APPARENT DIGESTIBILITY COEFFICIENTS OF DIFFERENTLY PROCESSED POULTRY AND FISH OFFAL MEALS FED TO THE AFRICAN CATFISH, *CLARIAS GARIEPINUS* (BURCHELL, 1822) JUVENILES

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ABSTRACT

Waste from poultry and fish processing plants whose disposal presently raises a major environmental concern may be a source of animal protein in fish diet, if properly processed. This study was carried out to determine the nutrient composition and apparent digestibility coefficient (ADC) of nutrients in differently processed poultry and fish offal in diets fed to Clarias gariepinus. The test ingredients were autoclaved poultry offal (P1), oven-dried poultry offal (P2), poultry offal paste with wheat offal as carrier (P3), autoclaved fish offal (F1), oven-dried fish offal (F2) and fish offal paste with wheat offal (F3). A 35 % crude protein (CP) reference diet (R) was formulated. Test diets contained 70 % reference diets and 30 % of test ingredients, with chromic oxide as the inert marker. Triplicate groups of C. gariepinus (5.50 ± 0.50 g) were fed diets for 8 weeks. CP content in ingredients was significantly high (p<0.05) in P2 (56.88 ± 0.00 %), with the lowest values recorded in F3 (35.00 ± 0.03 %) and P3 (31.50 ± 1.20 %). Linoleic and arachidonic acids were recorded in all fish offal meals, while only oven-dried poultry offal meal had arachidonic acid. ADC of nutrients varied significantly across treatments (p<0.05). ADC of CP was significantly highest in P2 (83.36 ± 0.49 %) and least in P1 (56.06 ± 0.36 %). ADC of phosphorus increased from 74.31 ± 0.55 % in P3 to 99.57 ± 0.75 % in P1. The result of this study revealed that nutrient digestibility by C. gariepinus was best in oven-dried meals compared to treatment methods.

Keywords: *Clarias gariepinus*, Poultry offal, Fish offal, Heat, Digestibility

INTRODUCTION

Nutrition plays a critical role in intensive aquaculture as it influences not only the production cost but also fish growth, health and waste production (Gatlin, 2002). For profitability and success in fish farming, ingredients for feed production must be readily available, cheap and the nutrients must be bioavailable (Falaye *et al*., 2014). The conventional feed ingredients for fish are mainly from plant and animal products especially by-products of processing plants. Some of these products are also used as human food (Gatlin, 2010). Feed is the single most expensive factor in aquaculture production and protein mostly accounted for by fishmeal constitutes the highest cost (Aniebo *et al.,* 2009). The proportion of protein in fish diets is higher than those of other cultured animals, thus making feeds very expensive (Aniebo *et al.,* 2009). Depending on the stage of growth, studies have shown that the African catfish requires between 35 – 50 % crude protein in their diet, with resultant cost implication (Wilson and Moreau, 1996; Adebayo and Quadri, 2005). For sustainable and profitable fish farming, there is therefore a need to reduce feed cost

through the use of locally available, cheap and accessible feed stuff.

Waste generated from poultry and fish processing plants are potential protein source for cultured fish. In Nigeria, there is a rapid expansion of small and medium-scale poultry farms with huge amount of waste generation. Similarly, the fish processing industry generates waste consisting of discarded parts (internal organs such as liver, heart, kidney, gonads, gills, and bone and sometimes head) which are not usually consumed by humans. The huge quantity of waste has caused some serious environmental havoc such provision of habitat for insect vectors, vermin, bacteria and viruses, which may result in water contamination (leaching of nutrients and pathogenic microorganisms) and air pollution (Satia, 2017). These wastes can however be utilized to produce fish feed and indirectly helps towards a greener environment, which is hampered by eutrophication caused by excessive nutrient loads in the aquatic environment (Carpenter, 2005).

The utilization will however require some form of processing, as feeding of fresh fish offal to fish was reported to cause mycobacteriosis (Francis-Floyd, 2011). According to Sauli *et al.* (2015), the reduction or elimination of pathogens is mostly achieved through heat treatment (boiling, roasting, toasting and autoclaving), as it is simple and easy to be adopted by local farmers. They however have the potential to damage useful nutrients if appropriate processing technique is not applied (Orisasona *et al*., 2016). It is also of utmost importance that the nutrients present in feedstuffs are totally available to the animal for growth and development, else large portions of the nutrients will be excreted in the faeces when not digested and assimilated. Digestibility study is thus very important in the selection of feed ingredients for feed formation, as it is one of the most important aspects in evaluating the potentials, efficiency of animal feedstuffs and basic requirements for formulating fish diets (Cho and Kaushik, 1990; Allan *et al.,* 2000).

This study is therefore aimed at determining the nutrient composition and digestibility of differently heat treated poultry and fish offal meals fed to *Clarias gariepinus* Burchell 1822.

MATERIALS AND METHODS

Processing of Offal for Meals: Offal of fish and poultry were procured from processing plants in Ile-Ife, Osun State, Nigeria. The fish and poultry offal were divided into three portions each for heat treatments. 10 kg each of fish and poultry offal were autoclaved at 15 psi for 20 minutes and then oven dried at 55^{o}C for 48 hour (Giri *et al.,* 2000), milled and designated as F1 and P1 respectively. Another 10 kg each of fish and poultry offal each was dried in hot air oven at 55^{0}C for 48 hour (Giri *et al*., 2000), milled and designated as F2 and P2 respectively. While another 10 kg each of fish and poultry offal were blended into paste (using an electric blender, VTCL India) and mixed with wheat offal at ratio 7:1 (Fish offal: Wheat offal), a slight modification of Makinde and Sonaiya (2012) method, oven dried at 50^{0}C for 48 hour, milled and designated as F3 and P3 respectively.

Chemical Analysis of Meals: The differently processed meals were analyzed for proximate and mineral compositions using methods described by the Association of Official Analytical Chemists (AOAC, 2005). The mineral composition samples were ash in a furnace at 600^{o}C for 3 hours, and then refluxed with 20 % hydrochloric acid. Fatty acid profiles for differently processed meals were carried out as described by Axelsson and Gentili (2014). Chromic oxide contents were determined as described by Farukawa and Tsukahara (1966).

Experimental Diets: A reference diet was formulated using Pearson square method to contain 35 % crude protein (Table 1). Test ingredients for digestibility test were autoclaved fish offal (F1), autoclaved poultry offal (P1), oven-dried fish offal (F2), oven-dried poultry offal (P2), fish offal paste with wheat offal (F3) and poultry offal paste with wheat offal (P3). The test diets contained 70 % reference diet and 30 % of each of the test ingredients on a dry weight basis (Dong *et al.,* 2010; Falaye *et al.,* 2014), with chromic oxide (Cr_2O_3) as inert marker (Cho and Slinger, 1979).

Table 1: Ingredients composition in reference and experimental diets formulations fed to *Clarias gariepinus* juveniles

Ingredient (g/100g)	Reference Diet	F1	F2	F3	P1	P2	P3
Fish meal	8.70	6.13	6.13	6.13	6.13	6.13	6.13
Soybean meal	43.75	30.63	30.63	30.63	30.63	30.63	30.63
Groundnut cake	17.50	12.25	12.25	12.25	12.25	12.25	12.25
Maize	24.49	17.14	17.14	17.14	17.14	17.14	17.14
Vitamin premix	1.00	0.70	0.70	0.70	0.70	0.70	0.70
Dicalcium phosphate	1.00	0.70	0.70	0.70	0.70	0.70	0.70
Lysine	0.50	0.35	0.35	0.35	0.35	0.35	0.35
Cr_2O_3	0.50	0.35	0.35	0.35	0.35	0.35	0.35
Salt	0.50	0.35	0.35	0.35	0.35	0.35	0.35
Starch	1.00	0.70	0.70	0.70	0.70	0.70	0.70
Palm Oil	1.00	0.70	0.70	0.70	0.70	0.70	0.70
AFO	-	30	-	-	-	-	-
OFO	-	-	30	-	-	-	-
FOPW	-	-	-	30	-	-	-
APO	-	-	-	-	30	-	-
OPO	-	-	-	-	-	30	-
POPW	-	-	-	-	-	-	30
Total (g)	100	100	100	100	100	100	100

APO, autoclaved poultry offal; OPO, oven-dried poultry offal; POPW, poultry offal paste with wheat offal as carrier; AFO, autoclaved fish offal; OFO, oven-dried fish offal; FOPW. fish offal paste with wheat offal

Test ingredients were thoroughly mixed with other ingredients with cassava starch as binder. The mash was then pelletized with 2 mm die hand-driven pelletizer. The diets were sundried at atmospheric temperature and humidity for 2 days and packed into well-labelled air-tight plastic containers until ready to use.

Experimental Design and Procedure: The experiment was laid out in a completely randomized design of seven treatments with each treatment replicated thrice and each replicate having 15 catfish juveniles. The experiment was carried out in rectangular plastic tanks of 0.42 m x 0.29 m x 0.25 m with water volume maintained at 20 litre in each tank. After 7-day acclimatization to laboratory conditions, a total of 315 *C. gariepinus* juveniles with an average weight (5.50 ± 0.50 g) were randomly allocated into 21 experimental plastic tanks at the rate of 15 fish per tank. Diets were fed to triplicate groups of fish twice daily, between 7.00 - 8.00 am and 4.00 - 5.00 pm at 5 % body weight throughout the experiment. The ration was adjusted every two weeks when new mean weights of fish for the various experimental units were determined. Leftover (uneaten) feed in each tank was siphoned 30 minutes after feeding to avoid leftover feed contaminating the faeces. Faeces in each tank were gently siphoned out using siphoning hose of 2 mm diameter every 8 hours after feeding. The faeces were pooled for each treatment and dried.

Apparent Digestibility Coefficient (ADC): The apparent digestibility coefficient (ADC) of protein, lipid and phosphorus for test and reference diets were calculated using the method of Cho and Slinger (1979) thus:

$$ADC\ nutrient = 100 - 100\left(\frac{Cr_2O_3\ in\ diets}{Cr_2O_3 in\ feaces} \times \frac{Nutrient\ in\ feaces}{Nutrient\ in\ diets}\right).$$

Since the test ingredients substituted 30 % of the reference diet, the ADC of the ingredients were calculated according to the equation of De Silva and Anderson (1995) thus:

$$ADCn = ADC_{TD}-(Y \times ADC_{RD})/Z,$$

where ADCn = apparent digestibility coefficient of nutrient in test ingredient, ADC_{TD} = apparent digestibility coefficient in test diet and ADC_{RD} = apparent digestibility coefficient in reference diet, Y is the reference diet proportion and Z is the test diet proportion.

Statistical Analysis: All data resulting from the experiment were subjected to one way analysis of variance (ANOVA) and significant means were separated using Duncan's new multiple range test at $p<0.05$. All Analyses were carried out using SAS (Statistical Analysis System) Version 9.1 (SAS, 2003).

RESULTS

Results of the proximate composition of differently processed offal are presented in Table 2. Moisture content in ingredients ranged from 4.07 ± 0.00 to 6.42 ± 0.01 % at the level of 50^{o}C heat application for 48 hours. Ash ranged from 5.48 ± 0.30 % in P3 to 11.82 ± 1.00 % in F3. Among fish offal meals, ash content was significantly reduced ($p<0.05$) by autoclaving (F1), however values of ash in fish offal meals were significantly higher ($p<0.05$) than values recorded for poultry offal meals. Autoclaving and oven-drying of offal containing wheat offal resulted in a significant decrease ($p<0.05$) in ash content of poultry offal meals. Crude fibre ranged from 0.12 ± 0.03 % in P2 to 4.29 ± 0.01 % in P3. The values increased in treatments with wheat offal (F3 and P3) and were significantly higher ($p<0.05$) compared to other meals. Similarly, nitrogen free extract (NFE) ranged from 3.70 ± 0.05 in P1 to 28.09 ± 0.50 in P3 and were significantly higher ($p<0.05$) in meals containing wheat offal; F3 and P3. It is also observed that autoclaving caused a reduction in NFE content when compared with oven-dried meals. The crude protein (CP) content in ingredients ranged from 31.50 ± 1.20 % in P3 to 56.88 ± 0.50 % in P2. Oven-dried offal meals (F2 and P2) recorded significantly higher ($p<0.05$) CP contents (45.94 ± 0.00 and 56.88 ± 0.00 % respectively) than autoclaved meals and meals containing wheat. Lipid content ranged from 24.22 ± 0.02 % in P3 to 36.67 ± 0.04 % in P3. The result for lipid content showed higher values (35.92 ± 0.00 and 36.67 ± 0.04 % for F1 and P1 respectively) in autoclaved offal.

A reduction in calcium content was observed in autoclaved samples of fish and poultry offal. Values for calcium ranged from 1.14 ± 0.00 mg/g in P1 to 9.81 ± 0.00 mg/g in F2. The addition of wheat offal as an absorbent increased the magnesium content of the meal. The least value for magnesium (0.80 ± 0.03 mg/g) was observed in F2, while the highest value (2.00 ± 0.01 mg/g) was recorded in P3. Phosphorus content varied significantly ($p<0.05$) across treatments, with values ranging from 0.01 ± 0.00mg/g in F3 to 0.014 ± 0.00 mg/g in F2. Zinc content is processed offal ranged from 67.75 ± 2.10 µg/g in F3 to 261.30 ± 0.29 µg/g in P3.

Linoleic and arachidonic acids are the two polyunsaturated fatty acids (PUFAs) recorded in fish offal meal, while arachidonic acid was recorded in oven-dried poultry offal meal (Table 3). Linoleic acid ranged from 0.0 in P3 to 0.21 in F1, while he range for arachidonic acid was 0.0 in P1 and P3 to 0.87 in F1. The monounsaturated oleic acid was observed in all meals and the values in F1 and F2 (0.178 and 0.16 respectively) were significantly higher ($p<0.05$) than the values recorded in other treatments, with the least value of 0.098 recorded in P1. Myristic acids were not recorded in F1, F2 and P3. The values 0.006 recorded in P1 and P2 was significantly higher ($p<0.05$) than that recorded in F3. Behenic and tricosanoic acids were not recorded in poultry offal meals, but present in fish offal meals. Lauric acid ranged from 0.001 in P2 to 0.034 in F2. Tridecaonic acid was not detected in P2, but had the highest value in F1. Pentadecaonic acid in processed offal had values ranging from 0.001 in P3 to 0.27 in F1, while palmitic acid ranged from 0.0002 in P1 and P2 to 0.087 in F3. Values for stearic acid ranged from 0.03 in P1 to 0.20 in F2.

The proximate composition of test diets is presented in Table 4. The moisture in the diets ranged from 7.68 ± 0.20 % in F2 to 8.92 ± 0.03 % in P2. Ash content in diets varied significantly ($p<0.05$) ranging from 6.75 ± 0.05 % in P3 to 10.26 ± 0.42 % in F2. P3 and F3 groups with wheat offal meal had the least ash contents among the two. Crude fibre values were significantly lower ($p<0.05$) in the P2 and F2 groups, with the highest value recorded in P3 group. Similarly, crude protein was significantly lower in P2 and F2. The crude protein is significantly higher ($p<0.05$) in P1.

Table 2: Proximate and mineral composition of differently processed poultry and fish offal meals fed to *Clarias gariepinus* juveniles

Parameters (%)	F1	F2	F3	P1	P2	P3
Moisture	4.07 ± 0.00^{d}	4.20 ± 0.03^{d}	4.12 ± 0.00^{d}	5.35 ± 0.01^{b}	4.43 ± 0.00^{c}	6.42 ± 0.01^{a}
Ash	10.86 ± 0.00^{b}	11.78 ± 0.03^{a}	11.82 ± 1.00^{a}	6.88 ± 0.00^{d}	7.11 ± 0.00^{c}	5.48 ± 0.30^{e}
Crude fibre	0.17 ± 0.00^{d}	0.13 ± 0.00^{d}	3.69 ± 0.00^{b}	0.59 ± 0.00^{c}	0.12 ± 0.03^{d}	4.29 ± 0.01^{a}
Crude protein	43.75 ± 0.02^{e}	45.94 ± 0.00^{d}	35.00 ± 0.03^{f}	46.83 ± 0.03^{c}	56.88 ± 0.33^{a}	31.50 ± 1.20^{g}
Lipid	35.92 ± 0.03^{b}	29.35 ± 0.00^{d}	23.15 ± 0.06^{g}	36.67 ± 0.04^{a}	24.80 ± 0.03^{e}	24.22 ± 0.02^{f}
NFE	5.23 ± 0.05^{f}	8.48 ± 0.00^{c}	22.22 ± 0.05^{b}	3.70 ± 0.05^{g}	6.6 ± 0.03^{d}	28.09 ± 0.50^{a}
Total Carbohydrate	5.40 ± 0.17^{e}	8.61 ± 0.57^{c}	25.91 ± 0.11^{b}	4.29 ± 0.01^{f}	6.71 ± 0.34^{d}	32.31 ± 0.17^{a}
Metabolizable energy (kcal/kg)	4530.85 ± 0.53^{b}	4084.47 ± 12.40^{d}	3257.81 ± 33.25^{e}	4808.63 ± 3.67^{a}	4283.30 ± 2.35^{c}	4095.17 ± 1.93^{d}
Calcium (mg/g)	9.36 ± 0.00^{b}	9.81 ± 0.00^{a}	3.69 ± 0.00^{e}	1.14 ± 0.00^{f}	5.53 ± 0.00^{c}	3.84 ± 0.00^{d}
Magnesium (mg/g)	1.10 ± 0.00^{d}	0.80 ± 0.03^{f}	1.48 ± 0.30^{b}	0.81 ± 0.02^{e}	1.31 ± 0.11^{c}	2.00 ± 0.50^{a}
Zinc (µg/g)	102.65 ± 0.08^{c}	70.79 ± 0.00^{e}	67.75 ± 2.10^{f}	93.06 ± 0.02^{d}	110.79 ± 0.07^{b}	261.30 ± 0.29^{a}
Phosphorus (mg/g)	0.012 ± 0.00^{c}	0.014 ± 0.00^{a}	0.012 ± 0.00^{c}	0.014 ± 0.00^{a}	0.013 ± 0.00^{b}	0.010 ± 0.00^{d}

Means on the same row with the same superscript are not significantly different ($p<0.05$), F1= autoclaved fish offal, F2= oven-dried fish offal F3= fish offal paste with wheat offal, P1= autoclaved poultry offal, P2= oven dried poultry offal, P3= poultry offal paste with wheat offal

Table 3: Fatty acid profile of differently processed poultry and fish offal meals fed to *Clarias gariepinus* juveniles

Fatty Acids (x10^{-2})	F1	F2	F3	P1	P2	P3
Lauric	0.30 ± 0.11^{b}	3.40 ± 0.57^{a}	0.30 ± 0.11^{b}	0.40 ± 0.17^{b}	0.10 ± 0.05^{b}	0.20 ± 0.03^{b}
Tridecanoic	1.50 ± 0.28^{ab}	0.80 ± 0.05^{bc}	0.70 ± 0.05^{c}	2.40 ± 0.05^{a}	0.00 ± 0.00^{c}	0.24 ± 0.05^{c}
Myristic	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.02 ± 0.00^{b}	0.60 ± 0.05^{a}	0.60 ± 0.04^{a}	0.00 ± 0.00^{b}
Pentadecanoic	27.00 ± 3.46^{a}	18.00 ± 1.15^{b}	18.50 ± 0.05^{b}	13.90 ± 0.05^{b}	5.70 ± 0.63^{b}	0.10 ± 0.05^{a}
Palmitic	0.08 ± 0.00^{b}	0.70 ± 0.05^{b}	0.25 ± 0.02^{b}	0.02 ± 0.00^{b}	0.02 ± 0.00^{b}	8.70 ± 1.15^{a}
Stearic	15.60 ± 0.57^{ab}	20.55 ± 0.63^{a}	17.50 ± 0.57^{ab}	3.06 ± 0.33^{c}	11.30 ± 0.63^{ac}	6.80 ± 0.05^{c}
Oleic	17.80 ± 0.57^{a}	16.00 ± 0.00^{a}	10.50 ± 0.51^{b}	9.80 ± 0.33^{b}	10.20 ± 0.51^{b}	10.30 ± 0.71^{b}
Linoleic	6.70 ± 0.11^{c}	21.80 ± 1.50^{a}	5.30 ± 0.03^{d}	21.60 ± 0.58^{a}	15.30 ± 0.63^{b}	0.00 ± 0.00^{e}
Arachidonic	87.80 ± 4.33^{a}	0.70 ± 0.11^{c}	0.07 ± 0.00^{c}	0.00 ± 0.00^{c}	33.00 ± 5.77^{c}	0.00 ± 0.00^{c}
Behenic	0.03 ± 0.00^{a}	0.30 ± 0.5^{a}	0.30 ± 0.05^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Tricosanoic	0.02 ± 0.01^{a}	0.30 ± 0.05^{a}	0.30 ± 0.03^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Means on the same row with the same superscript are not significantly different ($p<0.05$), F1= autoclaved fish offal, F2= oven-dried fish offal F3= fish offal paste with wheat offal, P1= autoclaved poultry offal, P2= oven dried poultry offal, P3= poultry offal paste with wheat offal

Table 4: Proximate composition of experimental diets formulated with poultry and fish offal meals fed to *Clarias gariepinus* juveniles

Parameter (%)	R	F1	F2	F3	P1	P2	P3
Moisture	8.86 ± 0.20^{a}	8.29 ± 0.17^{ab}	7.68 ± 0.20^{b}	8.76 ± 0.06^{a}	8.64 ± 0.27^{a}	8.92 ± 0.03^{a}	7.82 ± 0.05^{b}
Ash	7.57 ± 0.32^{d}	9.46 ± 0.29^{b}	10.26 ± 0.42^{a}	8.43 ± 0.18^{c}	7.03 ± 0.02^{f}	7.21 ± 0.22^{e}	6.75 ± 0.05^{g}
Crude Fibre	3.12 ± 0.09^{de}	3.57 ± 0.29^{ab}	2.99 ± 0.01^{e}	3.29 ± 0.35^{cd}	3.44 ± 0.30^{bc}	2.73 ± 0.28^{f}	3.70 ± 0.32^{a}
Crude Protein	38.50 ± 0.31^{d}	38.94 ± 0.12^{c}	37.63 ± 0.30^{e}	38.94 ± 0.04^{c}	39.81 ± 0.33^{a}	38.50 ± 0.15^{d}	39.38 ± 0.61^{b}
Lipid	7.31 ± 0.35^{f}	14.34 ± 0.58^{d}	16.41 ± 0.59^{c}	13.50 ± 0.37^{e}	21.53 ± 0.25^{a}	21.84 ± 0.09^{a}	17.86 ± 0.33^{b}
NFE	34.64 ± 0.37^{a}	25.40 ± 0.25^{c}	25.03 ± 0.38^{cd}	27.58 ± 0.48^{b}	19.55 ± 0.32^{f}	20.80 ± 0.58^{e}	24.49 ± 0.32^{d}
Carbohydrate	37.77 ± 0.01^{a}	28.91 ± 0.07^{c}	28.01 ± 0.01^{d}	30.62 ± 0.32^{b}	22.96 ± 0.04^{f}	23.57 ± 0.03^{e}	28.12 ± 0.07^{d}
Metabolizable Energy (Kcal/kg)	3165.77 ± 2.85^{f}	3445.41 ± 2.18^{e}	3552.66 ± 1.27^{d}	3446.52 ± 2.84^{e}	3866.89 ± 4.79^{b}	3885.80 ± 2.92^{a}	3714.91 ± 3.81^{c}

Means with the same superscripts along rows are not significantly different (p>0.05), R: Reference Diet, F1: Autoclaved Fish offal diet, F2: Oven-dried Fish offal diet, F3: Fish offal paste + Wheat offal diet, P1: Autoclaved Poultry offal diet, P2: Oven-dried Poultry offal diet, P3: Poultry offal paste + Wheat offal diet

Table 5: Apparent digestibility coefficients of nutrients in experimental diets formulated with poultry and fish offal meals fed to *Clarias gariepinus* juveniles

Parameter (%)	R	F1	F2	F3	P1	P2	P3
ADC Protein	66.55 ± 0.25^{d}	65.83 ± 0.57^{d}	76.96 ± 0.81^{c}	78.63 ± 0.14^{b}	56.06 ± 0.36^{f}	83.36 ± 0.49^{a}	57.09 ± 0.37^{e}
ADC Lipid	79.25 ± 0.27^{e}	73.94 ± 0.11^{f}	80.54 ± 0.19^{e}	81.37 ± 0.29^{d}	95.37 ± 0.41^{b}	91.74 ± 0.07^{c}	96.30 ± 0.38^{a}
ADC Phosphorus	87.80 ± 0.40^{c}	81.27 ± 0.38^{e}	97.27 ± 0.11^{b}	86.71 ± 0.33^{c}	99.57 ± 0.75^{a}	85.37 ± 0.49^{d}	74.31 ± 0.55^{f}

Means with the same superscripts along rows are not significantly different (p>0.05), R: Reference Diet, F1: Autoclaved Fish offal diet, F2: Oven-dried Fish offal diet, F3: Fish offal paste + Wheat offal diet, P1: Autoclaved Poultry offal diet, P2: Oven-dried Poultry offal diet, P3: Poultry offal paste + Wheat offal diet

Result of the apparent digestibility coefficients (ADCs) of nutrients is presented in Table 5. Apparent digestibility of protein varied significantly as a result of heat treatment. Protein digestibility was significantly highest in P2 (83.36 ± 0.49 %) and least in P1 (56.06 ± 0.36 %). The apparent crude fat digestibility coefficients varied significantly ($p<0.05$) across treatments, ranging from 73.94 ± 0.11 % in F1 to 96.30 ± 0.38 % in P3. The apparent phosphorus digestibility increased from 74.31 ± 0.55 % in P3 to 99.57 ± 0.75 % in P1.

DISCUSSION

The nutrient composition of differently processed offal showed a crude protein ranging from 31.5 to 56.9 % with higher values recorded in oven-dried meals, while lipids ranged from 23.15 to 36.67 %. The crude protein values in this study were lower than the 65.8 % reported by Omole *et al.* (2008) for local chicken offal. However, these values and that for lipid were within the crude protein (41 – 53 %) and lipid contents (12 - 26.66 %) ranges reported by Fowler (1991) and Orisasona (2018). Lipid content of poultry waste meal was much higher than the 14 % reported by Turker *et al.* (2005). This variation may be attributed to the processing methods and the components of poultry waste meal. The addition of wheat offal to either poultry offal or fish offal caused a significant reduction in the crude protein content of meals.

The results of this study revealed that autoclaving caused a reduction in the ash and subsequently, mineral contents of meals. Also the use of wheat offal as carrier of offal paste resulted in higher crude fibre and NFE contents, and a reduction in crude protein in meals. This was due to the high crude fibre content in wheat offal which is about 10 % (Olomu, 1995), thus contributing to the fibre and energy contents of meals F3 and P3. A reduction in calcium contents were observed in autoclaved samples of fish and poultry offal, this was in line with the findings of Tusnio *et al*. (2014) where decreased calcium and phosphorus were reported in selected diets using autoclaving for thermal sterilization. However, the addition of wheat offal as an absorbent increased the magnesium content of meals. The use of heat at 121^{o}C for autoclaving may have caused the reduction in mineral composition observed in this study. Heat treatment at very high temperature has generally been reported to cause reduction in nutrient values (Falaye *et al*., 2014). Similar findings were reported by Heuzé *et al*. (2017) for brewers grains subjected to various heat treatments.

The presence of two n-6 polyunsaturated fatty acids (linoleic and arachidonic acids) in fish offal meals is indicative of a better growth-promoting effect if fed to fish (Lim *et al*., 2011). Behenic and tricosanoic acids were not recorded in poultry offal meals, but present in fish offal meals. According to Akoh (2017), behenic acid occurs in very small quantities as ester of glycerol only in some fats and oils and it is present in very small amounts in fishery products, but not found in fresh red and white meat.

The apparent digestibility for crude protein in this study was lower than that reported by Hossain and Jauncey (1989), where observed apparent digestibility coefficient for crude protein of fish meal in carp was 88.9 %. Also higher value of fish meal digestibility for *Labeo rohita* Francis Hamilton 1822 was also reported by Salim *et al.* (2004). The ADC for protein obtained in P2, F3 and F2 are in agreement with the range of protein digestibility values of 75 to 95 % reported for freshwater fish fed selected diets (Koprucu and Ozdemir, 2005), while the ADCs of protein in F1, P3 and P1 are significantly lower than the range. It is important to note that protein content can be denatured by heat treatment (Falaye *et al.,* 2014), and subsequently, the digestibility as observed in F1 and P1 in this study. Part of the variation in the ADC of protein in different ingredients may also be explained by differences in the chemical composition resulting from processing techniques used for various feed ingredients (Köprücü and Özdemir, 2005; Watson, 2006). Excessive heat as demonstrated in autoclaved meals denatures protein and thus negatively affects digestibility as affirmed by Falaye *et al.* (2014).

The apparent digestibility coefficients of crude fat in F1, F2 and F3 in this study were lower than the values reported for fishmeal by NRC (1993), while the values of ADC of lipid in P1, P2 and P3 were similar to the reported values of 85 – 95 % for fish meal. The lower value in fish offal was significantly as a result of the variation in the composition of fishmeal and offal. Offal in this study comprise mostly fish visceral compared to fishmeal made of whole fish. Crude fat digestibility in F2 and F3 groups are similar to 81.35 % reported by Jalal *et al*. (2000). However, the apparent fat digestibility coefficients obtained in this study were higher than the 68 % reported by Gaylord and Gatlin (1996). Phosphorus was well digested all meals except in P3. Phosphorus is a very important factor in aquaculture, required by fish, however the excessive release of this nutrient in effluents will increase nutrient load and result in algae bloom in adjoining waters and possibly eutrophication (Falaye *et al.,* 2014).

Conclusion: Crude protein digestibility was reduced in diets with autoclaved meals, thus reducing the nutritive value, while the use of wheat offal as carrier resulted in increased crude fibre and nitrogen free extract, and reduced crude protein in both fish and poultry offal. This study reveals that oven-dried meals were better digested by *C. gariepinus* when ADC protein, lipid and phosphorus are considered and therefore should be explored in growth index of this species.

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