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Effects of feeding fry of *Oreochromis niloticus* on different agro-industrial by-products

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Abstract

This study was conducted at the Aquaculture Research and Development Centre at Akosombo, to observe the growth and economic performance of fry of *Oreochromis niloticus* fed on different dietary treatments. In the experiment, four isonitrogenous (36% crude protein) and isoenergetic (physiological fuel value gross energy (GE), 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 weight 0.11 ± 0.01 g) stocked at 50 fish/m^3 in out-door hapas for 8 weeks. The results showed that the growth performance was similar (P > 0.05) for fry of *O. niloticus* among all treatments. However, the incidence cost was highest (P < 0.05) for diet 4 and lowest for diet 2. Also, fishes fed on diet 2 had the highest (P < 0.05) profit index, while those fed on diet 4 had the lowest. It was therefore recommended that diet 2 be used in feeding fry of *O. niloticus*.

Key words: Pito mash, rice bran, groundnut bran, wheat bran, incidence cost.

INTRODUCTION

Although culture-based fisheries production in Ghana is showing very strong growth, the rate of growth is slow as it is bedeviled with constraints such as limited availability of good quality fish feed and seeds, limited direct domestic and foreign investment and credit facilities (Amisah et al., 2009); the major constraints being inadequate high-quality, affordable and available feed supply. The lack of production diets coupled with the raw materials to produce high quality feeds has been significant factors limiting the expansion of the industry. 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 (Liti et al., 2006; Mohanta et al., 2007).

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Amisah et al. (2009) indicated that in developing countries like Ghana, most feeds are farm-based and commercial fish feeds have to be imported using the limited foreign exchange of the state. The need to intensify the culture of fishes 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 and Jauncey, 1999). The need to find good quality, cheaper and readily available alternative resources so as to substitute the costly ingredients in traditional supplementary diets is also 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 (Oduro-Boateng and Bart-Plange, 1988; Kaur and Saxena, 2004). Among such non-conventional feed resources is pito mash (PM), a by-product from sorghum spent grains used in the production of a local bear called pito in Ghana. Rice bran (RB) and groundnut bran (GB) are also ideal for use as a good plant feed ingredient for the development of fish feed in Ghana because these by-products do not suffer severe competition as human food, livestock (including fish) and poultry feed like other sources, e.g. wheat bran (WB) or maize. This study was, therefore, carried out to assess the growth and economic performance of cultured fry of *Oreochromis niloticus* 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.

MATERIALS AND METHODS

Site description

The study was conducted at the Aquaculture Research and Development Centre (ARDEC), which lies between latitude 6° 13' North and the longitude 0° 4' East at Akosombo in the Eastern Region of Ghana, between January 2011 and March 2011.

Procurement of ingredients

Pito mash (PM) was purchased from pito brewers in the Akosombo community and rice bran (RB) from a rice milling factory at the Akuse community, all in the Eastern Region of Ghana. Groundnut bran (GB) was obtained from ARDEC feed store. 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 feedstuff were transported to ARDEC and processed into feed for used 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 and % crude fibre (CF). Nitrogen-free extract was computed using the formula: % NFE = 100 - (% CP + % CF + % EE + % Ash). The nutritional characteristics of feed ingredients were used in formulating experimental diets.

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 was added. The tubes were then placed in the digestion block (Model: 2012 Foss Tecator) under a fume hood and the temperature of the digester was gradually increased to about 370°C. Samples were allowed to heat overnight till the solution became colorless, 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 20 ml of the digest were pipetted into the steam section of a distillation apparatus, and then 10 ml of alkaline mixture were added to the digest. Next, the apparatus was 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:

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

Where A is the hydrochloric acid used in titration (0.0071 M); B is the normality of standard acid. The percentage of crude protein was calculated as: Crude protein (%) = nitrogen in sample multiplied by 6.25 (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 h overnight at 600°C using a Gallenkamp 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 expressed as a percentage of the original sample using the formula:

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

Where A is the crucible weight (g) + sample weight (g) before incineration; B is the crucible weight (g) + sample weight (g) after incineration; S is the weight of sample before incineration (AOAC, 1990).

Determinations of percentage (%) crude lipid (CL), ether extract (EE) and 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 to 60°C boiling point) was 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. The evaporated ether was condensed back into sample chamber in continuous cycle for about 6 h continuously. Extracted lipid plus ether in round bottom flask was oven-dried at 105°C for at least an hour for the ether to evaporate leaving the lipid. Subsequently, 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 following formula was used to express the lipid as a percentage of the original sample:

$$\% \text{ Crude lipid} = (W_2 - W_1) \times \frac{100}{\text{Weight of samples (g)}}$$

Where W_1 is the weight of the empty flask in grams and W_2 is the weight of the flask and the lipid in grams (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 min 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 filtration process. At the end of the boiling period, the flask was removed and allowed to rest 1 min 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 min and then the filter paper was washed with boiling water carefully to remove the residue and transferred to the flask containing 200 ml of boiling sodium hydroxide (about 1.25%) solution. This was boiled for another 30 min, after which a filtration crucible was pre-heated with boiling water and used to carefully filter the hydrolyzed mixture after allowing it to rest for 1 min. 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 h and 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 h. 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:

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

Where A is the weight of crucible with dry residue (g); B is the weight of crucible with ash (g); C is the 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.

Diet formulation and preparation

Using the following agro-industrial by-products as sources of carbohydrates: wheat bran, pito mash, rice bran and groundnut bran and with the trial and error method, four isonitrogenous (36% CP) and isoenergetic (18 MJ/kg physiological fuel value gross energy (PFV GE) were formulated were formulated. Feedstuff were finely ground at the corn mill and sieved with a nylon mesh (420 μ/cm^2) to remove stones and larger sized particles (dissimilar sizes results in unstable pellet). The ingredients were weighed according to the proportion based on the formulation for various treatments (using a top pan balance) and mixed together in a large basin. Broiler (vitamin/mineral) premix, lysine and methionine and palm oil were added and the mixture was mixed thoroughly. The feed prepared in powdered form were then stored in labeled bags in a cool dry place and used throughout the experimental period.

Experimental system and fish

The experiment was carried out in outdoor hapas set in an earthen pond (of size 0.2 ha) at ARDEC. Twelve (12) fine mesh hapas (size 1 mm) each of capacity 3 m^3 (1 m × 3 m × 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.

Hormonal sex reversed fry of *O. niloticus* were obtained from ARDEC and fed with the four diets prepared differently using the agro-industrial by-products. 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 3 m^3 (1 m × 3 m × 1 m) fine mesh hapas installed in the pond.

Feeding regime

Fry were fed three times daily at 0800, 1200 and 1500GMT and feed at 10% body weight. After every 2 weeks, at least 25% of the fry from each replicate were collected, weighed individually and the average wet weight recorded. Based on the weight measurement, feed was adjusted accordingly. The total quantity of feed used was also recorded. The experiment lasted 8 weeks, allowing all fish in all the treatments to reach at least 2 g. On the harvest day, fish were removed and the body weights and lengths measured. Based on the measurements, the following biological parameters were calculated:

(i) Mean weight gain (MWG): This was computed as:

MWG = Final mean weight of fish – Initial mean weight of fish (Effiong et al., 2009).

(ii) Specific growth rate: This was computed as:

$$SGR = \frac{\ln W_2 - \ln W_1}{T} \times 100$$

Where W_1 is the initial weight (g) at stocking; W_2 is the final weight (g) at the end of experiment; $\ln W_2 - \ln W_1$ is the natural logarithms of both the final and initial weight of fish; T is the duration (in days) of trial (Effiong et al., 2009)

(iii) Protein efficiency ratio (PER) as:

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

Where protein intake per fish is the total feed given multiplied by the % crude protein in feed (Effiong et al., 2009).

(iv) Feed conversion ratio (FCR) as (Effiong et al., 2009):

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

(v) Survival rate (SR) as (Charo-Karisa et al., 2006):

Table 1. Chemical composition of feed ingredients.

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	62.50	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
*PFV (MJ/kg)	18.19	17.82	11.26	16.75	16.50

* PFV, Physiological fuel value gross energy (GE) was calculated using the physiological fuel values of 23.64, 39.54 and 17.15 MJ/kg for protein, fat and carbohydrate, respectively according to Ali and Al-Asgah (2001).

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

(vi) Condition factor (K) computed as:

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

Where K is the condition factor; W is the weight of fish in grams and SL is the standard length of the fish in centimeters (Charo-Karisa et al., 2006).

Economic analysis

A simple economic analysis was used to assess the cost effectiveness of diets used in the feed trial. The cost of feed was calculated using market prices, taking into consideration the cost of feed and the transport fare with the assumption that all other operating costs remained constant (e.g. cost of constructing hapa, cost of fingerlings and labor). Indices for economic evaluation included:

(i) Incidence cost (IC), which was calculated as:

$$IC = \frac{\text{Cost of feed}}{\text{Weight of fish produced}}$$

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 (Nwanna, 2003; Abu et al., 2010)

(ii) Profit index (PI), which was calculated as:

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

Statistical analysis of experimental data

Biological and economic 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).

RESULTS

Chemical composition of feedstuff

Results of the proximate analysis of the feed ingredients expressed on a dry matter basis (to help standardize information on the ingredients) are shown in Table 1. Among the test by-products, pito mash (PM) recorded the highest crude protein (CP) (28.77%) and rice bran (RB) recorded the lowest CP (6.68%). In terms of ether extract (EE), groundnut bran (GB) had the highest (9.00 %), while 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%. The calculated nitrogen-free extract (NFE) was highest in WB (64.29%) and lowest in RB (36.25%) (Table 1).

Characteristics of diets for fry of *O. niloticus*

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

Table 2. Inclusion levels of diets for fry of *O. niloticus* reared in out-door hapas.

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4
Fish meal	45.0	24.0	54.0	36.5
Wheat bran	51.0	-	-	-
Pito mash	-	72.5	-	-
Rice bran	-	-	41.0	-
Groundnut bran	-	-	-	60.4
Methionine	0.1	0.1	0.1	0.1
Lysine	1.9	1.9	1.9	1.9
*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

*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, nicotinic acid, folic acid, biotin, choline, manganese, zinc, cobalt, iron, iodine, molybdenum and copper.

Table 3. Proximate analyses of diets for fry of *O. niloticus* reared in out-door hapas.

Proximate analysis	Diet 1	Diet 2	Diet 3	Diet 4
% Dry matter	99.41	99.25	98.64	98.73
% Calculate CP	36.00	36.00	36.00	36.00
% Actual CP	35.63	36.12	36.93	36.75
% 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
*PFV (MJ/kg)	16.95	16.86	16.60	18.93

* PFV, Physiological fuel value gross energy (GE) was calculated using the physiological fuel values protein, fat and carbohydrate, respectively, according to Ali and Al-Asgah (2001).

(26.87%). Although the gross energy (GE) physiological fuel value (PFV) 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.

Production data for the fry of *O. niloticus*

As shown in Table 4, the average initial weight (AIW) of fry *O. niloticus* fish fed on the various diets were not significantly ($P > 0.05$) different among the four treatments. After 8 weeks, the average final weight (AFW) and mean weight gain (MWG) were statistically similar ($P > 0.05$) among all the four 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. Fry fed on diets 2 (pito mash based diet) and 4 (ground bran based diet) overlapped throughout all the experimental period. Percent 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 fish fed on diets 1 had the highest (6.77 ± 0.22) specific growth rate and fish fed on diet 4 recorded the lowest (5.93 ± 0.49) specific growth rate (SGR), there were no significant ($P > 0.05$) difference among the treatments. Protein efficiency ratio (PER) and feed conversion ratio (FCR) for fish in all treatment were similar. Survival rate (SR) and condition factor were not significantly ($P > 0.05$) different among the four treatments.

Economic analysis of fry of *O. niloticus* fed on different dietary treatments in out-door hapas

As illustrated in Table 5, 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

Table 4. Harvest data for fry of *O. niloticus* fed on different dietary treatments in out-door hapas.

Parameter	Diets (mean ± standard error)			
	Diet 1	Diet 2	Diet 3	Diet 4
Average initial weight	0.09 ± 0.02[a]	0.09 ± 0.02[a]	0.07 ± 0.00[a]	0.09± 0.01[a]
Average final weight	3.73 ± 0.37[a]	2.60 ± 0.32[a]	2.83 ± 0.17[a]	2.57± 0.38[a]
Mean weight gain	3.64 ± 0.37[a]	2.48 ± 0.32[a]	2.76 ± 0.17[a]	2.48± 0.38[a]
Specific growth rate	6.77 ± 0.22[a]	6.03 ± 0.55[a]	6.58 ± 0.04[a]	5.93± 0.49[a]
Protein efficiency ratio	1.59 ± 0.26[a]	1.51 ± 0.21[a]	1.78 ± 0.34[a]	1.25± 0.15[a]
Feed conversion ratio	1.83 ± 0.27[a]	1.90 ± 0.24[a]	1.68 ± 0.31[a]	2.30± 0.33[a]
Survival rate (%)	64.67 ± 5.21[a]	62.33 ± 6.29[a]	62.33 ± 5.40[a]	53.67± 13.95[a]
Condition factor	4.37 ± 0.23[a]	4.03 ± 0.48[a]	3.03 ± 0.63[a]	4.37± 0.53[a]

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

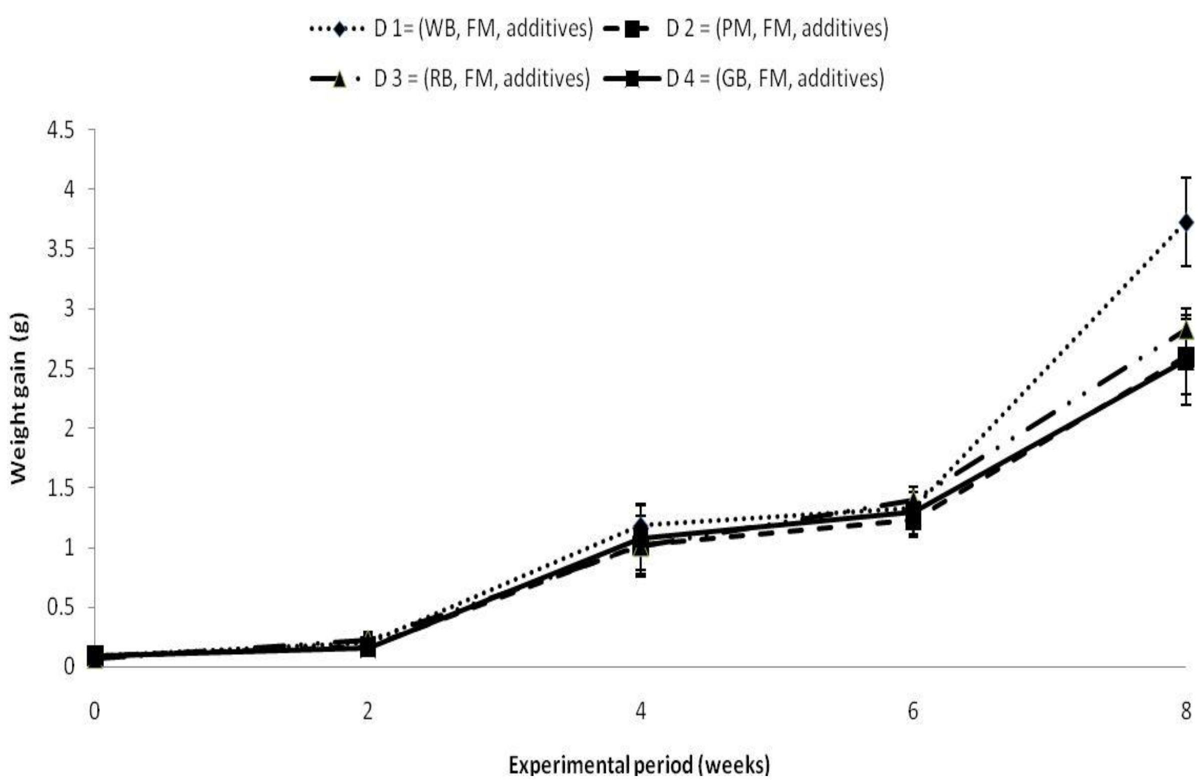

Figure 1. Growth curves for fry of *O. niloticus* fed on different dietary treatments for 8 weeks (vertical bars represent standard errors).

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 4(0.62 kg) with the lowest estimated value of GH¢ 31.25. Total harvested biomass and the estimated values for fish fed on diet 1 > diet 2 each of the fish groups was in the following order: diet 3 > diet 1 > diet 2 > diet 4.

Among the treatments, 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) for 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 for the fish fed 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 5. Economic analysis of fry of *O. niloticus* fed the experimental diets on different dietary treatments in out-door hapas for 8 weeks.

Diets	Cost per kg of feed (GH¢)	Feed input (kg)	Cost of feed input (GH¢)	Harvested biomass (kg)	Estimated value of biomass (GH¢)	IC	PI
Diet 1	0.98	1.59	1.57	0.94	46.78	1.72 ± 0.26^{ab}	0.06 ± 0.0^{b}
Diet 2	0.58	1.38	0.80	0.77	38.63	1.05 ± 0.14^{b}	0.10 ± 0.01^{a}
Diet 3	1.22	1.50	1.84	0.96	47.75	1.97 ± 0.37^{a}	0.05 ± 0.01^{b}
Diet 4	1.00	1.29	1.28	0.62	31.25	2.13 ± 0.29^{a}	0.05 ± 0.01^{b}

Superscripted alphabets in the columns denote homogenous means (LSD, P > 0.05; cost price per 2 g of fish at the farm gate at ARDEC = GH¢0.10). Market price per kilogram feed ingredients used in formulating the test diets (1, 2, 3 and 4) at the time of purchase were used in calculating the cost per kilogram of feed.

DISCUSSION

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 the 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 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 they (*O. niloticus*) have very long intestines necessary to digest plant materials.

In this study, mean weight gain (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 Yigit and Olmez (2010) who reported on *O. niloticus* fry 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 protein efficiency ratio (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 suggested 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 in the 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) also reported PER values for *O. niloticus* that fall within the same range.

The best feed conversion ratio (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 *Oreochromis mossambicus*) fed on fig jam by-product (FJB). On the other hand, 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 favorably with those of Siddiqui et al. (1991), but were below those FCR values obtained by El-Dakar et al. (2008). The slight differences may be from the differences in feed sources (such as 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 (mono-saccharides, disaccharides and/or polysaccharides).

Also in this study, survival rates (SR) were similar for in all treatments. The low SR recorded could be attributed to handling stress. This corroborates 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. The experimental fish fed on all the diets indicated no significant (P > 0.05) differences in their condition factor (K) physiological well being (K). It is possible that this might have contributed to the slight variations observed in average final weight (AFW), MWG, specific growth rate (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 (in terms of incidence cost (IC)) in raising the fry of *O. niloticus* to an average weight of 2 g was lowest for fish fed on diet 2 (pito mash based diet). This implies that it could be cheaper to raise fry of *O. niloticus* when fed on diet 2. 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. It was also noticed from the study that the lower the IC value in the use of a diet, the higher the returns (the higher the profit index (PI) value). Therefore, it was concluded that pito mash would be a more economical ingredient in diet formulation since using diet 2 (pito mash based diet) to raise fry *O. niloticus* was inexpensive.

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