UNIVERSITY OF CAPE COAST

GROWTH PERFORMANCE OF FRY AND FINGERLINGS OF *OREOCHROMIS NILOTICUS* FED ON DIFFERENT AGRO-INDUSTRIAL BY-PRODUCTS

BY

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MAY 2011

DECLARATION

Candidate’s Declaration

I hereby, declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this University or elsewhere.

Candidate’s Signature:…………………… Date:……………........

Emmanuel Delwin Abarike

Supervisors’ Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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Dr. Felix Y.K. Attipoe

ABSTRACT

The study was conducted at the Aquaculture Research and Development Centre at Akosombo to observe the growth performance of fry and fingerlings of *O. niloticus*; and also assess the cost-effectiveness of the different dietary treatments. In experiment 1, four isonitrogenous (36% crude protein) and isoenergetic (gross energy 18 MJ/kg) diets were formulated to contain agro-industrial by-products including: wheat bran (diet 1), pito mash (diet 2), rice bran (diet 3) and groundnut bran (diet 4) and fed to fry of *O. niloticus* (average initial weight 0.11 ± 0.01 g) stocked at 50 m^{-3} in out-door hapas for 8 weeks. In experiment 2, four isonitrogenous (30% crude protein) and isoenergetic (gross energy 18 MJ/kg) diets were formulated from the same by-products as in experiment 1 and fed to *O. niloticus* fingerlings (average initial weight 7 ± 0.23 g) stocked at 20 m^{-3} for 24 weeks.

Growth performance was similar ($P > 0.05$) for fry *O. niloticus* among all treatments. However, incidence cost was highest for diet 4 and lowest for diet 2. Fish fed on diet 2 had the highest ($P < 0.05$) profit index and those fed on diet 4 had the lowest. Growth performance in fingerlings was highest ($P < 0.05$) in diet 1 and least in the control. Whiles incidence cost was highest ($P < 0.05$) for fish fed diet 4 and lowest ($P < 0.05$) for fish fed diet 2.

In conclusion, the growth performances were similar ($P > 0.05$) for fry of *O. niloticus* among all treatments. For *O. niloticus* fingerlings, diet 1 produced the fastest growth. Diet 2 was the most cost-effective diet. From this study, diets 1 and 2 for rearing of *O. niloticus* are recommended for feeding.

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DEDICATION

I dedicate this work to my father Mr. Joseph Azumah Abarike and my wife Sheila Akingya.

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DEFINITION OF ACRONYMS

Acronym	Definition
ARDEC	Aquaculture Research and Development Center
CF	Crude fibre
CHO/LIP	Carbohydrate/Lipid
CP	Crude protein
DGS	Distillers grains with solubles
DO	Dissolved oxygen
EAA	Essential amino acid
EE	Ether extract
FAO	Food and Agriculture Organization
FCR	Feed conversion ratio
FJB	Fig jam by-product
FM	Fish meal
GAFCO	Ghana Agro Food Company Limited
GB	Ground bran
GDP	Gross domestic product
IC	Incidence cost
K	Condition factor
MB	Maize bran
MWG	Mean weight gain
NF	Naturally available food
NFE	Nitrogen free extract
NSP	Non-starch polysaccharides
NTU	Neophelometric turbidity unit

PER	Protein efficiency ratio
PI	Profit index
PKC	Palm kernel cake
PM	Pito mash
PWG	Percentage weight gain
RB	Rice bran
SGR	Specific growth rate
SR	Survival rate
TSS	Total suspended solids
WB	Wheat bran

CHAPTER ONE

INTRODUCTION

This chapter explains what the problem is and why the study is important.

Consumption and demand for fish as food

Fish is a key ingredient in the global menu and an important basis for livelihood worldwide. Consumption of fish generally cuts across ecological, socio-economic, cultural and religious boundaries, leading to its predominant use as animal protein. Presently, fish accounts for over 50% of total animal protein consumed in most developing countries and global estimate stands at 15.5% (Delgado, Wada, Rosegrant, Meijer & Ahmed, 2003; Agbo, 2008).

Fish improves protein nutrition in that it has a high biological value in terms of high protein retention and assimilation as compared to other animal protein sources (Ahmed, IIona & George, 2005). In addition, fish has low cholesterol content; as a result, it is regarded as one of the safest sources of animal protein. Nutritionally, fish is one of the cheapest and direct sources of rich protein (i.e. it contains the three essential amino acids: lysine, tryptophan and methionine not found in plant proteins); and a vital source of micro nutrients such as: iron, zinc, calcium, iodine, vitamin A and B vitamins for millions of people in Africa. Fish serves as food and provides nutritional security to about 200 million Africans. Fishing, like other hunting activities, has been a major source of animal protein for the human race and has put an end to the unsavoury outbreak of

Anaemia, and Kwashiorkor. World total supply of fish has risen five folds over the last forty years from 20 million metric tonnes to 98 million metric tonnes in 1993 and projected to exceed 150 million metric tonnes by the year 2010 (Olagunju, Adesiyan & Ezekiel, 2007). In Africa, as much as 5% of the population depends wholly or partly on the fisheries sector for their livelihood. It is estimated that by 2050, when world population is projected to be over 9 billion, Africa would have to increase its food production by 300%, Latin America by 80% and Asia 70% to provide minimally adequate diets for the projected population of 2 billion, 810 million and 5.4 billion people in the respective regions. In Africa, the consumption and demand for fish as a cheap source of protein is on the increase, because of the level of poverty (Baluyut, 1989; Bene & Heck, 2005; FAO, 2005; Gabriel, Akinrotimi, Bekibele, Onunkwo & Anyanwu, 2007).

The vast majority of the fish supply in many countries in most cases comes from the marine environment, rivers, dams and lakes. However, in recent times with the increasing demand and consumption of fish worldwide, supply from capture fisheries based on species that are presently exploited seems to have reached its natural limits. Unlike some other animal products, fish is widely acceptable (Gabriel *et al.*, 2007).

Statistics on the consumption of fish in Ghana indicates that about 69% of the dietary animal protein for Ghanaians comes from fish. The increasing demand for fish is partly attributed to the increasing population because it is relatively cheaper in price compared to the other animal proteins. The demand for fish in

Ghana is always greater than the country can supply and the gap is widening year after year. Hiheglo (2008) reported that even though the national demand for fish in 2007 was 913, 992 tonnes, the country was able to supply only 511, 836. There is therefore need to intensify aquaculture to argument fish supplies.

Aquaculture, a panacea to augment fish supplies

With a steady decline in capture fisheries, aquaculture is a readily veritable tool in the provision of fish to augment the protein needs of people who depend a lot on supply from captured fisheries (Pillay & Kutty, 2005; Stickney, 2005; Gabriel *et al.*, 2007). The importance and potential for the development of the aquaculture industry in Ghana is gradually gaining attention. This is because aquaculture is an assured potential in augmenting Ghana's fish requirements. Through productive aquaculture the widening gap for example in 2007 between fish supplies (511,836 tonnes) and demand (913,992 tonnes) creating a deficit of (402,156 tonnes) can be narrowed (Hiheglo, 2008). Investments in aquaculture can also increase the country's GDP since about 10 % of the land surface is covered with water and there are a number of land areas that can be conveniently used for aquaculture without interfering with crop productions. However the development of the aquaculture industry would call for the development of fish feeds.

The need for development of fish feed

Fish feed development in Sub-Saharan Africa has not made any significant progress in aquaculture as expected. Fish feed technology is one of the least developed sectors of aquaculture particularly in Africa and other developing countries of the world (FAO, 2003). Feed remains one of the major inputs and fundamental challenges facing the development and growth of aquaculture in the African continent. In the development and management of an aquaculture enterprise, fish feed plays a vital role in its growth and expansion. In fact, it is a major factor that determines the profitability of aquaculture (Gabriel *et al.*, 2007).

Nearly one third (1/3) of the world's wild fish caught are reduced to fish meal and fish oil which are used to feed livestock, poultry and also farmed fish. With the increasing rate in the establishment of fish farms in Ghana, it is obvious that the quest for fish feed will continue to persist. This means that economically viable fish farming activities would depend on low-cost but nutritionally balanced diets (Hiheglo, 2008) on small scale or commercial basis. According to Attipoe, Nelson and Abbran (2009), most fish culturists in Ghana are small scale producers and, at best, use single items such as wheat bran and fish meal as in preparing farm-based feed.

Importance of fish meal

The development of commercial aquatic feeds has traditionally been based on fish meal (FM) as the main protein source because of its high protein content, balanced essential amino acid (EAA) profile, essential source of fatty acids, digestible energy, minerals and vitamins. Therefore, it is not surprising that FM is the most expensive protein source in terrestrial animal and aquatic feeds.

Results of experiment are mixed. Soy bean meal has been a suitable contender of fish meal (FM) but its use has been limited by the presence of anti-nutritional factors (Pouomogne, Takam & Pouemegne, 1997; El-Sayed, 1998;

Falaye & Jauncey, 1999; Ogunji, Toor, Schulz & Kloas, 2008; Nguyen & Davis, 2009; Abu, Sanni, Erondu & Akinrotimi, 2010; Sule & Sotolu, 2010). Coupled with that, the price per kilogram of locally produced soy bean meal competes favourably with that of tuna fish meal on the Ghanaian market. The price increase in soy bean is attributed to its multiple uses as food for human consumption and feed for livestock including fish and poultry production. These accounts still leave FM the most widely used animal protein especially in farm-based livestock, poultry and aqua feeds in Ghana.

Fish meal (FM) is an expensive protein source, because its production is now limiting as a result of dwindling catches. Despite its increasing cost it is still highly demanded as a standard protein source in animal feed production. The incorporation of FM as in fish feed for intensive fish production has been reported to be largely responsible for the high cost of about 50 % of the cost of feed in aquaculture production. As a result of the high cost of fish meal, aquaculturist and fish nutrition experts have been in continuous search for alternative sources of animal and plant protein sources which may be available and affordable for replacement of FM in aqua feed production.

Carbohydrates

The fact that high levels of dietary protein may lead to the consumption of protein for energy purposes has led to the investigation of the use of non-protein energy sources for fish diets. Providing adequate energy from carbohydrates and lipids for fish diets can minimize the use of costly protein. Regardless of the protein source, the use of carbohydrate-rich diets has been considered economical as fish would utilize the inexpensive carbohydrate as a source of energy (Chou & Shiau, 1996; Ali & Al-Asgall, 2001; Krogdahl, Hemre & Mommsen, 2005; Liti, Mugo, Munguti, & Waidbacher, 2006; Mohanta, Mohanty & Jena, 2007; Tran-Duy, Smit, Dam & Schrama, 2008).

Raj, Haniffa, Seetharaman and Appelbaum (2008) indicated that carbohydrate specifically refers to the nitrogen-free extract (NFE) portion of a feed, which is physiologically digestible and fetches an energy value of 4.0 kcal = 16 kJ/g. Dietary carbohydrates are the cheapest source of food energy but they are not well utilized by all animals.

The amount of non-protein energy in the diet is one of the factors influencing the quantitative dietary protein requirement of a fish species. This is because part of the dietary protein may be utilized as an energy source, if the diet is deficient in non-protein energy. The use of protein for energy is wasteful from the nutritional, economic and ecological points of view, and when compared to lipids and carbohydrates, it is worthwhile supplying as much of the required energy as possible in the form of lipids and carbohydrates (Manjappa, Keshavanath & Gangadhara, 2002). Unless sufficient dietary energy is provided the quality and quantity of dietary protein could not reflect protein synthesis. The optimum protein to energy ratio in a diet is very important for the maintenance of quality reduction of dietary cost. High levels of protein without sufficient energy in the diet might be harmful to fish (Page & Andrews, 1973). Larger size fish requires more energy and less protein when compared to small fish (Prather & Lovell, 1973).

Solomon, Tiamiyu and Agaba (2007) suggested that appropriate levels of carbohydrates for fish diets be provided so that protein and lipids will not be catabolized disproportionately for the supply of energy and metabolic intermediaries for the synthesis of other biological compounds. Partial replacement of lipid with carbohydrate improves fish quality and productivity. In a report by Abu *et al.* (2010) about 10 – 40 % by weight of most aqua feeds constitutes energy sources, with maize being the major source of energy. However, the high cost of maize as a result of its multiple uses such as human food and livestock feed including that of fish has led to the use of unconventional (i.e. locally available feed stuffs that are not standardized) feeds as sources of energy.

Agro-industrial by-products

The need to intensify the culture of the fish has made it essential to develop biological effective, acceptable and suitable feeds either for supplementation in ponds and cages or as for complete feeding in tanks (Falaye & Jauncey, 1999). For the purpose of nutrition and economic benefits, previous researches have made attempts at increasing the use of non-conventional plant part such as cassava leaves, yam bran, sweet potato leaves; and animal in various forms e.g. maggots, earthworms and tadpoles to replace conventional feed ingredients like fish meal, wheat bran, rice bran for fish feed ration (Gabriel *et al.*, 2007; Sogbesan & Ugwumba, 2008; Abu *et al.*, 2010).

According to Kaur and Saxena (2004), the continued dependence on traditional feed ingredients like oil cakes and fish meal has led to increase in the prices of these components. This in turn, determines the profitability of aquaculture enterprises. Improving the basis for the assessment of ingredient cost and their availability is perhaps one of the key issues in maximizing opportunities for optimum use of feed ingredients as replacement in feed formulation for aquaculture enterprises (Abu *et al.,* 2010). The need to find good quality, cheaper and readily available alternative resources so as to substitute the costly ingredients in traditional supplementary diets is imperative (Gabriel *et al.,* 2007).

Sogbesan and Ugwumba (2008) reported that non-conventional feed resources are credited for being non competitive in terms of human consumption, very cheap by-products or waste products from agriculture, farm made feeds and processing industries and are able to serve as a form of waste management in enhancing good sanitation. Apart from availability, the nutrient quality of feed ingredients is one of the major prerequisites (which sometimes is a function of cost and season) for production of good quality feeds. The use of agro-industrial wastes/by-products holds a promise in this direction. Many agro-industrial by-products such as pito mash (Oduro-Boateng & Bart-Plange, 1988), cocoa husk (Pouomogne *et al.,* 1997; Falaye & Jauncey, 1999), brewery waste (Kaur & Saxena, 2004), maize, rice and wheat brans (Liti *et al.,* 2006), fig jam by-product (El-Dakar, Abd-Elmonem & Shalaby, 2008) and palm kernel cake (IIuyemi, Hanafi, Radziah & Kamarudin, 2010) have been used in evaluating the growth of fish. Substantial quantities of crop residues and industrial by-products could be used in formulation of fish diets. However, many of these unconventional feeds are not maximally utilized by fish producers due to insufficient evaluation of their nutritive value and/or their inadequace benefits (El-Dakar *et al.*, 2008).

Amisah, Oteng and Ofori (2009) indicated that the greatest limitation to fish farming in Ghana is lack of suitable fish feed. Most feeds are farm-based and commercial fish feeds have to be imported, using the limited foreign exchange of the state. The main source of carbohydrate in many farm-based fish diets in Ghana is wheat bran (WB) and maize. However, the widespread uses of wheat bran and maize in livestock and fish feed production is causing a price increase in these feed ingredients and hence feed cost. The alarming factor is that, WB is not produced in Ghana or even in the West African sub-region and so it is not internationally traded. This subjects it to global market shocks and votility should there be shortage of supply. However, a fair proportion of industries in Ghana are agriculture-based and produce a range of by-products e.g. rice bran, pito mash, groundnut bran and maize bran which could be rich ingredients for the formulation of fish feed as they already contribute to livestock and poultry feed.

There is therefore the need to look for alternative sources of carbohydrates that are nutritionally rich and locally available. Pito mash (PM), rice bran (RB) and groundnut bran (GB) are agro-industrial by products that are of great importance for developing more nutritive and economical fish diets in developing countries like Ghana. However, information available on the nutritive value of some of these agro-industrial wastes/by-products (i.e. PM, RB and GB) in the formulation of fish feed is rather scanty in Ghana.

Pito mash (PM), RB and GB are ideal for use as a good plant feed ingredient for the development of fish feed in Ghana. This is because these by-products do not suffer severe competition as human food, livestock (including fish) and poultry feed as it may be with other sources, e.g. wheat bran (WB) or maize. Although not much of the by-products have been used in aqua feed production in Ghana, a few researchers have advocated the incorporation of these ingredients in animal feed because of their nutrient richness. For instance, Oduro-Boateng and Bart-Plange (1988) recommended the use of PM as a full dietary protein replacement for fish meal for *Tilapia busumana*, with considerable economic savings. Amisah *et al.* (2008) incorporated about 15 % of GB in the diets of *Clarias gariepinus* to reduce the cost of feed as well as to improve the nutrient richness of the experimental diets.

Pito mash (PM) can be obtained in large quantities at a very low or no cost at all especially in the two Upper Regions of Ghana where it is produced as a by-product from the local production of local beer popularly known as “pito”. In other areas for example, part of the Volta Region as well; PM can be obtained as a by-product from the production of local beer popularly known as “brukutu”. The good news is that, PM is produced, though not in very large quantities throughout the country.

The Upper East, Central and Volta regions constitute the major rice producing areas in Ghana and Rice bran (RB) is a by-product produced form the milling of rice. It is readily available and is largely used in pig rations. Groundnut bran GB) is largely produced from groundnut seed from the production of groundnut oil with major industries in the Northern Region of Ghana.

Availability of these agro-industrial by-products is a significant step towards more efficient utilization of plant by-products. It will also help to boost the income generated by the local industries involved, hence raising the standard of living of the persons involved. Improved productivity and profitability of fish farmers especially in developing countries like Ghana are constrained by both the availability and cost of pelleted fish feeds. Hence, there is a need to encourage farmers to formulate their own pelleted feed using ingredients produced on-farm as far as possible. This would require close examination and evaluation of the nutritional quality and economic feasibility of ingredients that would be used as feed for fish production. This study was carried out therefore to assess the growth performance of cultured Nile tilapia, *Oreochromis niloticus* and the economic benefits when fed on different dietary treatments formulated and prepared using different agro-industrial by-products such as pito mash, rice bran, groundnut bran and wheat bran. The study was an attempt to address two-tailed concerns:

1. Assessing the feasibility of pito mash, rice bran and groundnut bran for use in producing formulated aqua feed in Ghana.
2. Assessing the profitability of these feedstuffs in reducing the dependence on the uses of wheat bran as well as mitigating the high cost of FM in aqua feed production for the aquaculture industry in Ghana.

Research problem

Aquaculture constitutes the fastest growing food production sector in the world. Though the contribution of aquaculture to the national economy of Ghana has not been disaggregated and its importance is not fully recognized, production is on the increase. For instance production increased from 950 metric tonnes in 2003 to 5,600 metric tonnes in 2008 as a result of proliferation of commercial fish farming especially on the Volta Lake. Though culture based fisheries production in Ghana is showing very strong growth, the rate is slow as it is bedeviled with constraints such as limited availability of good quality fish feed and seeds, inadequate extension and training services, limited direct domestic and foreign investment and credit facilities, undefined or poorly defined land and water rights and lack of legislation specifically for aquaculture (Agbo, 2008; Hiheglo, 2008; Amisah *et al.,* 2009). The major constraint though is inadequate high-quality, affordable and available feed supply. The lack of production diets coupled with the raw materials to produce high quality feeds have been significant factors limiting the expansion of the industry.

In aquaculture, feeding of fish has been acknowledged generally to constitute the major cost component incurred during the production cycle. The cost of feed accounts for about 60-70% of the running expense involved in operating an aquaculture enterprise. This, in most cases reduces the profit of the farmer resulting in just a marginal profit. The high cost of feeding has affected the development and expansion of aquaculture enterprises in most African countries. The situation has contributed in no small way, to the low protein intake in many developing African countries, a result of which many people especially children are malnourished because of low protein diet intake (FAO, 2003; Gabriel *et al.*, 2007; Abu *et al.*, 2010).

According to Ashitey and Flake (2009) in Ghana, feed requirements in the aquaculture sector is about 15,000 MT a year. Only one company (GAFCO) produces fish feed but sales are slow because they produce low quality feed. Most of the commercial aquaculture operators purchase pelletized extruded floating fish feed imported from countries such as Israel and Brazil. The cost of the pelletized imported feed is $2,500/ton for fingerling feed, and $1,200/ton for continued culture feed. Hence the need to focus on fish feed in the current research.

Null hypotheses testing:

1. There is no significant difference in the growth performance of fry and fingerlings of *O. niloticus* fed on different dietary treatments.
2. There is no significant difference in terms of cost-effectiveness using different dietary treatment in the culture of fry and fingerlings of *O. niloticus* fed on different dietary treatments.

Objectives

The objectives were to;

1. determine the growth performance of fry and fingerlings of *O. niloticus* fed on fed on different dietary treatments;
2. assess the cost-effectiveness of each dietary treatment;

3. monitor changes in water quality parameters (temperature, dissolved oxygen, pH, turbidity, total suspended solids, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, phosphorus, total alkalinity and total hardness).

CHAPTER TWO

LITERATURE REVIEW

This chapter provides relevant literature support for the study.

Biology of tilapia

The word “Tilapia” includes many genera of the Cichlidae family. These fish are endemic to Africa and the Middle East, but they have been introduced into most tropical and subtropical countries for aquatic weed control and aquaculture (IIuyemi *et al.,* 2010). Tilapias are deep-bodied, perch-shaped fish that grow very fast many of which reach 1-2 kilograms in weight. There are three major taxonomic groups in the family Cichlidae. Species of the genus *Tilapia* are substrate brooders which deposit their eggs in nests excavated in the sediment. Species of the genus *Oreochromis* which are maternal mouth brooders, i.e. the females incubate the eggs in their mouths after external fertilization. Species of the genus *Sarotherodon* are bi-parental mouth brooders (Boyd, 2005).

Sklan, Prag and Lupatsch (2004) reported tilapia fishes to be generally omnivores. These fishes utilize a wide spectrum of foods and have digestive systems that differ both from those of carnivores and from many herbivorous fish. Tilapia feed on plankton, green leaves, benthic organisms, aquatic invertebrates, larval fish, detritus, and decaying organic matter (Liti, Mac’were & Veverica, 2002). They also readily adapt to eating pelleted fish feed. Nevertheless, they often are considered to be filter-feeders because they can trap plankton in mucus excreted from their gills and swallow the plankton-rich bolus. They have a long intestine necessary to digest plant material. Moreover, tilapias are continuous feeders and therefore when cultured, feed should be offered 3 to 4 times per day if practicable (Boyd, 2005).

Optimum growth of tilapia usually is achieved from 28 and 32 ^{o}C declining greatly with decreasing temperature at 22 ^{o}C and below (Teichert-Coddington, Popma & Lovshin, 1997). Feeding usually stops at temperatures below 16 ^{o}C and temperatures below 10 ^{o}C could be lethal. Tilapias are freshwater species, but the commonly cultured tilapias grow well in salinities up to 25 ‰. The wide tolerance of tilapias to variation in environmental conditions, their amazing capacity to reproduce and their great ability to compete with other species is a major concern when they are introduced outside their native range. Escapees from weed control or aquaculture projects have reproduced in other surrounding waters and tilapia have become the major species in local fish populations at the expense of native species (Boyd, 2005).

The characteristics of fish flesh are important in the market. The flesh of tilapia usually is light gray to white, but some dark or red muscle tissue may accumulate along the lateral line and on the surface of the lighter-colored muscle in other areas. The red muscle can give tilapia meat a darker colour than desired by many consumers. The peritoneal lining of pure tilapias is black and must be removed to avoid consumer complaints. The meat of both red and white tilapia hybrids generally has a whiter colour than that of pure tilapia species. Also, red muscle tends to be a greater problem for fish larger than 600 g in weight. When fillets having red muscle tissue attached are frozen, an objectionable fishy taste can result. Tilapias also have bones along the rib cage and small pin bones among the muscle tissue which must be removed from fillets to avoid consumer complaints. The dressed-out percentage of tilapia is rather low. The usual fillet yield is about 33 to 35% of live weight (Boyd, 2005).

Culture of tilapia

Tilapia has been raised as food for human consumption for a long time. Illustrations from Egyptian tombs suggest that the species i.e. Nile tilapia, *Oreochromis niloticus* of the genus *Oreochromis* was cultured more than 3000 years ago (Maar, Mortimer & Vander-Lingen, 1966). According to Popma and Masser (1999) tilapia is referred to as "Saint Peter's fish" in reference to biblical passages about the fish fed to the multitudes. Although endemic to Africa their distribution has been extended by introduction to include much of the tropics and subtropics (IIuyemi *et al.*, 2010). Currently, tilapia culture is widely practiced in many tropical and subtropical regions of the world (El-Sayed, 1998). More than 22 species of the genera of the Cichlids are being cultured worldwide. However, *O. niloticus, O. mossambicus, O. aureus, O. hornorum, O. galilaeus, T. zillii* and *T. rendalli* are the most commercially cultured Cichlids. Tilapias are used in commercial farming systems in almost 100 countries and are developed to be one of the most important fish for aquaculture in this century (Fitzsimmons, 2000).

According to FAO (2005) aquaculture in Ghana is mostly Nile tilapia, *Oreochromis niloticus* and the African catfish, *Clarias gariepinus*. Tilapia forms about 80 % of aquaculture production without any algae, shrimps, crabs and frogs being farmed. The widespread culture of *O. niloticus* is due to the fact that they are undemanding and can be easily bred in captivity under a wide variety of climatic conditions. They are prolific breeders with a fast growth rate, good quality flesh, few disease problems and have high fecundity. These exclusive features make *O. niloticus* an excellent aquaculture species and explain why they have become one of the most important domesticated fishes around the world especially in tropical and subtropical environments (Stickney, 1979; Hillary & Claude, 1997; Liti, Cherop, Munguti & Chhorn, 2005; Ahmad, 2008; Azaza *et al.,* 2009; Nguyen & Davis, 2009; Shlapobersky *et al.,* 2010).

Nutritional requirements of Tilapia

Nutrition is the most expensive component in aquaculture, particularly intensive culture where it accounts for over 50% of operating costs (El-Sayed, 1998; Agbebi, Otubusin & Ogunleye 2009). Tilapias are very good aquaculture species because they are able to produce high quality protein from less refined protein sources. The genus *Oreochromis* generally feed on algae, aquatic plants, small invertebrates, detrital materials and associated bacterial films. Individual species may have preferences among these materials. *Oreochromis* spp. can utilize a wide variety of feeds and therefore are considered as opportunistic feeders. This provides an advantage to farmers because the fish can be reared in extensive situations that depend upon the natural productivity of a water body or in intensive systems that can be operated with lower cost feeds (Effiong, Sanni & Fakunle, 2009 The best growth performance of tilapia is exhibited when they are fed a balanced diet of protein, carbohydrates, lipids, vitamins, minerals and fibre.

Nutritional requirements of fish differ for different species and more importantly vary with life stage. Fry and fingerlings require diets with higher protein, lipids, vitamins, minerals and lower carbohydrates for rapid growth and development of muscles, internal organs and bones with rapid growth (Agbo, 2008).

Protein requirement

Protein is an important nutrient which provides amino acids required for synthesizing new tissue and/or replacing worn out tissues and also provides energy when other energy sources are limited. Dietary protein is therefore the most important nutrient considered when formulating fish feed to avoid any deficiency which may lead to poor growth and loss of weight. The protein component alone for fish diets represents about 50 % of feed cost in intensive culture (El-Sayed, 2004). Therefore selection of dietary protein of the right quantity and quality is necessary for successful fish culture. There are 10 different (i.e. Methionine, Lysine, Tryptophan, Proline, Phenylalanine, Valine, Threonine, Isoleucine, Arginine and Leucine) essential amino acids that cannot be synthesized by fish at rates sufficient for maximum growth and development and have to be supplied in the diet (Audu, Adamu & Binga, 2008).

From various studies, the protein requirements of fingerlings tilapia have been reported by Boyd (2005) to range from 30-56 %. It however decreases as the fish grows older. Bahnassawy (2009) reported that, there are significant differences in feeding different dietary protein levels (17 %, 25 % 30 % and 35 %) to *O. niloticus* on their growth performance and body composition. Diets containing 30 % crude protein is considered optimal for growth of the fish species.

Lipid requirement

Lipids are composed of fatty acids; some of which are also essential for some species of fish. High crude fat is known to enhance energy production and hence better growth rates as it spares the breakdown of protein for energy (Audu *et al.*, 2008). In a study by Chou and Shiau (1996) the minimum dietary lipid requirement for tilapia is was 5 % and the maximum 12 %. Manjappa, Keshavanath and Gangadhara (2002) reported the same dietary lipid range (5 - 12 %) required for optimal performance in carps. Growth of fish fed with diets which have higher lipid level (14.2 %) is poorer, reflecting a negative impact of dietary fat beyond the optimum level. This could be due to the imbalance in protein: fat ratio, thus reflecting the inability of fish to utilize lipid above a certain threshold level. According to Stickney (1979) excess of lipids can lead to fatty livers in a variety of animals as well as decreasing the dress-out percentage of the crop.

Results in a study by Ali and Al-Asgall (2001) indicated that, *O. niloticus* is capable of utilizing lipids up to a level of 14 % with a minimum level of 29 % carbohydrates in their diets. Lowering the carbohydrate level beyond this limit with a simultaneous increase in lipid level even on an energy equivalent basis not only affected their growth performance but also the overall efficiency of energy and protein utilization. According to Liti *et al.* (2006) a feedstuff could have a higher level of lipid but this source of energy probably may not be readily available to the fish because of poor utilization of the feedstuff.

Fibre content

Fibre refers to indigestible plant matter such as lignin, cellulose, hemicellulose, pentosans and other complex carbohydrates found in feedstuffs. Fibre provides physical bulk to feed and may improve pelletability. However, it is not desirable to have a fibre content exceeding 8 -12 % in diets for fish as increase in fibre content would consequently lead to the decrease of the quantity of a usable nutrient in the diet. Older fish seem to cope with higher dietary fibre content (a maximum of 8 -10 %) than younger ones at about 6 - 8 %. Excessive fibre content could also result in decrease in total dry matter and nutrient digestibility of the diet resulting in poor performance (Agbo, 2008).

Liti *et al.* (2006) reported that in rice bran (RB) fed on diets, the total carbohydrate was in the form of fibre, which probably contributed to the poor feed utilization efficiency and lower growth of *O. niloticus* observed in that treatment. Because fibre is indigestible, it adds to the faecal waste which negatively affects the water quality and hence fish performance.

It has been observed that, elevated crude fiber (beyond 10.5%) content for fish diets may exert a negative effect on the digestibility of nutrients (Ali & Al-Asgall, 2001). This was supported by Attipoe *et al.* (2009) who found out that, higher fibre reduced the digestibility of diets and resulted in poor growth. The diet with the lowest fibre content (13.64 %) contributed to easier digestibility than other diets with higher fibre contents (17.35% and 20.23 %).

Carbohydrates include fibre, starches and sugars and while not usually considered essential, they can be an effective source of energy and improve food conversion efficiency when included at moderate amounts. Although no specific recommendation have been put forth, excess of it may lead to dangerous levels of liver glycogen (Stickney, 1979). Carbohydrates are usually the cheapest sources of energy although different species of fish differ in their ability to use carbohydrates. Tilapias can perform equally well on diets containing 17 – 42 % carbohydrates. However, low growth performance for fish could result from high crude fibre (Chou & Shiau, 1996; Gonzalez & Allan, 2007; Audu *et al.,* 2008).

In Hemre, Mommsen and Krogdahl (2002), the efficiency of dietary carbohydrate on protein sparing vary, even within a single species. This variability may be because of the particular strain of fish used, environmental factors, including temperature, light regime and season, or the type and amount of sugar/starch supplied in the diet. The complexity of the carbohydrate may also impact carbohydrate utilization. For instance, in feeding studies with tilapia, atlantic salmon and channel catfish growth was improved with gelatinized starch compared with pure glucose or other mono-saccharides.

Guimaraes, Pezzato, Barros and Tachibana (2008) in a research to evaluate the nutrient digestibility of cereal grain products and by-products demonstrated the use of complex carbohydrates (starch) more efficiently than less complex forms (mono and disaccharides) by Nile tilapia. The efficient use of complex carbohydrates was attributed to their feeding habits i.e. the fact that these fish are omnivores and appear to use starch more efficiently than carnivores.

Replacing dietary corn with barley seed in *O. niloticus*, Belal (1999) concluded that, mixing different source of carbohydrates would probably have an advantage over using one source in producing a cheaper and more efficient diet.

Minerals and vitamins

Minerals and vitamins are critical for good and balanced nutrition in tilapia and a lot of research (Stickney, 1979; Roem, Stickney & Kohler, 1990; El-Sayed & Teshima, 1991; Watanabe, Kiron & Satoh, 1997) have been conducted to determine these requirements. Minerals are important for normal skeletal development of fish but some also have a vital role in the functioning of enzymes and other metabolic functions. The ash content of an ingredient is the total amount of minerals (or inorganic matter) present within food. Vitamins are complex organic compounds required in small amounts for normal growth, reproduction, health and general metabolism. Diets lacking adequate levels of vitamins and minerals can result in growth and development disorders and death in severe cases of deficiency. Many vitamins especially Vitamin C (ascorbic acid) are easily damaged by heat, light and humidity and this reduces their usefulness to fish. Vitamins and minerals are contained in some feed ingredients but premixes are also often added to feeds, especially where fish or prawns are stocked at high densities obtain most of their nutrients from the added feed rather than natural food. Fish eat primarily to satisfy energy requirements. If there is too much energy compared with protein, animals will stop eating before they consume enough protein for maximum growth. Too much energy from dietary fat or carbohydrate can also lead to high body fat, low dress out yield and poor shelf life in market size animals. If there is too little energy compared with protein, part of the dietary protein will be used for energy. It is therefore important to determine the optimum ratio of energy to protein for different species of fish. This ratio can also be affected by the size of the animal. Generally the ratio of energy to protein increases as the animal gets bigger (Stickney, 1979; Roem *et al.*, 1990; El-Sayed & Teshima, 1991; Watanabe *et al.*, 1997).

Feeding schedules in fish culture

The delivery of feed is one of the most important practices in aquaculture because it directly influences growth, production and food conversion ratio (FCR) and consequently economic viability. Poor feeding management can be an important source of farm waste. Given the opportunity, fish would generally consume more feed than they can use efficiently. Fish should be fed in the morning after the dissolved oxygen (DO) has reached an acceptable high level and in the afternoon when the water is not at its maximum temperature for the day. Catfish have grown best when fed to satiation twice daily (Stickney, 1979).

In an effort to feed Sunshine Bass (i.e. a cross between *Morone chrysops* and *Morone saxatilis*) efficiently, promote optimal growth and reduce labor costs associated with feeding, sunshine bass were fed one of four feeding schedules: once per day, twice per day, once every other day and twice every other day for 10 weeks (Thompson, Webster, Morgan & Grisby, 2000). At the conclusion of the feeding trial, percentage weight gain (PWG) and specific growth rate (SGR) of Sunshine Bass fed twice/day were significantly ($P < 0.05$) higher (342 %) and (1.85 %/day), respectively compared to fish fed all other feeding frequencies.

Feed consumed and feed conversion ratio (FCR) were higher for fish fed twice/day that all other feeding frequencies.

In a related study, Riche, Oetker, Haley, Smith and Garling (2004) reported no significant differences in growth and feed efficiency in triplicate groups of fingerlings *O. niloticus* fed two, three and five times daily, but all were statistically different from those feed once daily. Feeding rate (allowance) in practical feeding of fish involves two options; one is to feed the fish to satiation and the other is to feed a restricted ration. Best growth is normally achieved by feeding to satiation. But satiation levels are not necessarily the most economic feeding levels, because food conversion at satiation levels is often poor. Also, it is difficult to determine satiation levels for fish because food consumption occurs in the water medium. This may lead to overfeeding, which is wasteful and deleterious to water quality. As a result, restricted rations are recommended for feeding fish.

Biochemical composition of fish

According to Solomon *et al.* (2007), knowledge of the body composition of fish and factors affecting it allow the assessment of fish health and the determination of efficiency of transfer of nutrients from the food to the fish. This makes it possible to predict and modify carcass composition. In a study on the effect of feeding different grain sources on the growth performance and body composition of tilapia by Solomon *et al.* (2007), a significant difference ($P < 0.05$) was reported in carcass protein of the fishes. Thus, the final carcass protein was higher than the initial carcass protein. Also the initial carcass ash and ether extract were significantly different ($P < 0.05$) from the ones obtained for the final. However, the nature of the cereal grains seems not to affect the crude protein and ash content of fish as there was no significant difference ($P > 0.05$) in the values of crude protein and ash.

According to Raj *et al.* (2008), carbohydrate dietary level did not significantly influence the carcass moisture, dry matter, biochemical composition and ash in freshwater catfish *Mystus montanus.* High protein content (68.8 %) was observed in the flesh of fish fed on diet containing 11.69 % dietary carbohydrate level. The dietary nutrient levels were not influenced by the carcass composition, because fish fed a low dietary protein (42 % dietary protein) had a high carcass protein (68.8 %), but fish fed a high dietary protein (43 % dietary protein) had a low carcass protein (67.2 %). There was no significant change in lipid, carbohydrate and ash contents. However the deposition of high lipid content for fish fed with high amount of carbohydrates which was attributed to the availability of sufficient energy.

Ali and Al-Asgall (2001) reported that, the body composition of fish appear to correlate positively with growth performance as the dietary lipid content has a positive effect on the carcass lipid for fish. Body moisture and crude protein contents decreased whereas the lipid and ash contents increased with a decrease in carbohydrate/lipid (CHO/LIP) ratio. They suggested that the optimum dietary CHO/LIP ratio for maximum growth performance of *O. niloticus* was between 2.06 and 4.95.

The results of El-Dakar *et al.* (2008) revealed that, no significant differences ($P > 0.05$) in crude protein, ether extract, ash and energy contents were observed among all fish groups fed on diets containing fig jam by-product (FJB) and the control group. Higher FJB levels resulted in a decrease in protein and ether extract contents, while ash and energy contents were not affected by increasing FJB levels in diets.

Feeding oil-supplemented diets resulted in higher levels of carcass lipid in common carp. This suggested a significant positive correlation between fish weight and carcass lipid levels, as found in Manjappa *et al.* (2002)

. Metwally and El-Gellal (2009) reported significant difference in *O. niloticus* fed on diets containing different materials. Fish groups fed olive and date stone mill diets had higher crude lipids in their bodies than other groups fed on barley and wheat bran. Also significant differences were noticed in ash contents among fish fed different diets. On the contrary, Iluyemi *et al.* (2010) reported a decrease in lipids and dry matter contents in tilapia fed *Trichoderma longibrachiatum* palm kennel cake (TL-PKC) attributable to be due to the presence of non-starch polysaccharides (NSPs).

In a report by Ochang, Fagbenro and Adebayo (2007) in observing the influence of dietary palm oil on growth response, carcass composition of *O. niloticus*, final carcass crude protein of fish was significantly ($p < 0.05$) higher for fish groups fed with 6 % than those fed with lower (4 % and 2 %) and no (0 %) palm oil and those of the initial fish. The crude lipids were not significantly different between treatments. The ash contents of fish fed on diets with no palm oil were significantly lower than with the other diets.

Biological evaluation of the growth performance of fish

Mean weight gain (MWG)

In a study by Kaur and Saxena (2004), net weight gains were higher in both *Catla catla* and *Lobeo rohita*, with 30 % brewery waste incorporated in supplementary diets in an attempt to replace rice bran than those in the control (0 % brewery waste). This was attributed to better absorption and utilization ability of these fishes. However, in *Cirrhina mrigala*, final body weights in all the treated groups were lower than in the control. In channel cat fish, distiller's grain with solubles (DGS) and soyabean meal totally replaced fish meal in the diet without reducing weight gain and feed conversion efficiency (Webster, Yancey & Tidwell, 1992). In tilapia, Wu, Rosati and Brown (1996) too observed maximum weight gain for fish fed on a diet containing 35 % corn DGS.

El-Dakar *et al.* (2008) in Egypt observed that when fig jam by-product (FJB) replaced wheat bran at 0 %, 25 % or 50 % in glass aquaria, no significant differences ($P > 0.05$) were observed among these replacement levels compared to the control regarding body weight and specific growth rate, while the higher levels of 75 or 100 % substitution showed negative effects on performance of Florida red tilapia. This they attributed to the higher crude fibre content of FJB (11.9 %).

In Scotland a related experiment was conducted by Falaye and Jauncey (1999) in circular plastic tanks incorporating cocoa husk for fish diets at 0, 100 and 200 g/kg-1 resulted in a decrease in weight gain with increasing cocoa husk content. The lower fish growth was attributed to the elevated crude fibre of the feed at higher cocoa husk level and its possible effects on the digestibility of protein and dry matter which were significantly ($P < 0.05$) reduced.

Wu, Rosati, Warner and Brown (2000) found that, weight gain for fishes depended on the amount of fish meal in the diets of fishes as lower weight gains was recorded for diets without fish meal, intermediate for diets with 4 % fish meal and higher for diets with 8 % fish meal, although the differences were not significant ($P > 0.05$).

In a study by Liti *et al.* (2006) using three brans (maize, wheat and rice), *O. niloticus,* fed on maize bran (MB) had the highest mean weight followed by those in wheat bran (WB). Fish on rice bran (RB) treatment had the least individual mean weight. Gross yields of *O. niloticus* from WB and MB treatments were similar ($P > 0.05$) but significantly higher ($P < 0.05$) than those from RB.

According to Metwally and El-Gellal (2009), *O. niloticus* fed with barley and wheat bran exhibited higher weight gain and specific growth rate than the fish fed on olive mill and date stone mill containing diets. They attributed the higher weight gain in barley and wheat to lower FCR meaning better feed utilization.

Compounded diets comprising wheat bran and groundnut bran yielded better mean final weight gain, mean net weight gain and mean daily growth rate than diets with rice bran, groundnut bran and fish meal also compounded. However the good performance of fish fed with diet formulated with rice bran, fish meal and groundnut bran was as a result of the manifestation of the fish meal in the diet which is known to have an excellent biological value for growth (Attipoe *et al.*, 2009).

Specific growth rate (SGR)

Iluyemi *et al.* (2010) observed the feed utilization and growth parameters of *T. longibrachiatum* fed on fermented palm kernel cake (TL-PKC) and reported a significant decrease in SGR and protein efficiency ratio (PER) for tilapia. They attributed the reduced growth rate to decreased digestibility of TL-PKC. The poor digestibility of TL-PKC observed might have primarily been due to the presence of non-starch polysaccharides (NSP), which were reported to be the product of fermentation as well as part of fungal cell wall material.

Protein efficiency ratio (PER)

Protein efficiency ratio (PER) is defined as the ratio between the weight gain of fish and the amount of protein fed. Protein efficiency ratio (PER) values provides a simple, if imperfect, means of comparing protein quality of feedstuff and diets. The PER values are a measure of the amount of weight gained per unit protein consumed and values for fish meal range from 3.1 to 3.7. Comparing the most commonly used plant ingredients to fish meal, plant proteins which are generally lower in CP, have a lower PER (Drew, Borgeson & Thiessen, 2007).

In a study by El-Dakar *et al.* (2008) using FJB as an energy source in replacing WB at various levels, protein utilization decreased with increasing FJB levels. However, at 25 % FJB substitution level protein efficiency ratio and productive protein value were similar to the control group. Higher levels of FJB (75 and 100 % replacement level) gave the poorest protein utilization.

Chatzifotis *et al.* (2010) demonstrated that, reduced growth and PER of the fish fed high lipid diet is indicated that, excessive dietary lipid levels not only spare proteins, but can also result in higher fat accretion and impaired growth performance.

Feed conversion ratio (FCR)

Feed conversion ratio (FCR) is defined as the amount of dry feed fed per unit live weight gain. It often serves as a measure of efficiency of the diet. The more suitable the diet for growth, the less food is required to produce a unit weight gain, i.e. a lower FCR.

Glencross, Booth and Allan (2007) indicated that, for an assessment to be made on the nutrient utilization of a diet and by reference to an ingredient, there is the need to measure feed intake (often reported as both an amount (g $fish^{-1}$) and rate (g $fish^{-1}$ day^{-1}). Utilization of diets is measured using the feed conversion ratio (FCR) which is expressed as the dry weight of feed offered divided by the weight gained by the animal. Feed conversion ratio (FCR) becomes lower as the efficiency of feed utilization increases. At feeding rates above or below the optimum for the conditions that exist during the experiment, the FCR will increase with the lowest FCR value occurring at the feeding level where food conversion efficiency was highest (Stickney, 1979).

Feed conversion ratio (FCR) of fishes would differ for fish fed with diets containing different crude protein and energy levels stemming from using different feedstuff in formulating feed. Diets with higher crude protein and energy content would result in better growth than those of lower levels of protein and energy (Attipoe *et al.*, 2009).

El-Dakar *et al.* (2008) reported an FCR between 0.99 – 1.17 for Florida Red Tilapia, *O. niloticus* crossed with *O. mossambicus* with various inclusion levels (0, 25, 50, 75 and 100 %) of Fig Jam by- product (FJB) for fish diets. No significant differences ($P > 0.05$) in feed and protein intakes among fish fed on diets containing FJB levels were observed. No significant differences ($P > 0.05$) in FCR values were found among treatments contained FJB up to 50 % compared to the control group. However, FCR values were poorest in diet of fish given either 75 or 100 % of FJB replaced wheat bran.

Feed conversion ratio (FCR) of *O. niloticus* fed experimental and control diets in a study by Wu *et al.* (2000) indicated the best FCR (1.67) with an initial mean weight of 9 g fed 36 % protein diets for 84 days. Siddiqui, Howlader and Adam (1991) reported FCR values of 1.7 - 2.3 for tilapia with an initial weight of 19 g fed 34 % protein diet for 98 days in out-door concrete tanks. However, in other experiments, FCRs were higher; for example, Falaye and Jauncey (1999) reported an FCR range between 3.7 - 4.9 for *Oreochromis niloticus* fed on diets containing cocoa husk. Liti *et al.* (2006) reported FCR for *Oreochromis niloticus* and *Clarias gariepinus* to range between 3.40 - 4.04. Apparent FCR, which included the weight gain of *Clarias gariepinus*, was significantly higher ($P < 0.05$) in diets with RB than in MB or WB treatments. No significant differences ($P > 0.05$) in FCR were observed between MB and WB treatments.

Condition factor (K)

The fatness or wellbeing (state of health of the fish) of the fishes was assessed using the condition factor (K) based on the hypothesis that heavier fish of a particular length are in a better physiological condition. Condition factor is a useful index for the monitoring of feeding intensity, age and growth rates for fish (Bauer, Musselius & Strelkov, 1973).

Anene (2005), in his investigation on the condition factor (K) of four cichlids in a lake in Nigeria reported that, the K in the four cichlids (*Chromidotilapia guntheri, Tilapia cabrae, Tilapia zillii* and *Tilapia mariae*) varied with their standard lengths in two - three easily distinguished phases. In *Chromidotilapia guntheri* the condition factor significantly decreased from 4.10 ± 0.10 at a length of 90 mm to 3.91 ± 0.1 at a size of 110 mm. In phase II, there was a significant increase from 3.91 ± 0.10 (110 mm) to 4.6 ± 0.60 at a length of 120 mm ($P < 0.05$). In the third phase, there was a decline to 3.70 ± 0.40 at a standard length of 150.mm. In *Tilapia cabrae*, the size spectrum of condition factor showed that there were two phases of significant slump separated by a plateau. The plateau size ranged between 100 and 120 mm in smaller fish. The condition factor significantly decreased from 7.2 ± 0.6 at a length of 70 mm to 5.10 ± 0.5 at 100 mm ($P < 0.01$). The second phase of the significant decrease was observed between 120 mm (4.91 ± 0.71) and 140 mm (1.82 ± 0.2) ($p<0.05$). Condition factor values of *Tilapia mariae* registered a significant and progressive decrease ($p < 0.05$) between the size range of 120 mm and 150 mm from 5.58±0.34 to

5.16±0.51, respectively. It significantly increased between 150 and 170 mm from 5.16 ± 0.51 to 5.53 ± 0.1, respectively ($P < 0.05$) (Anene, 2005).

Economic efficiency evaluation of agro-industrial by products

In evaluating three test diets from agro-industrial by-products, a diet compounded with rice bran, groundnut bran and fish meal was the most costly diet whiles a diet compounded with rice bran and groundnut bran was the cheapest (Attipoe *et al.*, 2009).

The cost of diets reduced when expensive ingredients were partially or completely replaced by less expensive and readily available ingredients. In this light, cassava root meal is a profitable alternative source of energy for partial or total replacement of maize in the feeding of hybrid catfish (Abu *et al.,* 2010). Fish farmers are encouraged to use alternative ingredients for a profitable aquaculture enterprise. The cost-benefit analysis of feeding red tilapia diets containing FJB as an energy source indicated a gradual decrease in price per kg diet by increasing FJB level. The incidence cost for diets containing up to 50% FJB was insignificant ($P > 0.05$) when compared with the control diet. Similar trends were found with the profit index. Using FJB up to 50% in diets of red tilapia was economically efficient (El-Dakar *et al.*, 2008).

In a related study, Liti *et al.* (2006) studied the effects of supplementary bran (maize, wheat and rice) on *O. niloticus* growth in fertilized ponds. On the economic performance of *O. niloticus* based on the minimum market price per kilogramme available animal protein sources, wheat bran (WB) and maize bran (MB) posted positive net returns above both variable and total costs with WB posting higher returns than MB. At the same sale price, RB treatment posted negative returns above both variable and total costs. At retail price the three test-feeds posted positive returns above both variable and total costs with WB again positing the highest returns.

Water quality parameters

Environments can be described as bad or good depending on their effect on the target trait, with bad being the case where expression of the trait is suppressed and good where it is enhanced (Charo-Karisa *et al.,* 2006). Tilapia culture can cause water pollution in the pond environment with likely impacts on water quality arising from increased loads of nutrients, oxygen demand, and suspended solids in water fed on effluent from tilapia culture. Nitrogen and phosphorus are the two nutrients of most concern because they are responsible for eutrophication. The oxygen demand and suspended solids result primarily from uneaten feed, faeces, plankton, and mineral particles (Boyd, 2005).

Temperature

Most aquatic organisms are poikilothermic (i.e., "cold-blooded") which means they are unable to regulate their body temperature. Fish species have an optimum temperature range for growth, breeding and reproduction. Tilapias generally grow best in temperatures ranging from 21 ^{0}C to 32 ^{0}C (El-Sherif & El-Feky, 2009).

Temperature is one of the most important factors affecting fish growth in any water body. Growth increases with increasing temperature to a maximum and rapidly declines. Within these limits, metabolism and food requirements increase with increasing temperature. For every 10 ^{o}C increase in water temperature, metabolic rate doubles and oxygen demand increases (i.e. the oxygen carrying capacity of the water decreases making oxygen less available for metabolic activity). The most obvious reason for temperature change in water bodies is the change in seasonal air and daily temperatures (Stickney, 1979).

Xie *et al.* (2010) demonstrated that the specific growth rate and protein retention efficiency of *O. niloticus* were significantly affected at a temperature of 37 ^{o}C. However, fish reared in a temperature range of 25 – 34 ^{o}C were not significantly affected as they had higher specific growth rate and protein retention. Though increase in water temperature could increase feed intake and fish growth, excessively high water temperature could suppress growth, feed efficiency with decrease feed intake.

Dissolved oxygen (DO)

Fish growth is affected by several variables, key among them being fish size, DO, and water temperature, photoperiod and food availability (Charo-Karisa *et al.,* 2006). The oxygen demand from plankton is expressed much more slowly than the oxygen demand of uneaten feed and faeces (Boyd & Gross, 1999). Thus, there is less likelihood of dissolved oxygen depletion around outfalls from ponds than from other culture systems. Also, ponds have a relatively long hydraulic retention time and most coarse particles have already settled from the water. Therefore, the likelihood of sediment accumulation around pond outfalls also is less than for outfalls of other culture systems. Dissolved oxygen concentration in intensive tilapia culture units may be quite low at times. Tilapias are rather tolerant to low dissolved oxygen, and concentrations of 3 to 4 mg/L apparently are not extremely harmful to them even with long-term exposure (Boyd, 2005). Although one excellent attributes of tilapia is their tolerance of low DO concentrations, extended periods of hypoxia may reduce growth and cause mortality. FCR for fish depends directly on DO availability and food as these two factors are interrelated and can act to limit growth in hapas (Charo-Karisa *et al.*, 2006).

pH

The lethal effects of elevated pH are recognized as a potential factor contributing to the variable success of tilapia production. The pH of pond waters may increase above 9 during periods when photosynthesis is high. Waters discharged during afternoon from ponds may sometimes have a pH above the maximum pH of 8.5 to 9 often recommended for natural water bodies (Boyd, 2005). According to El-Sherif and El-Feky (2009), in the culture of *O. niloticus*, the best pH for optimum growth is at the level of pH 7 - 8. Above or below could depress growth. SGR values of tilapia increased by 0.53, 1.16, 1.11 and 0.95 % for the groups under pH 6, 7, 8, and 9, respectively. The differences among pH levels (6, 7, 8 and 9) for the SGR of tilapia were significant ($P \leq 0.05$); whereas, it was not significant ($P \geq 0.05$) between pH 7 and 8 (El-Sherif & El-Feky, 2009).

Turbidity

Turbidity in simple terms refers to the cloudiness of a water body. Light's ability to pass through water depends on how much suspended material is present. Turbidity may be caused when light is blocked by large amounts of silt, microorganisms, plant fibers, sawdust, wood ashes, chemicals and coal dust. Turbid water interferes with sunlight penetration consequently affecting the production of oxygen by water plants. This adversely may affect growth of aquatic life especially fish (Stickney, 1979).

In a study by Ardjosoediro and Ramnarine (2002) on the influence of turbidity on growth of the Jamaica Red Tilapia, results of the experiment clearly show that increased levels of clay turbidity have significant impacts on growth rates and survivorship of tilapia fingerlings. Growth rate decreases significantly at even intermediate turbidity levels of 50 NTU. At the higher levels of 100 - 200 NTU, although there is a decrease in growth rates, there is no significant difference at the various levels. Highly turbid water resulted in higher FCR, lower MWG and poorer survivorship.

Total suspended solids (TSS)

These are bits of particulate matter, larger than 0.45 μ found in the water column (Stickney, 1979). Suspended solids are made up of sediments particles, organic matter (detritus composed of plant and animal remains, waste food particles and faecal material), as well as phytoplankton cells and other living microorganism. Higher concentration of suspended matter in the water makes the water more turbid (Stickney, 1979).

Ammonia-Nitrogen (NH_3-N)

Knowing the concentrations of ammonia that limit growth and impair respiration is useful for aquaculture management and may assist in the maximization of production. Frances, Nowak and Allan (2000) reported that growth of fish exposed to 0.36 mg/l depressed growth as some of the energy derived from feed consumption may have to be expended on metabolic maintenance rather than growth.

Ammonia is toxic, not only to fish but also to all aquatic animals especially in pond aquaculture at low concentrations of dissolved oxygen. The toxic levels of un-ionised ammonia for short-term exposure usually are reported to lie between 0.6 and 2 mg/l, while some consider the maximum tolerable concentration to be 0.1 mg/l. Increase in NH_3-N concentration have been reported to increase FCR in *O. niloticus* by 4.3 fold in levels over 0.068 mg/l. Ammonia levels (0.068 mg/l) have been reported to progressively decrease the protein efficiency ratio (El-Shafai, El-Gohary, Nasr, Steen & Gijzen, 2004). At sub-lethal levels NH_3-N tends to block oxygen transfer from the gills to the blood and can cause both immediate and long term gill damage. The mucus producing membranes can be destroyed, reducing both the external slime coat and damaging the internal intestinal surfaces. Fish suffering from NH_3-N poisoning usually appear sluggish, often at the surface as if gasping for air (El-Shafai *et al.*, 2004).

Nitrite-Nitrogen (NO_2-N)

Nitrite is the immediate product in the breakdown of ammonia to nitrate and can be toxic to fish. Studies conducted to determine the toxicity of nitrites to cultured freshwater fish show that toxicity of nitrites varies widely. Silver perch exposed to increasing nitrites concentration (1.43 - 16.2 mg/l) exhibited reduced growth (Frances, Allan & Nowak, 1998).

Das, Ayyappan, Jena and Das (2004) reiterated that an increase in nitrite content in the water exerts considerable stress on the fish resulting in growth suppression, tissue damage and mortality resulting in poor biomass production. Fish up-take of nitrites primary across the gill and accumulates in the gills, plasma, liver, brain, spleen and muscle. Cytological studies by Das *et al.* (2004) on the effects of nitrite toxicity on *Cirrhinus mrigala* indicated exposure to 2 mg/l and above resulted in shrunken and irregular shaped erythrocytes. According to Al-Harbi and Siddiqui (2000) the growth of *O. niloticus* culture in tanks at different stocking densities treatments was not affected with NO_2-N concentrations ranging from 0.2 to 0.52 mg/l in the tanks as this level is lower than the lethal level.

Nitrate-Nitrogen (NO_3-N)

Nitrate is produced by the autotrophic nitrobacter bacteria combining oxygen and nitrite in the bio-converter and to a lesser degree on the walls of the pond. A zero nitrate reading, combined with a non-zero nitrite reading, indicates the Nitrite-Nitrate bacterial converter action is not established. Nitrate levels will normally stabilize in the 50 - 100 ‰ range. Concentrations from zero to 200 ‰ are acceptable. Nitrate is essentially harmless (Frances *et al.*, 1998).

Phosphorus

Excess phosphorus loading particularly has been associated with algal bloom leading to eutrophication especially in tropical waters. This problem becomes worse with intensive aquaculture because large quantities of feed are introduced to achieve increased fish production (Nwanna, 2003).

Total hardness

Total hardness is defined as the characteristics of water that represent the total concentration of just the calcium and magnesium ions expressed in terms of milligrams per liter of calcium carbonate. The concentration of these divalent cations (calcium and magnesium) determines it hardness (American Public Health Association [APHA], 1975). Total hardness between 20 to 150 ml/l is recommended for most freshwater species. Low hardness can adversely affect some aquaculture animals as some e.g. *Sciaenop ocellata* may not be able to osmoregulate (Stickney, 1979).

Total alkalinity

The capacity of the natural water to resist changes in pH is known as alkalinity or the acid neutralization capacity (APHA, 1985). It is measured in terms of the amount of bicarbonate and carbonates ions that are available in the system. Total alkalinity between 30 and 200 mg/l in fresh water system is recommended (Stickney, 1979).

CHAPTER THREE

MATERIALS AND METHODS

This chapter explains how the study was conducted.

Site description

The study was conducted at the Aquaculture Research and Development Centre (ARDEC) of the Water Research Institute (WRI) of the Council for Scientific and Industrial Research (CSIR) at Akosombo in the Eastern Region of Ghana from October 2010 to March 2011. Aquaculture Research and Development Centre (ARDEC) lie between the latitude 6 ^{o} 13 ' North and the longitude 0 ^{o} 4' East.

Plate 1: Aerial view showing the layout of the ponds at the site where the study was carried out

NB: Arrows show the pond in which the experiment was carried out.

Procurement of ingredients

Pito mash (PM) was purchased from pito brewers at the Akosombo community and rice bran (RB) from a rice milling factory at Akuse all in the Eastern Region of Ghana. Groundnut bran (GB) was obtained from Kumasi in the Ashanti Region of Ghana. Other ingredients such as broiler premix, palm oil, wheat bran and fish meal were purchased from Ashaiman timber market in the Greater Accra Region of Ghana. The feedstuffs were transported to ARDEC and processed into feed for use during the trial experiment.

Chemical analysis of feed items

Proximate analyses of the feed ingredients for the experiment were carried out at the Animal Nutrition Laboratory of the School of Agriculture of the University of Cape Coast following the procedures that broadly adhere to the Association of Official Analytical Chemists [AOAC] (1990). The protocol was used in determining the percentage (%) dry matter (DM), Crude protein (CP), % Ash, % Crude lipids (CL) also known as the Ether Extract (EE) of fat, % Crude fibre (CF) and % moisture. Nitrogen-free extract (NFE) was computed using the formula: % NFE = (100 - % CP + % CF + % EE + % Ash). The nutritional characteristics of feed ingredients were used in formulating experimental diets. Formulated diets were also analyzed to ascertain their nutritional characteristics and to see if they conform to the desired protein and energy requirements of the species under study based on the formulation. This information helped in discussion results on the growth performance, feed conversion ratio and protein efficiency in relation to the cultured fish.

Determination of percentage (%) moisture

Moisture content was determined by air-drying the samples in an oven at 105 ^{o}C for 24 hours. It is a gravimetric measurement of water in the feedstuffs, diets and carcass expressed as a percentage of the initial sample weight.

NB: % Dry matter was computed by subtracting the % moisture in samples measured from 100%.

Determination of percentage (%) crude protein (CP)

The Micro-Kjeldahl method according to AOAC (1990) was used for the determination of CP of samples in triplicates. Two hundred and twenty milligrams (220 mg) of each sample were weighed into Micro-Kjeldahl tubes and about 5 ml of concentrated sulphuric acid added. The tubes were placed in the digestion block (Model: 2012 Foss Tecator) under a fume hood and the temperature of the digester increased gradually to about 370 ^{o}C. Samples were allowed to heat overnight till the solution became colourless indicating that the digestion was completed. The digestion tubes were allowed to cool and the digests poured into volumetric flasks and the volume made up to 100 ml with distilled water. About twenty milliliters (20 ml) of the digest were pipetted into the steam section of a distillation apparatus. Ten milliliters (10 ml) of alkaline mixture were added to the digest and the apparatus set to produce steam containing nitrogen which was condensed in the condenser and trapped in 5% boric acid. The distillate of about 50 ml was collected into a flat-bottomed flask and titrated against 0.0071 M hydrochloric acid. Percentage protein in the sample was calculated using the formula:

$$\text{Nitrogen in sample (\%)} = 100 \left\{\frac{\text{A X B}}{\text{weight of sample}} \text{ X } 0.014\right\}$$

Where: A = hydrochloric acid used in titration (0.0071 M)

B = normality of standard acid

Crude protein (%) = nitrogen in sample multiplied by 6.25

(Source of formula: AOAC, 1990)

Determination of percentage (%) ash

This measures the total inorganic matter by incineration (AOAC, 1990). Approximately 1 g of each sample was weighed in a pre-weighed crucible and incinerated for about 12 hrs overnight at 600 ^{o}C using a Gallankamp muffle furnace size 2. The furnace was opened and the crucibles with the ash removed and allowed to cool in a desiccator. The crucible plus ash were weighed afterwards and the difference in weight between the incinerated sample and sample before the incineration represented the ash content of the sample. This was e expressed as a percentage of the original sample using the formula:

$$\% \text{ Ash} = \frac{A - B}{S} \text{ x } 100$$

Where A = Crucible weight (g) + sample weight (g) before incineration

B = Crucible weight (g) + sample weight (g) after incineration

S = Weight of sample before incineration

(Source of formula; AOAC, 1990)

Determination of percentage (%) crude lipid (CL) or ether extract (EE) or fat

Crude lipids samples were determined using the Soxhlet solvent extraction method. Approximately 5 g of each sample was weighed into a thimble and corked with cotton. The thimble was inserted into a Soxhlet liquid/solid extractor (Model: Soxhlet foss 2020). The Soxhlet extractor was fitted onto a pre-weighed 150 g dry round bottom flask and about 80 ml of petroleum-ether (40 - 60 ^{o}C boiling point) poured into the Soxhlet apparatus containing the thimbles and the sample. The extraction apparatus was clamped to a metal stand to hold it over a heating source. A condenser was then fitted into a unit underneath the thimble in the Soxhlet extractor to condense evaporated petroleum ether back into the system during the extraction process. Extraction involved boiling (heat provided by the heating source) the petroleum ether in the round bottom flask which extracted the fat from the sample in the thimble. Evaporated ether was condensed back into sample chamber in continuous cycle for about 6 hrs continuously. Extracted lipid plus ether in round bottom flask was oven dried in an oven at 105 ^{o}C for at least an hour for the ether to evaporate leaving the lipid. The flask was cooled in a desiccator and the weight of the flask and the lipid weighed (W_2 g). The weight of the empty flask (W_1 g) was subtracted from the weight of the flask and the extracted lipid (W_2 g). The mathematical relation below was used to express the lipid as a percentage of the original sample.

$$\%\ \text{Crude lipid} = (W_2 - W_1)\ \text{x}\ \frac{100}{\text{weight of sample (g)}}$$

Where: W_1 = Weight of the empty flask in grams

W_2 = Weight of the flask and the lipid in grams

(Source of formula; AOAC, 1990)

Determination of percentage (%) crude fibre (CF)

About 1 to 2 g of defatted, dry sample was placed in a flask containing 1.25 % of 200 ml of boiling sulphuric acid solution. The flask was placed on a hot plate for exactly 30 minutes with constant swirling to periodically remove particles adhering to the sides. A Buchner funnel pre-heated with boiling water was then lined with an ashless filter paper to be used for the fitration process. At the end of the boiling period, the flask was removed and allowed to rest one minute after which the solution was filtered by connecting a suction pump to the Buchner funnel to filter the contents carefully. Filtration was carried out in less than 10 minutes. The filter paper was washed with boiling water carefully removing the residue and transferring it to the flask containing 200 ml of boiling sodium hydroxide (about 1.25 %) solution and boiled for another 30 minutes. A filtration crucible was pre-heated with boiling water and used to carefully filter the hydrolyzed mixture after letting it rest for 1 minute. The residue was again washed with boiling water, with the HCI solution and then again with boiling water, finishing with three washes with petroleum ether. The filtration crucible was placed in a kiln set at 105°C for 12 hours then cooled in a dryer. The weight of the crucible with the residue (A) inside was determined and place in the crucible furnace at 600 °C for 12 hours. The weight of the crucible and ash (B) was measured again after cooling in a dryer. The crude fibre was computed by using the mathematical relation below:

$$\%\ \text{Crude fibre} = \frac{(\text{A} - \text{B})}{\text{C}}\ \text{x}\ 100$$

Where:

A = weight of crucible with dry residue (g)

B = weight of crucible with ash (g)

C = weight of sample (g)

Determination of percentage (%) nitrogen-free extractives (NFE)

This was estimated by subtracting the total of % crude protein, % crude lipid, % ash and % crude fibre from 100.

Experiment 1

The experiment was conducted to assess the growth and economic performance of fry of *O. niloticus* fed on different agro-industrial by-products in out-door hapas. Four isonitrogenous-isoenergetic feeds were formulated using the following agro-industrial by-products as sources of carbohydrates: wheat bran, pito mash, rice bran and groundnut bran. The diets were formulated with the trial and error method (Olatunde & Moji, 2008; Rahman, Ang & Ramli, 2010) and prepared following the procedures of Pillay and Kutty (2005).

The study consisted five treatments, four (treatments) of which the fry of *O. niloticus* were fed with the four diets prepared differently using the four different test feeds (agro-industrial by-products) and the remaining or fifth treatment (control) depended on naturally available food in the pond. Fry reared on supplementary feed contained 36 % protein with a gross energy (GE, 18 MJ/kg). Fry of average weight (0.11± 0.01 g) were bulk weighed with a digital scale (Model DIGI DS 671) and stocked in triplicate groups at 50 m^3 in 1 m x 3 m x 1m fine mesh hapas installed a 0.2 ha pond (Plate 1).

Fry were fed three times daily at 0800 GMT, 1200 GMT and 1500 GMT at 10 % body weight. After every 2 weeks, at least 25% fry from each replicate were sampled, weighed individually and the average wet weight recorded. Based on the weigh measurement, feed was adjusted accordingly. The total quantity of feed fed to fry was recorded. The experiment lasted 8 weeks. On the harvest day, fish were removed and the body weight and length measured. Based on the measurements, the following parameters were calculated: mean weight gain (MWG), per cent weight gain (PWG), specific growth rate (SGR), protein efficiency ratio (PER) and feed conversion ratio (FCR) (see section for parameters calculated for details). Parameters such as the incidence cost (IC) and the profit index (PI) were calculated and used to access the cost-effectiveness of the different dietary treatments (see section on economic evaluation for details).

Experiment 2

The experiment was conducted to assess the growth and economic performance of fingerlings *O. niloticus* fed on different agro-industrial by-products in out-door hapas. Similar to experiment 1, fingerlings of *O. niloticus* fish depended on naturally available pond food (NF) and/or with supplements of a 30% protein formulated feed using different agro-industrial by-products.

Diet formulation and preparation

The Trial and Error Method (Olatunde & Moji, 2008; Rahman *et al.*, 2010) was used to formulate four isonitrogenous (30 % CP) and isoenergetic diets (GE, 18 MJ/kg). Feedstuff were sun dried and finely ground at the corn mill and sieved with a 420μ/cm^2 nylon mesh to remove stones and larger sized particles to improve pellet stability. The ingredients were weighed using a top pan balance according to the proportion based on the formulation for various treatments and mixed together in a large basin. Broiler (vitamin/mineral) premix, lysine and methionine and palm oil were added and the mixture further mixed thoroughly. During the first few weeks of experiment, fish were fed with powered feed till they were capable of feeding on pellets of about 2 mm. A little quantity of water was added to moisten the mixed proportions of the prepared feed to enable pelleting. The moistened materials were then pelletized using a pelletizing machine. Pelleted feed were sun dried, bagged and stored in dry and cool environment for use throughout the study (De Silva, Shim & Khim, 1990; Anderson *et al.*, 1991; Pillay & Kutty, 2005; Gonzalez & Allan, 2007; Bahnasawy, 2009).

Experimental set-up/system for growth trial for fingerlings of O. niloticus

The experiment was carried out in hapas installed in a 0.2 ha earthen pond (of size 0.2 ha) which was filled by means of 3 m pipes using an electrical machine pump by drawing water from the downstream flow of the Akosombo dam. Fifteen (15) fine mesh hapas (size 1 mm) each of capacity 10 m^3 (5 m x 2 m x 1 m) were installed in the pond such that three quarters (¾) of the height of the hapas were submerged and one quarter (1/4) above the water surface to prevent the fish from escaping. The hapas were suspended by means of nylon ropes tied to bamboo poles, inserted into the bed of the pond. See Plate 2 below showing the experimental set up.

Plate 2: Experimental set-up showing the hapas mounted in a 0.2 ha pond for *O. niloticus* fingerlings

Experimental fish for growth trial

About 98% hormonal male sex reversed *O. niloticus* fingerlings of average weight 7 ± 0.23 g were obtained from ARDEC and stocked at a density of 200 fingerlings per 10 m^3 in each of the fifteen net hapas at 20 fish per meter cube. Fish were measured of their body length and weight and stocked in hapas in the experimental unit for them to acclimatize to the experimental conditions for about three–four days before the start of the actual feeding trial experiment. During this period they were kept on the same standard diets. The weight of fish were measured using a dry celled digital balance (model: Tanita KD 160) to the nearest 1 g and the standard and total lengths measured using a fish measuring board to the nearest 0.1 cm before being transferred to the experimental hapas. Five treatments were given to the experimental fish. Fish in four of the five treatments were fed with supplementary diets prepared using agro-industrial by-products and the fifth treatment served as control with no supplementary feed. Each of the five treatments were in triplicate groups and randomly assigned to the hapas installed in the pond. The fish were reared and observed for 24 weeks during which fortnight body measurement (weight and length measurements) were taken to evaluate their growth and response to the feeding on the diets administered.

Feeding regime

Fish were fed by hand-casting twice daily from 0830 – 0930GMT and between 1500-1600GMT at 10 % weight for 6 weeks (i.e. at the start of the experiment), 7 % following another 6 weeks, 4 % for another 6 weeks and 2 % for the last 6 weeks making 24 weeks in all. The fishes were fed for 6-7 days a week and the daily ration equally divided between feeding times. Daily feed intakes were recorded and feed adjustments made fortnightly by sampling 25 % of the fishes from each triplicate of the various treatments and weighed to provide a good significant estimate of the average weight. Samples were returned to hapas. The lengths and weights of fishes from each replicate were pooled for each treatment and based on these measurements (lengths and weights), the ration was adjusted accordingly.

Based on the measurements, the following parameters were calculated: mean weight gain (MWG), per cent weight gain (PWG), specific growth rate (SGR), protein efficiency ratio (PER) and the feed conversion ratio (FCR) (see section on parameters calculated for details). Parameters such as the incidence cost (IC) and the profit index (PI) were calculated and used to access the cost-effectiveness of the different dietary treatments (see section on economic evaluation for details). The number of dead fish found floating was recorded and survival rate calculated fortnightly.

Parameters calculated

Mean weight gain (MWG)

Mean weight gain (MWG) was computed as:

$$\text{MWG} = \text{Final mean weight of fish} - \text{Initial mean weight of fish}$$

(Charo-Karisa *et al.*, 2006; Adewolu, 2008; Ogunji *et al.*, 2008; Effiong *et al.*, 2009; Sawhney & Gandotra, 2010; Sule & Sotolu, 2010)

Per cent weight gain (PWG)

Per cent weight gain (PWG) was computed as:

$$\text{PWG} = \frac{\text{final weight} - \text{initial weight}}{\text{initial weight}} \text{ x } 100$$

(Sawhney & Gandotra, 2010)

Specific growth rate/day (SGR)

Specific growth rate was computed as (SGR):

$$\text{SGR} = \frac{\text{In } W_2 - \text{In}W_1}{\text{time travel}} \times 100$$

Where:

W_1 = initial weight (g) at stocking

W_2 = final weight (g) at the end of experiment

InW_2 – InW_1 = Natural logarithms of both the final and initial weight of fish.

Time travelled in days

(Charo-Karisa *et al.*, 2006; Adewolu, 2008; Ogunji *et al.*, 2008; Effiong *et al.*, 2009; Sawhney & Gandotra, 2010)

Protein efficiency ratio (PER)

Protein efficiency ratio was computed as:

$$\text{PER} = \frac{\text{total weight gained by fish}}{\text{total protein fed to fish}}$$

Where protein intake per fish is total feed given multiplied by the % crude protein in feed (Adewolu, 2008; Ogunji *et al.*, 2008; Effiong *et al.*, 2009; Sawhney & Gandotra, 2010).

Feed conversion ratio (FCR)

The FCR of fish fed various diets was calculated using the relationship:

$$\text{FCR} = \frac{\text{total feed given}}{\text{total weight gained by fish}}$$

(Adewolu, 2008; Ogunji *et al.*, 2008; Effiong *et al.*, 2009; Sawhney & Gandotra, 2010)

Survival rate (SR)

Survival rate (SR) of fish under various treatments was determined as:

$$\%\text{SR} = \frac{\text{Initial number of fish stocked} - \text{mortality}}{\text{Initial number of fish stocked}} \text{ x } 100$$

(Charo-Karisa *et al.*, 2006; Ogunji *et al.*, 2008)

Condition factor (K)

In assessing the physiological condition of the fishes used during the trial, the standard lengths of fishes were measured using a fish measuring board to the nearest 0.1 cm and their respective weights measured to the nearest 0.01 g using a Tanita (model: KD 160). The formula below was used to compute the condition factor:

$$K = \left(\frac{W}{SL^3}\right) x\ 100$$

Where: K = condition factor, W = weight of fish in grams and SL = the standard length of the fish in centimeters (Bauer *et al.*, 1973; Anene, 2005; Charo-Karisa *et al.*, 2006; Ogunji *et al.*, 2008).

Biochemical evaluation of *O. niloticus* fingerlings

Knowledge of the body composition of fishes is important in assessing the efficiency of transfer of nutrients from the feed to the fish thus making it possible to predict the effect of different diets on the flesh composition of fish. Ten (10) fishes were killed by hitting the head against a hard surface immediately after taking their weight measurements and stored in a refrigerator below zero degrees celsius to preserve them and the initial flesh quality determined later. When the experiment was terminated five (5) fishes from each treatment were randomly selected to determine the final flesh quality. That which could not be determined immediately were preserved in a refrigerator and determined later.

The flesh of fish was analyzed following the procedures that broadly adhere to AOAC (1990) to determine the crude protein, crude fat, crude fiber, moisture, ash and nitrogen free extract contents.

Sensory evaluation of cooked *O. niloticus*

A seven (7) member panelists (regular fish eaters) were selected from the Water Research Institute, Akosombo for their interest and availability as well as sensorial capabilities of discriminating likeness for sensory attributes such as colour (appearance) of the flesh, odour (smell), flavour (taste), texture (tenderness) and overall acceptability of fish from various dietary treatments. The panelists were orientated on how to fill a sensory evaluation form designed following the description of Omolara and Olaleye (2010) prior to serving of the fish. Fish from each treatment were processed and cooked separately in pots containing about 3 g of salt dissolved in 300 ml of pipe water at 100°C for 5 - 10 minutes. The fish from each treatment was assigned codes; 01, 02, 03, 04 and 05 representing the five dietary treatments and served in individual plates and given to the panelists to describe and rate the attributes based on a 9-point hedonic scale of 1 (dislike extremely) and 9 (like extremely). Drinking water was provided to rinse their mouths after tasting each sample.

Economic evaluation

A simple economic analysis was used to assess the cost effectiveness of diets used in the feed trial. The cost of feed and the transport fare were used in the calculations with the assumption that all other operating costs remained constant (e.g. cost of constructing hapa, cost of fingerlings and labour). Cost of the feeds was calculated using market prices of ingredients factoring in the cost of transport as well (as indicated earlier) in Ghana as at the time of purchasing the feed. Agbo (2008) proposed what he called Incidence Cost (IC), which is governed by the unit cost of the feed and its apparent FCR. Incidence Cost (IC) was determined using the formula:

Incidence cost (IC) as:

$$\text{IC} = \frac{\text{cost of feed}}{\text{weight of fish produced}}$$

(Nwanna, 2003; Agbo, 2008; Abu *et al.*, 2010)

IC is actually the cost of feed to produce a kg of fish (relative cost per unit weight gain), and the lower the value the more profitable using that particular feed.

According to Agbo (2008), another parameter to evaluate the cost effectiveness of feed is by calculating the profit index (PI). The value of fish was calculated using the farm gate market price per kilogramme of fish taking into consideration the size ranges of fish at farms in Akosombo and its environs.

Profit index (PI) as:

$$\text{PI} = \frac{\text{Weight or value of fish produced}}{\text{cost of feed}}$$

Water quality analysis

Water samples from the pond were collected biweekly between 0800 GMT - 0900 GMT for the analysis of physical (temperature, dissolved oxygen, pH, turbidity, total suspended solids) and chemical (ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, phosphorus, alkalinity and total hardness) water quality parameters.

It has been established over the years at WRI, Akosombo that, there is no significant ($P > 0.05$) differences in water quality when taken from different sampling points within ponds (F.Y.K Attipoe, personal communication, October

10, 2010). Therefore water samples were taken at random from the pond and analyzed for various water quality parameters.

Temperature and DO

An InLab Oxi Level 2 meter was used to measure both temperature and dissolved oxygen (DO) concurrently to the nearest 0.1 ^{o}C and 0.00 mg/l respectively. The probe of the instrument was lowered into the pond and the meter reading recorded into a field note book.

pH

The pH of water samples were measured *in situ* using a Hach (model: EC 20 pH/ISE) meter. After calibration instrument using pH buffers of 4 and 7, the meter was lowered into the pond and the meter reading recorded into a field note book.

Water samples were collected into 1000 ml bottles and taken to the ARDEC laboratory for analysis of turbidity, total suspended solids (TSS), ammonia-nitrogen (NH_3-N), nitrite-nitrogen (NO_2-N), nitrate-nitrogen (NO_3-N), phosphorus (PO_4-P) alkalinity and hardness. The procedures were as follows;

Turbidity

The Nephelometric method was used to determine how turbid the pond water was. A turbidimeter (model: ELE paqualab) after calibration with the distilled water (deionized water) blank of 000 NTU and a standard of 040 NTU. Water samples were thoroughly shaken till air bubbles disappeared and about 5 ml poured into the turbidimeter tube. Turbidity of samples was read directly from the turbidimeter in NTU.

Total suspended solids (TSS)

With the Photometric method, the TSS of water samples was measured using a Hach DR/2000 Direct reading Spectrophotometer at a wavelength of 810 nm. Twenty five milliliters (25 ml) of deionized water blank were poured in a cuvette to calibrate the meter to 0 mg/l. After calibration about 25 ml of water samples were measured and the readings recorded (APHA, 1975; 1985).

Ammonia-Nitrogen (NH_3-N)

Using the Hach DR/2000 Direct Reading Spectrophotometer at a wavelength of 425 nm, the Direct Nesslerization method was used to determine the NH_3-N content of water samples. The meter was standardized using distilled water zero blank and a standard of 1.00 mg/l NH_3-N solution. Water samples were prepared by adding to 25 ml a drop of EDTA reagent and the solution swirled to mix. One milliliter (1 ml) of Nesslers reagent was added and further swirled to mix thoroughly. After about 10 minutes, the concentration of NH_3-N solutions wAS measured directly from the spectrophotometer reading in two decimal places (APHA, 1975; 1985).

Nitrite-Nitrogen (NO_2-N)

Diazotization method using the Hach DR/2000 Direct Reading Spectrophotometer at a wavelength of 507 nm was used in determining the NO_2-N of water samples. The instrument was standardized using deionized water 0.000

mg/l and 0.250 mg/l NO_2-N standard. About 1 ml of 0.4 M sodium hydroxide (NaOH) solution plus 1 ml of colouring reagent were added to 20 ml of the water sample and swirled to mix. The spectrophotometer was then set to have a reaction time of about 15 minutes after which the concentration of NO_2-N in prepared samples was measured directly in mg/l to three decimal places (APHA, 1975; 1985).

Nitrate-Nitrogen (NO_3-N)

The procedure in determining the nitrates took the same format as that of nitrites, except that the hydrazine reduction method was used. The spectrophotometer at a wavelength of 507 nm was standardized with deionized water blank 0.00 mg/l and 0.25 mg/l NO3-N standard solution. To 20 ml of the water sample, 1 ml 0.3 M NaOH solution and $CuSO_4$/hydrazine (reduction mixture) solution were added with swirling to mix. Prepared samples were warmed for about 10 min in a water bath at about 60 ^{o}C. Samples were allowed to cool to room temperature and 1 ml of colouring reagent added. The spectrophotometer was then set to have a reaction time of about 15 minutes after which the concentration of NO_3-N in prepared samples was measured directly in mg/l to two decimal places (APHA, 1975; 1985).

Phosphorus (PO_4-P)

The Stannous Chloride method using the Hach, DR/2000 spectrophotometer at a wavelength of 890 nm after calibration using deinonized waster blank, 0.00 and 0.50 mg/l PO_4-P, was employed in determining the phosphorus level in water samples. To 25 ml of water samples, 1 ml of ammonium molybdate reagent I and 2 drops of stannous chloride reagent I was added with thorough swirling after each addition. After about 10 minutes of reaction time, the concentration of PO_4-P in prepared water samples was measured directly in mg/l to two decimal places (APHA, 1975; 1985).

Total alkalinity

The Visual Colour Change (Indicator) method was used to determine the total alkalinity of water samples. About 100 ml of the water samples were measured and poured into a flat bottom flask. Three drops of phenolphthalein were added and swirled to effect a colour change to pink (indicating phenolphthalein alkalinity). If not, 3 drops of bromcresol green-methyl red (second) indicator solutions were added and swirled to mix to effect a colour change to light blue. The sample was titrated with 0.02 N H_2SO_4 standard acid until the blue colour changed to light pink (APHA, 1975; 1985). The amount of acid used-up was read and the mg/l $CaCO_3$ was computed to one decimal place using the relation below:

$$\text{Alkalinity, } CaCO_3\text{, mg/l} = \frac{\text{A x N x 50,000}}{\text{ml of water sample}}$$

Where A = ml standard acid used

N = normality of standard acid (in this case, 0.02 N H_2SO_4)

Total hardness

The EDTA titrimetric method (this measures the calcium and magnesium ions) was used in measuring the hardness of the water (APHA, 1985). To 50 ml of the water samples 1 ml of the buffer solution was added and swirled to mix. A pinch of indicator powder (Eriochrone black dry powder) was added and swirled to mix. Exactly 0.01 M EDTA solution was titrated against the prepared sample until a colour change from reddish tinge to blue was observed. The amount of EDTA used-up to neutralize the sample was read and the mg/l $CaCO_3$ as hardness calculated and the result presented in two decimal places (APHA, 1975; 1985). Total hardness was calculated as:

$$\text{Total hardnes}, CaCO_3, \text{mg/l} = \frac{\text{A x B x 1,000}}{\text{ml of water sample}}$$

Where A = ml EDTA titrated

B = mg/l equivalent to 1 ml EDTA titrant

Analysis of experimental data

Experimental data gathered during the growth trial for both fry and fingerlings *O. niloticus* were used to determine various biological parameters (growth performance, food conversion ratio, protein efficiency ratio and condition factor) and economic parameters (incidence cost and profit index). Water quality parameters were analyzed as described in Standard Methods for the Examination of Water and Wastewater (APHA, 1975; 1985).

Biological, economic, sensory and biochemical data were subjected to one-way analysis of variance (ANOVA) using the SPSS version 16 at 5% ($P < 0.05$) significant level. Variance of data was presented as standard error of means. Where significant differences occurred, treatment means were compared using Fisher's Least Significant Difference (LSD) (Solomon *et al.,* 2007; Bahnassawy, 2009).

CHAPTER FOUR

RESULTS

This chapter introduces the outcomes of the study. The research findings are presented in Tables, Figures and Plates. Statistical tools used in analyzing the results include: LSD and the Chi-square tests.

Chemical composition of feedstuff

Results of the proximate analysis of the feed ingredients expressed on a dry matter basis (i.e. to help standardize information on the ingredients) are shown in Table 1. Among the test by-products, groundnut bran (GB) recorded the highest (93.96%) dry mater and rice bran (RB) recorded the lowest (91.78%) dry matter. Pito mash (PM) recorded the highest crude protein (CP) (28.77%) and RB recorded the lowest CP (6.68%). In terms of ether extract (EE), groundnut bran (GB) had the highest (9.00 %) and wheat bran (WB) had the least (4.59%). The crude fibre (CF) content of RB was the highest with 31.47 % and lowest in WB with 10.48 %. Ash content was lowest (4.42%) in PM and highest (16.87%) in RB. The calculated nitrogen-free extract (NFE) was and highest in WB (64.29%) and lowest in RB (36.25%). Gross energy was highest (17.82%) and lowest (11.26%) in RB.

Table 1: Chemical proximate analysis of the feed ingredients (on dry matter basis)

Type of Analysis	Fish meal	Pito mash	Rice bran	Groundnut bran	Wheat bran
% Dry matter	94.09	92.93	91.78	93.96	92.68
% Crude protein	48.95	28.77	6.68	21.69	15.46
% Ether extract	12.54	7.81	8.76	9.00	4.59
% Crude fibre	0.88	12.77	31.47	17.51	10.48
% Ash	27.93	4.42	16.89	4.78	5.18
% Nitrogen-free Extract	9.70	46.23	36.25	47.02	64.29
*GE (MJ/kg)	18.19	17.82	11.26	16.75	16.50

*Gross energy (GE) was calculated using the biological fuel values of 23.64, 39.54 and 17.15 MJ/kg for protein, fat and carbohydrate, respectively according to Ali & Al-Asgah (2001)

Experiment 1

Characteristics of diets for fry of O. niloticus

Of the formulated test diets (Table 2), the amount (i.e. quantity) of fish meal was highest in diet 3 (54%) and lowest in diet 2 (24%). Palm oil was similar for diets 1, 2 and 5 but higher for diet 3. However, methionine, lysine and broiler premix were the same for all the diets.

Dry matter contents were similar among the test diets. Though all the diets were similar ($\chi^2 < 0.35$, $P > 0.05$) in terms of the crude protein levels, diet 3 (36.93%) had the highest and diet 1 (35.63%) had the lowest. Ether extract (EE) was highest in diet 4 (14.26%) and lowest in diet 1 (6.45%). Ether extract level in diets 2 (6.96%) and 3 (7.90%) were intermediate. Fibre in the diets was in the following increasing order diet 1 < diet 4 < diet 2 < diet 3. Ash content was highest in diet 3 (19.19%) and lowest in diet 4 (14.26%) among the test diets. Nitrogen-free extract was highest in diet 1(34.83%) and lowest in diet 4 (26.87%). Although the gross energy (GE) was highest in diet 4 (18.93 MJ/kg) and lowest in diet 3 (16.60 MJ/kg), there was no significant differences ($\chi^2 < 0.35$, $P > 0.05$) among all the diets.

Table 2: Percentage inclusion levels and proximate analysis (on dry matter basis) of diets for fry of *O. niloticus* reared for 8 weeks

(%) Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5 (control)
Fish meal	45.0	24.0	54.0	36.5	-
Pito mash	51.0	-	-	-	-
Rice bran	-	72.5	-	-	-
Groundnut bran	-	-	41.0	-	-
Wheat bran	-	-	-	60.4	-
Methionine	0.1	0.1	0.1	0.1	-
Lysine	1.9	1.9	1.9	1.9	-
[1]Broiler premix	0.5	0.5	0.5	0.5	-
Palm oil	1.0	1.0	2.0	1.0	-
Total	100	100	100	100	-

(Table 2 *continued*)

Proximate analysis (on dry matter basis)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
% Dry matter	99.41	99.25	98.64	98.73	-
% Calculate CP	36.00[a]	36.00[a]	36.00[a]	36.00[a]	-
% Actual CP	35.63[a]	36.12[a]	36.93[a]	36.75[a]	-
% Ether extract	6.45	6.96	7.90	14.26	-
% Crude fibre	7.84	8.09	8.27	7.86	-
% Ash	15.25	16.37	19.19	14.26	-
% NFE	34.83	32.46	27.71	26.87	-
[2]Gross energy (MJ/kg)	16.95	16.86	16.60	17.03	-

Where:

1. Two thousand five hundred grams (2500 g) of the broiler premix contains; Vit A, D_3, E, B_1, B_2, B_6, B_{12}, pantothenic acid, calcium, selenium, ash, nitotinu acid, folic acid, biotin, choline, manganese, zinc, cobalt, iron, iodine, molybdenum and copper
2. Gross energy was calculated using the biological fuel values of 23.64, 39.54 and 17.15 MJ/kg for protein, fat and carbohydrate, respectively according to Ali & Al-Asgah (2001)

Note: Similar superscript alphabets in the columns and rows denote homogeneous means ($\chi^2 < 0.35$, $P > 0.05$)

Production data for fry of O. niloticus

As shown in Table 3, the average initial weight (AIW) of fry *O. niloticus* fish fed on the various diets were not significantly (P > 0.05) different among the five treatments. After 8 weeks, the average final weight (AFW) and mean weight gain (MWG) were statistically similar (P > 0.05) among all the five treatments. The growth curves of fish in response to the test diets over the 8 weeks experimental period are shown in Figure 1. Fish fed on diet 1 (wheat bran based diet) maintained the highest growth differentiating clearly after the 6th week of culture and diet 5 (control) maintained the least trend in growth. Fry fed on diets 2 (pito mash based diet) and 4 (ground bran based diet) keep overlapping throughout all the experimental period.

Per cent weight gain (PWG) was highest for fish fed on diet 3 (2724.70 ± 388.30 %) but similar (P > 0.05) to fish fed on wheat bran based diet or rice bran based diets. Although PWG was lowest for fish fed on diet 5 (1233.7 ± 83.56 %) the PWG was not significant (P > 0.05) among fish fed on diets 2 and 4. Although fish fed on diets 1 had the highest (6.77 ± 0.22) specific growth rate and fish fed on diet 5 recorded the lowest (5.63 ± 0.50) specific growth rate (SGR) there were no significant (P > 0.05) different among the five treatments.

Protein efficiency ratio (PER) and feed conversion ratio (FCR) for fish fed on supplementary diets were similar (P > 0.05). However the PER and FCR of fish in the control was not calculated because they were not fed., Survival rate (SR) and condition factor were not significantly (P > 0.05) different among the five treatments.

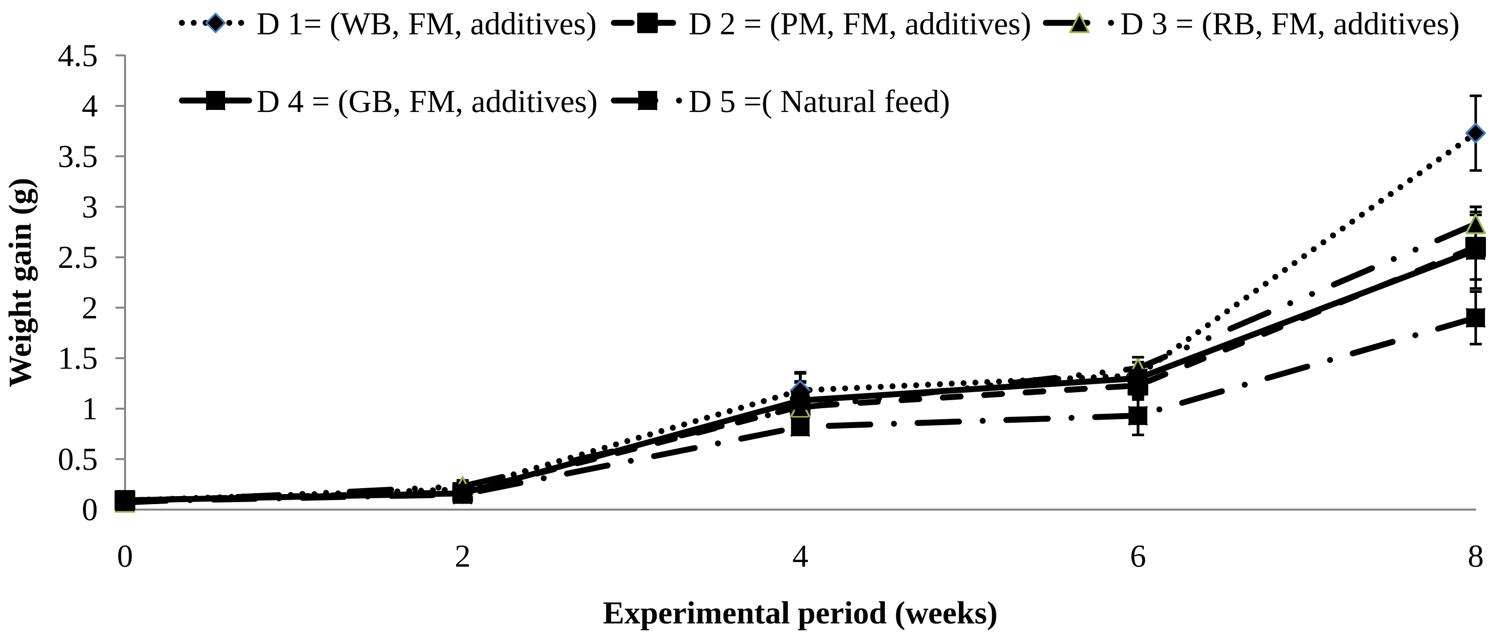

Figure 1: Growth curves for fry of *O. niloticus* fed on different dietary treatments for 8 weeks (vertical bars represent standard errors)

Table 3: Harvest data for fry of *O. niloticus* fed on different dietary treatments for 8 weeks

	Treatments (mean ± standard error)				
Parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
AIW g/fish	$0.09^{a} \pm 0.02$	$0.09^{a} \pm 0.02$	$0.07^{a} \pm 0.00$	$0.09^{a} \pm 0.01$	$0.08^{a} \pm 0.01$
AFW g/fish	$3.73^{a} \pm 0.37$	$2.60^{a} \pm 0.32$	$2.83^{a} \pm 0.17$	$2.57^{a} \pm 0.38$	$1.90^{a} \pm 0.26$
MWG g/fish	$3.64^{a} \pm 0.37$	$2.48^{a} \pm 0.32$	$2.76^{a} \pm 0.17$	$2.48^{a} \pm 0.38$	$1.82^{a} \pm 0.25$
PWG g/fish	$2235.60^{ab} \pm 215.71$	$1850.40^{ac} \pm 412.14$	$2724.70^{a} \pm 388.30$	$1372.70^{ac} \pm 337.12$	$1233.70^{c} \pm 83.56$
SGR %/day	$6.77^{a} \pm 0.22$	$6.03^{a} \pm 0.55$	$6.58^{a} \pm 0.04$	$5.93^{a} \pm 0.49$	$5.63^{a} \pm 0.50$
PER	$1.59^{a} \pm 0.26$	$1.51^{a} \pm 0.21$	$1.78^{a} \pm 0.34$	$1.25^{a} \pm 0.15$	-
FCR	$1.83^{a} \pm 0.27$	$1.90^{a} \pm 0.24$	$1.68^{a} \pm 0.31$	$2.30^{a} \pm 0.33$	-
SR %	$64.67^{a} \pm 5.21$	$62.33^{a} \pm 6.29$	$62.33^{a} \pm 5.40$	$53.67^{a} \pm 13.95$	$45.17^{a} \pm 6.84$
K	$4.37^{a} \pm 0.23$	$4.03^{a} \pm 0.48$	$3.03^{a} \pm 0.63$	$4.37^{a} \pm 0.53$	$4.41^{a} \pm 0.72$

Note: Similar superscript alphabets in the rows denote homogenous means (LSD, $P > 0.05$), Average initial weight = AIW; Average final weight =AFW; Mean weight gain =MWG; Per cent weight gain =PWG; Specific growth rate = SGR;

Protein efficiency ratio = PER; Feed conversion ratio = FCR; Survival rate =SR; Condition factor = K and dash (-) denotes parameters not calculable for because no supplementary feed was given.

Cost-benefit analysis of fry of O. niloticus fed on different dietary treatments in out-door hapas for 8 weeks

As indicated in Table 4, the cost per kilogram of feed was highest for fish fed on diet 3 (GH¢1.22) and lowest for fish fed on diet 2 (GH¢ 0.58). That of the fish fed on diet 4 (GH¢1.00) was also higher than fish fed on diet 1 (GH¢ 0.98). Feed administered was highest for the test fish fed on diet 1 (1.59 kg) and lowest for the test fish fed on diet 4 (1.29 kg).

The total biomass harvested was highest for test fish fed on diet 3 (0.96 kg) with the highest estimated value of GH¢ 47.75, and lowest for test fish fed on diet 5 (0.52 kg) with the lowest estimated value of GH¢ 26.18. Total harvested biomass and the estimated values for fishes fed on diet 1 > diet 2 > diet 4.

Among the treatments (with respect to the test fish fed with supplementary feed), diet 4 recorded significantly ($P < 0.05$) the highest Incidence cost [IC] (2.13 ± 0.29) followed by diet 3 (1.97 ± 0.37), diet 1 (1.72 ± 0.26) and diet 2 (1.05 ± 0.14). However, the IC for diet 4 was not significant ($P > 0.05$) from diets 1 and 3. Diet 2, although recorded the least IC (1.05 ± 0.14) was not significant ($P > 0.05$) from diet 1. However it differed ($P < 0.05$) from diets 3 and 4.

The profit index (PI) was significantly higher ($P < 0.05$) for fish fed diet 2 (0.10 ± 0.01) than the rest of the other diets (1, 3, and 4). The PI of fish fed on diets 1, 3 and 4 were similar ($P > 0.05$).

Table 4: Cost-benefit analysis of fry of *O. niloticus* fed on different dietary treatments for 8 weeks

Diets	Cost/kg. of feed (GH¢)	Feed input (kg)	Cost of feed input (GH¢)	Harvested biomass (kg)	Value of biomass (GH¢)	[1]IC	[2]PI
Diet 1	0.98	1.59	1.57	0.94	46.78	$1.72^{ab} \pm 0.26$	$0.06^{b} \pm 0.0$
Diet 2	0.58	1.38	0.80	0.77	38.63	$1.05^{b} \pm 0.14$	$0.10^{a} \pm 0.01$
Diet 3	1.22	1.50	1.84	0.96	47.75	$1.97^{a} \pm 0.37$	$0.05^{b} \pm 0.01$
Diet 4	1.00	1.29	1.28	0.62	31.25	$2.13^{a} \pm 0.29$	$0.05^{b} \pm 0.01$
Diet 5	-	-	-	0.52	26.18	-	-

Where: Dash (-) = Parameters were not calculable for, because no supplementary feed was given. Cost price per 2 g of fish at the farm gate at ARDEC = GH¢0.10. Similar superscript alphabets in the columns denote homogenous means (LSD, $P > 0.05$)

1 Incidence cost (IC) = cost of feed consumed (kg/ GH¢) / Weight fish produced (kg)

2 Profit index (PI) = value of fish crop /cost of feed consumed

Experiment 2

Inclusive levels and chemical composition of diets for fingerlings of O. niloticus

Table 5 shows the composition and chemical analysis of diets for *O. niloticus* fingerlings. Among the test agro-industrial by-products, diet 3 had the highest amount of fish meal (56%) and palm oil (2.58%) and diet 2 had the lowest amount of fish meal (16%) and palm oil recorded the least (1.14%). The amount of fish meal in diet 1 (45.5%) was higher than in diet 4 (34%). Methionine, lysine and broiler premix were the same for all the diets, because specific quantities were needed in all diets to supplement those naturally occurring in the diets.

The proximate analysis of the test diets showed that, dry matter contents of the test diets were similar among all diets. The calculated crude proteins were similar to the actual crude protein for each of the diets. Dry matter was highest (91.45%) in diet 3 and lowest in diet 1 with about 88.54% dry matter. All the four prepared diets had similar ($\chi^2 < 0.35$, $P > 0.05$) crude protein levels. Diet 4 had the highest amount of ether extract (EE) (18.74 %) and diet 2 had the lowest EE (8.68 %). Crude fibre (CF) levels in the diets was in the following descending order diet 2 > diet 3 > diet 1 > diet 4. Ash content was highest in diet 3 (22.32%) and lowest in diet 2 (13.94%). Diet 2 (41.05%) had the highest nitrogen-free extract (NFE) and diet 3 (28.64%) had the lowest. Although the gross energy (GE) was highest in diet 4 (19.98 MJ/kg) and lowest in diet 3 (17.11 MJ/kg), there was no significant differences ($\chi^2 < 0.35$, $P > 0.05$) among all the diets. Diet 5 represented fish that were not fed with any supplementary diet, therefore no proximate composition was computed.

Table 5: Percentage inclusion levels and proximate analysis (on dry matter basis) of diets for *O. niloticus* fingerlings

Ingredients (%)	Treatments				
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5 (cont.)
Fish meal	45.5	16	56	34	-
Wheat bran	50.4	-	-	-	-
Pito bran	-	80.27	-	-	-
Rice bran	-	-	39		-
Groundnut bran	-	-	-	62	-
Methionine	0.1	0.1	0.1	0.1	-
Lysine	1.9	1.9	1.9	1.9	-
[1]Broiler premix	0.5	0.5	0.5	0.5	-
Palm oil	1.5	1.14	2.58	1.45	-
Total	100	100	100	100	-
Proximate analysis					
% Dry matter	88.54	91.22	91.52	91.45	-
% Calculated crude protein	30.06	30.22	30.02	30.24	-
% Actual. crude protein	30.42	30.36	30.14	30.25	-
% Ether extract	8.68	9.98	12.84	18.74	-
% Crude fibre	5.86	8.07	6.06	3.54	-
% Ash	14.95	13.94	22.32	16.76	-
% Nitrogen-free extract	40.09	41.05	28.64	30.71	-
[2]Gross energy (MJ/kg)	17.67	18.15	17.11	19.98	-

Where for Table 5:

1. Broiler premix of about two thousand five hundred grams (2500 g) contain; Vit A, D_3, E, B_1, B_2, B_6, B_{12}, pantothenic acid, calcium, selenium, ash, nitotinu acid, folic acid, biotin, choline, manganese, zinc, cobalt, iron, iodine, molybdenum and copper
2. Gross energy was calculated using the biological fuel values of 23.64, 39.54 and 17.15 MJ/kg for protein, fat and carbohydrate, respectively according to Ali & Al-Asgah (2001)

Buoyancy (pellets sink rate) of experimental diets for O. niloticus fingerlings

The four experimentally prepared diets sank very slowly after about 1 minute of visual observation. However, diet 4 was the most buoyant with about 80 % of the pellets still floating after 1 minute. Diet 2 and diet 1 had about 60 % of the pellets still floating and diet 3 was the least buoyant, with about 30 % of the pellets still floating. However, pellets of all the four diets sank completely after 5 minutes.

Acceptance of experimental diets by O. niloticus fingerlings

By visual observation, all diets were accepted by the experimental fishes as they voraciously and aggressively fed on the diets administered to them at each feeding time. However it was observed that, the best feeding response (eagerness to consume feed) was in the following order: diet 1 > diet 2 > diet 3 > diet 4. Whiles fish fed on diet 1 were always eagerly waiting to received the feed, those fed on diet 4 tendered to shy away from the feed.

Production data for O. niloticus fingerlings

Data on the growth performance of fingerlings of *O. niloticus* (Table 6) indicate that, the average initial weights (AIW) of the test fish were found to vary slightly but not significantly (P > 0.05) among the five treatments. However, at the end of the trial, the average final weights (AFW) were significantly (P < 0.05) different among the treatments. Fish fed on diet 1 (88.0 ±1 1.43 g) were the heaviest and the lightest was fish fed on diet 5 (12.40 ± 0.21 g). The AFW of other diets took the following descending order diet 3 > diet 2 > diet 4.

Among the treatments, diet 1 supported the best mean weight gain [MWG] (80.80 ± 3.48g) and the control, diet 5 supported the worse MWG (5.10 ± 0.04 g). Among the test agro-industrial by-products, diet 1(80.80 ± 3.48 g) recorded the best and diet 4 (44.30 ± 5.41 g) recorded the worse MWG. The growth curves of fish in response to the test diets over the 24 weeks (6 months) experimental period are shown in Figure 2. Fish fed on diet 1 maintained the highest growth differentiating clearly after the 10^{th} week of culture and diet 5 maintained the least trend in growth.

The effect of dietary treatment on percentage weight gain (PWG) was highest for fish fed on diet 1 (593.07 ± 28.23 %) and lowest for fish fed on diet 5 (12.00 ± 35.28 %). There were no significant differences (P > 0.05) among fish fed on diets 1, 2 and 3. The PWG of fish fed on diet 4 was significantly (P < 0.05) different from fish fed on diet 1, 3 and 5 but similar (P > 0.05) to fish fed on diet 2. The PWG of fish fed on diet 5 was significantly (P < 0.05) different from all the other diets.

Among the treatments, fish fed on diet 1 had the highest specific growth rate [SGR] (1.49 ± 0.02 % d^{-1}) and fish fed on diet 5 had the lowest SGR (-0.77 ± 0.00 % d^{-1}). However, the SGR were not significantly ($P > 0.05$) different among fish fed on diet 1 and those feed on diet 2. Also the SGR for fed on diet 2 were not significantly ($P > 0.05$) different from fish fed on diet 3.

Although, protein efficiency ratio (PER) as observed in study were not significantly ($P > 0.05$) different between treatments, PER was highest for fish feed diet 3 (0.75 ± 0.05) and lowest for fish fed on diet 4 (0.51 ± 0.14). The PER of fish fed on diet 5 was not calculated because no supplementary feed was administered.

The best performing diet in terms of feed conversion ratio (FCR) was lowest (i.e. better utilization) for fish fed on diet 3 (4.46 ± 0.28) and highest (i.e. poor utilization) was for fish fed on diet 4 (8.60 ± 3.49). However, the FCR were not significantly ($P > 0.05$) different for fish fed various diets. The FCR of fish fed on diet 5 was not calculated because no supplementary feed was administered.

The condition factor (K) of fish fed on diets 1, 2 and 3 were similar ($P > 0.05$). However, fish fed on diet 4 was statistically ($P < 0.05$) different from the other treatments.

Plates 3-8 show the size of *O. niloticus* fingerlings at stocking and the maximum sizes attained for all the five treatments after the experiment was terminated.

Table 6: Harvest data for *O. niloticus* fingerlings fed on different dietary treatments for 24 weeks

Parameter	Diets (mean ± standard error)				
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
AIW g/fish	7.19^{a} ± 1.68	7.18^{a} ± 1.66	7.10^{a} ± 1.75	7.04^{a} ± 1.56	7.24^{a} ± 1.90
AFW g/fish	88.01^{a} ±1.43	64.53^{c} ± 0.86	75.27^{b} ± 1.18	51.35^{d} ± 1.07	12.40^{e} ± 0.21
MWG g/fish	80.80^{a} ±3.48	57.33^{b} ± 4.30	67.93^{b} ± 4.19	44.30^{c} ± 5.41	5.10^{d} ± 0.04
PWG g/fish	593.07^{a} ± 28.23	502.70^{ab} ± 101.57	549.30^{a} ± 62.95	271.80^{b} ± 110.27	12.00^{c} ± 35.28
SGR %/day	1.49^{a} ± 0.02	1.30^{bc} ± 0.09	1.38^{ab} ± 0.05	1.17^{c} ± 0.06	-0.77^{d} ± 0.00
PER	0.71^{a} ± 0.02	0.67^{a} ± 0.14	0.75^{a} ± 0.05	0.51^{a} ± 0.14	-
FCR	4.74^{b} ± 0.15	5.32^{a} ± 1.03	4.46^{b} ± 0.28	8.60^{a} ± 3.49	-
K	3.28^{a} ± 0.01	3.09^{a}± 0.10	3.23^{a} ± 0.0.02	2.38^{b} ± 0.48	1.40^{c} ± 0.05

Where: Average initial weight = AIW; Average final weight =AFW; Mean weight gain = MWG; Per cent weight gain = PWG; Specific growth rate = SGR; Protein efficiency ratio = PER; Feed conversion ratio = FCR; Condition factor = K and dash (-) denotes parameters not calculable for, because no supplementary feed was given. Similar superscript alphabets in the rows denote homogeneous means (LSD, $P > 0.05$)

Plate 3: Initial size of fingerlings of *O. niloticus* at stocking was 7 g of 6 cm standard length and 7.5 cm of total length

Plate 4: Maximum size of *O. niloticus* for diet 1 after 6 months of culture was 132 g of 15.5 cm standard length and 18.9 cm of total length

Plate 5: Maximum size of *O. niloticus* fed on diet 2 after 6 months of culture was 90 g of 13.9 cm standard length and 17.6 cm of total length

Plate 6: Maximum size of *O. niloticus* fed on diet 3 after 6 months of culture was 121 g of 15 cm standard length and 18.9 cm of total length

Plate 7: Maximum size of *O. niloticus* fed on diet 4 after 6 months of culture was 86 g of 14 cm standard length and 17.3 cm of total length

Plate 8: Maximum size of *O. niloticus* fed on diet 5 after 6 months of culture was 18 g of 8 cm standard length and 10.2 cm of total length

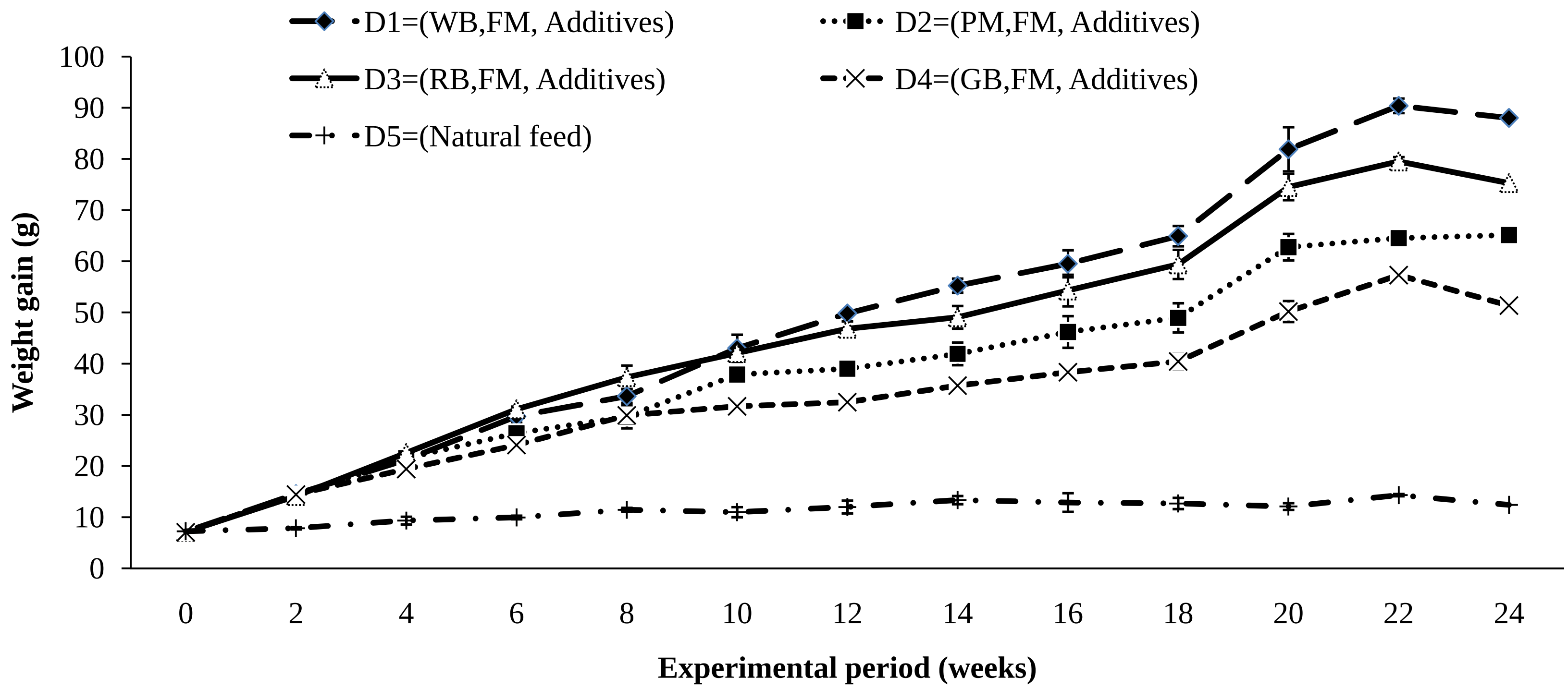

Figure 2: Growth curves for *O. niloticus* fingerlings fed on different dietary treatments for 24 weeks (vertical bars represent standard errors)

Survival rate (SR)

Survival rate (SR) was highest for fish fed on diet 3 (81.00 ± 0.88 %) and lowest for fish fed on diet 4 (62.17 ± 16.85 %). Survival rate (SR) for fish fed on diets 1, 2 and 5 was in the following descending order diet 1 > diet 2 > diet 5. However, there were no significant ($P > 0.05$) differences amongst treatments in terms of the fish survival rate. Mean biomass of fish was heaviest for fish fed on diet 1 (30.01 ± 0.41 kg) and lightest on fish fed on diet 5 (7.95 ± 0.50 kg). Mean biomass of fish did not differ significantly ($P > 0.05$) among fish fed on diets 1, 2 and 3. However, fish fed on diets 4 and 5 had significantly ($P < 0.05$) smaller biomass of which the biomass of fish fed on diet 4 (15.91 ± 1.59) was heavier.

Table 7: Survival rate of *O. niloticus* fingerlings after 24 weeks of culture

Diets	Survival rate % (mean ± standard error)	Total biomass (kg) (mean ± standard error)
Diet 1	$68.33^{a} \pm 0.88$	$30.02^{a} \pm 0.41$
Diet 2	$71.50^{a} \pm 7.50$	$26.18^{a} \pm 1.54$
Diet 3	$81.00^{a} \pm 4.48$	$28.39^{a} \pm 0.59$
Diet 4	$62.17^{a} \pm 16.85$	$15.91^{b} \pm 1.59$
Diet 5	$65.33^{a} \pm 21.06$	$4.88^{c} \pm 0.50$

Note: Similar superscript alphabets in the rows denote homogeneous means (LSD, $P > 0.05$)

Biochemical composition of O. niloticus

The whole body composition of the *O. niloticus* fingerlings fed on the different dietary treatments (Table 8) indicates that, fish fed on diet 5 (77.57±

0.28%) had the highest moisture content and those fed on diet 3 (74.39 ± 0.30%) had the lowest moisture content. The proximate compositional analysis showed significant differences (P < 0.05) in the moisture contents among fish fed on diets 3, 4 and 5. However, no significant (P > 0.05) difference was found among fish fed on diets 1 and 2.

Dry matter (DM) contents was highest for fish fed on diet 4 (24.87 ± 0.05%) and lowest for fish fed on diet 5 (22.43 ± 0.29%). There were no significant (P > 0.05) differences in DM among fish fed on diets 1, 2 and 4. Fish fed on diets 3 and 4 were similar (P > 0.05), whiles fish fed on diet 5 differed (had the least of 22.43 ± 2.90) (P < 0.05) from all the other treatments.

Crude protein (CP) was highest for fish fed on diet 2 (71.15 ± 0.07%) and lowest for fish fed on diet 3 (63.86 ± 0.26%). Whiles fish fed on diets 2, 3 and 5 were significantly (P < 0.05) different from all the other treatments. Fish fed on diet 1 and 4 were not.

Ether extract (EE) was highest for fish fed on diet 3 (10.58 ± 0.05%) and lowest for fish fed on diet 5 (3.77 ± 0.02%). The EE were not significantly (P < 0.05) different among fish fed on diets 2, 3 and 4. However, fish fed on diets 1 and 5 differed (P < 0.05) from all the other treatments.

Crude fibre (CF) was highest for fish fed on diet 1 (0.33 ± 0.00%) and lowest for fish fed on diet 2 (0.21 ± 0.00%). Crude fibre was not significant (P > 0.05) for fish fed on diets 1, 4 and 5. There were significant (P > 0.05) differences among fish fed on diets 2 and 3.

Ash content was highest for fish fed on diet 4 (3.44 ± 0.28%) and lowest for fish fed on diet 2 (2.13 ± 0.04%). However, fish fed on diet 4 differed ($P < 0.05$) from all the others, whiles no significant ($P > 0.05$) difference were found among fish fed on diets 1, 2, 3 and 5. The nitrogen-free extract (NFE) was highest for fish fed on diet 5 (25.03 ± 0.94%) and lowest for fish fed on diet 4 (15.62 ± 1.96%). The NFE were similar ($P > 0.05$) for fish fed on diets 3 and 5, for fish fed on diets 1, 2 and 4 and for fish fed on diets 1 and 3.

Table 8: Biochemical composition of *O. niloticus* fingerlings at the end of the experiment period (24 weeks)

Components	**Treatments (mean ± standard error)**				
(%)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Moisture	75.94^{b} ± 0.03	75.89^{b} ± 0.08	74.39^{c} ± 0.30	$75.1d^{e}$ ± 0.05	77.57^{a} ± 0.28
DM	24.07^{b} ± 0.03	24.12^{b} ± 0.75	24.61^{a} ± 0.30	24.87^{ab} ± 0.05	22.43^{c} ± 0.29
CP	69.99^{b} ± 0.03	71.15^{a} ± 0.07	63.86^{d} ± 0.26	70.31^{b} ± 0.05	67.99^{c} ± 0.35

Where: Dry matter =DM and Crude protein = CP

(Table 8 *continued*)

Components (%)	**Treatments (mean ± standard error)**				
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
EE	$7.74^{b} \pm 0.01$	$10.06^{a} \pm 0.01$	$10.58^{a} \pm 0.05$	$10.31^{a} \pm 0.01$	$3.77^{c} \pm 0.02$
CF	$0.33^{a} \pm 0.00$	$0.21^{c} \pm 0.00$	$0.25^{bc} \pm 0.00$	$0.32^{a} \pm 0.00$	$0.29^{ab} \pm 0.00$
Ash	$2.28^{b} \pm 0.09$	$2.13^{b} \pm 0.04$	$2.60^{b} \pm 0.09$	$3.44^{a} \pm 0.28$	$2.65^{b} \pm 0.17$
NFE	$19.66^{bc} \pm 1.06$	$16.45^{c} \pm 0.36$	$22.75^{ab} \pm 0.53$	$15.62^{c} \pm 1.97$	$25.03^{a} \pm 0.94$

Where: Ether extract = EE, Crude fibre = CF, Nitrogen-free Extract = NFE

Similar superscript alphabets in the rows denote homogenous means (LSD, P > 0.05)

Results of sensory analysis of O. niloticus

Results of the quality of flesh of *O. niloticus* fed on different dietary treatments (Table 9) indicate that, in terms of colour liking, fish fed diet 2 (pito mash based diet) (8.14 ± 0.14) had the highest score and fish fed on diet 5 (control) (6.14 ± 0.91) had the lowest score. However there were no significant (P > 0.05) differences in colour liking for fish fed on diets 2 (pito mash based diet) and 4 (groundnut bran based diet). Fish fed on diet 1 (wheat bran based diet), 3 (rice bran based diet) and 5 (control) were also similar (P > 0.05).

In terms of odour liking, fish fed on rice bran based diet (8.00 ± 0.34) had the highest score, whiles, fish fed on groundnut bran based diet (7.00 ± 0.49) had the lowest score. However, there were no significant (P > 0.05) differences among all the five treatments for odour liking.

Fish fed on pito mash based diet (7.71 ± 0.29) had the highest score, while fish fed on control diet (5.71 ± 1.01) had the lowest score for flavour (taste) liking by the panelists. Test fish fed on pito mash based diet was different (P < 0.05) from fish fed on the control, but similar (P > 0.05) to those fed on diets containing wheat, rice and groundnut brans. Fish fed on the control was not significantly (P > 0.05) different from those fed on diets 1, 3 and 4.

Concerning texture (tenderness), fish fed on diet 4 (7.86 ± 0.40) had the highest score and fish fed on diet 5(6.43 ± 0.78) had the lowest score. Fish fed on diet 4 differed (P < 0.05) from fish fed on diet 5. However, there were no significant (P < 0.05) differences for fish fed on diets 1, 2, 3 and 4, and those fed on diets 1, 2, 3 and 5.

With regard to overall acceptability, fish fed on diet 2 (8.14 ± 0.36) had the highest score and fish fed on diet 5 (6.14 ± 0.87) had the lowest score. While panelists demonstrated a lower overall acceptability for fish fed on diet 5 which was significantly (P < 0.05) different from the other treatments, there were no significant (P > 0.05) differences among fish fed on diets 1, 2, 3 and 4 in overall acceptability.

Table 9: Sensory properties of *O. niloticus* fed on different diets for 24 weeks

Attributes	Treatments (mean ± standard error)				
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Colour liking	$7.71^{ab} \pm 0.64$	$8.14^{a} \pm 0.14$	$7.71^{ab} \pm 0.47$	$7.86^{a} \pm 0.26$	$6.14^{b} \pm 0.91$
Odour liking	$7.71^{a} \pm 0.47$	$7.86^{a} \pm 0.14$	$8.00^{a} \pm 0.34$	$7.00^{a} \pm 0.49$	$7.00^{a} \pm 0.53$
Flavour liking	$6.43^{ab} \pm 0.36$	$7.71^{a} \pm 0.29$	$6.71^{ab} \pm 0.42$	$7.00^{ab} \pm 0.44$	$5.71^{b} \pm 1.01$
Texture liking	$7.29^{ab} \pm 0.18$	$7.29^{ab} \pm 0.36$	$7.29^{ab} \pm 0.42$	$7.86^{a} \pm 0.40$	$6.43^{b} \pm 0.78$
Overall acceptability	$7.71^{a} \pm 0.43$	$8.14^{a} \pm 0.36$	$7.71^{a} \pm 0.36$	$7.86^{a} \pm 0.37$	$6.14^{b} \pm 0.87$

Note: Sensory attributes were judged on a 9-point hedonic scale: 9 = like extremely, 8 = Like very much, 7 = like moderately, 6 = Like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = Dislike very much, 1 = dislike extremely

Cost-benefit analysis of fingerlings of O. niloticus fed on different dietary treatments in out-door hapas for 24 weeks

As indicated in Table 10, the cost per kilogram of feed was highest for fish fed on diet 3 (rice bran based diet) (GH¢0.76) and lowest for fish fed on diet 2 (pito mash based diet) (GH¢ 0.46). Feed administered was highest for fish fed on rice bran based diet (126.98 kg) and lowest for fish fed on diet 4 (groundnut bran based diet) (104.96 kg). The total biomass harvested was highest for fish fed on diet 1 (wheat bran based diet) (30.02 kg) and lowest for fish fed on diet 5 (control) (4.88 kg).

Fish fed on groundnut bran based diet recorded significantly ($P < 0.05$) the highest incidence cost of 5.88 ± 2.34 and those fish fed on pito mash based recorded significantly ($P < 0.05$) the lowest IC of 1.99 ± 0.33. Also the incidence cost of 3.47 ± 0.23 for fish fed on the rice bran based diets was higher and significantly ($P < 0.05$) different from fish that were fed on wheat bran based diet of incidence cost 2.87 ± 0.08.

The profit index was significantly ($P < 0.05$) different among all the diets. Among the test brans, fish fed on pito mash based diet recorded significantly ($P < 0.05$) the highest profit index of 4.76 ± 0.28 and fish fed on the groundnut bran based diet recorded significantly ($P < 0.05$) the lowest profit index of (2.02 ± 0.02).

Table 10: Cost-benefit analysis of *O. niloticus* fingerlings fed on different dietary treatments for 24 weeks

Diets	Cost / kg. of feed (GH¢)	Total feed input (kg)	Cost of feed input (GH¢)	Harvested biomass (kg)	Value of biomass (GH¢)	[1]IC	[2]PI
Diet 1	0.71	121.24	86.09	30.02	90.05	$2.87^{c} \pm 0.08$	$3.14^{b} \pm 0.03$
Diet 2	0.46	107.21	49.32	26.18	78.54	$1.99^{d} \pm 0.33$	$4.76^{a} \pm 0.28$
Diet 3	0.76	126.98	96.50	28.39	85.13	$3.47^{b} \pm 0.23$	$2.62^{c} \pm 0.05$
Diet 4	0.67	104.96	70.32	15.91	47.71	$5.88^{a} \pm 2.43$	$2.02^{d} \pm 0.20$
Diet 5	-	-	-	4.88	14.64	-	-

Note: Similar alphabets in the columns denote homogenous means (LSD, $P > 0.05$). Cost price per kilogram of fish (i.e. below 150 grams) at the farm gate = GH¢ 3. Market price per kilogram of test diets was based on cost per kilogram of feed ingredients used in formulating the test diets. Dash (-) = Parameters were not calculable for, because no supplementary feed was given

1. Incidence cost (IC) = cost of feed consumed (kg/ GH¢) / Weight (kg) fish produced
2. Profit index (PI) = value of fish crop/cost of feed consumed

Water quality parameters

Water quality parameters (Table 11) remained fairly stable throughout the study period. Temperature ranged from 31 .8 to 25.9 ^{0}C and a mean of 29. 72 ± 0.38 ^{0}C; dissolved oxygen (DO), from 8.25 to 3.48 mg/l and a mean of 5.49 ± 0.38 mg/l; pH, from 5.1 to 7.6 and a mean of 6.78 ± 0.23; total suspended solids (TSS), from 68 to 16 mg/l and a mean of 43.38 ± 5.37 mg/l and turbidity, from 005 to 027 NTU and a mean of 013.07 ± 1.08 NTU. Ammonia (NH_3-N) ranged from 0.01to 0.16 mg/l and a mean of 0.05 ± 0.01 mg/l; nitrite (NO_2-N), from 0.001 to 0.110 mg/l and a mean of 0.023 ± 0.01 mg/l; nitrate (NO_3-N), from 0.01 to 0.09 mg/l and a mean of 0.05 ± 0.01 mg/l; phosphorus, from0.01 to 0.05 mg/l and a mean of 0.02 ± 0.003 mg/l; total Alkalinity, from 26.0 to 49.0 mg/l and a mean of 41.2 ± 1.95 mg/l ; total hardness, from 21to 44 mg/l and a mean of 34.54 ± 2.00 mg/l.

Table 11: Water quality fluctuations in the experimental pond containing fry and fingerlings of *O. niloticus*

Parameters	Units	Range	Mean ± *S.E.
Temperature	^oC	25.9 -31.8	29.72 ± 0.38
Dissolved oxygen (DO)	mg/l	3.48-8.25	5.49 ± 0.38
pH	-	5.1-7.6	6.78 ± 0.23
Total suspended solid (TSS)	mg/l	16 - 68	43.38 ± 5.37
Turbidity	NTU	005 - 027	013.07 ± 1.08

Asterics (*) S.E. denotes standard error

(Table 11 ***continued*****)**

Parameters	Units	Range	Mean ± *S.E.
Ammonia (NH_3-N)	mg/l	0.01-0.16	0.05 ± 0.01
Nitrite (NO_2-N)	mg/l	0.001 – 0.110	0.023 ± 0.01
Nitrate (NO_3-N)	mg/l	0.01 – 0.09	0.05 ± 0.01
Phosphorus	mg/l	0.01 – 0.05	0.02 ± 0.003
Total Alkalinity	mg/l	26.0 – 49.0	41.2 ± 1.95
Total hardness	mg/l	21-44	34.54 ± 2.00

Asterics (*) S.E. denotes standard error

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CHARPTER FIVE

DISCUSSION

This chapter deals with the interpretation of the findings in this study with reference to the literature or previous findings.

Characteristics of feedstuff

The variability in the composition of agro-industrial by-products and diets formulated and prepared is reflected in growth and development of *O. niloticus.* This is because, growth of fish fed on various diets tended to differ, although not significantly among the tested diets. The ability of *O. niloticus* to utilize various diets could be attributed to wide spectrum of preference for foods. This is in agreement with Chou and Shiau (1996), Gonzalez and Allan (2007) and Audu *et al.* (2008) who, reported that, *O. niloticus* readily adapts to eating a wide variety of feeds, and that *O. niloticus* has very long intestines necessary to digest plant materials.

Growth performance of fry of *O. niloticus*

In experiment 1, the high level of acceptance of diets by *O. niloticus* could be attributed to the palatability of the agro-industrial by-products used in feed rations. Similar good consumption of agro-industrial by-products such as cocoa husk has been reported by Falaye and Jauncey (1999) and fermented palm kernel cake (PKC) by Iluyemi *et al.* (2010) for *Oreochromis* sp. These authors attributed acceptance of diets to the palatability of the by-products used in the feed rations.

In the present study, MWG was not statistically ($P > 0.05$) different among all the treatments suggesting that fry of *O. niloticus* could be raised to about 2 g with any of the diets used; and that the slight variations could be due to chance. Interestingly, the results obtained in this study are consistent with what Yigit and Olmez (2010) found when *O. niloticus* fry were fed with high levels of dietary canola meal. Comparing the findings in this study to other closely related studies, Mohanta *et al.* (2007) reported a lower weight gain range for Silver barb, *Puntius gonionotus* fry fed with carbohydrates.

Fish fed on diet 3 had the highest PER, because of its higher proportion of animal protein (fish meal) but lower plant protein. Conversely, diet 2 had highest proportion of plant protein (pito mash) but lower proportion of animal protein (fish meal). Support for this explanation can be drawn from Drew *et al*. (2007) who explained that, digestion of plant materials by fish resulted in a lower PER because, most plant materials had lower crude protein levels and are used as sources of energy in the form of carbohydrates. Although there was no significant difference among all the five diets in terms of PER in this study, the range of values are higher than those reported for *O. niloticus* fed with cocoa husk by Falaye and Jauncey (1999). Wu *et al.* (2000) reported PER values for *O. niloticus* that fall within the same range. Falaye and Jauncey (1999) had PER values which are comparable to those of Wu *et al.* (2000), perhaps because either source dealt with *O. niloticus.*

The best FCR obtained from diet 3 suggests better feed utilization but the similarity in FCR values for all the treatments indicates chance. El-Dakar *et al.* (2008) reported lower FCR values for Florida Red Tilapia (*O. niloticus* crossed with *O. mosambicus*) fed on fig jam by- product (FJB). Siddiqui *et al.* (1991) reported higher FCR values for *O. niloticus* fed on a commercially prepared diet. The current FCR values for fry *O. niloticus* compare favourably with those of Siddiqui *et al.* (1991) but were below those FCR values obtained by El-Dakar *et al.* (2008). The slight differences could stem from the differences in feed sources (i.e. the complexity of carbohydrate source), environmental conditions and the particular strain of species used. This explanation is in agreement with Hemre *et al.* (2002) and Guimaraes *et al.* (2008) who reported that, efficient utilization of diets may vary even within a single species, because of the particular strain of fish used, the environmental factors, season and the complexity of carbohydrate (i.e. mono-saccharides, disaccharides and/or poly-saccharides)

In this study, survival rates (SR) were similar in all treatments. The low SR recorded could be attributed to handling stress. This corroborates that of Attipoe *et al.* (2009) who, reported higher SR for *O. niloticus* and explained that, mortalities during the experimental period were attributed to handling stress and predation.

Fishes fed on all the diets indicate no significant ($P > 0.05$) differences in their physiological well being (K). It is possible that this might have contributed to the similarities in the observed AFW, MWG, SGR, PER and FCR among all the treatments.

Economic benefits of different dietary treatments for fry of *O. niloticus*

The economic benefits of using the test diets lies in the fact that, the cost of feed (i.e. in terms of incidence cost (IC)) in raising the fry of *O. niloticus* to an average weight of 2 grams was lowest for fish fed on diet 2 (pito mash based diet) although insignificant ($P > 0.05$) when compared to fish fed on diet 1. This means that, it could be cheaper to raise fry of *O. niloticus* when fed on either diet 2 or diet 1 under the current study. However, the higher IC for fish fed on diets 3 and 4 reflects much higher cost of feed. This is because the cost per kilogram of diet 3 or 4 was higher than diet 2 or diet 1.

In this study, it could be noticed that the lower the IC value in the use of a diet, the higher the returns (i.e. the higher the profit index (PI) value). It seems that, using diet 2 (pito mash based diet) to raise fry *O. niloticus* would be economical under the present study.

Acceptance of diets of *O. niloticus* fingerlings

For research to be categorized as nutritional research it has to be based on the ingestion of the nutrients by the fish. Irrespective of how digestible the nutrients and energy from a particular ingredient are, if such an ingredient reduces feed intake, it is of limited use in feed formulation. Palatability is defined as acceptable to the taste or sufficiently agreeable in flavour to be eaten. While it may be difficult to ascertain whether or not a fish ‘likes’ some flavour or not, it is certainly possible to determine differences in the amounts of feed eaten (Glencross *et al.*, 2007). The acceptability of the diets containing pito mash (PM), rice bran (RB), groundnut bran (GB) and wheat bran (WB) is a good indication of the palatability of the experimental diets, hence the feasibility of using these agro-industrial by-products in formulating feed for *O. niloticus* fingerlings. Similar results have been reported for *O. niloticus* by Pouomogne *et al.* (1997), Kaur and Sexana (2004), Liti *et al.* (2006) and Attipoe *et al.* (2009); and for Florida Red Tilapia, (*O. niloticus* crossed with *O. mosambicus*) by El-Dakar *et al.* (2008). In these reports, the acceptance of feed rations containing various agro-industrial by-products such as cocoa husk, brewery waste, rice bran, wheat bran, maize bran and fig Jam by-product by the tilapias demonstrates the opportunistic nature of tilapia in their feeding habits. This provides an advantage to farmers because the fish can be reared in intensive systems that can be operated with lower cost feeds.

Growth performance of *O. niloticus* fingerlings

In experiment 2, results from proximate analysis demonstrate that the test diets (1, 2, 3 and 4) differed both in nutritional quality and efficiency in promoting the growth of fingerlings of *O. niloticus*. Fish which were fed on diet 1 (wheat bran-based diet), grew significantly faster than those fed on the other diets. The best performance by the fish on fed on wheat bran-based diet, as observed in this study are similar to the reports by Liti *et al.* (2006) and Attipoe *et al.* (2009) that wheat bran-based diets improved the growth performance of tilapia compared with other brans.

The good performance of fish fed on diet 3 (rice bran-based diet) as observed in this study is at variance with the reported works of Liti *et al.* (2005; 2006) and Solomon *et al.* (2007). In these reports, rice bran-based diets gave the worst performance among other treatments. Though diet 3 (rice bran-based diet) performed well, diet 1 (wheat bran-based diet) demonstrated the best growth because the crude fibre level was lower. In addition, the nitrogen-free extract (NFE) a measure of the carbohydrate level in diets (Krogdahl *et al.*, 2005; Liti *et al.*, 2006; Mohanta *et al.,* 2007; Raj *et al.*, 2008; Tran-Duy *et al.,* 2008) was higher in diet 1 than in diet 3 suggesting greater the protein sparing effect (i.e. the use of carbohydrate to spare the use of protein for energy purposes). This is because, more energy in the form of NFE was available in diet 1 than it is in diet 3 to spare the use of protein as a energy source (Page & Andrews, 1973; Prather & Lovell, 1973).

Kaur and Saxena (2004) reported higher mean weight gain (MWG) in diets in which rice bran was replaced with brewery waste in a feed trail with *Catla catla* and *Labeo rohita*. This was attributed to better absorption and utilization by these fishes. However, in the current study, though with *O. niloticus,* the diet 3 (rice bran-based diet) exhibited higher MWG than diet 2 (pito mash-based diet). The superior growth of fish fed on the rice bran-based diet observed in this study could be a manifestation of the higher proportion of fish meal (FM) used in compounding diet 3. Attipoe *et al.* (2009) concluded that, diets with higher proportion of FM exhibited better growth because of their excellent biological value in enhancing growth. Though the weight gain of fish fed on diet 2 (pito mash-based diet) in this study did not exhibit the best growth, the higher proportion of pito mash (PM) in the diet 2 suggests that, PM can enhance the growth of *O. niloticus* by reducing drastically the quantity of FM (reducing the cost of feed in the process) in diets. This is in accordance with earlier findings of

Oduro-Boateng and Bart-Plange (1988), Webster *et al.* (1992) and Wu *et al.* (1996). All these authors also found that brewery waste could be used to completely or partially replace costly fish meal in the diets of tilapia.

According to Agbo (2008), crude fibre provides physical bulk to feed and may improve pelleting of feed. However, fibre decreases the quantity of usable nutrients in a diet. Although the crude fibre was lowest in diet 4 (3.54%) suggesting better utilization, growth could have been impaired by the higher ether extract per cent (18.74%). This is consistent with several other research findings as in Chou and Shiau (1996), Manjapa *et al.* (2001) and Audu *et al.* (2008). These researchers explained that, ether extract levels in the diet of tilapia should range between 5-12%, or when in excess (above 12%), results in poor growth because of an imbalance of protein to fat ratio.

Solomon *et al.* (2007) using different grain sources (maize, wheat, rice, sorghum and millet) to assess the growth of tilapia in out-door hapas, reported that the best mean weight gain (MWG) for fish fed with maize grain > wheat grain > sorghum grain > millet grain > rice grain. However, as observed in this study, pito mash-based diet recorded a lower MWG than rice bran-based diet. This can be attributed to the high crude fibre (8.07%) levels in pito mash-based diet as against the low crude fibre (6.06%) content of the rice bran-based diet. This assertion agrees with several other research findings (Chou & Shiau, 1996; Falaye & Jauncey, 1999; Ali & Al-Asgall, 2001; Gonzalez & Allan, 2007; Agbo, 2008; Audu *et al.*, 2008; El-Dakar *et al.*, 2008) that high fibre levels in the diet of tilapia resulted in poor weight gain and nutrient utilization.

The specific growth rate (SGR) as obtained in the current study was lowest for fish fed on diet 5 (no supplementary feed) and highest for fish fed on the diet 1(wheat bran-based diet). Higher SGR values of fish fed on the wheat bran-based diet is indicative of the fact that, the wheat bran-based diet was better utilized than the other diets. This gives credence to the views of Iluyemi *et al.* (2010). For comparison, the SGR obtained in this study ((-) 0.77 to 1.49) are higher than the SGR values (0.43 to 0.53) reported by Attipoe *et al.* (2009).

Chatzifotis *et al.* (2010) demonstrated that growth can be reduced and protein efficiency ratio (PER) lowered if fishes were fed with excessive dietary lipid levels. This is because excessive lipids not only spare proteins, but can also result in higher fat deposits and impaired growth performance. Although PER values were highest for fish fed on the rice bran-based diet and lowest for fish fed on the diet 4 (groundnut bran-based diet), yet statistically, there were no significant ($P > 0.05$) differences among the fish fed on all the diets. However, this was at variance with the finding of Wu *et al.* (2000) that, diets with higher proportion of fish meal (FM) exhibited higher PER because of more efficient utilization of FM by fish, the results obtained in this study can be explained according to Drew *et al.* (2007) who reported that, digestion of plant materials by fish resulted in a lower PER because most plant materials had lower crude protein levels which are used as sources of energy in the form of carbohydrates. However, an imbalance of carbohydrate and lipids ratio can suppress the uses of protein even if the proportion of FM is high in a diet.

A feed ingredient may appear from its chemical composition to be an excellent source of nutrients but will be of little actual value unless it can be digested and absorbed in the target species (Koprucu & Ozdemir, 2005). Utilization of feed measured by the feed conversion ratio (FCR) was lowest for fish fed on diet 1 (i.e. indicating better utilization) and highest for fish feed diet 4 (i.e. indicating poor utilization). Although the FCR values were not significantly ($P > 0.05$) different between fish fed on diets 1, 2 and 3, the higher FCR of fish fed on diet 4 may be explained by Manjappa *et al.* (2002) who reported that, growth of fish fed with diets which have higher lipid level (above 12 %) is poorer, reflecting a negative impact of dietary fat beyond the optimum level. Though crude fibre was lowest in diet 4, utilization of the diet might have been impaired by the higher ether extract level. Glencros *et al.* (2007) supported this fact when they found that, the FCR becomes lower as the efficiency of feed utilization increases. For comparison, the FCRs in this study were better than those obtained by Siddiqui *et al.* (1991), Falaye and Jauncey (1999), Wu *et al.* (2000) and Liti *et al.* (2006).

Survival rate was not significantly ($P > 0.05$) different between treatments after the disaste struck. However, mortalities that occurred before the disaster struck were mostly experienced a day or two after sampling which might not be due to difference in treatments but may be due to handling stress. This is in support of Attipoe *et al.* (2009) who did indicate that, survival of fish in culture conditions can be negatively affected by poor conditioning and handling stress. However, it is important to note that survival rate was high averaging about 85%

for all treatments until the disaster struck. This was because, after the 14th week of culture, mortalities were no longer observed suggesting that the test fish had completely acclimatized to the environment and frequent handling stress. The losses that occurred after the 14th week to the end of the experimental period (24 weeks) was the result of the escape of the fish following the frequent collapse of hapas by windstorms. In fact, the escape of the fish from various treatment replicates in the present study had a negative effect on the total biomass, hence on the final IC and the PI values as well.

In this study, the condition factor (K) recorded for fishes fed on diets 1, 2 and 3 were similar ($P > 0.05$) and differed ($P < 0.05$) significantly from those of fishes fed on diet 4 and diet 5 (control group). Bauer *et al.* (1973) and Ogunji *et al.* (2008) reported that, the higher the K the better the physiological state of the fish. This suggests that in the present study, fish fed on diets 1, 2 and 3 were in a better condition than those fed on diet 4 which, in turn, were in a better condition than fish fed on diet 5. The poor K of fish fed on diet 4 could be attributed to the poor utilization of supplemental feed (indicated by lower MWG and PER and a higher FCR). However, the poorer condition recorded for fish fed on diet 5 could be explained by the fact that, the natural food on which they depended was not sufficient to maintain themselves for growth in such a limited space (hapa space). For comparison, the lower K in the present study than those recorded by Anene (2005) for Cichlids: *C. guntheri, C, cabrae* and *T. mariae* could be ascribed to poorer utilization of supplementary feed.

Biochemical analysis of *O. niloticus* fingerlings

Higher protein levels for fish fed on diets 2 and 4 correlate positively with higher ether extract (EE)/lipid levels. This was explained by Raj *et al.* (2008) that, deposition of high lipid content for fish fed with higher amount of carbohydrates may be due to the availability of sufficient energy in those diets. This suggests that, the dietary protein could be used for growth, hence higher protein levels for fish fed on diets 2 and 4. Although EE in diet 3 was within acceptable levels according to Manjappa *et al.* (2002) for fish, it suggests that, some of the protein in the diet could have been used as a source of energy due to the lower NFE levels or perhaps an imbalance in the carbohydrates to lipid ratio as demonstrated by Ali & Al-Asgall (2001).

The lower EE in fish fed on diet 3 compared to the EE level in diet 3 (Table 5) suggests that, EE in diet 3 could have been used as a source of non-protein energy supplementing the NFE to spare protein for growth, thus, resulting in lower deposition in the bodies of fish fed on that diet. The results obtained in this study are in agreement with Iluyemi *et al.* (2010) who reported a decrease in EE in red tilapia fed with palm kernel cake (PKC) and other plant residues. However, this does not agree with Ali and Al-Asgall (2001) who, reported that, the EE in fish appear to correlate positively with the dietary lipid content.

It was noticed that, fish fed supplementary diets (1, 2, 3 and 4) deposited more EE in test fish than those raised without supplementary feed (fish in the control, diet 5). It appears the by-products used in this study have the potential to enhance better growth in *O. niloticus* because of the increase of the EE in the test fish. Ether extract (EE) in the range 7.74 - 10.58 fall within the acceptable levels for growth of fish as reported by Chou and Shiau (1996), Manjappa *et al.* (2002) and Audu *et al.* (2008).

In the present study ash was similar (P > 0.05) among fish groups fed on diets 1, 2, 3 and 5. A similar result was reported earlier by Metwally and El-Gellal (2009) when plant wastes used as feed for *O. niloticus* were evaluated with reference to the impact on growth and body composition. However, the significantly (P < 0.05) higher ash content recorded for fish fed on diet 4 suggests that, fish in this group were likely to contain more minerals than the other groups. This is in accordance with earlier reports by Stickney (1979), Roem *et al.* (1990), El-Sayed & Teschima (1991) and Watanabe *et al.* (1997) that, the ash content of an ingredient is the total amount of minerals (or inorganic matter) present within the food.

Sensory evaluation of *O. niloticus* fingerlings fed on different diets

Considering the following interpretation of the 9-point acceptability scale in discussion of the ANOVA results (Table 9): like moderately to like extremely was considered "positive' or "liked" part of the scale; dislike slightly to like slightly was considered "neutral" part of the scale, and dislike moderately to dislike extremely was considered "negative" or "disliked part of the scale.

The similarities between colour likeness for diets 2 and 4 might be alluding to the fact that, the by-products in these two diets have similar chemical (e.g. pigments) properties that have the same effect on the colour of the flesh of the fish. This is because, the physical colour of pito mash in diet 2 and that of groundnut bran in diet 4 looked same during and after diets were prepared.

Panelists "liked" the colour of the flesh of fish fed on supplementary diets (1, 2, 3 and 4) indicated by the mean scale rating range of 7.71 - 8.14 perhaps because the colour of the flesh from these treatments were desired by panelists. On the contrary, panelists were "neutral" to the colour of fish meat of fish that were not fed (diet 5) perhaps because the colour of flesh of fish from that treatment was not attractive. Support for these explanations could be drawn from Boyd (2005) who explained that, consumers desired tilapia meat with the normal light gray to white colour. A deviation from this widely accepted colour for tilapia meat is likely to be less desired and would attract consumer complaints.

Panelists demonstrated that the odour (smell) was not significantly ($P > 0.05$) different among all the five treatments. The insignificant difference among all the five treatments could be an indication that the different treatments had similar effects on the odour of the test fish. However, it is important to note that, the odour that resulted from the use of all the test diets in this study was "liked" as indicated by the mean score rating of range 7.00 - 8.00 from the panelists.

Flavour influences the decision to purchase and to consume a food product. Food flavour is a combination of taste and smell, and it is very subjective and difficult to measure. People differ in their ability to detect tastes and odours. People also differ in their preferences for flavour (Potter & Hotchkiss, 1999). However, the significant ($P < 0.05$) differences among fish fed on diets 2 and 5 in this study might be due to chance because fish fed on diets 1, 3 and 4 were similar in flavour liking to those fish fed on diets 2 and 5.

Potter and Hotchkiss (1999) reported that, texture of food refers to the qualities felt with the fingers, tongue, or the teeth. Textures in food vary widely, but any departure from what the consumer expects is a quality defect. The results in the present study suggest that, the texture of fish fed on diet 4 is strongly dissimilar to fish not fed (diet 5). However, the difference in between these two diets might have been due to chance for reasons that cannot be explained in the current study.

In general, the scores for overall flesh quality of all the test fish did not yield any significant difference as shown by the results of variance ANOVA. However, it appears fish fed on supplementary diets were "liked" by the panelists because, the component that gives good taste in fish (i.e. fat/oil) were higher in fish fed on supplementary diets. Panelist perhaps did not appreciate fish that were not fed, because they were small in sizes. The small sizes of fish was because the natural food they depended on probably did not have enough supply of energy for the excess to be stored in the form of fat, hence the "neutral" taste observed by the panelists (E.A. Obodai, personal communication, May 24, 2011).

Economic benefits of different dietary treatments of *O. niloticus* fingerlings

The cost-benefit analysis of using different feeds in terms of the incidence cost (IC) turned out to be dissimilar among all the four treatments with supplementary diets. It points to the fact that, it is less costly to use diet 2 to raise *O. niloticus* than it would be using any of the other diets. However, it is important to note that, in areas where larger quantities of these by-products exist, the cost per kilogram of feed may be lower and significantly reduce IC. For comparison, El-Dakar *et al.* (2008) reported an IC of 2.26 for diets containing up to 50% fig jam by-product (FJB) replacing wheat bran in the diet of red tilapia and recommended it as an economically efficient diet for red tilapia fry. However, the IC of *O. niloticus* fingerlings fed on diet 1 (wheat bran-based diet) in this study was higher. This might be because, wheat bran was the major source of carbohydrates and the use of FJB as a less expensive feed ingredient in their study reduced the cost of the diet hence lower IC reported.

In another study Attipoe *et al.* (2009) in evaluating three test diets prepared from agro-industrial by-products, fish fed on the diet (F2) (compounded with rice bran and groundnut bran) were reported to be the cheapest among the other diets. On the contrary, diet 4 (groundnut bran-based diet) was the most expensive in terms of incidence cost (IC) in the current study. The variance in results might be because, diet 4, was prepared with fish meal (FM) as the major source of protein which in itself is expensive (El-Sayed, 1998; Falaye & Jauncey, 1999; Ogunji *et al.*, 2008; Nguyen & Davis, 2009; Abu *et al.*, 2010; Sule & Sotolu, 2010). Coupled with that, the poor performance of the fish fed on diet 4, did not compensate for the rather high cost of feed in this study.

The profit index (PI) was highest in diet 2 and significantly different from all other diets. It may be economical and beneficial to use diet 2 for the culture of *O. niloticus* fingerlings. However, due to better feed utilization, growth was better for fish fed on diet 1. Comparing the performance of fish fed on diet 1 (wheat bran-based diet) in this study to the report in a closely related study by Liti *et al.* (2006) on the economic performance of *O. niloticus*, wheat bran-based diet gave higher returns than the other test brans for example rice bran. This because, wheat bran had lower fibre and higher levels of carbohydrates (nitrogen free extract) and than rice bran, hence, proving more energy to spare dietary protein for growth.

Water quality

Temperature range obtained fell within the tolerable limit for *O. niloticus* reported by El-Sherif and El-Feky (2009) and Xie *et al.* (2010).

Boyd (2005) recommended DO to range above 3 mg/l - 4 mg/l for tilapia. Records of the DO in this study were higher (3.48 - 8.25 mg/l) compared to that of Boyd (2005). This means that DO could not have been a limiting factor to growth in the current research.

pH was slightly acid (5.1) to neutral (7.6) mg/l. Although the pH in this study was not the best as recommended by El-Sherif and El-Feky (2009) for optimum growth (pH range 7 - 8) there were no observable effects (positive or negative) of pH on the growth of the test fish used.

Total suspended solids (TSS) did not have any observable negative effects on the growth of *O. niloticus* in this study as turbidity ranged between 005 - 027 NTU. This supports Ardjosoediro and Ramnarine (2002) who recommended turbidity levels lower than 50 NTU to enhance growth for the Jamaica red tilapia strain.

Given the levels NH_3-N as obtained in this study, there were no observable negative effects on the growth of the test fish (*O. niloticus*). This is in accordance with El-Shafai *et al.* (2004) who reported that, for some research scholars, NH_3-N levels in the range 0.6 and 2 mg/l could be toxic while some consider the maximum tolerable concentration to be 0.1 mg/l.

Nitrites (NO_2-N) concentrations obtained in the current study did not seem to affect the treatments either, supporting Al-Harbi and Siddiqui (2000) who found out that NO_2-N concentrations ranging from 0.2 to 0.52 mg/l were lower than the lethal level for *O. niloticus.*

The capacity of the natural water to resist changes in pH known as alkalinity (APHA, 1985) was within the recommended levels as reported by Stickney (1979).

The concentration of divalent cations (for determination of hardness of water) was within the recommended levels (21 - 44 mg/l) for freshwater species as indicated by APHA (1975) that hardness somewhere between 20 to 150 ml/l was preferred for most freshwater species.

Conclusions

In experiment 1, there was no significant difference in growth of fry *O. niloticus*. However in terms of economic benefits, diet 2 was the most economical and profitable diet. Fish fed on diet 4 was the least profitable diet among the tested agro-industrial by-products

In experiment 2, fish fed on diet 1 produced the fastest growth of *O. niloticus* fingerlings among the other test diets and the worse growth was recorded for fish fed not (diet 5). Biochemical analysis of the fish revealed, that the dietary treatments significantly influenced the body composition *O. niloticus.* The score for overall flesh quality by panelists for all the treatments showed no significant ($P > 0.05$) difference. However, fish fed on supplementary diets were “liked” (desired) and those fish without supplementary diet were perceived as “neutral” (less desired) by the panelists.

Water quality parameters in the pond were within the tolerable limits for the growth of *O. niloticus.*

Recommendations

Wheat bran-based diet and pito mash-based for rearing *O. niloticus* are recommended for feeding.

Lower stocking densities should be tried with test diets 1 and 2 to see if the stocking densities used in the study had any effect on growth performance of *O. niloticus.*

Further studies should be conducted by testing the diets used in this study in other culture systems such as in cages to assess the growth of *O. niloticus*.

Further studies should be conducted by combing the features of the cost-effective diet, 2 and fastest growing diet, 1 into a diet and compared with the existing commercially prepared diets to assess the growth and economic performance of cultured fish.

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APPENDICES

Appendix A: Formulated feed for fry of *O. niloticus* fed on different dietary treatments using the trial and error method

			Diet 1			**Diet 2**			**Diet 3**			**Diet 4**		
Feed items	%CP	GE(MJ/Kg)	%IF	%CP	GE	%IF	%CP	GE	%IF	%CP	GE	%IF	%CP	GE
Fish meal	61.4	20.3	45.0	27.6	9.1	24.0	14.7	4.9	54.0	33.2	11.0	36.5	22.4	7.4
Wheat bran	15.5	16.5	51.0	7.9	8.4	-	-	-	-	-	-	-	-	-
Pito mash	28.8	17.8	-	-	-	72.5	20.9	12.9	-	-	-	-	-	-
Rice bran	6.7	11.3	-	-	-	-	-	-	41.0	2.7	4.6	-	-	-
Groundnut bran	21.7	16.8	-	-	-	-	-	-		-	-	60.4	13.1	10.1
Methionine	-	-	0.1	-	-	0.1	-	-	0.1	-	-	0.1	-	-
Lysine	-	-	1.9	-	-	1.9	-	-	1.9	-	-	1.9	-	-

Where: Crude protein = CP, % = Per cent, In feed = IF, Gross energy = GE

(Appendix A *continued*)

			Diet 1			Diet 2			Diet 3			Diet 4		
Feed items	%CP	GE(MJ/Kg)	%IF	%CP	GE	%IF	%IF	%CP	GE	%IF	%IF	%CP	GE	%IF
Broiler premix	-	-	0.5	-	-	0.5	-	-	0.5	-	-	0.5	-	-
Palm oil	-	-	1.0	-	-	1.0	-	0.0	2.0	-	-	1.0	-	0.0
Total			100	36	18	100	36	18	100	36	16	100	36	18

Where: Crude protein = CP, % = Per cent, In feed = IF, Gross energy = GE

Appendix B: Weight gain of fry of *O. niloticus* fed on different dietary treatments for 8 weeks

Weeks	Treatments (mean ± standard error)				
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Initial	0.09 ± 0.02^{a}	0.09 ± 0.02^{a}	0.07 ± 0.00^{a}	0.09 ± 0.01^{a}	0.08 ± 0.01^{a}
Week 2	0.20 ± 0.07^{ac}	0.17 ± 0.02^{bc}	0.23 ± 0.06^{ab}	0.16 ± 0.00^{bc}	0.15 ± 0.05^{bc}
Week 4	1.18 ± 0.18^{a}	1.02 ± 0.24^{a}	1.01 ± 0.26^{a}	1.08 ± 0.27^{a}	0.82 ± 0.04^{a}
Week 6	1.33 ± 0.03^{a}	1.23 ± 0.12^{a}	1.40 ± 0.06^{a}	1.30 ± 0.21^{a}	0.93 ± 0.19^{a}
Week 8	3.73 ± 0.37^{a}	2.60 ± 0.32^{a}	2.83 ± 0.17^{a}	2.57 ± 0.38^{a}	1.90 ± 0.26^{a}

Note: Similar superscript alphabets in the rows denote homogenous means (LSD, $P > 0.05$)

Appendix C: Formulated feed for fingerlings of *O. niloticus* fed on different dietary treatments using the trial and error method

			Diet 1			Diet 2			Diet 3			Diet 4		
Feed items	%CP	GE(MJ/Kg)	%IF	%CP	GE	%IF	%CP	GE	%IF	%CP	GE	%IF	%CP	GE
Fish meal	49.0	18.2	45.5	22.3	8.3	16	7.8	2.9	56.0	27.4	10.2	34.3	16.8	6.2
Wheat bran	15.5	16.5	50.6	7.8	9.0	-	-	-	-	-	-	-	-	-
Pito mash	28.8	17.8	-	-	-	80.3	23.1	14.3	-	-	-	-	-	-
Rice bran	6.7	11.3	-	-	-	-	-	-	39.0	2.6	6.5	-	-	-
Groundnut bran	21.7	16.8	-	-	-	-	-	-	-	-	-	62.0	13.4	13.2
Methionine	-	-	0.1	-	-	0.1	-	-	0.1	-	-	0.1	-	-
Lysine	-	-	1.9	-	-	1.9	-	-	1.9	-	-	1.9	-	-

Where: Crude protein = CP, % = Per cent, In feed = IF, Gross energy = GE

(Appendix C *continued*)

			Diet 1			**Diet 2**			**Diet 3**			**Diet 4**		
Feed items	%CP	GE(MJ/Kg)	%IF	%CP	GE	%IF	%IF	%CP	GE	%IF	%IF	%CP	GE	%IF
Broiler premix	-	-	0.5	-	-	0.5	-	-	0.5	-	-	0.5	-	-
Palm oil	-	-	1.5	-	-	1.2	-	-	2.5	-	-	1.2	-	-
Total	-	-	100	30	17.0	100	31	17.2	100	30	16	100	30	17

Where: Crude protein = CP, % = Per cent, In feed = IF, Gross energy = GE

Appendix D: Weight gain of fingerlings of *O. niloticus* fed on different dietary treatments for 24 weeks

Weeks	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Initial (week 0)	7.19±0.02[a]	7.18±0.24[a]	7.09±0.22[a]	7.04±0.22[a]	7.42±0.10[a]
2	14.52±0.28[a]	14.09±0.28[a]	14.13±0.31[a]	14.43±0.31[a]	7.83±0.18[b]
4	21.24±0.40[bc]	21.53±0.40[abc]	22.55±0.50[ab]	19.42±0.44[d]	9.33±0.18[e]
6	29.71±0.76[a]	26.41±0.57[b]	31.09±0.85[a]	24.10±0.66[c]	9.94±0.24[d]
8	33.64 ± 0.82[b]	29.64±0.69[c]	37.34±1.02[a]	29.90±0.82[c]	11.44 ±0.24[d]
10	43 .00±0.94[a]	37.87±0.77[b]	42 .07±1.17[a]	31.66±0.97 [c]	10.96 ± 0.25[d]
12	49.81±1.06[a]	39.00±0.86[c]	46.82±1.21[b]	32.48±0.90[d]	11.97±0.27[e]
14	55.24±0.95[a]	41.91±1.26[c]	49.05±2.08[b]	35.71±0.82[d]	13.33±1.26[e]

Note: Similar superscript alphabets in the rows denote homogenous means (LSD, $P > 0.05$)

(**Appendix D** *continued*)

Weeks	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
16	59.52 ± 1.26^{a}	46.19 ± 2.07^{c}	54.28 ± 2.18^{b}	38.33 ± 1.32^{d}	12.86 ± 0.83^{e}
18	64.92 ± 2.54^{a}	48.95 ± 2.93^{b}	59.37 ± 2.00^{a}	40.43 ± 0.72^{c}	12.67 ± 1.76^{d}
20	81.87 ± 1.48^{a}	62.75 ± 0.96^{c}	74.50 ± 1.11^{b}	50.17 ± 1.04^{d}	12.89 ± 0.27^{e}
22	90.37 ± 4.31^{a}	65.13 ± 2.58^{c}	79.50 ± 3.01^{b}	57.30 ± 2.06^{d}	14.30 ± 0.67^{e}
24	88.01 ± 1.43^{a}	65.13 ± 0.86^{c}	75.27 ± 1.18^{b}	51.35 ± 1.07^{d}	12.4 ± 0.20^{e}

Note: Similar superscript alphabets in the rows denote homogenous means (LSD, $P > 0.05$)

Appendix E: Results of water quality analysis

	Water parameters										
	TP	DO	pH	TSS	TB	NH3-N	NO2-N	NO3-N	P	TA	TH
Weeks	(oC)	(mg/l)		(mg/l)	(NTU)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Initial	29.7	5.14	5.1	16	8	0.03	0.022	0.09	0.02	26.0	22.0
2	30.7	3.48	5.4	21	5	0.02	0.003	0.01	0.01	32.5	25.0
4	29.8	5.75	6.0	20	7	0.06	0.003	0.08	0.01	38.5	34.0
6	31.8	4.61	6.3	21	6	0.08	0.001	0.01	0.01	41.0	36.0
8	30.5	5.04	7.4	34	9	0.06	0.001	0.01	0.03	45.0	37.0
10	29.7	3.85	7.4	37	11	0.01	0.010	0.04	0.01	44.0	37.0
12	30.2	6.68	7.4	64	13	0.01	0.110	0.09	0.01	44.5	37.0

Where: Temperature = TP, Dissolved Oxygen = DO, Turbidity=TB, Ammonia-Nitrogen = NH3-N, Nitrite-Nitrogen= NO2-N, Nitrate-Nitrogen = NO3-N, Phosphorus = P, Total Alkalinity =TA and Total Hardness =TH

(**Appendix E** *continued*)

	Water parameters										
Weeks	TP (oC)	DO (mg/l)	pH	TSS (mg/l)	TB (NTU)	NH3-N (mg/l)	NO2-N(mg/l)	NO3-N (mg/l)	P (mg/l)	TA (mg/l)	TH (mg/l)
14	25.9	4.86	7.4	68	13	0.08	0.029	0.04	0.02	46.5	44.0
16	28.8	6.45	7.4	63	27	0.05	0.001	0.03	0.02	31.5	21.0
18	29.3	6.54	7.6	53	19	0.11	0.004	0.04	0.03	49.0	39.0
20	29.3	8.25	6.5	49	19	0.02	0.002	0.01	0.03	45.6	40.0
22	30.5	4.06	6.9	54	20	0.16	0.014	0.09	0.05	47.0	40.0
24	30.2	6.68	7.4	64	13	0.01	0.110	0.09	0.01	44.5	37.0

Where: Temperature = TP, Dissolved Oxygen = DO, Turbidity=TB, Ammonia-Nitrogen = NH3-N, Nitrite-Nitrogen= NO2-N, Nitrate-Nitrogen = NO3-N, Phosphorus = P, Total Alkalinity =TA and Total Hardness =TH

Appendix F: Sensory evaluation form

Sensory Evaluation form

Name: Phone number: Sample code:

Please tick one rating for each of the following sensory attributes; colour, odour, flavor and texture and overall acceptability.

	Sensory Attributes				
Rating	Colour (Appearance)	Odour (Smell)	Flavour (Taste)	Tenderness (Texture)	Overall Acceptability
9. Like extremely					
8. Like very much					
7. Like moderately					
6. Like slightly					
5. Neither like nor dislike					
4. Dislike slightly					
3. Dislike moderately					
2. Dislike very much					
1. Dislike extremely					