



Farmed Fish Feeds: Use of Non-Conventional Feed as Fishmeal Replacement in Nigeria

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ABSTRACT: Fish feeds are an integral part of commercial and personal aquaculture, which provides a balanced diet and nutrition for farmed fish. High cost and competition with human food of fish feed is a major concern amongst the livestock and aquaculture feed industries. The objective of this paper is to analyze the current state of understanding on the use of non-conventional feed to replace normal fish feeds in Nigeria using information from secondary data. The mastery and use of substitute sources of fishmeal at all stages of fish development is crucial to reducing the demand on aquatic resources caused by the use of fishmeal in fish feed. Non-conventional feed ingredients are not usually the traditional ingredients used for commercial fish feed production. Many unconventional sources are of very good nutrient profiles which when incorporated into feeds can meet parts of the protein and energy requirements of the fish. Most of these indigenous fish feed resources are non-competitive in terms of human consumption, their prices are relatively very low and sometimes are of no cost value. They are usually byproducts or waste products from agricultural industries, domestic waste, and wild plants, thus their utilization as feed resources can help to reduce the cost of fish feeds and fish production in Nigeria.

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In the development and management of an aquaculture enterprise, fish feed plays a vital role in its growth and expansion (Gabriel *et al.*, 2007) and constitutes 40–50% of the operational cost in the intensive and semi-intensive aquaculture system (Jabir *et al.*, 2012). Since fishmeal is getting more and more expensive as a feed ingredient, it has been found that using unconventional feedstuffs results in good growth and superior cost-benefit ratios. The aquaculture industry is working to meet the world's rapidly growing demand for fish in order to reduce hunger and improve food and nutritional security (FAO, 2018). Non-conventional feed resources (NCFRs) are feeds that are not usually common in the markets and are not the traditional ingredients used for commercial fish feed production (Devendra, 1988; Madu *et al.*, 2003). NCFRs are credited for being by-products or waste products from agricultural, farm-made feeds, and processing

businesses that are not competitive for human consumption, are extremely affordable to buy, and can be used as a form of waste management to improve good cleanliness.. Unconventional feed resources are credited for being noncompetitive in terms of human consumption, very cheap by-products or waste products from agriculture (Huyemi *et al.*, 2010). The sources of plant proteins, because of their very great availability, were the subject of several studies in the replacement partial or total of the fish meal in the food of several fish species (Imorou *et al.*, 2008; Adewolu 2008; Bairagi *et al.*, 2004; Richter *et al.*, 2003). NCFRs include all types of feedstuffs from animals (e.g. silkworm, maggot, termite, grub, earthworm, snail and tadpole); plants/ plant waste (jackbean seeds, cottonseed meal, soybean meal, pigeon pea, chaya, duckweed, maize bran, rice bran, palm kernel cake, groundnut cake and brewers waste) as well as wastes

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from animal sources and processing of food for human consumption such as animal dung, offal, shrimp head, feathers, fish silage, bone and blood. Recent high demand and consequent high prices for fishmeal, together with increasing production pressure on aquaculture, has led to the research on non-conventional animal proteins for aquaculture and livestock. Moreover, the sources of animal proteins like the termites, earthworms, the tadpoles, the snails, the maggots were used in the replacement of the fish meal with various conclusions (Monebi and Ugwumba, 2013; Kader *et al.*, 2010; Sogbesan *et al.*, 2007; Oyelese 2007; Madu and Ufodike 2003). The need to meet the optimum demand for fish production had in earlier times opened the way for researchers to gear into the search for local feedstuff consumed by man that could adequately compete with fish meal. Over time, this did not seem to solve the problem of fish feed ingredients because of the constant rise in the price of the feedstuff and increasing demand for these same food products by the human population. Fish feed constitutes about 40-60% of the recurrent cost of most intensive fish farming ventures and sometimes negates the economic viability of a farm if suitable feeds are not used. However, fish feed is one of the essential factors needed to promote and develop modern fish culture. More so, the use of a local, wild and untapped variety of plant parts (seeds, leaves and pods) incorporated into the feed ingredients for feeding fish may be worthwhile and economically viable (Eyo, 2001). These include all types of feedstuffs from animal (silkworm, maggot, termite, grub, earthworm, snail, tadpoles etc.), plant wastes (jack bean, cottonseed meal, soybean meal, cajanus, chaya, duckweed, maize bran, rice bran, palm kernel cake, groundnut cake, brewers waste etc.) and wastes from animal sources and processing of food for human consumption such as animal dung, offal, visceral, feathers, fish silage, bone, blood) (Devendra, 1988; Oyelese *et al.*, 1999; Fasakin *et al.*, 2000; Omitoyin and Faturoti, 2000). All these can be recycled to improve their value if there are economically justifiable and technological means for converting them into useable products.

Need of Non-conventional feed resources: There are serious shortages in animal feeds of the conventional type. The grains are required almost exclusively for human consumption. With increasing demand for fishery products as a result of rapid growth in the world economies and shrinking land area, future hopes of feeding the fishes and safeguarding their food security will depend on the better utilization of unconventional feed resources which do not compete with human food. The availability of feed resources and their rational utilization for fishes represents

possibly the most compelling task facing planners and aquaculturist in the world. The situation is acute in numerous developing countries where chronic annual feed deficits and increasing animal populations are common, thus making the problem a continuing saga. Thus non-conventional feeds could partly fill the gap in the feed supply, decrease competition for food between humans and animals, reduce feed cost, and contribute to self sufficiency in nutrients from locally available feed sources. It is therefore imperative to examine for cheaper non-conventional feed resources that can improve intake and digestibility of low quality forages.

Generation of NCFR: The generation of non-conventional feed resources is essentially from agriculture and various agro-based industries and is a function of many factors. Such factors include the quantity and quality of the materials produced which is dependent on the prevailing agro-climatic conditions and cropping patterns, the type of raw materials, the production process, the production rate, the type of inputs used, the regulations affecting product quality use and the constraints imposed upon effluent discharge (Devendra, 1985). Most non-conventional resources are usually regarded as waste which is an inaccurate description of this group of materials. They can be regarded as waste when they have not been shown to have economic value (Amata, 2014). When such waste can be utilized and can be converted by livestock to valuable products which are beneficial to man, they become new feed materials of importance. In addition, they can be used to supplement the existing limited feed resources (Amata, 2014). Recycling, reprocessing and utilization of all or a portion of the wastes, offers the possibility of returning these materials to beneficial use as opposed to the traditional methods of disposal and relocation of the same residues. The demonstration of potential value can thus make any of these waste products new feeds of value and importance (Amata, 2014).

Nutritional requirement of fish: The primary concern in fish culture is to increase fish production per unit of culture space. Quality nutrition in animal production systems is essential to economical production of a healthy, high-quality product especially in aquaculture, where approximately 50-60 percent of the variable production cost is invested on feed (FAO, 2009). Nutrient requirements of fish are reported as minimum dietary levels needed to support maximum performance of fish under experimental conditions when fed diets typically made using semi-purified ingredients (Small *et al.*, 2016). Nutritional requirement of fish varies with factors like species,

developmental stages, feeding habit, physico-chemical and biological parameters of water including primary productivity along with availability of natural food (De Silva and Anderson 1995). The recommended fish diet for semi-intensive culture practices consists of oilcake, fish meal, meat meal (protein source) and rice bran, wheat bran, maize (carbohydrate source) to fulfill the growth and energy requirements along with vitamin –mineral premix for supplementing the basic diet. Animals generally require protein, minerals, vitamins, lipids and energy for normal growth and other physiological functions but for instance in intensive fish farming, the nutrient contribution from natural food organisms is minimal hence nutrients and energy are primarily provided by prepared feed (Ogugua and Eyo, 2007).

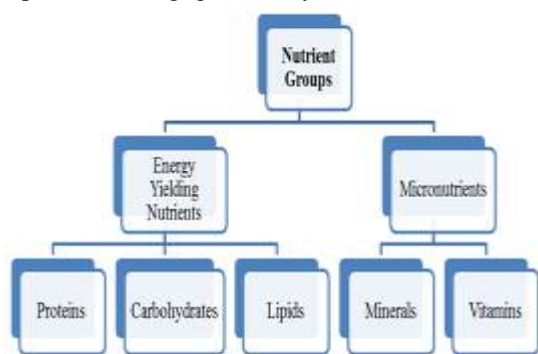


Fig 1: Flow chart showing different categories of major nutrient groups

Energy yielding Nutrients: These consist of feedstuffs containing less than 20% crude protein. They are essentially of plant origin such as maize, guinea corn, millet, cassava, wheat offal, rice bran etc. Carbohydrates have sparing effect on protein in artificial feed so that fish can utilize proteins efficiently for growth rather than for energy (Audu and Yola 2020). Food intake tends to be controlled by the energy need of the animal and, accordingly, energy requirement will regulate within certain limits the intake of nutrients. Therefore, it is important that the energy content of the diet be adjusted so as to promote the desired intake of all nutrients. A feature of energy requirement in poikilotherms is that it is affected by environmental temperature. This controls metabolic rate and in addition the maintenance energy requirement of cold-water fish is especially influenced by a rise in water temperature from low levels up to and above their (generalized) optimum.

Protein and amino acid: Protein is a chief and very relevant nutrient for the Fish. As a functional property of a nutrient, the protein will act as a source of energy for Maintenance, Growth, and Reproduction. This distribution will not remain constant throughout the

fish life (Gopika *et al.*, 2020). As in earlier stage protein is mainly used for growth and maintenance, and after attaining sexual maturity, it is utilized for reproduction contributing to lesser growth. The optimum requirement for any species can be obtained mainly from dose-response curves in response to graded increments of dietary protein in the diet (Gopika *et al.*, 2020) . However, the Protein requirement in fish depends on several factors like species, size and age, water temperature, water salinity, stocking density, and dietary Protein/Energy ratio. Protein quality affects fish performance. The amount and types of amino acids in a protein source determine its quality. Some protein sources like fish meal are high quality but also very expensive. Less expensive protein sources may be used if they meet the essential amino requirements of the fish. In most of the test diets used to measure amino acid requirements, the N component has consisted of both a crystalline amino acid mixture (making up about 50% of the N component) and some whole protein (Teles *et al.*, 2019). Such diets gave growth rates that were inferior, often markedly so, to diets of similar amino acid composition in which the N component was entirely protein. These are feedstuffs containing 20% crude protein or more and are regarded as protein supplement. They are made either of plant or animal material (Teles *et al.*, 2019). Animal proteins are of higher quality than those of plant origin. Protein is required for plastic purposes, synthesis of enzymes, hormones and other metabolites (NRC 2011). Therefore, from a zootechnical perspective, it is important that diets include an amount of protein that meets animals’ requirements for growth, maintenance, tissue repair and optimal health status. In fish, protein usually constitutes the dietary component that is included at a higher quantity. As proteins are expensive, it usually represents the most expensive dietary component. Therefore, from an economic perspective, it is important that diets do not include proteins in excess. Proteins are not stored in the body in a way similar to that of carbohydrates and lipids. Therefore, an excess of dietary protein is used as an energy source in intermediary metabolism or is converted to glucose or lipids as energy deposits (Dabrowski and Guderley 2002). In either case, the amino acids that constitute proteins need to be deaminated

and the ammonia produced is excreted by the gills and urine (Wilson 2002). As nitrogen is one of the main nutrients responsible for water eutrophication (the other one being phosphorus), an excess of dietary protein will negatively impact the environment (Cowey 1995). Thus, from zootechnical, economic and environmental perspectives it is important that dietary protein meet but not exceed animals’

requirements. Animal protein includes fishmeal, meat meal, bone meal, and blood meal. The best protein source for fish feed is fishmeal. Plant protein materials commonly used in fish feed are Soybean meal, groundnut cake and cottonseed cake. Similar to carbohydrates and lipids, protein can be used as an energy source to meet animals' energy needs. Thus, the overall dietary energy available cannot be disregarded when considering protein requirements. Indeed, when fed nutritionally balanced diets, animals seem to regulate feed intake to meet energy requirements (Bureau *et al.*, 2002). Therefore, if the diet has low protein: high energy ratio (LP:HE), animals may stop feeding before meeting their protein needs, with negative consequences in terms of growth performance and body composition. On the other hand, if the diet has high protein: low energy ratio (HP:LE) animals will eat an excess of dietary protein, which will be catabolized and used for energy purposes (Wilson 2002). This is particularly relevant in fish, which do not control amino acid catabolism efficiently, and therefore, N losses are high even when dietary protein levels are low (Cowey 1995; Kaushik and Seiliez 2010).

Carbohydrates: The nutritional value of carbohydrates varies among fish with warm water fish being able to utilize much higher levels of dietary carbohydrate than coldwater and marine fish (Asaeda *et al.*, 2008). No dietary requirement for carbohydrate has been demonstrated in fish. However, if carbohydrates are not provided in the diet, other nutrients such as protein and lipids are catabolized for energy and to provide metabolic intermediates for the synthesis of other biologically important compounds (Mumtaz *et al.*, 2015). Thus, it is important to provide the appropriate level of carbohydrate in the diet of the fish species being cultured (Steinbachova-vojtiskova *et al.*, 2006). The relative use of dietary carbohydrates by fish varies and appears to be associated with the complexity of the carbohydrate. For example, certain species have been shown to utilize simple sugars as well as, or better than, complex carbohydrates whereas other species do not utilize simple sugars as an energy source. The capacity of most fish to assimilate and metabolize dietary carbohydrate is limited. Given this caveat, warm-water fish in general appear better able to use dietary carbohydrate than do cold-water and marine fish. Fish do not have specific dietary requirement, but carbohydrates are always included in fish diets as they are inexpensive energy source and act as pellet binder (Mumtaz *et al.*, 2015). Carbohydrates also serve as precursors for formation of various metabolic intermediates needed for growth. Carbohydrates have been shown to have a protein sparing effect in many aquaculture species

(Steinbachova-vojtiskova *et al.*, 2006). Proper dietary balance of carbohydrates would enable fibre to move other nutrients in gastrointestinal tracts for proper digestion. Carps, tilapia, milkfish and prawns efficiently utilize carbohydrates as energy. However, the ability of fish to utilize dietary carbohydrate varies considerably and most carnivorous species have limited ability to metabolize it. In the absence of adequate dietary carbohydrates, fish utilize protein for energy at the cost of growth. Gelatinization of starch leads to its more efficient use. There is some species variation in utilization of mono- and disaccharides. Fructose, galactose and lactose are not well used by any species and in channel catfish (*Ictalurus punctatus*) this also holds true for maltose and glucose. Blood glucose concentration is not closely controlled in fish despite the fact that plasma insulin levels are comparable with those of omnivorous mammals. Fish may be said, therefore, to resemble mammals with non-insulin-dependent diabetes. Several recent studies examined the binding of insulin to receptors in skeletal muscle.

Lipid: Lipid energy is transferred from phytoplankton to fish *via* zooplankton. A good indication of the energetic importance of lipids for fish was demonstrated by Yaragina *et al.* (2000), who showed that total lipid energy is a predictor of reproductive potential in fish stocks. Lipids (fats) are high-energy nutrients and are about 15% of fish diets. Their main function in the diet are supplying essential fatty acids (EFA) and being fat-soluble vitamins transporters. Requirements for fish feeding are generally omega 3 and omega 6 fatty acids, this means n-3 and n-6 respectively. These lineal chains can be saturated fatty acids (with no double bonds), polyunsaturated (more than 2 double bonds) or highly unsaturated (more than 4 double bonds). Marine fish oils have a high content (more than 30 %) in omega 3 highly unsaturated fatty acids, so the supply of this fatty acids to the diet is so important, ranging around 0.5-2.0% of dry diet (Budge *et al.*, 2006). The two major essential fatty acids to be apported on diet are eicosapentaenoic acid (EPA: 20:5n-3) and docosahexaenoic acid (DHA:22:6n-3). Freshwater fish do not require the long chain highly unsaturated fatty acids, but often require an 18 carbon n-3 fatty acid, linolenic acid (18:3-n-3), in quantities ranging from 0.5 to 1.5% of dry diet (Budge *et al.*, 2006). This fatty acid cannot be produced by freshwater fish and must be supplied in the diet. Many freshwater fish can take this fatty acid, and through enzyme systems elongate (add carbon atoms) to the hydrocarbon chain, and then further desaturate (add double bonds) to this longer hydrocarbon chain (Devendra, 2009). Through these enzyme systems, freshwater fish can manufacture the longer chain such

as EPA and DHA which are necessary for other metabolic functions and as cellular membrane components (Budge *et al.*, 2006). As marine fish don't have this enzymes systems, these fatty acids are required to be added to the food, because is their only source. Fish are the most important sources of these fatty acids; fatty fish, such as sardines, mackerel, anchovies, and some salmon species, are rich in EPA and DHA. In these fish, the ratio of n-3 fatty acid to n-6 fatty acid approaches 7. Fish cannot synthesize these fatty acids; they obtain them from food they consume (algae and planktons)(Falk-Petersen *et al.*, 1998). However, lipid composition and thus fatty acid composition in fish differ depending on various factors: usually, their aquatic environment (marine water, freshwater, and cold or warm water) and the biological, physical, and chemical properties of that environment. Also, seasonal changes, migration, sexual maturity and spawning period, species, feeding habits, and whether reared in aquaculture or grown in natural habitats affect the lipid/fatty acid composition (Aras *et al.*, 2002).

Generation of NCFR: The generation of non-conventional feed resources is essentially from agriculture and various agro-based industries and is a function of many factors (Mekashaa *et al.*, 2002). Such factors include the quantity and quality of the materials produced which is dependent on the prevailing agro-climatic conditions and cropping patterns, the type of raw materials, the production process, the production rate, the type of inputs used, the regulations affecting product quality use and the constraints imposed upon effluent discharge (Devendra, 1985). Most non-conventional resources are usually regarded as waste which is an inaccurate description of this group of materials. They can be regarded as waste when they have not been shown to have economic value (Mishra *et al.*, 2003). When such waste can be utilized and can be converted by livestock to valuable products which are beneficial to man, they become new feed materials of importance. In addition, they can be used to supplement the existing limited feed resources. Recycling, reprocessing and utilization of all or a portion of the wastes, offers the possibility of returning these materials to beneficial use as opposed to the traditional methods of disposal and relocation of the same residues. The demonstration of potential value can thus make any of these waste products new feeds of value and importance.

Quality/Characteristics of NCFR: According to reports (FAO, 1985), non-conventional feed resources like conventional feed resources have several characteristics worthy of note.

- a) They are the end products of production processes and consumption that have not been used, recycled or salvaged.
- b) They are mostly of organic origin and can be obtained either in a solid, slurry or liquid form.
- c) The economic value of these non-conventional feed resources is usually less than the cost of their collection and transformation for use and consequently, they are discharged as wastes.
- d) Feed crops which generate valuable NCFR are usually excellent sources of fermentable nutrient molecules such as cassava and sweet potato and this is an advantage to livestock especially ruminants due to their ability to utilize inorganic nitrogen and non-protein nitrogenous sources.
- e) Fruit wastes such as banana rejects and pineapple pulp by comparison have sugars which are energetically beneficial.
- f) The majority of feeds of crop origin are bulky poor-quality cellulosic roughages with high crude fiber and low nitrogenous content which are suitable for feeding mostly ruminants.
- g) Some of these feeds contain anti-nutritional components which have deleterious effects on the animals and not enough is known about the nature of the activity of these components and ways of alleviating their effects.
- h) Non-conventional feed resources have considerable potential as feed materials and for some; their value can be increased if there were economically viable technological means for converting them into some useable products.
- i) Substantial information is required on chemical composition, nutritive value, the presence of anti-nutritional components and value in feeding systems.

Constraints to the uses of non-conventional feed resources: Non-conventional feed resources are presently underutilized and there are several reasons for this.

- Production is usually scattered and in some cases, the quality produced is low especially for use in processing of feed.
- Sometimes cost of collection can be unusually high, for example, rubber seeds.
- Processing of NCFR is usually difficult and can be problematic in certain cases.
- Lack of managerial and technical skills in the utilization of such feeds *in situ*.
- Limitation in the end uses of the products produced.
- The uncertainty about the marketability of the end products.
- Small farmers who form the backbone of traditional agriculture in tropical regions have neither the resources and know-how nor the quantity of residues to make any individual impact (Devendra, 1983).

- The availability in terms of time, location, seasonality and storage.
- Low nutritive value
- High moisture content
- Presence of anti-nutritional factors
- Lipid peroxidation (rancidity of high fat products)
- Mould growth such as aflatoxin which may cause toxicity

Growth response of fish fed non-conventional animal feedstuffs: The nutrition is one of the most important factor to consider in fish farming, because it contributes up to 50 % of fish production costs (Omoruwou and Edema 2011). Many scientists have reported on the growth response of some culturable fish species when fed non conventional feedstuffs and most fish farmers have put such findings into practice. Several studies attempted to substitute fish meal with non conventional animal protein sources such as earthworm in *Heterobranchus longifilis* (Sogbesan *et al.*, 2007), Heteroclaris fingerlings (Monebi and Ugwumba 2013), maggot in *Clarias anguillaris* (Madu and Ufodike 2003) and *Clarias gariepinus* (Oyelese 2007), *Clarias gariepinus* fingerlings (Kolawole and Ugwumba, 2018), *Oreochromis niloticus* fingerlings (Ezewudo *et al.*, 2015) snail, termite, tadpole (Tacon and Metian 2008). Blood meal was found to be a good dietary replacement for fishmeal when fed to *Clarias gariepinus* fingerling (Agbebi *et al.*, 2009). The authors stated that growth response of *Clarias gariepinus* fingerling in term of weight gain and feed utilization was most efficient for 25% blood meal. Their results show that fish meal can be replaced completely (100%) by blood meal with no adverse effects on growth, survival and feed conversion of *Clarias gariepinus* fingerling. Hamed *et al.*, (2017) in their study on Effects of blood meal as a substitute for fish meal in the culture of juvenile Silver Pompano *Trachinotus blochii* in a circulating aquaculture system showed highest growth of fish was obtained when 35% of the total dietary protein was replaced by blood meal. They further stated that the juvenile pompano readily accepted the diets at all levels of fish meal replacement by fermented and unfermented blood meals, as shown by the high feed conversion ratios, specific growth rate, and protein efficient ratios. Similar results were reported for other species including juvenile red snapper *Lutjanus argentimaculatus*, where fish protein was replaced with blood meal up to 23% without negative effects on growth performance (Lee *et al.*, 2001), and 40-50% fish meal replacement levels were reported in the diet of seabream, *Sparus aurata* (Davies *et al.*, 1991). In a feeding trial conducted to assess the Effects of Replacement of Fishmeal with Palm Grub (*Oryctes rhinoceros*) Meal on the Growth of *Clarias gariepinus*

(Burchell, 1822) and *Heterobranchus longifilis* (Valenciennes, 1840) Fingerlings. Fakayode and Ugwumba (2013) reported that the differences in the growth and nutrient utilization of the fingerlings on the various diets were generally insignificant ($p > 0.05$) above 25% inclusion level of palm grub. *C. gariepinus* and *H. longifilis* fingerlings fed 25% palm grub inclusion diet had the highest weight gain, relative and specific growth rates. They concluded that palm grub meal can be used to completely replace fishmeal in the diet of *C. gariepinus* and *H. longifilis* fingerling. However, for optimum growth and nutrient utilization, 25% level of replacement of fishmeal with palm grub meal is recommended.

Growth response of fish fed non-conventional plant feedstuffs: Sustainable aquaculture products require inexpensive plant by-products due to finite sources of fish meal (Tabassum *et al.*, 2021). Plant based ingredients used in aquaculture feeds are required to possess certain nutritional values such as low level of starch, fibers and anti-nutrients. There must be present of relatively high protein contents, nutrient digestibility and palatability with favorable amino acid profile (Hussain *et al.*, 2018). The variety of plants and their ingredients in aquaculture feeds includes canola, barley, peas/lupins, corn, cottonseed, wheat, Moringa, groundnut cake, rice bran, pigeon pea, duckweed, and soybeans has been used. Overall, the potential of replacing plant-based proteins into aquaculture feeds is very high but depends upon their availability, relative price and palatability for cultured species (Naylor *et al.*, 2009). Plant-based proteins are ideal and probably will continue to be the main substitute of fishmeal in aquaculture diets (Gatlin *et al.*, 2007; Olsen and Hasan, 2012). According to Hussain *et al.* (2018) costly fish meal can be replaced with cost effective plant by-product of *Moringa oleifera* leaf meal up to 10% without any adverse effects on fish growth performance and nutrient digestibility of *L. rohita* fingerlings. He stated that 10% MOLM inclusion is suitable for maximum increase in fish growth performance and highest nutrient digestibility. Tabassum *et al.* (2021) in their study of partial replacement of fish meal with *Moringa oleifera* leaf meal in practical diets of *Cirrhinus mrigala* fingerlings found that maximum growth performance and improved digestibility of nutrients were found in fish fed with diet at 10% replacement level as compared to fish fed on control diet and other test diets. Additionally, it was found that the red blood cells, white blood cells, hemoglobin and mean corpuscular hemoglobin concentration of fish showed a significantly ($p < 0.05$) inverse correlation with the increase in MOLM. Report on the possible replacement of rice bran with fishmeal in the diet of

fishes showed that 10 % of the fish meal protein in the feed can be replaced by ferment rice protein without any adverse effect on hybrid grouper nutritional status (He *et al.*, 2021). It was observed that there is no significant differences in weight gain rate, specific growth rate, and protein productive value between the fish meal and FRP10 groups, but significantly lower

rates in the FRP30 and FRP50 groups. The activities of the intestinal digestive enzymes (amylase, trypsin, and pepsin) and brush border enzymes (Na⁺/K⁺-ATPase, creatine kinase, and γ -glutamyl transpeptidase) were higher in the FRP-containing groups than in the FM group.

Table 1: Nutritive value of some non-conventional animal and plant protein feedstuff

Feedstuffs	CP %	CL %	CF %	Ash %	NFE %	DM %	G.E Kcal/100g	References
Blood meal	70.1	1.4	-	4.2	-	-	4017	Kwikiriza <i>et al.</i> (2016)
Palm grub	39.8	50.3	12.2	2.4	-	-	-	Fakayode and Ugwumba (2013)
Rice bran	10.7	11.4	14.4	8.2	-	-	-	Arlina and Sukanta (2012)
Moringa oleifera	19.9	-	15.7	5.5	34.6	-	-	Kolawole <i>et al.</i> (2022)
Maggot	45.5	9.0	3.0	12.0	-	-	-	Kolawole and Ugwumba (2018)
Termite	42.0	34.0	-	3.3	-	-	4555.7	Olaniyi <i>et al.</i> , (2016)
Earthworm	60.5	4.7	0.5	39.5	-	-	-	Dedeke <i>et al.</i> (2013)
Cottonseed cake	22.2	6.72	-	7.9	-	-	5025	Kwikiriza <i>et al.</i> (2016)
Duckweed	42.0	-	28.0	18.0	10.5	-	-	Anya and Ayuk (2018)
Carica papaya leaf	27.2	-	6.0	9.2	41.3	-	-	Akanmu and Adeyemo (2012)
Tadpole	43.5	-	34.8	4.3	3.4	97.2	1504.3	Sogbesan <i>et al.</i> (2007)
Chicken offal	56.5	2.6	-	11.3	-	-	4601	Kwikiriza <i>et al.</i> (2016)
Bean seed meal	23.5	1.2	-	8.9	-	-	3617	Kwikiriza <i>et al.</i> (2016)
Sun flower meal	30.1	16.4	-	10.4	-	-	2438.3	Kwikiriza <i>et al.</i> (2016)
Black soldier fly meal	55.0	9.0	-	10.9	-	-	-	Saputra and Fotedar (2023)

Keys: CP (Crude Protein), CL (Crude Lipid), CF (Crude Fibre), NFE (Nitrogen free extract), DM (Dry Matter), GE (Gross Energy)

Techniques to improve utilization of non-conventional feedstuff: A set of technologies has been investigated to improve the nutritive value of low quality feed sources. The most popular ones include ammonia treatment of cereal and rice straws and mixing of several agro-industrial-by products in the form of hard feed blocks (Amata, 2014).

Supplementation: Adequate supply of nutrients may improve the nutritive value of low quality feeds and from a practical point of view, it is believed that supplementation with grains and concentrate feeds is the only way to provide a balanced feed. However in drought conditions, the use of concentrates is usually high and this could lead to significant increases in the cost of feeding. Alternative feed sources may be used as feed for small ruminants but given the lack of definite knowledge of their nutritive value of such alternative sources; such diets given to these small ruminants are often unbalanced and may not be adapted to the physiological state of the animal. Appropriate use of several by-products and browse foliage could partially or totally replace common grains and concentrate feeds without causing any negative effects on livestock performance.

Chemical treatment: An alternative to the use of supplementary feeds is to treat the cereal crop residues by chemical treatment to improve its quality, however such a process requires additional labor and materials and this affects the flexibility of such a process. Chemicals such as ammonia gas or ammonia

generated from urea under anaerobic conditions renders fiber more fragile and disrupt the bond between lignin and other digestible components in fibrous feedstuff such as straws. Ammonia treatment increases crude protein content, feed intake and digestibility of treated straws thereby improving livestock productivity. The high cost of urea and to a less extent plastic sheet cover treated straw however is a main factor limiting adoption of this method by farmers. Attempts have been made to reduce the cost of ammonia straw treatment. Studies (Ben Salem *et al.*, 1995) have shown that mud could be used to cover urea-treated straw instead of plastic sheets.

Ensiling: Although numerous agro-industrial by-products are available in large amounts and are rich in certain nutrients, most of them are not widely used in livestock feeding; examples are tomato pulp which is high in crude protein and citrus pulp which is high in energy. Due to high moisture content of olive cake and tomato pulp for example, there is the tendency for such by-products to become rancid and moldy. Ensiling techniques can be safely used to extend the storage period of these byproducts separately or combined with other by-products such as molasses or wheat bran. Hadjipanayiotou (1999) observed that olive cake preserved well as silage, judging from its aroma, color, pH and the absence of molds and replacing parts of barley hay and straw with olive cake silage in the diets of lactating ewes, goats and cows did not have negative effects on milk yield and fat corrected milk yield. Results from studies on the incorporation of

citrus pulp and wheat straw silage in lamb diets to replace oat hay and 30 commercial concentrates (Scerra *et al.*, 2000) revealed similarities in live weight and carcass weights among the treatment groups. Lambs on silage produced carcasses with better muscular conformation and lower fatness score.

Feed block technology: Agro-industrial by-products especially those with high moisture content can be efficiently used through feed block technology. This technology (Ben Salem and Nefzaoui, 2003) provides flexibility to extension workers and farmers to choose ingredients to be included in the feed block and its use as supplements in drought and other harsh conditions. In addition, the blocks can be prepared when the ingredients' cost is low and stored for later use. These cost effective supplements are solidified mixtures of some known agro-industrial by-products such as olive cake, tomato pulp and molasses to mention a few, urea, binders such as cement and/or quicklime, minerals and vitamins. These block considered as catalytic supplements are able to enhance digestion of low quality fibrous feedstuff through balanced synchronized and fractional supply of main nutrients to the animal on poor diets. Feed blocks may also be used as vehicles for several minerals such as copper and zinc and to improve reproduction performance of small ruminants (Al-Haboby *et al.*, 1999) and as carriers of several reagents mainly polyethylene glycol (PEG) used to deactivate tannins in fodder shrubs and trees (Ben Salem *et al.*, 2000; Ben Salem *et al.*, 2002). Feed blocks may also be used to provide antihelminthic medicines to control gastrointestinal parasites in browsing animals (Anindo *et al.*, 1998) and rumen modifiers such as saponins to decrease protozoa in the rumen leading to higher efficiency of microbial protein production. Of particular interest is the possible use of feed blocks to partially or totally replace expensive concentrate feeds commonly distributed to ruminants on low quality roughages, thereby reducing feeding costs.

Deactivation of secondary compounds: It has been established (Ben Salem *et al.*, 2002) that the nutritive value of acacia foliage is low and animals feeding on this shrub tend to lose weight. These negative effects were attributed to tannins present in the acacia shrub. Satisfactory attempts to improve the nutritive value of this shrub were obtained after feeding trials with polyethylene glycol (PEG -400) in small ruminants (Getachew *et al.*, 2001). These authors showed that slow release of PEG in in vitro incubation system containing tannin-rich feed produced higher microbial protein in the rumen as compared to a one-time delivery of the same amount of PEG in the system. **Tannins in browse foliage:** Tannins in forage legumes

have generally been classified as antinutritional; however it is possible that tannins could be employed advantageously to improve production. In a recent study (Ben Salem *et al.*, 2002) it has been observed that acacia tannins could be advantageously used to increase rumen undegradable proteins in cactus-based diets fed to lambs.

Conclusion: Nigeria has considerable amounts of crop residues such as straws, molasses and other agro-industrial by-products. Several factors however may account for their limited use, among which is low nutritive value and difficulty in handling and using for extended periods. It is essential to increase feeds by growing more fodders, propagating agro and social forestry, improving the nutritive value of crop residues and utilizing other non-conventional feed resources. Many unconventional sources are of very good nutrient profiles which when incorporated into feeds can meet parts of the protein and energy requirements of the fish.

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