A.P.; Forster,I.; Gatlin, D.M.; Goldburg, R.J. ; Hua, K.; Nichols, P.D., (2009). Feeding aquaculture in an era of finite resources. *Proceedings of the National Academy of Sciences* 106,15103-15110

NRC (2011). National Research Coucil. Nutrient Requirements of fish and shrimp. Washington,DC: The National Academies press

Omeru, E. D.; Solomon, R. J. (2016) Comparative analysis on the growth performance of catfish (*Clarias Gariepinus*) fed with earthwork as a replacement of fish meal. *American Journal of Research Communication*, 2016, 4(6): 89-125} www.usajournals.com, ISSN: 2325-4076.

Omorinkoba, W.S and Bankole, N.O. (1985). A preliminary report on earthworm culture for sport fishing in Kainji lake research institute (KLRI) reservoirs. KLRI animal report 1986, 62-65

Oyenuga, V.A., (1968). Nigeria's foods and feeding stuffs. Their chemistry and nutritive value. 3rd edition. The Caxton press (West Africa) Ltd. Ibadan, 99p.

Peterson, B.C., Booth, N.J. & Manning, B.B. 2012. Replacement of fish meal in juvenile channel catfish, Ictalurus punctatus, diets using a yeast-derived protein source: the effects on weight gain, food conversion ratio, body composition and survival of catfish challenged with Edwardsiella ictaluri. Aquacult. Nutr., 18: 132–137

Rao DSP, Coelli TJ (1998). Catch-up and convergence in global agricultural productivity 1980-1995. Working paper No. 98, Centre for Efficiency and Productivity Analysis (CEPA), University of New England, Armidale.

Raufu, M.O., Adepoju, A.A., Salau, A.S. and Adebiyi, O.A. 2009. Determinants of yield performance in small scale fish farming in Alimosho local government area of Lagos State. *International Journal of Agricultural Economics and Rural Development*, 2(1): 9-14

Segun, O.A. (1987). Earthworms from Ile-Ife, western Nigeria. J. Natural history. 12:13-31

Shoelton, P (1993). A complete guide to the freshwater fishes of southern African halfway house: southern book publishers.

Sogbesan O. A (2014). Non-Conventional Animal Protein Feedstuffs for the Culture of Catfish. Ibadan University Press (tetfund). 1-3.

Sogbesan, A.O and Ugwumba, A.A (2008) Nutritional values of some non-conventional animal protein feedstuffs used as fish meal suypplement in agriculture practices in Nigeria. Turkish journal of fisheries and aquatic sciences 8:159-164.

Sotolu, A.O., 2008. Nutrient potentials of water hyacinth as a feed supplement in sustainable aquaculture. Obeche, 26: 45-51.

Tacon, A.G.J. (1983) The nutrition and feeding of farmed fish and Shrimp. A training Manual 2. Nutrient sources and composition. FAO/UNDP. Brazil pp:12

Tacon, A.G.J.; Metian, M..and Hassan, M.R., (2009). Feed ingredients and fertilizers for farmed aquatic animals. Sources and composition. FAO fisheries and Aquaculture technical paper, 540. FAO, Rome, Italy.

Tacon, AGJ., (1993). Feed ingredients for warm water fish and other processed feedstuffs. FAO fisheries circular No. 856, FAO, Rome, pp:64

Tengels, g. (1986). A systematic revision of the African species of the genus clarias (Pisces:dariidae). Annals Musee Royal de 1 afrique central, 247:1-199

Tewe, O.O. (2004). Cassava for Livestock feed in sub-sahara Africa. F.A.O. Rome Italy. 64pp.

Thompson, O.A., and Mafimiseb T.E. 2014. Profitability of selected ventures in catfish aquaculture in Ondo state, Nigeria. *Fisheries and Aquaculture Journal* 5(2):1-7

Ufodike, E.B.C. and Matty, A.J. (1983). Growth responses and nutrient digestibility in minor carp (Cyprinus carpio) fed different levels of cassava and nice. Aquaculture (31): 41 - 50.

Usman R., Palingi N.N. and Ahmad T, (2007). Utilization of local feed ingredients in tiger grouper grow out moist diets. *Aquacult. Asia Mag.*, April-June:33-36.

Viveen, W.J.A.R., C.J.J. Richter, P.G.W.J. Van Oordt, J.A.L. Janssen and E.A. Huisman, 1985. Practical manual for the culture of the African catfish (Clarias gariepinus). The Netherlands Ministry for Development Cooperation, Section for Research and Technology, pp:128.

Williams, S.B., Olaosebikan, B.D., Adeleke, A.O. ad Fagbenro,A.O. (2008). Status of African catfish framing in Nigeria. Proceedings of a workshop on the development of a genetic improvement program for Africna catfish, *Clarias gariepinus* Accra, Ghana, 5-9th November 2007. Edited by Paul W. ponzoni and H. Nguyen. The Worldfish Center 2008.