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Effects of feeding different agro-industrial by-products on carcass composition and sensory attributes of *Oreochromis niloticus*

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Abstract
The experiment was conducted to observe the response of *O. niloticus* in terms of carcass composition and consumer acceptability when fed on diets prepared using different agro-industrial by-products. Four diets were formulated containing: wheat bran; pito mash; rice bran; and groundnut bran and fed to *O. niloticus*. A biochemical analysis of the carcass of *O. niloticus* showed that different by-products impacts differently on fish flesh quality. Crude protein was significantly higher in fish fed on pito mash (71.15% ± 0.07) and lowest for fish fed on rice bran (63.86% ± 0.26). Ether extract was significantly higher in fish fed on rice bran (10.58% ± 0.05) and lowest for fish fed on wheat bran (7.74% ± 0.01) crude fibre was significantly higher for fish fed on wheat bran (0.33% ± 0.00) and lowest for fish fed on pito mash (0.21% ± 0.00). Sensory analysis flesh quality of the test fish did not affect consumer acceptance. The results showed no significant differences in colour and odour liking in fish fed on pito mash and groundnut bran; and on wheat bran and rice bran. These by-products could be used to improve growth of fish as well as enhance flesh quality of fish without adversely affecting consumer acceptance.

Keywords: Sensory, biochemical, *Oreochromis*, pito mash, rice bran, odour

1. Introduction

Although culture based fisheries production in many development countries such as Ghana is showing very strong growth, the rate is slow. This is because, the industry is bedeviled with constraints such as; limited availability of good quality fish feed and seeds, limited 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) [1, 2, 12] Among the above challenges, inadequate high-quality, affordable and available feed supply is the most worrying. Feed that is available for used in fish production are mostly made from conventional feed ingredients like fish meal, wheat bran and maize. 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 the quest to boost fish production to argument the protein needs of people, fish culturist, fish scientist and Aquaculturist have turned their focused on agro-industrial by-products as feed ingredients that could be used as feed for fish in culture systems (Gabriel *et al.*, 2007) [10].

Agro-industrial by-products as non-conventional feed are available and affordable in many localities throughout the world. The use of these by-products is becoming widespread due to the numerous recommendations from various research finding (El-Dakar *et al.*, 2008; Attipoe *et al.*, 2009) [9, 5]

However, using alternative feed ingredients can compromise flesh quality of the final product. Studies with fish such as *Oreochromis niloticus* have shown that, the source of nutritional such as dietary protein sources and fat sources (Ali and Al-Asgall, 2001) [2] can influence the physical and organoleptic flesh quality.

In Solomon *et al.* (2007) [18], 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. Using alternative feed sources to replace the costly but widespread usage of dietary fishmeal protein by vegetable proteins on flesh characteristics of harvest-size *O. niloticus* has not received much attention.

The purpose of this study was to evaluate the carcass composition and to examine effects on flesh characteristics and consumer acceptability of *O. niloticus* fed diets containing agro-industrial by-product.

2. Materials and Methods

2.1 Site description

The study was conducted at the Aquaculture Research and Development Centre (ARDEC) which lie between latitude 6 º 13 ' North and the longitude 0 º 4' East at Akosombo in the Eastern Region of Ghana between October 2010 and March 2011.

2.2 Experimental set-up and fish

Twelve (12) fine mesh hapas each of capacity 10 m^3 (5 m x 2 m x 1 m) were installed in a 0.2ha 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. Sex reversed fingerlings of *O. niloticus* of average weight 7 ± 0.23 g were obtained from ARDEC and stocked at 20 fish per meter cube in the hapas. Four isonitrogenous (30% CP) and isoenergetic (PFV 18 MJ/kg) diets were formulated to contain different 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 fish by hand-casting twice daily between 0830 - 0930 GMT and between 0300 - 0400 GMT at 10% for 6 weeks, 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 for 24 weeks. Feed adjustments were made fortnightly by sampling 25% of the fishes from each replicate of the various treatments and weighed to provide a good significant estimate of the average weight.

2.3 Biochemical Analysis

In assessing the efficiency of transfer of nutrients from feed to the fish, it is possible to predict the effect of different diets/feed on the flesh composition of fish. Upon termination of the experiment five (5) fishes from each treatment were randomly selected to determine the final flesh quality. Proximate analyses of the feed items, the prepared feed and carcass composition of fish 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 Association of Official Analytical Chemists [AOAC] (1990) [4]. 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 was computed using the formula: % NFE = (100 - % CP + % CF + % EE + % Ash).

2.4 Sensory evaluation of cooked *O. niloticus*

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 & Olaleye (2010) [16] 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 (i.e. 01, 02, 03 and 04 representing the four 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.

2.5 Statistical analysis of experimental data

Carcass and sensory 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 Duncan Multiple Range Test (DMRT).

3. Results

3.1 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, 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%) 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%. The calculated nitrogen-free extract (NFE) was and highest in WB (64.29%) and lowest in RB (36.25%).

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

*Physiological fuel value (PFV) 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).

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

Table 2 shows the composition and chemical analysis of diets for fingerlings of *O. niloticus*. 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. 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

Table 2: Inclusion levels and proximate analysis of diets for fingerlings *O. niloticus*

Ingredients	Diets			
	Diet 1	Diet 2	Diet 3	Diet 4
Fish meal	45.5	16	56	34
Pito mash	-	80.27	-	-
Rice bran	-	-	39	-
Groundnut bran	-	-	-	62
Wheat bran	50.4	-	-	-
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	1.5	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]PFV (MJ/kg)	17.67	18.15	17.11	19.98

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. Physiological fuel value (PFV) 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).

3.3 Biochemical analysis

Biochemical composition (shown in Table 3) of fingerlings of *O. niloticus* fed on the different dietary treatments indicates that, fish fed on diet 1 (75.94 ± 0.03) had the highest moisture content and those fish fed on diet 3 (74.39 ± 0.30). The proximate compositional analysis showed significant differences ($P<0.05$) in the moisture contents among fish fed on diets 3 and 4. However, no significant ($P>0.05$) difference was found among fish fed on diets 1 and 2. Dry matter (DM) contents were highest for fish fed on diet 4 (24.87 ± 0.05) and lowest for fish fed on diet 1 (24.07 ± 0.33). There were no significant ($P>0.05$) differences in dry matter (DM) among fish fed on diets 1, 2 and 4. Fish fed on diets 3 and 4 were similar ($P>0.05$). 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 and 3 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 1 (7.74 ± 0.01). The EE were not significantly ($P<0.05$) different among fish fed on diets 2, 3 and 4. However, fish fed on diet 1 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 and 4. 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 and 3. The nitrogen-free extract (NFE) was highest for fish fed on diet 1 (28.26 ± 1.06) and lowest for fish fed on diet 3 (15.85 ± 0.53). The NFE were similar ($P>0.05$) for fish fed on diets 1 and 4, for fish fed on diets 2 and 3.

Table 3: Biochemical composition of fingerling of O. niloticus at the of the experiment period (24 weeks)

Components (%)	Final composition in diets (mean ± *S.E.)			
	Diet 1	Diet 2	Diet 3	Diet 4
Moisture	$75.94^{b} \pm 0.03$	$75.89^{b} \pm 0.08$	$74.39^{c} \pm 0.30$	$75.1d^{e} \pm 0.05$
DM	$24.07^{b} \pm 0.03$	$24.12^{b} \pm 0.75$	$24.61^{a} \pm 0.30$	$24.87^{ab} \pm 0.05$
CP	$69.99^{b} \pm 0.03$	$71.15^{a} \pm 0.07$	$63.86^{d} \pm 0.26$	$70.31^{b} \pm 0.05$
EE	$7.74^{b} \pm 0.01$	$10.06^{a} \pm 0.01$	$10.58^{a} \pm 0.05$	$10.31^{a} \pm 0.01$
CF	$0.33^{a} \pm 0.00$	$0.21^{c} \pm 0.00$	$0.25^{bc} \pm 0.00$	$0.32^{a} \pm 0.00$
Ash	$2.28^{b} \pm 0.09$	$2.13^{b} \pm 0.04$	$2.60^{b} \pm 0.09$	$3.44^{a} \pm 0.28$
NFE	$28.26^{a} \pm 1.06$	$19.28^{b} \pm 0.36$	$15.85^{bc} \pm 0.53$	$24.62^{a} \pm 1.97$

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

Crude protein = CP, Ether extract = EE, Crude fibre = CF, Nitrogen-free Extract = NFE, Dry matter = DM and *Standard error = S.E.

3.4 Results of sensory analysis of *O. niloticus*

Results of the quality of flesh (fish meat) of *O. niloticus* fed on different dietary treatments (Table 4) indicate that, in terms of colour liking, fish fed on diet 2 (8.14 ± 0.14) had the highest score and fish fed on diet 1 (71.6 ± 0.47) had the lowest score. However there were no significant ($P>0.05$) differences in colour liking for fish fed on all diets 2.

In terms of odour liking, fish fed on diet 3 (8.00 ± 0.34) had the highest score, whiles, fish fed on diet 4 (7.00 ± 0.49) had the lowest score. However, there were no significant (*P*>0.05) differences among all the treatments for odour liking. Fish fed on diet 2 (7.71 ± 0.29) had the highest score, while fish fed on diet 1 (6.43 ± 1.01) had the lowest score for flavour (taste) liking by the panelists. Test fish fed on all diets were similar (*P*>0.05). Concerning texture (tenderness), fish fed on diet 4 (7.86 ± 0.40) had the highest score and fish fed on diet 1 (7.29 ± 0.18) had the lowest score. However, there were no significant (*P*<0.05) differences for fish fed on all diets. With regard to overall acceptability, fish fed on diet 2 (8.14 ± 0.36) had the highest score but did not differ from all the other diets.

Table 4: Sensory properties of *O. niloticus* fed on different diets for 24 weeks in out-door hapas

Attributes	Diets (mean ± *S.E)			
	1	2	3	4
Colour liking	$7.71^a \pm 0.64$	$8.14^a \pm 0.14$	$7.72^a \pm 0.47$	$7.86^a \pm 0.26$
Odour liking	$7.71^a \pm 0.47$	$7.86^a \pm 0.14$	$8.00^a \pm 0.34$	$7.00^a \pm 0.49$
Flavour liking	$6.43^a \pm 0.36$	$7.71^a \pm 0.29$	$6.71^a \pm 0.42$	$7.00^a \pm 0.44$
Texture liking	$7.29^a \pm 0.18$	$7.29^a \pm 0.36$	$7.29^a \pm 0.42$	$7.86^a \pm 0.40$
Overall acceptability	$7.71^a \pm 0.43$	$8.14^a \pm 0.36$	$7.71^a \pm 0.36$	$7.86^a \pm 0.37$

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

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

*Standard error = S.E.

4. Discussions

4.1 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 & Shiau (1996) [8], Gonzalez & Allan (2007) [11] and Audu *et al.* (2008) [6] 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.

4.2 Biochemical analysis of fingerlings *O. niloticus*

It appears higher protein levels for fish fed on diets 2 and 4 correlates positively with higher ether extract (EE)/lipid levels. This was explained by Habib *et al.* (1994) cited in Raj *et al.* (2008) [17] 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) [14] 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) [2].

The lower EE in fish fed on diet 3 compared to the EE level in diet 3 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) [13] 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 & Al-Asgall (2001) [2] who, reported that, the EE in fish appear to correlate positively with the dietary lipid content.

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 & Shiau (1996) [8], Manjappa *et al.* (2002) [12] and Audu *et al.* (2008) [6].

In the present study ash were similar (*P*>0.05) among fish groups fed on diets 1, 2 and 3. A similar result was reported earlier by Metwally & El-Gellal (2009) [15] 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) [19], and Watanabe *et al.* (1997) [20] that, the ash content of an ingredient is the total amount of minerals (or inorganic matter) present within the food.

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

Considering the following interpretation of the 9-point acceptability scale in discussion of the ANOVA results (Table 4): 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. There were similarities between colour likeness for diets 2 and 4. This 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. Support for these explanations could be drawn from Boyd (2005) [7] 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 four treatments. The insignificant difference among all the 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.

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.

5. Conclusion

Biochemical analysis of the fish revealed, that the dietary treatments significantly influenced the body composition of *O. niloticus.* The by-products; pito mash, rice bran, groundnut bran and wheat bran used in this study might have slightly different effects on the sensory attributes to include; colour, odour, flavor and taste qualities of the fish. However, the impact does not affect consumer acceptance.

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