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Development of Aquacultural Feeds from Locally Available Feedstuff: A Giant Step towards Food Security in Nigeria

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Abstract
As Nigeria aims for food security for her expanding population, there is need to access the aquaculture sector as a major contributor of animal protein in order to ensure availability and prevent malnourishment. Since the major obstacle to intensive aquaculture profitability is feed availability, importation and subsequently its high price, this paper reviews alternative sources of fish feed production using locally available materials at a lower cost which will help develop this important sector.

Introduction

The boom in global and of course, local population has raised fears in the area of availability of infrastructure, housing, security and employment. However food security may most likely be the most threatening problem. In developing countries, 13.6% i.e. one in seven people are termed “hungry” or are undernourished (FAO, 2010). Protein Energy Malnourishment is the most lethal form of malnutrition/hunger as protein is vital for key body functions including the provision of essential amino acids and development and maintenance of muscles.

Fish is an important source of animal proteins, as 115 million tons were consumed in 2008 (17 kg per capita) all over the world (FAO, 2010; Delgado et al., 2003). In 2007, fish accounted for 15.7% of global animal protein intake and 6.1% of all protein consumed (Delgado et al., 2003). According to FAO (2010), aquaculture continues to be the fastest-growing annual food producing sector and its global growth and succeeded in outpacing population growth (per capita supply increased from 0.7kg in 1970 to 7.8kg in 2008). The fishing sector is a significant source of income and livelihood for millions of people around the world as employment in fisheries and aquaculture has also grown at an average rate of 3.8% yearly since 1980. In 2007, more than 45 million people were directly or indirectly engaged in fish production and about 12% of them were women. In 1980, only 16.7 million people were involved in fish production. Also, estimates from the Food and Agricultural Organization show that for every person involved in fish production, about three more jobs are created in post-harvest processing, sales, marketing and others (FAO, 2010). Nigeria consumes 1.5 million tons of fish annually (about 10kg per capita). However, only about 579,537 metric tons (2005) are locally produced via capture fisheries and aquaculture (USAID, 2008) and more than 900,000 metric tons are

imported. Nigeria, in spite of the gap between demand and supply of fish manages to export aquatic products worth more than 56 million US dollars every year (USAID, 2008). Table 4 outlines the top ten seafood products exported by value.
This large dependency on fish imports is adversely affecting the Nigerian economy and mostly foreign reserves. However aquaculture is rapidly growing in Nigeria. Available data shows a growth from 20,000 metric tons in 1994 to 96,000 metric tons in 2000 (Fagbenro et al., 2003).

Table 1. Regional share of aquaculture production by continent.

Region	% of World Production
Asia	91.22
Europe	4.02
South America	1.96
North America	1.60
Africa	0.97

Source: FAO (2003); (Gabriel et al., 2007)
Table 2. Ten biggest aquaculture producers in Africa (2001 - 2003).

Country	2001 (metric tons)	2002(metric tons)	2003(metric tons)
Egypt	342,310	376,296	445,181
Nigeria	24,398	30,663	30,677
Madagascar	7,749	9,713	9,507
Tanzania	7,300	7,630	7,002
Ghana	6,000	6,000	6,200
Zambia	4,520	4,630	4,501
South Africa	4,329	5,555	7,720
DR Congo	2,744	2,965	2,965
Uganda	2,360	4,915	5,500
Zimbabwe	2,285	2,213	2,600

Source: (FAO, 2003; Gabriel et al., 2007)

Table 3. Human population and fish demand in Nigeria (2010 to 2020).

Year	Population (millions)	Demand (million tons)
2010	158.8	3.02
2011	163.9	3.11
2012	169.1	3.21
2013	180.1	3.42
2014	180.1	3.42
2016	191.9	3.65
2018	204.3	3.88
2020	217.6	4.13

Source: FDF, 2007.
Note: From 2011, the figures are projections

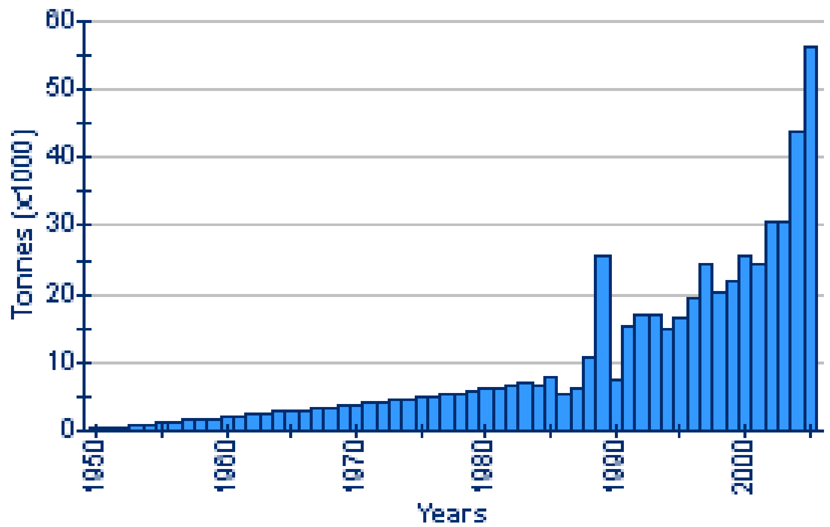

Figure 1: Nigerian fish production (wild capture) Source: FAO (2003)

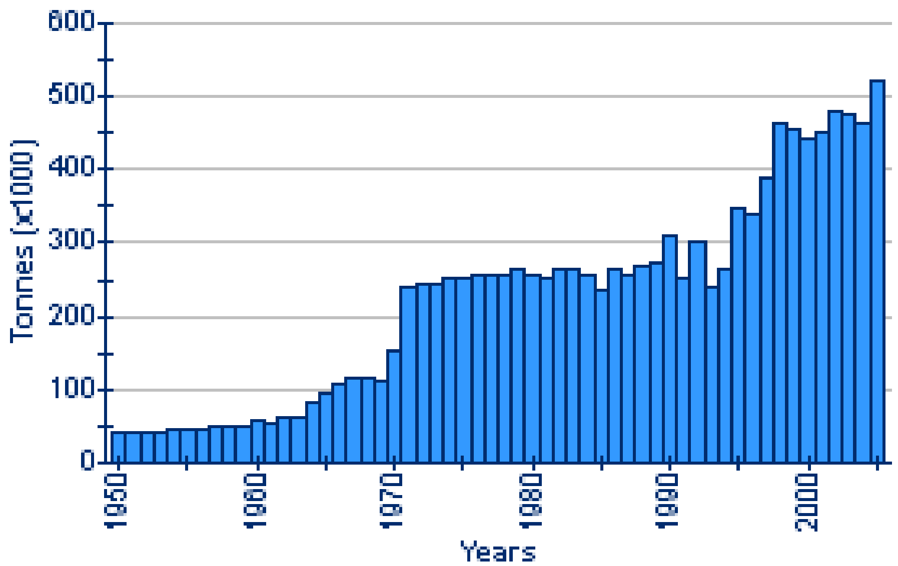

Figure 2: Nigerian Fish production (Aquaculture) Source: FAO (2003)

Capture fishery, practiced in riverine areas has been badly affected by rural-urban migration of youths and most importantly oil discovery and subsequent pollution of Niger Delta waters (Gabriel et al., 2007) and communities which once thrived on fishing have been forced to abandon their trade as oil spillage has destroyed the necessary balance for the fish to thrive. Aquaculture, however, is increasing and rapidly expanding due to easy nature and low space requirements (unlike capture fishery). Species of fish produced in Nigeria include: *Clarias gariepinus, Heterobranchus bidorsalis, Clarias nigrodigitatus, Heteroclarias spp, Tilapia, Sarotherodon galilaeus, S. melanopleura, Chrysicthys nigrodigitatus, Cyprinus carpio, Carasius spp, Heterotis nilticus, Mugil cephalus, Liza falxipinnis, Parachanna obscura.* Table 5 shows the amounts of each species produced in Nigeria in 2003.

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Table 4: Top 10 fish species exported by value

Shrimp and prawns	52,100,000
Frozen crab	1,100,000
Fish fillet	900,000
Cuttlefish	600,000
Marine fillet fish (frozen)	200,000
Dried Fish	100,000
Molluscs	100,000
Crab meat	60,000
Shrimps and prawns, not frozen	40,000
Crustaceans	30,000

Source: FAO (2003)

Table 5. Aquaculture production in Nigeria in year 2003.

Species	Tons produced
Tilapia, (*O. niloticus*), *O. niloticus* × *Oreochromis aureus* hybrid)	11,363
Tilapia *Sarotherodon galilaeus, Sarotherodon melanopleura, T. zilli, T. guinensis*	3,025
Mud catfishes (*C. gariepinus, C. anguillaris, C .isheriensis*)	6,553
Catfish *Heterobranchus bidorsalis, H. longifilis*, *Heterobranchus* × *Clarias* hybrids	2,832
Brackish water catfish (*Chrysicthys nigrodigitatus*)	1,515
Carp (*Cyprinus carpio*); goldfish (*Carasius* sp.)	1,280
Heterotis (*Heterotis niloticus*)	654
Mullets (*Mugil cephalus*, *Liza falcipinnis*)	336
Snakehead (*Parachanna obscrura*)	297
Other fishes	2,921
Total	30,776

Source: (Fagbenro et al., 2003).

From the above table, the predominant species of fish commonly cultured are Tilapia and Catfish.

According to Fagbenro et al (2011), tilapia culture in Nigeria began in 1951 at Onikan. Nigeria, is the second largest producer of tilapia in Africa, behind Egypt with 19,546 tons in 2005 with tilapia accounting for over 42% of total aquaculture production. (Fagbenro et al., 2003).

Over 25 species of tilapia exist, but six main species are cultured. They are *Oreochromis aureus, Oreochromis niloticus, Sarotherodon galilaeus, Sarothodon melanotherm, Tilapia guineensis* and *Tilapia zili.*

These species are preferred because they grow fast, use naturally occurring aquatic food efficiently and consume a vast variety of supplementary feeds (as they are omnivorous). They are also resistant to disease and handling, tolerate wide ranges or fluctuations in water and environmental conditions while reproducing quickly with high survival rates.

The last feature is an advantage as well as a disadvantage as pond crowding is common-place in grow-out tanks resulting in stunting due to poor availability of natural food organisms in the pond and competition (Fagbenro et al., 2003). This leads to the use of a range of control measures of which the use of predatory fish has been reported to be the best (Fagbenro et al., 2003). Fish species used as control include *Clarias spp* like *C. isheriensis, C. gariepinus, C. lazera, Heterobranchus bidorsalis,, H. longfiliis, Parachanna obscura, Hernichromis fasciatus.* Tilapia is cultivated in ponds, cages, hapas and concrete tanks. In 2000, more than 14,000 tons were produced. This figure increased to 19,546 tons in 2005 (Fagbenro et al., 2011).

The African catfish, according to Udo and Umoren (2011), has been identified as one of the fish species with the greatest potential to contribute to the growth of fish production in Nigeria as it contributed about 35% of total production in 2003.

To perpetuate the proliferation of aquaculture in Nigeria and its growth, there is need to tackle the challenges it is currently facing. These include poor management, inadequate supply of good seed stock (estimated minimum fingerling requirement is 4.3 billion while supply is a paltry 55.8million), lack of sufficient capital, faulty data collection, lack of environmental impact assessment, poor marketing skills and importation and subsequently high cost for feed and drugs.

Fish feed consist of natural food and artificically prepared rations.

Natural food includes microscopic plants (phytoplankton), microscopic animals (zooplankton), insects, crustaceans, copepods and mollusks. Their presence can be induced or multiplied in a pond by the process called ‘fertilization’. This is accomplished by releasing necessary nutrients required for their optimal growth into the water. Locally, this is achieved by submerging poultry droppings into the pond for about five days before fish is introduced (Sikiru et al., 2009; Faruque et al., 2010; Wurts, 2003). Fish can survive on natural food alone if it is abundant in the ponds. However, for practical aquaculture, fish are stocked at very high densities and fertilization of ponds may not reach optimal levels. Also, competition in the pond leads to quick depletion of natural food. Thus, there is need for supplementation of natural food with artificially formulated feeds which must contain all essential nutrients. These feeds are compounded from plant and animal sources of nutrients. They are utilized in aquaculture as they enable the farmer to increase stocking density, increase yield and to monitor the fish while feeding (to know when fish are sick or not feeding well). It also promotes faster growth of fish (as feed is always available) while promoting the growth of natural pond organisms (as uneaten artificial feed can help fertilize the pond).

However, Nigerian feed resources have, according to Udo and Umoren (2011) been declining due to the stagnant or diminishing output of important crops. Statistics released by FAO (2008) report a chronic dependence on imports for an expanding livestock/aquaculture industry. This is evident in the ever-increasing prices of feedstuff and food stuff in the country. The importation of fish and fish products is an urgent reminder that the demand for aquacultural products is at at all-time high and will keep increasing. The most important question, however, is “Can aquacultural products be obtained at a competitive price when compared to imports and capture fisheries? To answer this question, aquacultural costs have to be drastically reduced.

Table 6: Animal populations and feed production in Nigeria (as at year 2000)

	Traditional management (%)	Commercial management (%)	Population (millions)	Feed (tones)	%
Poultry	72.79	27.21	155.28	2,591,732	68.20
Pig	91.11	8.89	7.91	1,084,214	28.53
Rabbits	98.50	98.50	2.23	88,509	2.33
Fish	81.36	18.64	65.8	35,570	0.94
Total			231.22	3,800,025	100

Source: (Fagbenro and Adebayo, 2003)

Table 7: Nutrient Composition (dry matter basis) of zooplankton

Proximate (%)		**Amino Acids (% Protein)**					
Dry Matter	77	Arginine	7.1	Glycine	4.8	Aspartic acid	7.9
Crude Protein	72.5	Histidine	3.0	Serine	4.1	Glutamic Acid	12.5
Crude Fat	6.2	Isoleucine	4.1	Tyrosine	6.1	Proline	4.3
Fiber	10.7	Leucine	7.3	Threonine	4.5	Lysine	6.8
NFE	8.1	Methionine	2.3	Tryptophan	0.9	Phenylalanine	3.9
Ash	2.6	Cysteine	1.1	Valine	4.6	Alanine	8.0

Vitamins				**Mineral (%)**			
D	110.0 IU/lb	Niacin	141.0ppm	Phosphorus	0.93	Iron	622 ppm
E	115.0 ppm	Panthothenic Acid	20 ppm	Calcium	0.39	Manganese	113 ppm
B_1	3.4 ppm	Inositol	1,565ppm	Sodium	0.15	Zinc	76 ppm
B_2	100 ppm	Biotin	1.5 ppm	Potassium	0.38	Copper	16 ppm
B_6	2.5 ppm	C	164 ppm	Sulphur	0.72		
B_{12}	2.2 ppm	Folic Acid	1.2 ppm	Magnesium	0.12		

Fatty Acids (% Fat)			
14:0	1.3	20:4 n-6	12.0
16:0	16.4	20:5 n-3	4.3

16:1	7.1	22:5 n-3	1.5
18;0	6.2	22:6 n-3	13.9
18;1	4.1	Total n-3 HUFA	28.4
18:2 n-6	6.3	Total n-6 HUFA	11.1
18:3 n-3	5.9	n-3/n-6 ratio	2.6

Source: (Robinson et al., 2001)

Feed is, without question, the single most expensive input in intensive fish culture (Agbebi et al, 2009) especially for catfish which needs a high protein diet (as it is cannibalistic). This is due to the cost of raw materials, which are usually imported and are necessary for its production (fish meal and wheat offal or corn products). Research has shown that most imported feedstuff can be replaced by locally available feedstuff (Agbebi et al., 2009; Tacon, 1990; Otubusin et al., 2009; Gabriel et al., 2007; Narrejo et al., 2010; Okanlawon and Oladipupo, 2010; Faruque et al., 2010). This, therefore, entails the production of fish feed from locally available materials using local technology in order to reduce the cost and improve availability of feed to farms.

Fish require a lot of protein, especially catfish species, which incidentally are increasingly farmed in Nigeria. They also require a source of carbohydrates and fibre. Fats and oil are also required minimally. Out of the 10 Essential Amino Acids (EAA) required for optimum fish growth only three have been exhaustively studied (methionine, lysine and arginine). In order to formulate and compound aqua-feeds that will meet the nutrient requirements of the catfish at affordable cost, several conventional and non-conventional animal by-products and plant residues have been tested to substitute or replace fishmeal. For example, Olele (2011) used earthworms, Nnaji et al (2010) used three leaf meals including *Manihot esculenta,* Effiong et al (2009) used duckweed, Akagbejo-Sampson and Fasakin, (2008) used rendered animal proteins such as blood meal and meat meal, Fagbenro (1998) tested various oilseeds and cakes, Adebayo et al (2004) used *Cassia fistula* meal, Agbebi et al (2009) used blood meal, Otubusin et al (2009) used soybean meal and blood meal, and Okanlawon and Oladipupo (2010) investigated snail offal meal. Feeding development has moved from the use of single ingredient, broadcasting unpelleted meal to use of multiple-ingredient pelleted feeds. Fish may be fed sinking or floating pelleted feeds. The sinking pelleted feeds are fairly common and less costly to manufacture than the floating, or extruded, floating feeds. However, the use of pelleted floating feed has made a big difference to aquaculture development in Nigeria as *C. gariepinus* is being raised to maturity within 6 months (Sikiru et al., 2009). Better feed conversion ratios (FCR) are obtained in general with floating feeds than with sinking feeds as floating feeds offer the fish more time to swallow them.

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Table 8: Amount of some crop residues produced in Nigeria

Crop Residues	Availability ('000 tons)
Rice Bran	292
Rice Straw	1,947
Maize Offal	25
Maize Stover	11,186
Cowpea vines	9,367
Soybean Haulm	702
Beniseed Haulm	1,934
Groundnut Haulm	3,477
Cottonseed Cake	12
Cassava peels	636
Yam peels	2
Sweet Potato peels	5
Sweet Potato vines	1
Total	29,586

Table 9: Amount of Agricultural crops produced in Nigeria and their cost (2000)

Crops	Amount Produced (tones)	Price per kilogram (Naira)*
White maize	5,472,850	320
Yellow maize	3,216,118	330
Sorghum	7,442428	280
Millet	6,265,590	210
Rice	1,862,119	400
Wheat	1,862,119	400
Maize bran	587,068	500
Rice bran	217,856	100
Wheat offal	25,172	140
Sorghum bran	189,580	80
Broken rice	17,184	180
Distiller's spent grain	285,450	110
Shrimp heads	24,000	US $300
Shrimp shells	10,900	US $180

Prices may not be accurate due to market fluctuations (1 US dollar=155naira) Source: (Fagbenro et al., 2001)

The following locally available materials have been used in the formulation of fish feed.

Table 10: Proximate Contents of Some Local feedstuff available in Nigeria

Feedstuff	% Protein	% Fat	Fibre (%)	CHO (%)	% Dry Matter	Mineral (%)	C.R.
Maize (white)	9.3	5.0	2.4	70.9	88.0	1.8	5
Maize (yellow)	10.8	3.6	3.5	71.2	88	1.9	5
Guinea corn	11.2	2.5	2.3	74.1	88	1.8	5
Palm Kernel Cake	19.1	7.6	43.2	17.9		5.5	8
Cottonseed cake	40.1	8.3	31.9	12.4	91	5.1	5
Rice Bran/Husk	9.9	4.4	40.2	8.7	91	21.8	5
Groundnut Cake (Industrial)	48.0	13.2	8.1	18.9	93	6.3	5
Groundnut Cake (Kuli-kuli)	40.6	23.4	6.0	19.0	93	6.2	5
Raw Soybean	40.7	22.0	6.3	16.6	90	6.4	4
Soybean meal (slightly toasted)	46.2	24.8	4.7	17.2	90	7.9	4
Soybean meal (toasted severally)	48.1	23.9	4.1	20.7	90	7.9	4
Fish meal (Tilapia)	57.7	1.8	5.2	-	92	33.6	2
Cow Blood Meal	86.0	0.7	2.1	6.5	92	5.0	2
Millet	9.0	5.0	0.7	83.2	90	2.3	5
Flour Mill Sweepings	12.5	14.5	7.5	58.0	-	-	-
Brewer’s Waste	22.8	17.8	18.8	46.4	93	-	10
Cassava (Peeled)	2.6	0.5	0.4	94.1	88	2.4	18
Cassava (Peels only)	5.3	1.2	21.0	66.6	88	6.0	18
Cassava (Unpeeled)	2.7	0.5	3.1	91.0	88	16.1	18
Cassava Leaves	14.7	8.4	15.6	45.2	88	16.1	18
Water Leaf	21.1	1.5	10.3	87.4	-	4.6	-
Duckweed meal	24.8	-	12.06	-	92.3	-	-
Distiller’s Grains	29.0	3.7	7.8	-	91	-	-
Canola meal	38	3.8	11.1	-	91	-	-
Hydrolysed Feathers	85	2.5	1.5	-	93	-	-
Poultry by-product	58	14	2.5	-	94	-	-
Wheat grain	13.5	1.9	3	-	88	-	-
Wheat middlings	17.7	3.6	7	-	89	-	-
Shrimp waste meal	58.9	-	33.5	-	79.5	-	-
Cocoyam	25.1	-	28.56	-	87.0	-	-
Cowpea	16.6	19.0	4.3	40	-	-	-
Cassava (flour)	1.6	0.5	1.7	83.3	-	-	-
Yam	1.5	0.1	0.9	25.6	-	-	-
Palm Kernel Cake	19.9	8.9	14.0	53.0	-	-	-
Sugar Cane Fiber	1.3	0.64	0.0	55.4	-	-	-
Banana (whole)	6.5	1.8	5.3	79.2	-	-	-
Pawpaw leaves	32.6	0.8	17.2	18.38	-	-	-

Paw-paw fruits	4.1	0.6	11.5	24.6	-	-	-
Cocoyams	9.4	0.75	8.8	33.18	-	-	-
Cocoyam peels	20.62	11.7	12.2	9.43	-	-	-
Plantain	4.59	1.6	8.0	27.43	-	-	-
Plantain peels	9.2	5.6	17.2	18.4	-	-	-
Banana peels	7.9	11.6	13.4	14.1	-	-	-
Sweet potato	5.4	0.5	1.0	28.1	-	-	-
Sweet Potato peels	6.3	0.2	4.6	11.7	-	-	-
Sweet Potato leaves	24.7	3.6	11.5	12.5	-	-	-
Rice (Unpolished)	7.5	0.5	0.2	79.9	-	-	-
Rice (Polished)	13.7	11.9	6.8	37.0	-	-	-
Spinach	2.1	0.2	0.8	4.5	-	-	-
Groundnut shells	4.0	1.0	46.7	46.3	-	-	-
Locust	25.5	2.0	0.0	1.4	-	-	-
Mussels	18.4	0.8	0.0	0.0	-	-	-
Chironomids	9.1	13.1	0.0	0.0	-	-	-
Silkworm (pupae)	55.9	24.5	0.0	6.6	-	-	-
River snails	12.2	1.4	0.0	4.3	-	-	-
Palm Kernel Cake	20.40	9.00	-	-	91.60	-	
Shrimp waste meal	58.90	3.35	-	-	79.50	-	
Earthworm Meal	63	1.9	-	-	91.4	-	-
Garden Snail Meal	66.8	7.9	-	-	91	-	-
Termite Meal	46.3	30.1	-	-	96.3	-	-
Un-skinned dried Tadpole Meal	43.5	17.2	-	-	93.2	-	-

Source: (Udo and Umoren, 2011; Eyo et al., 2004; Okanlawon and Oladipupo, 2010; Gabriel et al., 2007; Sikiru et al., 2009; Agbebi et al., 2009; Otubusin et al., 2009)

Table 11: Availability and Price (US$/ton) of feedstuff in Nigeria (as at 2000)

Fishmeal	Source	Quantity (tons)	Price (US$/ton)	Availability
Local Production	Commercial	8,050	650	Low
	Artisanal	710	530	Low
Imports	65% C.P.	44,386	870	Low
	72% C.P.	12,107	1350	Scarce

Product	Quantity (tons)	Price (US$/ton)	Availability
Blood Meal	55,094	320	Adequate
Poultry by-product meal	23,750	200	Low
Hydrolyzed feather meal	18,656	125	Low
Groundnut cake	632,749	320	Adequate
Cottonseed cake	520,160	300	Adequate
Palm Kernel Cake	405,144	75	Adequate
	80,204	480	Low

Soybean (Local) cake (Imported)	208,746	550	Adequate
Sesame seed cake	39,825	100	Low
White maize	5,972,850	320	Adequate
Yellow maize	3,216,118	330	Adequate
Sorghum	7,422,428	280	Adequate
Millet	6,265,590	210	Adequate
Rice	1,862,119	400	Low
Wheat	587,068	500	Low
Maize bran	217,856	100	Adequate
Rice bran	392,946	150	Adequate
Wheat Offal	25,172	140	Low
Sorghum bran	189,580	80	Adequate
Broken rice	17,184	180	Low
Distiller's spent grain	285,450	110	Adequate
Shrimp Heads	24,000	300	Adequate
Shrimp Shells	10,900	180	Low

Product	Price (US$/ton)	Availability
Pigeon pea	250	Low
Jack/sword bean	100	Low
Winged bean	250	Low
Cowpea	370	Adequate
Locust bean	90	Adequate
Bone meal	0.36	Adequate
Oyster shell meal	0.08	Adequate
Sodium Chloride	0.15	Adequate
Lysine	5.20	Low
Methionine	5.20	Low
Fish oil (imported)	3.75	Scarce
Palm oil	1.15	Adequate
Groundnut oil	1.70	Adequate
Soybean oil	1.45	Adequate
Coconut oil	2.30	Scarce
Corn oil	1.35	Scarce
Olive oil	1.10	Scarce
Mixed Vegetable oil	1.10	Low

Source: (Fagbenro and Adebayo, 2003)

Other feed stuff include beans such as Mucuna bean, lima bean, jack bean, sesame seed, roselle seed, kenaf seeds, mango seeds, defatted cocoa cake, cocoa pod husk, sorghum and cassia seed meal. Certain feed stuff designated as Non-Conventional Feed Resources (NCFR's) include silk worms, housefly maggots, termites, earthworms, grubs, snails and tadpoles (Sogbesan and Ugwumba, 2008; Okonlawon and Oladipupo, 2010). They are non-competitive in terms of human consumption and are cheap by-products or waste products and their use sometimes enhances environmental sanitation.

Fish, like other animals require nutrients for normal metabolic functions and adequate growth and development, which is the goal of every aquaculturist. Fish nutrition, however, is an inexact science as it is affected by many factors including sex, feed intake, natural interactions, availability, presence of toxins or molds in diet, expected level of performance, natural variance between individuals of a given species and environmental factors such as water quality (Robinson et al., 2001).

Nutrition

Basically, two types of feeding regimes are practiced in fish culture

Natural food/pond organisms supplied by the pond which is akin to pasture grazing in terrestrial animals and the use of artificial feeds which may be likened to stall feeding.

Feeding regimes are dependent on the feeding habits of the fish species under culture. Filter-feeding fishes such as (*Oreochromis niloticus*) feed primarily on natural pond organisms. These organisms include zooplankton and phytoplankton such as copepods, cladeceras and larvae or adults of some invertebrates and amphibians. The growth and proliferation of pond organisms (including *Daphnia spp, Moina spp, Branchiones spp, Asplanchma priodonta* and *Chlorella spp)* can be encouraged by 'fertilizing' the pond. Fertilization of the pond can be achieved by the introduction of organic or inorganic fertilizers. Organic fertilizers include cow dung, abattoir wastes, poultry wastes or entrails and compost. Inorganic fertilizers include NPK (15:15:15), urea or phosphatic fertilizers. For inorganic fertilizers, those in liquid formulation are preferred.

The use of organic fertilizers is preferred over inorganic fertilizers as they are widely available, cheaper and are easy to use. Poultry droppings or waste seems to be the preferred organic fertilizer in use. Within three to five days, an algal bloom is evident.

When natural pond organisms are not available or insufficient, artificial feeds must be used to supplement feeding. These feeds are produced from locally available or imported nutrient sources.

Traditionally and prior to the oil boom of the 1970's, Nigeria relied heavily on agricultural production to supply major portion of GDP. The following crops were produced in large quantity:

Cereals: Maize, millet, acha, sorghum, rice, wheat, guinea corn

Grain legumes: cowpeas, soybean, green peas, pigeon pea, lentils, jack beans, lima beans and groundnuts.

Root crops/Tubers: Cassava, yam, cocoyam, sweet and irish potatoes

Oilseeds: Beniseed, cottonseed, palm kernel and soybean

Industrial crops: Cotton, tobacco, kenaf, sugar cane, eucalyptus, gmelina

Nuts: kola nut, cashew nut, coconut, palm nut

Tree crops: Cocoa, palm products, copra, coffee, tea and rubber.

These plants and the animal husbandry sector are a good source of feedstuff.

Several nutrients are indispensable for fish metabolism, growth and development. They include

Protein

Since protein makes up more than 70% of the dry weight of fish muscle, a continous supply must be ensured. Fish require a source of non-specific nitrogen and indispensable amino acids. Several species such as *Clarias spp* are carnivorous and thus require higher protein level in feed. Age affects protein requirements also as fry and fingerlings require higher levels of protein (more than 40%) for quick development, while growers and brood fish require 35-38% protein.

Feedstuff containing 20% or more crude protein is considered as protein supplements (Gabriel et al., 2007; Wurts, 2003; Robinson et al., 2001). Plant protein supplements locally available include legumes and their derivatives such as soybean and groundnut (and their cakes or meals).

Plant protein supplements are, however, deficient in amino acids such as lysine and methionine and may contain toxins or anti-nutritional agents or factors that may not be destroyed or inactivated during feed processing (Robinson et al., 2001).

Animal protein supplements are the major source of high quality amino acids in feed formulation. They consist of inedible tissues from meat packaging industries, milk products and marine sources. These include blood, hydrolyzed feathers, meat, bone meal and fish meal (Abowei and Ekubo, 2011; Adeniji and Balogun, 2003).

Fish meal is an important source of proteins in the commercial feed production industry. It is obtained from the undecomposed carcass of waste fish, usually from marine trawlers or fish processing wastes such as heads or entrails (Robinson et al, 1994; Effiong et al, 2009). The use of raw fish, however, as an ingredient in fish feeds has been shown to be detrimental to the optimal growth and development of fish due to the presence of thiaminase, a potent anti-nutrient which destroys thiamine (vitamin B_1) (Robinson et al., 2001). Raw fish has also been implicated in the spread of diseases/pathogens such as mycobacterium and botulism Robinson et al., 1994). Thiaminase is mostly found in fresh water fish and is deactivated by heat. Fish meal contains 60-80% protein of excellent quality which is highly palatable to fish (Effiong et al., 2009). It may be used at levels of up to 50% for fry feeds, 12% in fingerling feeds and 8% in grow-outs (Robinson et al., 2001). However, fish meal is very costly and this has, in a bid to reduce costs, precipitated research into substitution with other supplements. Agbebi et al (2009) showed that fish meal can be partially or completely replaced by other animal protein sources (like blood meal) in diets for grow-outs with even better results.

Other animal protein sources include

Blood Meal: Rich in lysine, but deficient in methionine, blood meal is prepared from clean fresh animal blood and is the most protein dense supplement (80-90% crude protein). It is readily available, cheap and has been used to replace fish meal in grow-out feeds with excellent results (Agbebi et al., 2009).

Meat/Bone Meal: Meat/Bone meal contains about 50% crude protein but is considered inferior to whole fish meal as it contains less lysine and has very variable consistency. It is a very rich source of minerals but its high ash content limits its use in feed production (Akagbejo-Sampsons and Fasakin, 2008; Robinson et al., 1994).

Poultry By-Product Meal: This consists of dried and ground carcasses of slaughtered poultry. It may contain wastes such as heads, feet and visceral organs or underdeveloped eggs. It contains up to 60% crude protein. Its supply is erratic and unstable and it may not be readily available for use (Sogbesan and Ugwumba, 2008).

Hydrolyzed Poultry Feathers: These are obtained from high pressure treatment (in the presence of calcium hydroxide) of clean undecomposed poultry feathers. It is high in digestible protein but is seldom used due to lack of technology and difficulties in collecting significant quantities of feathers.

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Housefly (*Musca domestica*) larvae thrive in damp, decaying organic matter which serves as food and breeding ground for adults and also sustains larvae. These conditions may be simulated with waste fish, finely ground maize or soybeans and dung. Processing is via oven drying, kiln smoking or pulverizing. They can be fed whole or processed with the substrate.

Earthworm (*Lumbricus terrestris, Allobophora spp)* meal: Earthwrom are detritivorous terrestrial oligocheate worms. They live in soil, feed on decaying matter and other organic matter, egesting worm caste while breaking down human and animal waste. They are hermaphrodites and so reproduce very quickly. Commercial production usually involves the heaping of organic wastes in swampy land and harvest may commence in six months. Processing is also by pulverizing, kiln smoking or pulverizing.

Shrimp meal: The Nigerian shrimp industry is predominantly an export-oriented industry with annual revenues of about US$2.4million and annual production of 72,000 tons. Processing of the shrimp generates about 35,000 tons of waste (heads and shells) from which it is calculated that 8,820 tons of dry shrimp meal can be produced per annum (Fagbenro et al., 2003). Shrimp meal acts an attractant and protein source although its high chitin content restricts its inclusion in animal feeds.

Tadpole meal: Frogs and toads breed at the commencement of the rainy season and eggs which hatch into tadpoles are laid in stagnant pools of water. Since these tadpoles metamorphose into adults in 2-3 months, they can be cultivated just like fish. Processing is also by drying, smoking or pulverizing. They can also be fed whole to fish. It has been evaluated as a cost effective substitute for fish meal in feeds.

Adewumi et al (2011) reported that the effectiveness of cow, chicken and pig manure as a direct fish feed has been tested in a variety of fish including Common carp (*Cyprinus carpio),* tilapias (*Sarotherodon mossambica),* channel catfish (*Clarias gariepinus)* and goldfish (*Carassius auratus).* They were incorporated into standard feed pellets as replacements for higher quality feed stuff. They were found to be more cost effective (at almost zero cost) although they contained lower quality protein.

Table 12: Dietary Protein Requirements of some locally cultured fish species

Fish species	Fry	Fingerlings	Juveniles	Adult
Tilapia (*Oreochromis niloticus)*	50-55	35-40	30-35	25-30
Catfish (*Clarias spp)*	50-55	40-45	35-40	35-40
Carp (*Cyprinus carpio)*	50-52	38	30-35	25-30
Grass Carp (*Cternopharynglo idella)*	50	41-43	30	25

Source: NAERLS (2002)

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Table 13: Essential Amino Acid Profile of some Non-conventional Feed Materials

Essential Amino Acids (%)	Earthworm	Fly Larvae	Fish Meal	Garden Snail	Termite	Unskinned Dried Tadpole	Soy Bean Meal
Arginine	3.17	5.42	5.82	11.99	2.87	3.63	3.11
Histidine	1.38	3.50	2.22	1.77	1.28	2.65	1.12
Isoleucine	2.20	4.13	4.05	6.23	1.70	2.32	2.42
Leucine	4.11	6.95	7.35	6.79	3.11	3.26	-
Lysine	2.52	7.37	7.85	5.10	2.82	6.97	2.67
Methionine	1.11	3.06	3.54	1.33	1.68	2.08	6.66
Phenylalanine	2.02	15.05	7.80	5.04	1.97	3.98	-
Threonine	2.48	4.53	4.55	5.91	1.67	3.73	1.88
Tryptophan	0.44	1.45	1.33	-	-	-	0.88
Valine	2.52	5.60	5.65	5.90	2.26	3.86	2.42
Total EAA	37.11	-	50.36	50.66	19.36	32.48	21.16
Crude Protein	63.04	-	71.64	66.96	46.32	43.50	47.5

Source: (Sogbesan and Ugwumba, 2008; Abowei and Ekubo, 2011; Solomon et al., 2007)

Table 14: Comparism of Chemical Score, EAA:CP ratio and CS/CP ratio of some non-conventional protein source

Animal Protein Meal	Chemical Score	CS/CP	EAA:CP
Earthworm Meal	71.5	54.5	0.60
Garden Snail Meal	95.9	68.9	0.76
Termite Meal	37.5	38.9	0.43
Un-skinned Dried Tadpole Meal	62.6	69.1	0.76
Fish Meal	64.9	64.9	0.72

CS/CP: Chemical Score divided by Crude Protein EAA:CP Essential Amino Acid : Crude Protein Ratio Source: (Sogbesan and Ugwumba, 2008)

Energy

Two nutrients are responsible for the supply of energy in fish feed formulations. They are carbohydrates and lipids. Carbohydrates are the most inexpensive sources of energy, tissue constituents and may also serve as precursors for hormones and other metabolic intermediates. Fish, however, can obtain energy from proteins and lipids and as such there is no carbohydrate requirement. Carbohydrates are obtained from grains (and their by-products). They consist of starch, sugars, cellulose and gums. They replenish blood glucose (which is maintained at 0.05-0.1%). Certain carbohydrates are used more efficiently than others. Starch or dextrin, for example, has been found to be used more efficiently than sugars such as glucose and sucrose. In feed formulation, carbohydrates help to bind the feed together and increase the expansion of extruded feeds so that they are water stable and can float.

Lipids (fats and oils) are an important source of concentrated energy (more than two times the energy content of carbohydrates of same weight). They supply essential fatty acids and help in absorption of fat soluble vitamins. They also increase feed acceptance and may serve

as precursors to hormones and possibly pheromones. Certain fatty acids cannot be synthesized by fish. These are known as essential fatty acids (EFA) and must be supplied in the diet. These requirements can be met from natural pond organisms such as planktons and as such deficiencies are rarely found in naturally growing fish.
Even though it is more economical to use the energy dense lipids instead of the more expensive proteins as an energy source, lipid content is usually limited to 5% as feeds high in lipid content are difficult to pellet. Supplemented lipids are then sprayed on top of the finished feeds and they help in reducing fines, dust and also increase buoyancy of the feeds in water (since oils float on water). Also, a mixture of vegetable and animal lipids is recommended as high inclusions of fish oil can impart a 'fishy' flavor to the fish.

Table 15: Nutrient Requirements of *Clarias gariepinus* grow-outs

Nutrient	Recommended
Protein (%)	26-32
Essential Amino Acids (% of proteins)	
Arginine	4.3
Histidine	1.5
Isoleucine	2.6
Leucine	3.5
Lysine	5.1
Methionine	2.3 (Cystine can replace 60% of methionine requirement
Phenylalanine	5.0 (Tyrosine can replace 50% of phenylalanine requirement
Threonine	2.0
Tryptophan	0.5
Valine	3.0
Digestible (kcal/g protein)	8.5-10
Lipid (%)	4-6
Carbohydrate (%)	25-35
Crude fibre (%)	7% max

Source: (Robinson et al., 2001)

Vitamins
are highly diverse organic substances that are required in minute quantities for optimum growth, health and reproduction. Their absence leads to conspicuous deficiency signs or diseases in fish. However, vitamin deficiencies in fish are very rare in nature as natural pond organisms are a rich source of vitamins. Vitamin requirements are subject to variations due to sex, fish size, feed formulation, disease and environmental factors such as water quality.

Table 16: Vitamin Requirements of *Clarias gariepinus* grow-outs

Vitamin	Requirements
A	1,000 IU
D	3500IU
E	30ppm
K	4.4ppm
Thiamine	2.5ppm
Riboflavin	6ppm
Pantothenic acid	15ppm
Biotin	0
Nicotinic acid	0
B_{12}	0.01ppm (Synthesized in catfish intestines
Choline	None (abundant in most feedstuff)
Inositol	0
Ascorbic Acid	50ppm

Source: (Robinson et al., 2001)

However, due to processing methods especially extrusion techniques, many vitamins included in feed are destroyed. The retention of vitamins in feed is particularly influenced by the source of the vitamin and the coating or preservative agents added. Retention of vitamins in feed varies from 43% for ethyl cellulose coated ascorbic acid to 100% for vitamin E, riboflavin and pantothenic acid. The following table illustrates the retention of vitamins in extrusion-processed feeds.

Table 17: Retention of vitamins in extrusion-processed feeds

Vitamin	Retention (%)
Vitamin A	65
Vitamin E (D L-alpha-tocopherol acetate)	100
Thiamine (thiamine mononitrate)	64-67
Riboflavin	100
Vitamin B-6 (pyridoxine hydrochloride)	67-70
Folic acid	91
Niacin	96
Pantothenic acid	100
Ascorbic acid (ethyl cellulose coated)	43-48
Ascorbic acid (fat coated)	57
Ascorbic acid (L-ascorbyl-2-polyphosphate)	77-83

Source: (Robinson et al., 2001)

Minerals

Are required to maintain adequate osmotic balance between body fluids and the immediate environment. Fish also require minerals for metabolism and for optimum development of skeletal structure. Minerals may be classified into micro- or macro-nutrients depending on amount required in the diet. Studies on minerals are usually complicated by dissolved minerals already present in the water, variable mineral contents of pond organisms and the observation that fish absorb minerals from the water. For example, a study on zinc has to be conducted with water completely devoid of zinc.

Catfish feeds are usually supplemented with a trace mineral premix that contains all essential minerals usually at their dietary requirements.

Table 18: Mineral Requirements of *Clarias gariepinus* grow outs

Mineral	Requirement
Calcium	None (0.45% in calcium-free water)
Phosphorus	0.3-0.35%
Magnesium	None (abundant in feedstuff)
Sodium	None (abundant in feedstuff)
Potassium	None (abundant in feedstuff)
Chloride	None (abundant in feedstuff)
Sulfur	None
Cobalt	0.05ppm
Iodine	2.4ppm
Zinc	200ppm
Selenium	0.1ppm
Manganese	25ppm
Iron	30ppm
Copper	5ppm

Source: (Robinson et al., 2001)

Table 19: Vitamin and mineral deficiency signs and minimum dietary requirements for *Clarias gariepinus*

Vitamin	**Deficiency Signs**	**Minimum Dietary Requirement**
A	Exophtalmia, edema, hemorrhagic kidneys, skin depigmentation	450-900IU/lb
D	Low body ash, calcium and phosphorus	110-450IU/lb
E	Muscular dystrophy, exudative diathesis, skin depigmentation, erythrocyte haemolysis, splenic and pancreatic hemosiderosis,fatty liver, ceroid deposition	25-50 ppm
K	Haemorrhagic skin	-
Thiamine	Loss of equilibrium, nervousness, dark colour	1 ppm
Riboflavin	Short-body dwarfism	6-9 ppm
Pyridoxine	Greenish-blue colour, tenany, nervous disorders, erratic swimming	3 ppm

Panthotenic acid	Clubbed gills, emaciation, anemia, eroded epidermis	10-15 ppm
Niacin	Skin and fin lesions, exophthalmia, deformed jaws, anemia	7.4-14 ppm
Biotin	Hypersensitivity, skin depigmentation, reduced liver pyruvate carboxylase activity	R
Folic acid	Anemia	1.5 ppm
B_{12}	Anemia	R
Choline	Fatty liver, haemorrhagic liver and intestine	400 ppm
Ascorbic acid	Scoliosis, lordosis, internal and external haemorrhage, fin erosion, reduced bone collagen formation	11-60 ppm
Mineral	**Deficiency Signs**	**Minimum Dietary Requirement**
Ca	Reduced Bone Ash	None
P	Reduced Bone Ash, Calcium	0.3-0.4%
Mg	Sluggishness, muscle flaccidity	0.02-0.04%
Na, Cl, S, Co, I	ND	ND
Zn	Reduced serum alkaline phosphatase activity, bone Ca	20 ppm
Se	Reduced liver/plasma glutathione peroxidase activity	0.25 ppm
Mn	None	24 ppm
Fe	Reduced haemoglobin, hematocrit, erythrocyte count, serum iron and transferin saturation levels	20 ppm
Cu	Reduced heart cytochrome oxidase, reduced hepatic Cu-Zn superoxide dismutase activity	4.8 ppm

Source: (Robinson et al., 2001)

Feed Additives

Certain additives are added to feeds for many reasons including

- To preserve its nutritional characteristics prior to feeding
- To facilitate feed ingestion
- To improve acceptance of the feed
- To supply essential nutrients in purified or concentrated form

They include

Antioxidants/Preservatives: Feeds are very susceptible to oxidative damage with the consequent production of free radicals which are very destructive to animal cells. As they are highly nutritious (as feed), they present the optimum requirements for microbial growth (especially when moisture content increases beyond 15%). Microbial attack reduces the nutritional value of the feed and mold proliferation may result in the production of mycotoxins which are deadly to fish and humans. Antioxidants prevent oxidative damage to the feed and also prevent the formation of free radicals with their attendant side effects. They include vitamin C, E, Butylated Hydroxy

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Anisole (BHA), Butylated Hydroxy Toluene (BHT) and ethoxyquin. BHA and BHT are used at 0.02% dietary fat content while ethoxyquin is used at 150 parts per million (ppm).

Antimicrobial preservatives include propionic, sorbic and benzoic acids, potassium or sodium metabisulphite, salt and propylene glycol.

Binders: Binders are substances used to improve feed manufacturing efficiency, to reduce feed wastage (in form of fines and dust) and to produce a water stable pellet. They also increase pellet hardness. Binders include bentolites, lignosulphonates, hemicellulose and carboxymethyl cellulose. Inclusion levels generally vary between 1 to 2% of the dry weight of the feed. Starchy plants (or their products) such as cassava starch, potato starch, bread/wheat flour or rice/maize are also used to achieve binding via heat treatment and starch gelatinization. Other natural binders include alginates, carrageenins, plant gums, agar, high gluten wheat flour, beef heart, locust bean, agar, carageenin, gum Arabic, pectin and gelatin. Salt may also be used. Effectiveness of binding agents depends on feed particle size, manufacturing process, pellet diameter and diet composition.

Feeding Stimulants: Feeding stimulants increase the feed's appeal to fish appeal to fish before and after ingestion. They alter feed appearance (size and colour), texture, density or buoyancy and attractiveness (smell or taste) to produce optimal feeding response.

Feeding stimulate include feed ingredients which impact specific attractants properties such as worms, fish meal, fish oils and soybean. Synthetic feed stimulants include mixtures of L-amino acids (glycine, alanine, proline and histidine), quaternary amine glycine betaine, inosine and inosine-5-monophosphate, the nucleotide uridine-5-monophosphate, trimethyl ammonium hydrochloride.

Food Colourants: Food colourants are substances added in trace amounts in trace amounts to impact suitable colours to feedstuff and facilitate its ingestion via improved visibility of feed particles or to impact a desirable colouration within the carcass of the cultured fish.

Dendrinos et al (1984) improved feeding efficiency of larval and post larval sole via the use of different food colouring (blue, yellow, black, red, pink). Feed colourants include lycopen, lutein, cryptoxanthin, zeaxanthin, sunset yellow, brilliant black.

Natural colourants include carotenoids (such as astaxanthin, canthaxanthin and β-carotene) from yellow corn, alfalfa, algae, palm oil, marigold, carrots, phaffia yeast extracts, beef heart, spirulina, dried shrimp meal, blue-green algae, red pepper, cyanobacteria, palm oil, locust bean.

The use of herbs as feed additives has been practiced since antiquity as natural feed additives of plant origin are believed to be safer as they pose little or no hazards to man, the animal and the environment. Many herbs and plant extracts possess antimicrobial activity and antioxidant or phytochemical properties while many synthetic additives are toxic.

Kaleeswaran et al (2011) noted that *Cynodon dactylon* increased the growth response, feed conversion ratio and protease activity of *Catta catta.* Mohamad and Abasali (2010) proved the antimicrobial activity of *Inula helenium, Tussilago farfara, Brassica nigra, Echinacea purpurea* and *Chelidoniume majus* on *Aeromonas hydrophila* infection of *Cyprinus carpio.* Prathreepa et al (2010) showed the immunomodulatory effect of *Agele marmelus* leaf extract on *Cyprinus carpio* infected by *A. hydrophila* while John et al (2011) evaluated the health promoting effect of *Ocimum bascilicum, Adathoda vasica* and *Calendula officinalis* on *Aeromonas hydrophila* infected *Labeo rohita.*

Equipments Necessary for Local Fish Feed Formulation

Certain processes are necessary for the production of feed from locally available feed materials. They include

Milling: Milling involves change in the physical size of the feedstuff. It involves the crushing and subsequent size reductionof the feed ingredient t facilitate mixing. It also increases the surface area of the feed material allowing the nutrients to become readily available for digestion. Feedstuff that usually undergo milling include cereals such as maize, wheat and guinea corn. Others include bones, whole fish, soybeans and groundnut.

Milling is usually accomplished using a hammer mill.

Drying: Drying is used to reduce liquid feed ingredients to solid form. It also reduces the moisture content of feed stuff prior to milling. Examples of feedstuff which require drying are blood and poultry offal.

Mixing: Mixing is used to bring together all feed ingredients into a homogenous powder, paste or dough. It is necessary to ensure adequate/homogenous mixing to ensure maximum water stability and attractiveness to the fish. Feedstuff may be mixed by hand or with a mechanical mixer. Water may then be added to form a dough or paste. Binders are necessary during mixing to ensure proper agglutination of feedstuff. Binders include cassava starch, corn starch and other cereal crops such as millet.

Pelleting: Pelleting involves the shaping of the feeds to ensure maximum water stability and increase floatability. It also makes for longer shelf life and durability. The stability of a pellet is enhanced by the presence of a solid adhesive medium such as powdered milk, sugar or carbamide, developed by heating or steaming of starch especially from grains, connection of interface strengths of liquid between two grains and adhesion which includes the capillary suction effect between two particles.

Pelleting can be easily achieved using locally fabricated pelletizers, pasta makers or a meat grinder.

Drying: Since the pellets are usually wet when produced, they must be dried prior to use to ensure maximum shelf life and improve water stability. Feeds may be either air-dried or oven-dried.

To reduce dust during drying, animal or vegetable oil is then sprayed on the pellets.

Conclusion

It has been established that feeds account for more than 35% of costs in aquaculture. Local feeds can be produced for a minute fraction of the costs of imported or commercial fish feed without affecting the growth parameters of the fish species under culture.

The use of locally produced feed can reduce feed costs from 335 naira/kg (US$1=150 naira) (fish meal) to 53 naira/kg (soybean meal) or 63 naira/kg (groundnut). This will essentially affect the cost incurred for raising 1kg of fish which was estimated as 737 naira (Otubusin et al, 2007) to about 127 naira. This represents a 580% reduction in cost.

As aquaculture expands in Nigeria and indeed Africa, much research is on-going to increase production efficiency via genetic engineering and better farm management techniques. The key, however, to meeting the skyrocketing demand for aquacultural products and meet food security requirements has to be local production of aquacultural feeds *in situ*.

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