International Scholars Journals

Advances in Aquaculture and Fisheries Management ISSN 2756-3278 Vol. 8 (4), pp. 001-008, April, 2020. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Review

The role of dietary phytase in formulation of least cost and less polluting fish feed for sustainable aquaculture development in Nigeria

U. U. Gabriel[1]*, O. A. Akinrotimi[2], P. E. Anyanwu[2], D. O. Bekibele[2] and D. N. Onunkwo[2]

[1]Department of Fisheries and Aquatic Environment, Rivers State University of Science and Technology, P. M. B. 5080, Port Harcourt, Nigeria.

[2]African Regional Aquaculture Centre/Nigerian Institute for Oceanography and marine Research, P. M. B. 5122, Port Harcourt, Nigeria.

Accepted 21 January, 2020

The production of fish meal in Nigeria from the wild sources has for some period now been dwindling and when available are very expensive, because most of the fish meal used in fish feed formulation are imported. Hence viable alternatives have to be found for the sustainability of the aquaculture industry in the country. Plant based protein sources, which are relatively cheap, readily available and easily accessible hold the solution to this, but with limitations in utilization, due to the presence of phytic acid, an anti-nutritional agent present in virtually all plant ingredients. Phytic acid reduces bioavailability and digestibility of nutrients like proteins, phosphorus and other minerals, there by promoting accumulation of dissolved solids which ultimately leads to pollution. Hence, the need to create awareness of the efficiency of phytase treated diets, for the survival of the industry in the nearest future is imperative for the overall success of aquaculture venture. The role of dietary phytase in the formulation of fish feed using plant based protein sources which is cost effective, and reduces the incidence of aquatic pollution by making the nutrients and minerals in the feed more available to fish are thoroughly discussed in this paper.

Key words: Fish feed, phytase, cost effective, diet, sustainable aquaculture.

INTRODUCTION

The last few years has witnessed spectacular growth in aquaculture, in Nigeria, due to spurred interests of many people in fish farming, and this will continue to play an increasingly important role in meeting the demand for fish (AIFP, 2004). Most production in Nigeria is realized from pond based, tanks and water re-circulatory culture systems using polyculture farming techniques. However, the bulk of high-value fresh and brackish water finfish in these parts of the world are produced by intensive farming systems using inputs in the form of nutritionally complete formulated diets (Hassan, 2001). According to Heindl (2002) about 8 million tonnes of fish are produced in China alone with the use of mixed or manufactured feed. While Fagbenro et al. (2003) reported about 0.46 million tonnes of fish was produced in Nigeria by using artificial diet.

As aquaculture production becomes more and more intensive in Nigeria (Table 1) . Fish feeds will be a significant factor in increasing the productivity and profitability of aquaculture. According to Jamu and Ayinla (2003) feed management determines the viability of aquaculture as it accounts for at least 60 percent of the cost of fish production.

The level of growth and intensification witnessed in aquaculture in recent times has raised several issues that need to be addressed for the sustainability of the Industry. The high cost of fishmeal due to depletion of catch from the wild and competitive demand from other industries such as poultry and livestock, necessitating the need for the development of fish feed from high quality inexpensive sources and methods for reducing the level of anti-nutritional factors to the barest minimum (Baruah et

*Corresponding author. Email: ugwemg@yahoo.com

Table 1. Domestic Fish Production by Section (tonnes).

Year	Artisanal	Industrial	Aquaculture
1990	291,864	36,226	15,840
1992	283,943	39,365	20,041
1994	201,176	30,486	27,112
1996	180,112	26,117	49,364
1998	340,116	27,114	86,122
2000	120,121	23,121	121,112
2002	100,126	21,121	300,114

Source: Adapted from Eyo (2003)

Table 2. Fish Feeds Production (Tones) in Nigeria

Feed type	Farm-made	Commercial	Total
Tilapia	14,258	6,554	20,812
Catfish	10,552	4,206	14,758
Total	24,810	10,760	35,570

Source: Fagbenro et al. (2003).

et al., 2004).

Interestingly, Cheng and Guillaume (1984) reported a beneficial effect of purified phytic acid on growth and exoskeleton development in shrimp *Penaeus japonicus*. Similarly, McClain and Gatlin (1988) reported reduced zinc bio availability in tilapia *Oreochromis aureus* fed 1.5% phytate; fish growth was improved compared with control fish fed with no phytate. More over, recent studies with mammals, suggested that phytic acid have a beneficial effects within the animal body by suppressing the incidence of colonic cancer by acting as a food antioxidant and forming iron-chelates that inhibit iron- catalyzed hydroxyl radical formation and lipid peroxidation (Empson et al., 1991; Graf and Eatin, 1993; Tacon, 1995). Hence, this paper critically discusses dietary phytase as one of the best options in formulating a cost effective growth promoting and low polluting fish feed for sustainable aquaculture development.

Fish feed development

The pivotal role of nutrition in aquaculture cannot be over emphasized as demonstrated in several studies (NRC, 1983; Falaye, 1983; Adiukwu, 1999; Fasakin et al., 2003; Gabriel and Keremah, 2003; Ibiyo and Olowosegun, 2004).

For any aquaculture venture to be viable and profitable it must have a regular and adequate supply of balanced artificial diets for the cultured fishes. This is so because the dissolved nutrients that promote primary and secondary production in the natural environment are seasonal and might be insufficient or may not occur in required proportion to meet the nutritional demand for culture fishes. Supplementary feeding satisfies this need and ensures that the fish gets the appropriate spectrum of its basic food requirement for maximum growth (Ugwumba and Ugwumba, 2003).

Artificial feeds also known as supplementary feeding are well-compounded mixture of feedstuffs in mash form or pellets that could be fed to fish. Mash feeds are fed to fry and pellets to fingerlings, juveniles and adults depending on pellet size (Eyo, 2003). Artificial feeding of fish has many known advantages which include, enhancement of high stocking density especially in polyculture system resulting in high yield, promotion of growth and enables the farmer to observe the behaviour of his fish during feeding in order to detect any abnormality (Gabriel et al., 2000; Gabriel and Keremah, 2003). Unlike in the past, when fish depends on natural food in the pond, the production of fish feed is becoming popular with each passing day in the country. About 35,370 tonnes of feed were produced in 2003 (Table 2), using locally available feed ingredients.

Nutrient requirements of fish

Fish like other animals have a requirement for essential nutrients in order to grow properly (Table 3). Irrespective of the culture system in which they are grown, growth, health and reproduction of fish is primarily dependent upon an adequate supply of nutrient both in terms of quantity and quality. Supply of inputs (feed) has to be ensured so that the nutrients and energy requirements of the species under cultivation are met so that the production goals of the system can be achieved (Tacon, 2000). The essential nutrient requirements of fish are proteins, lipids, carbohydrates, vitamins and minerals. Protein is a major constituent of fish diet. Knowledge of the protein requirement of fish is essential for the formulation of a well-balanced artificial diet for economical fish feeding (Lovell, 1989). Protein requirement is linked with the general energy requirement of the fish at a given water temperature and the ability of the fish to gain weight at its inherent capacity (Eyo, 2003) . According to Gabriel and Keremah (2003) protein and energy levels significantly influenced food conversion efficiency of *Heterobranchus bidorsalis* , however the efficiency was not high enough to influence carcass composition and condition of fish.

Necessity for plant based protein source

Research in fish nutrition in recent years seems to focus on the replacement of animal protein sources by plant based proteins (Table 4) with the aim of reducing the cost of supplemental feeds (De Silva, 2001). The aquaculture feed industry relies heavily on the use of fish meal because of its balanced amino acid profile that closely matched the fish's requirement pattern. The commonly used rates in fish feeds ranges from between 25 and 65% (average 35%). However, the increasingly scarce supply of fish-

Table 3. Protein Requirement of Commonly Cultured Fish species in Nigeria.

Species	Fry to fingerlings	Fingerling to Juveniles	Adults to brood stock	Reference
Oreochromis nilotics	35-40	30-40	20-30	Ballarin and Haller (1982)
Satherodon galilaeus	35	35	35	Omoniyi and Fagate (2003)
Clarras gariepinus	37.5	32.5	40	Ayinla and Akande (1988)
Heterobranchus Sp	36-40	35	40	Ayinla (1991)
Hybrid catfish Heteroclarias	42.5	35	35	Eyo and Faloyi (1999)
Common Carp	40	38	38	Fagbaro *et al*. (2000)
Heterotis niloticus	30.1	25.30	25	Otubusin (1987)

Table 4. Animal and Alternative Plant based feedstuff in Fish Diets.

Nutrient	Conventional feedstuffs	Percent ration	Alternative feedstuffs	Maximum inclusion rate (%)
Protein	Fish meal	40	Groundnut cake	25
			Palm kernel cake	15
			Cottonseed cake	20
			Jackbean	10
			Soyabean	45
	Cod liver oil	10	Corn oil	20
			Soybean oil	10
			Palm oil	10

Source: (Eyo, 2003).

meal with its concomitant rise in price and the increased competition from other livestock industry necessitates seeking a cost-effective replacement to supply dietary protein in aquaculture feeds. This aspect of fish feed development research is centered on the search for inexpensive, readily available and nutritious protein sources which can supply all the nutritional needs of the fish. One obvious approach involves the greater utilization of proteins from plant sources, which has been extensively investigated with promising results (Eyo and Olatunde, 1996; Desilva, 2001; Olufeagba et al., 2002; Eyo, 2003; Alegbeleye et al., 2004). However, the results from such studies reviewing the fact that these plant materials are not maximally utilized by the fish when compared with animal protein sources (Ofojekwu and Kigbu, 2002). This is commonly attributed to anti-nutritional factors especially phytic acid.

Limiting factors to the utilization of plant based protein sources

Phytic acid or the hexaphosphate of myoinositol occurs naturally throughout the plant kingdom (Table 5) and is present in considerable quantities within many of the major legumes and oils seeds (Tacon, 1995). According to Matyka et al. (1993) 46.73% of the total phosphorus within plant based ingredients is organically bound phytin phosphorus which is largely unavailable to fish. This is due to the absence of the enzyme phytase within the digestive tract of fish (Lovell, 1989). Besides, it acts as a strong chelator, forming protein and mineral-phytic acid complexes; the net result being reduced protein and mineral bioavailability (Davies and Gatlin, 1991; Hossain and Jauncey, 1993; NRC, 1993).

Furthermore, most fish lack intestinal phytase that can digest the salts of phytic acid (phytins), hence they are released into the environment in the form of phytate phosphorus which in turn are acted upon by micro-organisms that release the phosphorus leading to pollution (Alvarado, 1997).

Interestingly, pollution from phytic acids in plant protein sources can be reduced to the barest minimum by including phytase in plant based protein ingredients when formulating fish feed.

Need for phytase inclusion in formulation of fish feed

Phytase is an enzyme which is microbial in nature, and as most monogastric animals like fish cannot produce this enzyme; hence it must be supplied by inclusion in formulated diet of plant origin. Over the years, plant products such as oil seed cakes and meal have been evaluated as fish feed ingredients. With advanced processing techniques, their nutritive values have been enhanced to such an extent that they are now considered conventional ingredients in aquafeeds (Ayinla and Akande, 1988;

Table 5. Toxic Constituents of Selected Plant Feedstuffs.

Source	Toxic Factor	Preventative Treatment
Soya bean	Trypsin inhibitor	Toasting, steaming or boiling
	Haemagglutinins	
	Saponins	
	Phytic acid	Phytase treated
Groundnut cake	Aflatoxins	Proper storage
	Phytic acid	Phytase treated
Cotton seed	Gossypol Phytic acid	Pre-Press thoroughly to extract the oil
		Phytase treated
Pigeon Pea	Linamarin	boiling for 20 minutes
	Phytic acid	Phytase treated
Kidney bean	Heamagglutinin phasiolin phytic acid	Boiling for 20 minutes Auto claving Phytase treated
Lima bean (phaseolus lonatus)	Saponnis phytic acid	Toasting Phytase treated

Source: Jackson et al. (1996).

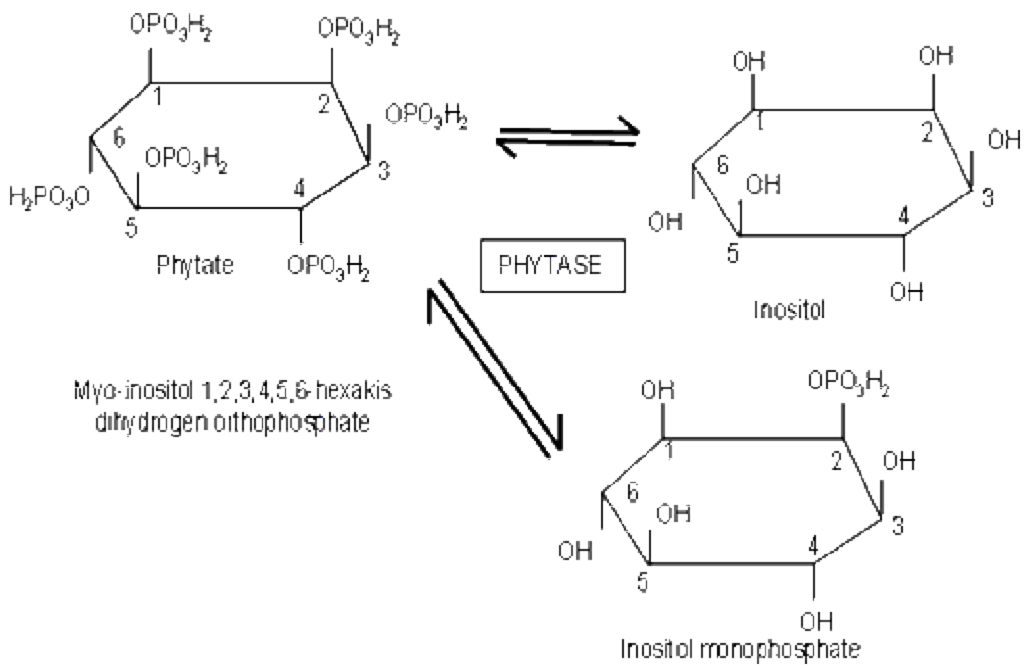

Figure 1. Action of phytase.

Ayinla, 1991; Fagbenro 1999; Eyo et al., 2003).

Addition of microbial phytase either in powdery or liquid form has been reported to improve the utilization of plant phosphorus in fish diets considerably (Forst et al., 1999; Robinson et al., 2002; Debnath, 2003). Its inclusion improves optimal utilization in plant based protein diet for fish thereby enhancing fish growth, leading to maximum profit in aquaculture. Therefore, inclusion of dietary phytase will play a major and significant role in increasing the level of production and utilization of plant protein based artificial diet used mostly in the poor and developing nations of the world.

Phytase pathway of action

Phosphorous in plants normally remains in an associated form with a molecule called phytic acid (phytate). Phytic acid consists of a sugar (similar to glucose) called myo-inositol, to which phosphate (PO^{-4}) groups are covalently linked. Phytase releases these phosphates from the inositol ring as shown in (Figure 1) (Baruah et al., 2003). Release of phosphorus depends on the pH of the intestine. The optimum microbial phytase activity occurs phytase (FTU) is defined as the quantity of enzyme that liberates 1 µmole of inorganic phosphorus per minute from

Table 6. Average percentage apparent availability of phosphorus determined for catfish using dietary phytase.

Feed Stuff	Non Supplemented Phosphorus Availability %	Supplemented Dietary phytase Average) diet %
Wheat middling	28	40
Corn	25	38
Soyabean meal	50	75
Cotton seed meal	43	56
Ground nut cake	46	70
Palm kernel cake	36	46
Sorghum	31	42
Jack been	38	47

Source: Yan and Reigh (2002)

Table 7. Average apparent protein digestibility coefficients of phytase supplemented and non-supplemented Atlantic Salmon diet.

Feed stuff	Non supplemented (digestibility) %	Phytase supplemented digestibility %
Corn	60	72
Cotton seed meal	61	84
Soya bean meal	75	89
Wheat bran	68	82
Rice bran	68	78
Ground nut cake	70	82
Sorghum	63	80
Palm kernel cake	69	76

Source: Debnath (2003).

0.0015 mol/L sodium phytate at pH 5.5 and 37 C (Von Sheuermann et al., 1988).

Roles of dietary phytase in fish feed formulation

The important roles of dietary phytase as veritable option in the preparation of least cost diets from locally available and cheap plant protein sources cannot be overemphasized. The use of phytase may revolutionise the future of aquaculture industry, world-wide. This is because fish meal, a major source of protein in aquafeed is produced from fish caught from the wild. With the rapid depletion of fish in the wild and stocks reaching its maximum biological limits, the aquaculture industry is already in crisis. Hence the need for plant based protein sources as viable alternative.

The roles of phytase in plant protein based diets are as follow:

Increased bio availability of phosphorus and other minerals

Phytic acid is reported to chelate metal ions such as calcium, magnesium, zinc, copper and iron to form and secondly at pH 2.5 (Simons et al., 1990) . One unit of at two pH values; the highest activity being at pH 5.0 - 5.5 insoluble complexes that are not readily absorbed from the gastrointestinal tract of fish (Hendricks and Bailey, 1989).

Microbial phytase is effective in enhancing the bioavailability of phosphorus considerably, thereby reducing the faecal phosphorus output (Baruah et al., 2004). It also improves the apparent absorption of magnesium, zinc, copper and iron in plasma, bone and the whole body of fish (Vielma et al., 1998). Yan and Reigh (2002) further assert that phytase supplementation at 500 units per kilogram of diet was sufficient to improve the retention of calcium phosphorus and manganese by catfish, *Ictalurus punctatus* fed on an all-plant protein diet (Table 6).

Improvement of protein digestibility

Phytase supplementation in fish diet has been reported to improve protein digestibility and retention (Storebakken et al., 1998). It was further confirmed by Debnath (2003) that apparent net protein utilization and digestibility in Atlantic Salmon was significantly improved by the enzyme supplementation (Table 7), while non-enzyme supplemented groups showed a low digestibility. Many researchers (Kornegay, 1995; Vielma et al., 1998; Baruah et al., 2004) have also observed that phytase-supplementation in plant-based practical diets has been reported to increa-

Table 8. Growth response of *Clarias gariepinus* fed on phytase treated soybean meal based diet.

Parameter	Rate of phytase inclusion (%)					
	0	2	4	6	8	10
Mean Initial Weight (g)	7.25	7.28	7.28	7.39	7.40	7.60
Mean final Weight (g)	10.32	12.41	14.32	17.92	18.11	19.01
Mean weight gain	3.07	5.13	7.04	10.53	10.71	11.41
Feed Conversion Ratio (FCR)	16.28	9.74	7.10	4.73	4.66	4.38
Specific growth rate (SGR)	0.14	0.24	0.33	0.50	0.51	0.54

Source: Van Weerd et al. (1999)

Table 9. Physico-chemical conditions of farm effluents in rainbow trout tank culture fed phytase treated soyabeans meal with untreated diet.

Parameters	Phytase treated diet	Untreated diet
pH	6.7	6.0
Dissolved Oxygen (D.O mg L^{-1}	3.3	1.1
NH_3-N (mg L^{-1})	0.18	2.01
NO_2 –N (mg L^{-1})	0.02	0.09
PO_4^{3-} (mg L^{-1})	0.6	3.01

Source: Hassan (2001).

se protein digestibility by breakdown of phytin-protein complexes.

Enhancement of fish growth and performance

Incorporation of microbial phytase, in the diet of fish fed predominantly on plant based protein, have been reported to result in increased weight gain in *I. punctatus* (Jackson et al., 1996). Weight gain and feed consumption was increased by 23.52 and 11.59 percent, respectively compared to a control group in *Pangasius pangasius* (Debnath, 2003). Also Van Weerd et al. (1999) observed that African catfish, C*larias gariepinus* performed better on phytase supplemented diets (Table 8).

Reduction of incidence of aquaculture pollution

The environmental impact assessment of the aquaculture industry is getting increasing attention and rigorous restrictions are being set on this industry by governments and environmentalists (Baruah et al., 2004). Given the fact that feed is the biggest source of nutrient loading in aquaculture production, a clear understanding of its impact is essential for sustainable development either in intensive or semi-intensive aquaculture (Hassan, 2001). Most discharge of farm effluents is majorly phosphorus, which leads to eutrophication.

Dietary phosphorus in plant protein source is generally unavailable to finfish, hence, making fish to excrete predominantly phosphorus in soluble and particulate forms. These soluble forms of organic phosphorus and phosphates affect water quality directly (De Silva and Anderson, 1995). However, addition of microbial phytase in the diet of fish overcome this problem (Table 9), by making the chelated phosphorus available to fish and lessen faecal excretion thereby reducing environmental pollution (Alvarado, 1997; Hassan and Ahmed, 2001; and Baruah et al., 2004).

Enablement of least cost feed formulation

Least cost feed is a feed formulation in which there is optimum utilization of the contents of feed ingredients by careful combination resulting in maximum yield at minimal cost (De Silva and Anderson, 1995) . It involves production of feed at the most cost effective level in terms of resources -material, time, energy and money by minimizing input while maximizing output (Sadiku, 2003). Inclusion of phytase in fish diets have over the years enabled the fish nutritionists to formulate a cheaper feed based on plant source protein. Protein from plants origin is cheaper and readily available, and easily accessible than the animal protein sources. Despite its cheapness their inclusion in fish feed formulation is limited due to some activities of anti-nutritional factors. But with inclusion of phytase which reduces the effects of these anti-nutritional factors the plant protein sources can be maximally utilized. Fish nutritionist can therefore, formulate and produce feed, majorly, from plant source ingredients which is far cheaper than the fish meals, thereby reducing the cost of feed, which will ultimately leads to profit maximization in the entire farming enterprise.

Conclusion

Heavy dependence on plant based feed in aquaculture is inevitable in the nearest future as this is essential to the sustainability of this industry. Increasing demand for fishmeal by the livestock and poultry, industry, coupled with declining harvest of fish stock from the wild, demand that fish nutritionists find alternative sources of qualitative fish feed that will enhance fish performance in aquaculture practices. This now shifts the emphasis on plant source protein as a viable option. On the other hand, plant ingredients limited by the presence of phytic acid, which makes the phosphorus unavailable, thereby limiting their inclusion levels in most fish feed formulation, can be maximally used in fish formulating by adding dietary phytase. However it is evident that phytase supplementation improves the bioavailability of the phosphorus and nitrogen (protein) which leads to reductions in feed costs. Therefore awareness of the efficiency of these enzymes has to be created among fish culturists, as an effective and efficient approach in the formulation of cost effective, growth promoting and low polluting fish feed for profitable aquaculture venture.

REFERENCES

AIFP (2004). Farming Nigerian water Newsletter of the Aquaculture and Inland Fisheries project of the *National special programme for food* security in Nig. F.A.O Office Abuja, Nigeria 3(4): 2-4.

Adiukwu IA (1999). Aquaculture in Nigeria: problem and prospects. J. Fishery Technol. (1): 11-27.

Alegbeleye WO, Oresegun U, Akegbejo Samson, Obasas SO (2004). Replacement of groundnut cake with rubber seed cake in diets for nile tilapia (*Oreochromis niloticus*) J. Aquatic Sc. 19(1) 27-31.

Alvarado JL (1997). Aquafeeds and the environ. In A. Tacon and B. Basurco (eds). Feeding tomorrow's fish, Proceeding of the workers of the CIHEAM Network of Technol. in Aquaculture in the Mediterranean (TECAM), jointly organized by CIHEAM FAO and IEO, Mazarron, Spain, CIHEAM, Apodo, Spain. pp. 281-289.

Ayinla OA (1991). Fish feed and Nutrition, paper presented at FISON symposium, Gingiyer Hotel, Sokoto.

Ayinla OA, GR Akande (1988). Growth responses of *Clarias gariepinus* (Burchell 1822) on silage-based diets*.* Nig Inst. Oceanogr and Mar*.* Res. Tech. Paper 37:19.

Ayinla OA (1991). Fish feed and Nutrition. Paper presented at Fisheries society of Nigeria FISON Symposium, Gingiya Hotel, Sokoto.

Ayinla OA, Akande GR (1988). Growth response of *Clarias gariepinus* on silage based diets. NIOMR Technical paper Nigerian Institute of Oceanography and Marine Research, Lagos. 37: *p.* 19.

Ballarin JD, Haller RD (1982). The intensive culture of tilapia in tanks raceways and cagesJ.F. Mor and R. J. Pobot (eds) recent advances in acquaculture. Croon Heln ltd., London. pp. 265-356.

Baruah K, Sahu NP, Debnath D (2004). Dietary phytase: An ideal approach for a cost effective and low polluting aqu feed NAGA, 27(3):15-19.

Cheng WW, Guillaume J (1989). Effect of sodium phytate on growth and tissue mineralization of *Penaeus japonicus* and *Penaeus vannamei* juveniles. *Aquaculture* 77:145-156.

Davies DA, Gatlin DM (1991). Dietary mineral requirements of fish and shrimp. pp. 49-67. In: D.M. Akiyama and R. Tan (eds). *Proceedings of* the Aquaculture Feed Processing and Nutrition Workshop, Thailand and Indonesia, pp. 19-25.

De Silva SS (2001) Performance of *Oreochromis niloticus* fry maintained on mixed feeding schedules of different protein levels Aquac. Fish. 16: 621-633.

De Silva SS, Anderson TA. (1995). Fish nutrition in aquaculture. Chapman and Hall London. p. 319

Debnath D. (2003) Effect of dietary microbial phytase supplementation on growth performance and body composition of *Pangasius pangasius* fingerlings. Central Institute of Fisheries Education Versoves, Mumsai, India M.F. Sc. Thesis p. 106.

Empson KL, Labuza TP, Graf E (1991). Phytic acid as a food antioxidant. F. Food Sci. 50(2): 560-563.

Eyo AA, Olatunde AA (1996). The effect of replacement of soyabean meal with blood meal on the growth of mud fish *clarias anguillaris* finguling. Trop. Agric. Res. (2). 12-14.

Eyo AA, Falayi SA, Oduba IA (2003). Evaluation of extruded soybean meal (Glycine max) in the diets of catfish. J. of sustainable Trop. Agric. Res. (1): 10-18.

Eyo AA. (2003). Fundamentals of fish nutrition and diet development. In: A. A. Eyo (eds) National Workshop on fish feed development and feeding practices at NIFRI, New Bussa pp. 3-10

EyoA. A, Falayi BA. (1999). Optimal protein requirements of juvenile hybrids (*Clarias anguillaris* X *Heterobranchus longifilis*). NIFFR Annual Report. 92 -96. pp. 50-52.

Fagbenro O. A. (1999) Formulation and evaluation of production diets for *Clarias gariepinus* made by partial replacement of fish meal with unique bean seed meal. Aquac. Res. 30: pp. 1-9.

Fagbenro OA, Ade Parusi EO, Fapohunda OO (2003) Feedstuffs and dietary substitution for farmed fish in Nigeria, In A. A. Eyo (ed). National Workshop on Fish Feed development and feeding practises in Aquaculture held at National Fresh Water Fisheries Research Institute pp. 60-65.

Fagbenro OA, Smith MAK, Amoo AI (2000). Acha (Digitaria exilis stapf) meal compared with maize and sorghum meals as a dietary carbohydrate source for nile tilapia (*Oreochromus niloticus*). Israeli J. Aquac. 52: 3-10

Falaye AC. (1983) The use of hydrolyzed feather meal alone or in combination with supplemental amino acid as a dietary source of tilapia (*Oreochroms niloticus*). M. Sc. Thesis,, University of Stirly U.K.

Fasakin EA, Balogun AM, Ajayi OO (2003). Evaluation of full -fat and defatted maggot meals in the feeding of clariid catfish, *Clarias garicpinus*. Aquac. Res. 34(9): 733-738.

Forst I, Higg DA, Dosanjh BS, Rowshandeli M, Pari J. (1999). Potential for dietary phytase to improve the nutritive value of canola protein concentrate and decrease phosphorus output in rainbow trout held in 11^0C fresh water. Aquac. 179: 109-125.

Gabriel UU, Keremah RI (2003) . Effects of varying dietary protein: energy on carcass composition, feed conversion efficiency and condition of *Hetero branchus bidorsalis* fingeling. The Zool. 2(2): 19-29.

Gabriel UU, Inko Tariah MB, Allison ME. Davies OA. (2000). Growth of *Hetero branchus bidorsalis* fingerlings fed varying dietary protein and energy rations. J. Agric Biotech and Environ*.* 2(12): 35-41.

Gatlin RH, Wilson TA (1984). Effect of dietary phytase on fish Int. J. Aquac. (2): 31 10-16.

Graf E, Eatin JW (1993). Suppression of colonic cancer by dietary phytic acid Nutrition and Cancer. 19(1): 11-19.

Hasan MR (2001) Nutrition and feeding for sustainable Aquaculture Development in the Third millennium In Roha P. Subasinghe (ed). Aquaculture in the Third millennium Technical proceedings of the conference on Aquaculture in the third millennium. Bangkole, Thailand. pp. 193-211.

Hassan MR, Ahmed GU (2001). Issues in Carp hatcherics and nurseries in Bangladesh with special reference to health manage-ment paper presented in FAO/NACAI/DPID. Asia Regional Scoping Workshop on primary Aquatic Animal Health care in Rural, small-scale Aquaculture Development, Aquaculture Development, Dhaka, Bangladesh, pp. 27-30

Heindl U (2002). Phytase: How does the enzyme work in fish nutrition? Asian Aquac. Magazine 2(6): 19-24.

Hossain MA, Jauncey K (1990). Detoxification of lin seed and sesame meal and evaluation of their nutritive value in the diet of common carp (*Cyprinus carpio*). Asian Fish. Sci. 3(2): 169-183.

Ibiyo LMO, Olowosegun T (2004) On-farm feed: The potential for improving profitability in Aquaculture In P.A. Araoye (ed) Conference proceedings of fisheries, society of Nigeria, Ilorin, Nigeria. pp. 80-90

Jackson LS, Li MH, Robinson EH (1996). Use of microbial phytase in channel catfish *letalurus punctatus* diets to improve utilization of phytate phosphorus J. World Aqua soc. 27: 209-313.

Jamu DM, Ayinla OA (2003). Potential for the development of aquaculture in Africa *NAGA*, 26 (3): 6-13.

Kornegay ET (1995). Important considerations for using microbial phytase in broiler and turkey diets, In W. Van Harting Sveldl, M. Hessing J. P. Vander Light and W. A. E. Somen (eds). Proceedings of second symposium on feed Enzymes (ESFEZ). Noord wij kerhout, Netherlands, TNO Nutrition and food Research Institute, Zeist. pp. 189-197.

Lovell RT (1989). Fish Nutrition in Aquaculture. Van Nostrand Reinhold. New York. p. 260.

Matyka S, Bogusz G, Korol W (1993). Phytate contents in cereal grains, legume and rape seeds *Biulelyn Informacying Prezemyslu Paszowedo* (Poland). 32(1): 37-43.

McClain WR, Gallin DM (1988). Dietary zinc requirements of *Oreochromis aurea* and effects of dietary calcium and phytate on zinc bioavailability. *J. Word Aquacult. Soc.*, 19: 103-108.

NRC (National Research Council) (1993). Nutrient requirements of fish. Committee on Animal Nutrition, Board on Agriculture, National Research Council, National Academy Press, Washington DC, USA. p.114.

NRC (Nation Research Council) (1983). Nutrient requirements of warm water fishes and shellfishes, Washington DC, National Academy press, p.102.

Ofojekwu PC, Kigbu AA (2002). Effects of Substituting Fish meal with sesame (*Sesamum Indicum*) cake on growth and food utilization of the Nile Tilapia, *Oreochromis niloticus* J. of Aquatic Sciences 17(1): 45-49.

Olufeagba SO, Aluko PO, Eyo AA (2002). Dietary Protein Requirement of Triploid *Heterobranchus Longifilis* fed Formulated diets. J.*of Aquatic Sciences* 17(1): 1-4.

Omoniyi IT, Fagade SO (2003). Effect of Different Dietary Protein levels on the Growth performance of Hybrid Tilapia (*Oreo chromis* x *Sarotherodn galilaeus*) fry. *Nig. J. of fish* 1(1): 22-32.

Otubusin SO (1987). Effects of different level of blood meal in pelleted feeds on tilapia *Oreochromis niloticus* production in floating bamboo net-cages. *Aquaculture* 65(3-4): 263-266.

Pointillart A, Foundin AA, Fontaine N. (1987). Importance of cereal phytase activity for phytate phosphorus utilization by growing pigs fed diets containing triticale or corn. J. Nutr. 29: 207-912.

Robinson EH, LMH Manning BB (2002). Companism of microbial phytase and dicalcium phosphate for growth and bone mineralization of pond-raised channel catfish, *ictalurus punctuatus* J, Appl. Aqua. 12: 81-88.

Sadiku SOE (2003). Least-cost feed formulation, p56-59. In: A. A. Eyo (ed) *National Workshop on fish feed development and feeding practices in Aquaculture, National Institute for Freshwater Fisheries Research (NIFFR) New Bussa,* p. 114.

Store Bakken T, Shearer KD, Roem AJ (1998). Availability of protein, phosphorus and other elements in fish meal, soy-protein concentrate and phytase-treated soy-protein concentrate-based diets to Atlantic Salmon, *Salmo salar*. *Aquaculture* 161: 365-379.

Tacon AGJ (2000) Standard method for the nutrition and feeding of farmed fish and shrimp, Washington D.C., U.S.A. Argent Laboratories, Press. p.454.

Tacon AGJ, Jackson A (1985). Protein and amino acid requirementsIn: P. Tytler and P. Calour (eds) fish energetics: new perspectives, Croom Hum, Beckenham, UK. , pp. 155-183.

Ugwumba AA, Ugwumba AO (2003). Aquaculture Options and the future of fish supply in Nigeria. *The Zoologist* 2 (2): 96-122.

Van Weerd JH, Khalaf KHA, Aarlsen FJ, Tijsses PA (1999). Balance trials with African catfish *Clarias gariepinus* fed phytase treated soybean meal-based diets. *Aqua. Nutrition* 5: 135-142.

Vielma J, Lall SP, Koskela J, Schoner FJ, Mattila P (1998). Effects of dietary phytase and chole calciferol on phosphorus bioavailability in rainbow trout *(Oncorhynchus Mykiss) Aquaculture* 163: pp.309-323.

Von Shuemann SE, Lantzoch, Marke KH (1988). in vitro and in vivo experiments on the hydrolysis of phy tate. Activities of plant phytase. J. Anm. Phy. *Animal Nutr*: 60: pp. 64-75.

Yan W, Reigh RC. (2002). Effects of fungal phytase on utilization of dietary protein and minerals, and dephosphorylation of phytic acid in the alimentary tract of channel catfish *Ictalurus punctatus* fed an all-plant-protein diet. *J. World Aqua. Soc.* 33:pp. 10-12.