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Response of Broiler Chickens Fed Diets Containing Differently Processed Bambara Groundnut Offal

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Abstract

A 56-day feeding trial was conducted to evaluate the effects of differently processed bambara groundnut offal (BGO) on the performance, carcass traits, haematology, and lipid profile of broiler chickens. A total of 150 day-old Abor Acre broilers were randomly assigned to five dietary treatments with three replicates of 10 birds each in a Completely Randomised Design. The diets consisted of: T1 (control, 0% BGO), T2 (10% toasted BGO), T3 (10% raw BGO), T4 (10% boiled and sundried BGO), and T5 (10% raw BGO + enzyme), with soybean meal partially replaced as the protein source. Birds were fed and watered ad libitum under standard management conditions. Results indicated significant differences ($p < 0.05$) in growth performance across treatments. At the starter phase, birds on T5 (raw BGO + enzyme) recorded the highest body weight (737.65 g) and best feed conversion ratio (2.68), followed by T2 (toasted BGO). During the finisher phase, T3 (raw BGO) yielded the highest body weight (1488.56 g), while T2 (toasted BGO) followed closely (1312.13 g). Carcass traits such as thigh, drumstick, and back cut varied significantly, with T2 exhibiting the highest dressing percentage (69.19%). Among organ weights, only spleen weight showed significant differences. Haematological indices, including PCV, Hb, WBC, MCH, and MCHC, varied significantly, with T3 and T1 showing superior values. Lipid profile analysis revealed differences in cholesterol, HDL, and LDL levels, with T4 and T5 showing higher values for cholesterol and HDL, respectively. In conclusion, raw BGO supplemented with an enzyme improved growth, FCR, and lipid profile without adverse health effects, indicating its potential as a sustainable alternative to soybean meal in broiler diets. Heat processing is also beneficial to reduce anti-nutritional factors, provided nutrient losses are minimised.

Keywords: *broiler chickens, bambara groundnut offal, enzyme supplementation, growth performance, lipid profile*

Introduction

Feed remains a critical determinant of efficiency and productivity in livestock production (Kehinde *et al*., 2006). The need for new feed ingredients which will reduce costs of production is the basis for some research in livestock feed and production. Man and livestock compete for similar basic feed ingredients that are not sufficiently produced in adequate quantities (Omojola and Adesehinwa, 2007). However, the prime factor that affects intensive livestock production in Nigeria is high feed cost due to costly feed ingredients, especially soyabean meal, maize and groundnut cake. Broiler feed is based primarily on cereal grains and oil seed cakes which are required to meet their energy and protein requirements. The high cost of feed and poultry products necessitates the utilization of low-cost inputs such as cheaper agro-industrial by-products as feed stuffs that are cheaper and locally available (Balogun and Adeniji, 2002). There has been tremendous increase in the evaluation of agro- industrial by-products (AIBPs) as animal feed during the past decades because of obvious need to conserve grains and legumes for human consumption in underdeveloped countries. One of such by-products is bambara groundnut offal, which is derived from milling industry. This experiment was therefore designed to evaluate to evaluate the response of broiler chickens fed diets containing differently processed bambara groundnut.

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Materials and Methods

Experimental site

The experiment was carried out at the Poultry Unit of the Teaching and Research Farm, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. The area falls within the tropical rain forest zone with an annual rainfall of 2177mm, temperature range between 22-36^{o}C, with relative humidity of 50-90%, depending on season (NRCRI, 2017).

Source and processing of bambara groundnut offal

Raw bambara groundnut offal was procured from a commercial dealer in Ubani Ibeku Market in Bende L.G.A. of Abia State.

Toasted bambara groundnut offal

Toasting of bambara groundnut offal was carried out according to Udensi *et al*. (2004) and Ani (2006). Raw bambara groundnut offal was processed by toasting for 30 minutes at 100^{0}C. Five kilogram of bambara nut offal was transferred into an open cast-iron dry pan set over fire, then stirred to prevent it from sticking to the pan and burning until the offal turned brownish and produced a sweet smelling aromatic flavor.

Boiled and sundried bambara groundnut offal

Raw bambara groundnut offal was processed by boiling in water for 30 minutes at 100^{0}C. Five Kg of bambara groundnut offal was added in an open cast-iron dry pan set over fire, while Ten litres of water were added. It was stirred also to prevent it from sticking to the pan until the offal changed in colour showing that heat was applied. The boiled bambara groundnut was later sundried.

Procurement of other feedstuffs

Maize, soyabean meal, palm kernel cake, bone meal, salt, vitamin/mineral premix, lysine, methionine and Kenzyme® which were later used in diet formulation were procurred from a commercial dealer. The Kenzyme® used is a stabilized,multipurpose enzyme feed ingredients designed to improve the digestibility of raw materials and increase the nutrient level of feed. It is a product of Kemin Industries, Inc., USA and the inclusion level was 0.04% and 0.05% at starter and finisher level respectively.

Experimental birds and management

A total of 150day-old Abor Acre broiler were procured from Amo Byng® farms for the experiment. The initial weight of the birds were taken and randomly divided into 5 treatment groups with 10 birds per replicate, comprising 30 birds in each group, and the birds were brooded together with a 60W bulb. Each group was raised in floor pens with wood shavings as litter materials, feeders and drinkers were respectively provided for the supply of *ad -libitum* feed and water for a duration of eight weeks. The birds were vaccinated against Gumboro disease at 10th and 18th days of life while Newcastle vaccine was administered at the 28th day. Coccidiostat was administered in drinking water within the second week and third week of the experiment.

Experimental diets

Five (5) experimental broiler diets were formulated for the experiment such that the control diet (T_1) did not contain bambara groundnut offal, while Diets T_2-T_5 contained bambara groundnut offal at 10% each respectively. Diet T_5 contained bambara groundnut and Kenzyme® during the starter and finisher phases. The composition of broiler chickens diets and calculated analysis are shown in table 1.

Table 1: Ingredient Composition of diets containing differently processed bambara groundnut offal fed to Broiler starter birds

Ingredients (%)	$T_{1(10}$%$_{)}$	$T_{2(10}$%$_{)}$	$T_{3(10}$%$_{)}$	$T_{4(10}$%$_{)}$	$T_{5(10}$%$_{)}$
Bambara	0	10	10	10	10
Kenzyme	0.00	0.00	0.00	0.00	0.04
Maize	53.20	43.20	43.20	43.20	43.16
Soyabean	35.00	35.50	35.00	35.00	35.00
PKM	8.00	8.00	8.00	8.00	8.00
Bone meal	3.00	3.00	3.00	3.00	3.00
Lysine	0.20	0.20	0.20	0.20	0.20
Methionine	0.10	0.10	0.10	0.10	0.10
Premix	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Calculated Composition					
Crude protein (%)	21.50	22.14	22.14	22.14	22.14
Metabolizable energy (Kcal/Kg)	2874.16	2758.0	2758.0	2758.0	2758.0

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Vitamin-mineral premix supplied Vitamin A-2,000,000IU; Vitamin D3-4,000,000IU; Vitamin E-8.00g; Vitamin K3-0.40g; Viamin B1-0.32g; Vitamin B2-0.96g; Vitamin B6-0.56g; Vitamin C-2,400mg; Vitamin B12-400g; Folic acid-0.16g; Biotin-8.00mg; Zinc-7.20g; Copper-0.32g; Iodine-0.25mg; Cobalt-36mg; Selenium-16mg; BHT-125g. $T_{1=}$ Control; T_2=Toasted Bambara groundnut offal; T_3= Raw Bambara groundnut offal; T_4 = Boiled and Bambara groundnut offal; $T_{5\ =}$ Raw Bambara groundnut offal plus enzyme.

Table 2: Ingredient composition of diets containing differently processed bambara groundnut offal fed to broiler finisher birds

Ingredients (%)	$T_{1(10}\%)$	$T_{2(10}\%)$	$T_{3(10}\%)$	$T_{4(10}\%)$	$T_{5(10}\%)$
Bambara	0	10	10	10	10
Kenzyme	0.00	0.00	0.00	0.00	0.05
Maize	57.20	47.20	47.20	47.20	47.15
Soyabean	29.00	29.00	29.00	29.00	29.00
PKM	10.00	10.00	10.00	10.00	10.00
Bone meal	3.00	3.00	3.00	3.00	3.00
Lysine	0.20	0.20	0.20	0.20	0.20
Methionine	0.10	0.10	0.10	0.10	0.10
Premix	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Crude protein (%)	19.42	20.25	20.25	20.25	20.25
Metbolizable energy (Kcal/Kg)	2906.4	2792.0	2792.0	2792.0	2792.0

Vitamin-mineral premix supplied Vitamin A-2,000,000IU; Vitamin D3-4,000,000IU; Vitamin E-8.00g; Vitamin K3-0.40g; Viamin B1-0.32g; Vitamin B2-0.96g; Vitamin B6-0.56g; Vitamin C-2,400mg; Vitamin B12-400g; Folic acid-0.16g; Biotin-8.00mg; Zinc-7.20g; Copper-0.32g; Iodine-0.25mg; Cobalt-36mg; Selenium-16mg; BHT-125g. $T_{1=}$ Control T_2=Toasted Bambara groundnut offal; T_3= Raw Bambara groundnut offal; T_4 = Boiled and sundried Bambara groundnut offal; $T_{5\ =}$ Raw Bambara groundnut offal plus enzyme.

Data Collection

Growth performance

Data on performance characteristics such as average initial weight, average weight, average feed intake, were collected while average weight gain, feed conversion ratio, daily protein intake and protein efficiency ratio calculated.

Carcass evaluation

At the end of the experiment, two (2) birds of similar body weight were selected from the treatment groups, fasted, weighed and slaughtered by severing the injugular vein. They were thoroughly bled and scalded by dipping in hot water of 60^{o}C and defeathered. The carcass values from head, shank, neck and visceral were removed in order to determine the dressed weight as described by Ojewola and Longe (1999).

$$\text{Dressing \%} = \frac{\text{Dressed weight}}{\text{Live weight}} \times \frac{100}{1}$$

$$\text{Organs} = \frac{\text{Heart/liver/kidney/intestine/proventriculus}}{\text{Live weight}} \times \frac{100}{1}$$

Haematological indices

Blood samples (10mls) were taken from the jugular vein of each of the birds under each of the treatment diets at the end of the experiments using sterile needle and syringe to withdraw the blood; from which 5mls each were kept in a sample containing Ethylene Diamine Tetra Acetic Acid (EDTA), an anti-coagulant to prevent blood clotting. Each of the blood samples collected were put into properly labelled and sterilized tube and taken to the laboratory for haematological assessment during the starter and finisher phases. The following were determined; Packed Cell Volume (PCV), Red Blood Cells (RBC), White Blood Cells (RBC), Haemoglobin (Hb), Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration(MCHC).

Mean Corpuscular Haemoglobin (MCH)

$$\frac{\text{Hb x 10}}{\text{RBC}}$$

Mean Corpuscular Volume (MCV)

$$\frac{\text{PCV x 10}}{\text{RBC}}$$

Mean Corpuscular Haemoglobin Concentration (MCHC)

$$\frac{\text{Hbx100}}{\text{PCV}}$$

Lipid profile

Total cholesterol, low density lipoprotein, high density lipoprotein and triglycerides were determined. Blood sample was collected and put in glass vials with heparin at 15IU/ml as

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anticoagulant. Plasma was separated and stored at -20^{0}C till analysis was carried out (Prasad *et al*., 2009). Parameters evaluated were as follows:

Total cholesterol determination: This was carried out by employing Chemistry Auto Analysing Kit AUTOPAK® supplied by Bayer Diagnostics India LTD using enzymatic and colorimetric method. The results were expressed as M/dl of plasma.

High density lipoprotein (HDL): This was determined using phosphotungstate method. The result was expressed as M/dl of plasma.

Very lowdensity lipoprotein (VLDL): It was estimated by employing Friedwald formula and results were expressed as M/dL of plasma.

$$\text{VLDL-chol} = \text{plasma} + \frac{\text{triglyceride}}{5}$$

Low density lipoprotein (LDL): This was estimated as the difference between the total cholesterol and the sum of VLDL-cholesterol and HDL-chol. Results were expressed in M/dL of plasma. (Prasad *et al*., 2009).

Statistical Analysis

All data generated were statistically analysed using the Analysis of Variance (ANOVA) procedure described by Steel and Torrie (1980) in a Completely Randomized Design (CRD), and significant means were separated using Duncan Multiple Range Test (Duncan, 1995) taking $P<0.05$ as significance level.

Results and Discussion

Proximate composition

The proximate compositions of raw, toasted, boiled and sundried bambara groundnut offal are presented in table 3. Raw bambara groundnut offal contained a dry matter of 89.15%, ash 3.20%, crude protein 15.75%, ether extract 1.32%, crude fibre 25.15%, nitrogen free extract 44.73% and ME 2791.00(Kcal/kg). Toasted bambara groundnut contained dry matter 89.40%, ash 3.00%, crude protein 13.13%, ether extract 1.28%, crude fibre 27.25%, ME 2734.00 (Kcal/kg) while boiled and sundried bambara groundnut contained dry matter 88.78%, Ash 3.50%, crude protein 14.88%, ether extract 1.26%, crude fibre 28.50%, nitrogen free extract 40.64%, ME 2774.00(Kcal/kg). The proximate composition of plant feedstuffs according to NRC (1994) can vary due to factors such as crop variety, soil conditions and processing methods. The bambara groundnut offal used in this study was obtained from cream coloured bambara groundnut seed variety.

Table 3: Proximate compositions of raw, toasted, boiled and sundried bambara groundnut offal

The proximate compositions of broiler starter diets containing differently processed bambara groundnut offal are shown in table 4.

Parameters	Raw	Toasted	Boiled and sundried
Dry matter(%)	89.15	89.40	88.78
Ash(%)	3.20	3.00	3.50
Crude protein(%)	15.75	13.13	14.88
Ether extract(%)	1.32	1.28	1.26
Crude fibre(%)	25.15	27.25	28.50
Nitrogen free extract(%)	44.73	44.74	40.64
Metabolizable energy(Kcal/kg)	2791.00	2734.00	2774.00

Diets 1 (control), 2 (raw), 3 (toasted), 4 (boiled and sundried), and 5 (raw bambara groundnut and kenzyme) contained dry matter, 91.50%, 91.14%, 91.08%, 91.10% and 91.10%, respectively; ash, 7.90%, 7.00%, 6.30%, 5.50%, and 7.90%, respectively; crude protein, 23.63%, 22.75%, 22.75%, 21.88%, and 20.13%, respectively; ether extract, 4.20%, 4.12%, 4.08%, 4.02%, and 4.02%, respectively; crude fibre, 5.80, 8.30, 9.80, 9.35, and 8.50%, respectively; nitrogen free extract, 49.97%, 48.97%, 47.75%, 50.35%, and 50.55%, respectively. According to NRC (1994) can vary due to factors such as crop variety, soil conditions and processing methods. The bambara groundnut offal used in this study was obtained from cream coloured bambara groundnut seed variety.

Table 4: Proximate composition of broiler starter diets containing differently processed bambara groundnut offal.

Parameters	$T_{1(10}\%)$	$T_{2(10}\%)$	$T_{3(10}\%)$	$T_{4(10}\%)$	$T_{5(10}\%)$
DM	91.50	91.14	91.08	91.10	91.10
Ash	7.90	7.00	6.30	5.50	7.90

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CP	23.63	22.75	22.75	21.88	20.13
EE	4.20	4.12	4.08	4.02	4.02
CF	5.80	8.30	9.80	9.35	8.50
NFE	49.97	48.97	47.75	50.35	50.55
ME	2762.00	2791.00	2734.00	2774.00	2754.00

DM: Dry matter; CP: Crude Protein; EE: Ether Extract; CF: Crude Fibre; NFE: Nitrogen Free Extract; ME: Metabolizable Energy

The proximate composition of broiler finisher diets containing differently processed bambara groundnut offal is shown in table 5. Diets 1 to 5 contained a dry matter of 91.38%, 91.25%, 91.08%, 91.05%, 91.10% respectively. Ash 7.30%, 7.30%, 7.69%, 7.78%, 7.88% respectively. Crude protein 19.69%, 18.59%, 18.59%, 18.59%, 18.59% respectively. Ether extract 3.48%, 3.30%, 3.30%, 3.28%, 3.15% respectively. Crude fibre 5.90, 9.05, 9.75, 9.85, 9.50% respectively. The proximate composition of plant feedstuffs according to NRC (1994) can vary due to factors such as crop variety, soil conditions and processing methods. The bambara groundnut offal used in this study was obtained from cream coloured bambara groundnut seed variety.

Table 5: Proximate composition of finisher broilers fed diets containing differently processed bambara groundnut offal.

Parameters	$T_{1(10}\%)$	$T_{2(10}\%)$	$T_{3(10}\%)$	$T_{4(10}\%)$	$T_{5(10}\%)$
DM	91.38	91.25	91.08	91.05	91.10
Ash	7.30	7.30	7.69	7.78	7.88
CP	19.69	18.59	18.59	18.59	18.59
EE	3.48	3.30	3.30	3.28	3.15
CF	5.90	9.05	9.75	9.85	9.50
NFE	55.01	53.01	51.75	51.55	51.98
ME	3347.17	3332.96	3315.24	3310.37	3301.57

DM: Dry matter; CP: Crude Protein; EE: Ether Extract; CF: Crude Fibre; NFE: Nitrogen Free Extract; ME: Metabolizable Energy

Growth performance

The results of growth performance of starter broilers fed differently processed bambara groundnut offal is presented in Table 6. Statistically, there were no significant differences ($p>0.05$) on initial body weight and protein efficiency ratio (PER). But there were statistical differences ($p<0.05$) on final body weight, total weight gain, average daily weight gain, average daily feed intake, total feed intake, feed conversion ratio and protein intake. Starter birds fed raw bambara groundnut offal with enzyme (T_5) had the highest value on final body weight of 902.65g, total weight gain of 737.65g and average daily weight gain of 26.34g followed by diet 2. Birds fed diet 2 (toasted bambara offal) had higher values of 827.22g, 660.56g, 23.59g for final body weight, total weight gain and average daily weight gain respectively than T_4 (boiled and sundried) and this is in disagreement with Ironkwe and Esonu (2012) who reported that toasted bambara groundnut offal reduced the average weight gain of broilers as a result of protein denaturation due to heat treatment. The values in T_5 could be ascribed to improved nutrient availability which manifested in improved growth rate while the control diet had the least value on final body weight. But for average daily feed intake (ADFI) and total feed intake (TFI), birds fed diets 4 (boiled bambara nut offal) had the highest value followed by birds fed raw bambara groundnut offal with enzyme supplemention having the least value. Also, birds fed diet 5 with the fcr value of 2.68 made more efficient use of the nutrients in the diet than other treatment groups. The observed average daily weight gain (ADWG), total weight gain (TWG), protein efficiency ratio (PER) showed that enzyme supplementation in the diet 5 helped in nutrient digesibility. This may be due to cleavage of non-starch polysacharides (NSPs) and other antinutritional factors (Carsten, 2013). Enzyme supplemention and toasting of bambara groundnut offal can enhance weight gain in broilers without adverse effects. ADWG and TWG values in T_2 and T_4 shows that heat treatment improved nutrient value and intake which is supported by Essien and Udedibie (2007). ADFI and TFI were lower in T_3 62.58g and1752.33g respectively which may be due to antinutritional factors. Amaefule and Osuagwu (2005) observed poor feed intake of broilers fed raw bambara groundnut offal and cowpea due to presence of antinutritional factors in legumes. Protein Efficiency Ratio was high 1.63 in T_2 showing that heat treatment improves nutritive value. PER reduced in T_3 1.42 and this could be due to trypsin inhibitor that affects protein utilization, by binding to the intestinal wall, reducing protein utilization and efficiency.

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Table 6: Growth performance of starter broilers fed diets containing differently processed bambara groundnut offal.

Parameter(g/bird)	$T_{1(10\%)}$	$T_{2(10\%)}$	$T_{3(10\%)}$	$T_{4(10\%)}$	$T_{5(10\%)}$	SEM
Initial weight	166.67	166.67	166.67	165.00	165.00	1.11
FinalWeight	686.67^{b}	827.22^{ab}	718.52^{b}	800.00^{ab}	902.65^{a}	28.15
Weight Gain	520.00^{b}	660.56^{ab}	551.85^{b}	635.00^{ab}	737.65^{a}	27.82
ADWG	18.57^{b}	23.59^{ab}	19.71^{b}	22.68^{ab}	26.34^{a}	0.99
ADFI	57.00^{c}	65.51^{ab}	62.58^{bc}	72.09^{a}	70.68^{a}	1.71
Total Feed Intake	1595.91^{c}	1834.28^{ab}	1752.33^{bc}	2018.61^{a}	1979.13^{a}	47.82
FCR	3.07^{b}	2.78^{c}	3.18^{a}	3.18^{a}	2.68^{d}	0.06
Protein Intake	12.25^{c}	14.50^{ab}	13.86^{b}	15.96^{a}	15.65^{a}	0.40
PER	1.52	1.63	1.42	1.42	1.68	0.04

^{a,b,c,d} Means within the rows with different superscripts are significantly different (P<0.05); SEM-Standard Error of the mean. FW:Final Weight; WG: Weight Gain; ADWG: Average Daily Weight Gain; ADFI: Average Daily Feed Intake;TFI: Total Feed Intake; FCR: Feed Conversion Ratio; PI: Protein Intake; PER: Protein Efficiency Ratio.

The results of growth performance of finisher broilers fed differently processed bambara groundnut offal are presented in Table 7. The finisher phase recorded significant differences (p<0.05) on initial weight, final body weight, total weight gain, average daily weight gain, average daily feed intake, total feed intake, feed conversion ratio, protein intake and protein efficiency ratio. Birds fed bambara groundnut offal diet with kenzyme (T_5) had the highest value of 902.65g on initial weight (p<0.05) followed by birds fed T_2 diet (toasted bambara offal) with initial body weight (827.22g), final body weight (2139.35g), total weight gain (1312.13g) and average daily weight gain (46.86g). The high values in T_2 (toasted bambara nut offal) compared to control group disagree with Ironkwe and Esonu (2012) who reported that toasted bambara groundnut offal reduced the average weight gain of finisher broilers as a result of protein denaturation due to heat treatment. Finisher birds fed raw bambara groundnut offal diet (T_3) recorded the highest values of 2207.08g for final body weight, 1488.56g for total weight gain, 53.16g for average daily weight gain and this could be due to the bulky nature of bambara nut offal. Birds fed the control diet (T_1) recorded the least values. Results show that the highest values recorded in ADFI and TFI were on birds fed T_4 (boiled), T_5 and T_2 (toasted) showing that heat treatment improved nutritive value of legumes and its intake (Essien and Udedibie, 2007). Also, according to Onyimonyi and Okeke (2007), the increased ADFI and TFI could be due to aroma emanating from toasted bambara nut offal. The feed conversion ratio was statistically different (p<0.05) from diets 1 to 5, the highest FCR values recorded was in T_5 (3.15) followed by T_4 (3.02) but reduced in T_3 and which could be due to effects of antinutritional factors which reduced protein metabolism, absorption and utilization of minerals. Trypsin inhibitor affected protein utilization in rats adversely thereby increasing cysteine and methionine requirements. Also, antinutritional factors can resist proteolysis, accumulate in the body of animal, binding to the intestinal wall, reducing feed utilization and efficiency.

Table 7: Growth performance of finisher broilers fed diets containing differently processed bambara groundnut offal.

Parameter(g/bird)	$T_{1(10\%)}$	$T_{2(10\%)}$	$T_{3(10\%)}$	$T_{4(10\%)}$	$T_{5(10\%)}$	SEM
Initial Weight	686.67^{b}	827.22^{ab}	718.52^{b}	800.00^{ab}	902.65^{a}	28.15
Final Weight	1877.04^{b}	2139.35^{ab}	2207.08^{a}	2085.42^{ab}	2105.12^{ab}	41.77
Total Weight Gain	1190.37^{b}	1312.13^{ab}	1488.56^{a}	1285.42^{ab}	1202.47^{b}	39.87
ADWG	42.51^{b}	46.86^{ab}	53.16^{a}	45.91^{ab}	42.95^{b}	1.42
ADFI	119.46^{b}	135.11^{a}	132.57^{ab}	138.69^{a}	135.43^{a}	2.49
Total Feed Intake	3344.79^{b}	3783.08^{a}	3711.87^{ab}	3883.32^{a}	3792.04^{a}	69.68
FCR	2.81^{d}	2.88^{c}	2.49^{e}	3.02^{b}	3.15^{a}	0.06
Protein Intake	23.20^{b}	27.36^{a}	26.84^{a}	28.08^{a}	27.42^{a}	0.58
PER	1.82^{ab}	1.72^{ab}	1.98^{a}	1.63^{b}	1.57^{b}	0.05

^{a,b,c,d,e} Means within the rows with different superscripts are significantly different (P<0.05); SEM-Standard Error of the mean. FW:Final Weight; WG: Weight Gain; ADWG: Average Daily Weight Gain; ADFI: Average Daily Feed

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Intake;TFI: Total Feed Intake; FCR: Feed Conversion Ratio; PI: Protein Intake; PER: Protein Efficiency Ratio.

Carcass characteristics

The results of the carcass characteristics of finisher broilers fed differently processed bambara groundnut offal based are shown in Table 8**.** Studies have shown that broiler chickens fed diets containing processed bambara groundnut offal have significantly higher live body and dressed carcass compared to those fed a control diet. The dressing percentage significantly differed ($p<0.05$) with diets 2 and 5 recording the highest values 69.19% and 67.06% respectively while birds fed T_3 diet (raw bamabara groudnut offal) recorded the least value 63.20%. This could be due to the presence of antinutritional factors such as tannins, protease inhibitors, phytate, and haemagglutinins in raw bambara groundnut offal and as a result of low nutrient availability. Tormehen *et al*. (2020) reported that raw bambara groundnut offal may not supply the balanced nutrient levels in broilers leading to reduced growth performance and carcass quality. Shank, drumstick and backcut showed statistical differences ($p<0.05$) with the highest values of 6.60%, 17.01% and 22.80%, respectively, recorded in birds fed T_5 diet. Thigh did not differ significantly ($p>0.05$) and this tallies with the study of Onyeyirichi (2023) who observed no significant differences on some carcass characteristics of finisher broilers fed raw bambara groundnut offal.

Organ proportion

The results of organ characteristics of finisher broilers fed differently processed bambara groundnut offal based are shown in Table 9. There were **s**ignificant differences ($p<0.05$) only on spleen with T_1 and T_2 having similar values of 0.14% and 0.14%, respectively, while diets T_4 and T_5 had similar values of 0.07% and 0.07%, respectively. The increased values in T_1 and T_2 could imply that the spleen enlarged in size maybe as a result of liver problem, leukamia, parasites, bacteria or virus and this could affect the spleen's role in blood filtration and immunity. But there were no significant differences ($p>0.05$) among other organs such as liver, kidney, lungs, heart, large intestine, small intestine, gizzard, proventriculus, crop, gallbladder and pancreas. This implies that the inclusion levels of bambara groundnut offal were not high as to adversely affect organs and that processing methods such as heat treatments helped to reduce antinutritional effects (Ekenyem and Odo, 2010). According to Onyeyirichi (2023) and Chima (2023),organ characteristics of broiler birds fed bambara groundnut offal-based diet were not generally affected while some studies reported improved organ weights.

Table 9: Organ characteristics of finisher broilers fed diets containing differently processed bambara groundnut offal.

Parameter (%)	$T_{1(10\%)}$	$T_{2(10\%)}$	$T_{3(10\%)}$	$T_{4(10\%)}$	$T_{5(10\%)}$	SEM
Kidney	0.60	0.42	0.42	0.37	0.45	0.03
Liver	2.66	2.42	2.23	2.27	2..57	0.13
Spleen	0.14^{a}	0.14^{a}	0.10^{ab}	0.07^{b}	0.07^{b}	0.01
Lungs	0.60	0.56	0.53	0.66	0.56	0.04
Heart	0.44	0.41	0.40	0.47	0.38	0.02
Large intestine	0.67	0.63	0.61	0.54	0.56	0.03
Small intestine	3.70	3.72	3.42	3.32	3.81	0.15
Gizzard	2.09	2.11	1.86	2.04	2.06	0.08
Proventriculus	0.38	0.50	0.47	0.60	0.80	0.06
Crop	0.40	0.45	0.37	0.36	0.36	0.02
Gall bladder	0.11	0.09	0.10	0.08	0.06	0.01
Pancreas	0.40	0.29	0.31	0.29	0.37	0.03

^{a,b} Means within the rows with different superscripts are significantly different ($P<0.05$); SEM-Standard Error of the mean

Haematological indices

The results of the haematological indices of finisher broilers fed differently processed bambara groundnut offal is presented are Table 10. There were significant differences ($p<0.05$) in the Packed Cell Volume (PCV), Haemoglobin Concentration (Hb),White Blood Cells (WBC), Mean Cell Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC). Birds fed T_3 diet had the highest PCV value of 29.17% followed by birds fed diets T_2, T_5, T_4 and T_1 with values of 27.50%, 26.67%, 26.17% and 25.33%, respectively. Birds fed T_1 diet had the highest Hb value of 11.15g/dl followed by birds fed diets T_4, T_2, T_5 and T_3 respectively. Amongst the birds fed bambara nut offal, boiled and sundried, toasted bambara offal diets have higher haemoglobin (Hb) concentration 8.45g/dl and 8.11g/dl respectively, than other treatment groups, showing higher tendency of the birds to overcome respiratory stress. When there is high haemoglobin (Hb) it implies high oxygen carrying capacity, but when Hb is below normal it means the

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oxygen carrying capacity is low and the birds can easily succumb to respiratory stress (Aderemi and Alabi, 2013). Hb serves as a measure of the animal to withstand respiratory stress. Inclusion of toasted bambara nut offal helped in boosting the bird's immune system and the view is strongly corroborated by the report of Joshi *et al.*, (2002a) who reported that blood profile is an indicator of the health of an organism and acts as pathological reflector of the body. Also, processing method (toasting) helped to remove the antinutritional factors (cyanogens, tannins, lectins and phytate) in bambara groundnut offal and improve nutrient value (Ikekwem, 2023). RBC values did not show significant differences ($p>0.05$) but diet T_4 had the highest value of 2.33 µl followed by diets T_5, T_2, T_3 and T_1 respectively. Low RBC values 1.95 µl in T_3 could be due to antinutritional factors in raw bamabara nut offal such as tannins, lectins which affects RBC formation by detaching heam from haemoglobin . White blood cell value was highest value in diet 1 (17.97 10^3/µl) followed by T_2, T_5, T_4 and T_3. Mean corpuscular volume recorded highest in T_1 followed by T_3, T_2,T_5 and T_4, respectively and values were 154.43fl, 149.08fl, 138.69fl, 132.36fl and 120.20fl, respectively. Mean corpuscular haeamoglobin differed significantly ($p<0.05$) with T_1 having the highest value of 66.50pg followed by T_2, T_4, T_5 and T_3, respectively. Mean corpuscular haemoglobin concentration differed amongs the treatment groups with the highest value of 43.82g/dl occuring in T_1 followed by T_4. These shows that the birds cannot easily succumb to anaemia since low levels indicate anaemia (Aster, 2004). Haematological parameters are affected by factors such as management, environment, age, starvation, drug administration, nutrition, sex, breed and physiology. All the packed cell volume values were within the normal range of 25-45% and were within the accepted range of for broiler chickens according to the study of Ikekwem (2023) who reported that processed bambara groundnut offal diets did not adversely affect carcass and haematological parameters on broiler birds.

Table 10: Haematological indices of finisher broilers fed diets containing differently processed bambara groundnut offal.

Parameter	T_1(10%)	T_2(10%)	T_3(10%)	T_4(10%)	T_5(10%)	SEM
PCV (%)	25.33^{b}	27.50^{ab}	29.17^{a}	26.17^{b}	26.67^{a}	0.46
Hb (g/dl)	11.15^{a}	8.45^{b}	7.77^{b}	9.12^{ab}	8.11^{b}	0.43
RBC ($\times10^6$/ µl)	1.83	2.01	1.95	2.33	2.19	0.12
WBC ($\times10^3$/µl)	17.97^{a}	11.57^{b}	10.23^{b}	10.53^{b}	10.72^{b}	0.987
MCV (fl)	154.43	138.69	149.08	120.20	132.36	7.28
MCH (pg)	66.50^{a}	42.49^{b}	39.94^{b}	41.60^{b}	41.25^{b}	3.58
MCHC (g/dl)	43.82^{a}	30.70^{b}	26.83^{b}	34.85^{b}	30.36^{b}	1.86

^{aa,b} Means within the rows with different superscripts are significantly different ($P<0.05$); SEM-Standard Error of the mean. PCV: Packed Cell Volume;Hb: Haemoglobin; RBC: Red Blood Cell; WBC: White Blood Cell; MCV: Mean Corpuscular Volume; MCH: Mean Cell Haemoglobin; MCHC: Mean Corpuscular Haemoglobin Concentration.

Lipid profile

The findings on the lipid profile of finisher broilers fed differently processed bambara groundnut offal are shown in Table 4.11. There were significant differences ($p<0.05$) on total cholesterol with T_4 having highest value of 103.49mg/dl, T_5 (99.12mg/dl), T_3 (74.64mg/dl), T_2 (73.22mg/dl) and T_1 (65.53mg/dl). High density lipoprotein (HDL) also had significant differences ($p<0.05$) with the highest value of 66.55gg/dl recorded in T_5 followed by T_4 (58.55mg/dl), T_3 (42.99mg/dl), T_2 (39.56mg/dl) and T_1 (36.07mg/dl) respectively. There were no significant differences ($p>0.05$) in LDL but highest value of 25.25mg/dl was recorded in T_4. Triglyceride, and VLDL among the treatment groups did not show significant differences ($p>0.05$) but VLDL values were similar in T_1 and T_2 (20.58mg/dl respectively). Significant differences in total cholesterol may be due to protein, amino acids composition, lipid fraction and fibre which affects metabolism mechanism, affecting cholesterol synthesis and excretion of bile acids. Reduction of cholesterol in T_3 could be as a result of antinutritional factors in raw bambara nut offal. This is supported by the report of Martins *et al.* (2004) which showed lower total cholesterol level in plasma of piglets fed raw peas. Isoflavonoids in raw legumes can lower cholesterol and triglyceride levels (Yousef *et al.*, 2003). Triglyceride values were highest in T_5 and lowest in T_3. T_2 and T_4 birds had the highest values showing that heat treatment may increase triglyceride levels. It is widely accepted that the values of these parameters in broiler chickens depend on

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several factors like age, sex, genetic type, feeding and environment.

Table 4.11: Lipid profile of finisher broilers fed diets containing differently processed bambara groundnut offal.

Parameter	T_1(10 %)	T_2(10 %)	T_3(10 %)	T_4(10 %)	T_5(10 %)	SEM
Cholesterol(mg/dl)	65.53^{c}	73.22^{bc}	74.64^{bc}	103.49^{a}	99.12^{ab}	5.16
HDL (mg/dl)	36.07^{b}	39.56^{b}	42.99^{b}	58.55^{a}	66.55^{a}	3.40
Tg (mg/dl)	102.91	102.91	95.34	98.40	103.59	1.70
LDL (mg/dl)	8.89^{b}	13.08^{ab}	12.78^{ab}	25.25^{a}	11.85^{ab}	2.52
VLDL (mg/dl)	20.58	20.58	19.07	19.68	20.72	0.34

^{a,b,c} Means within the rows with different superscripts are significantly different (P<0.05); SEM-Standard Error of the mean. HDL: High Density Lipo-protein;Tg:Triglycerides; LDL: Low Density Lipo-protein; VLDL: Very Low Density Lipo-protein.

Conclusion

The present findings suggest that raw bambara groundnut offal supplemented with enzyme can replace soyabean in broiler chicken diets as this was evident in total weight gain, FCR, haematological parameters, lipid profile components without adverse effects. Enzyme supplementation is also recommended as it increased performance through digestion of nutrients and breakdown of Non-Starchy Polysaccharides (NSPs) in the diet. Also, heat treatment is recommended to reduce deleterious effects of anti-nutritional factors (ANFs) in the bambara groundnut offal but carefulness must be employed not to denature some nutrients.

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