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Growth Performance, Nutrient Digestibility, Carcass Characteristics and Organoleptic Properties of Broiler Chicken Fed Cocoa Bean Shell

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The high cost of conventional feed ingredients has forced poultry farmers to concentrate on more accessible and reasonably priced alternative feed sources having considerable nutritional potential. One of these alternative feed sources is cocoa bean shell (CBS), which is widely available, inexpensive, and nutritious. There is limited research on the application of fermentation of bovine

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rumen filtrate on CBS in poultry production. A feeding trial for 56 days was conducted to investigate the dietary effect of rumen filtrate fermented cocoa bean shell (RFCBS) as partial replacement for maize on the performance of broiler chickens. Fresh cocoa bean shell was mixed with rumen filtrate obtained at ratio 1:1, fermented for 24 hours and then dried. The dried fermented cocoa bean shell (FCBS) was incorporated into the experimental diets at varying levels; 0, 5, 10, 15 and 20% respectively to formulate five experimental diets. Ross 308 broiler chicks (n=150) were randomly allotted into five treatments groups of thirty (30) birds per treatment and three replicates containing ten birds each in a completely randomized design (CRD). Data on performance indices, hematological, nutrient digestibility, carcass characteristics and sensory evaluation collected during the experiment were subjected to ANOVA at α = 0.05. Results revealed that fermentation method employed had significant influence (P<0.05) on the chemical composition of cocoa bean shell used in this study. The crude protein (CBS: 8.18% – FCBS: 5.10%), ash (CBS: 10.40% - FCBS: 9.08%), nitrogen free extract (CBS: 57.64% - FCBS: 57.07%) content of the cocoa bean shell reduced after being fermented but increased its crude fibre content from 10.27% to 15.26%. It also helped to improve the phytochemical constituents of CBS. Dietary supplementation up to 10 % FCBS had comparable weight gain, feed intake and the best feed conversion ratio. Birds fed 10% FCBS based diet had improved (P<0.05) nutrient digestibility values when compared with other diets. Birds on 0 (2088.89g/b), 5 (2044.44g/b) and 10 (1944.44g/b) % FCBS had similar dressed weight but recorded significantly the highest value. Birds fed 10% FCBS based diet recorded the highest tenderness (8.33), juiciness (8.37), flavour (8.43), colour (8.30), aroma (8.37) and taste (8.00) values. Results indicated that the cost of the feed per kg (#2178.92 - 2229.23) decreased across the dietary treatments as the FCBS increased. It is concluded that FCBS can be incorporated up to 10 % in broiler chickens' diet for better output in terms of weight gain, feed intake, feed conversion ratio, carcass trait sensory evaluation and better health status of the birds.

Keywords: Conventional feedstuff; fermentation; farmers; animal protein; by-product.

1. INTRODUCTION

Nutrition remains the most important factor in livestock management, with competition between humans and animals for feed ingredients driving up costs [1]. High feed costs and reliance on imported ingredients contribute to unemployment, animal protein scarcity, and reduced broiler production [2]. The high cost of conventional feed has led to increased interest in unconventional feedstuffs [2]. Cocoa bean shell (CBS) emerges as a promising alternative feed source due to its widespread availability, affordability, and nutritional value [3]. A byproduct of cocoa bean processing, CBS can be incorporated into animal feed [3]. Significant biomass waste is generated during cocoa processing, including cocoa pod husks, pulp, and shells [4]. CBS constitutes approximately 10-20% of the cocoa bean's weight [5]. Improper disposal of CBS by farmers can lead to environmental pollution [6]. Well-processed CBS has the potential to reduce waste from cocoa processing facilities and lower livestock feed costs [6]. Prior research has had explored the use of CBS in animal feed, particularly for poultry. However, its value is limited by theobromine content, a stimulant similar to caffeine that can be harmful to animals in high doses [7]. Solid-state fermentation has been shown to improve the nutritional quality of CBS meal for poultry [8]. Microbial fermentation and enzyme supplementation are established methods for enhancing the nutritional content of CBS in poultry production [8]. Research on using rumen-fermented CBS in poultry feed remains limited (current study). The high cost of conventional feed, environmental concerns regarding CBS disposal, and under-utilized rumen filtrate from cattle digestion necessitate investigating the component and important importance of rumen-fermented CBS in poultry feed. This research aims to determine the fermentation's effect on the nutritional value of CBS for chicken feeding and performance.

2. MATERIALS AND METHODS

2.1 Experimental Site

This study was conducted at the poultry unit of the Teaching and Research Farm of Animal Science Department, Faculty of Agriculture, University of Abuja, and the experiment lasted for a period of 56 days.

2.2 Collection and Processing of Test Ingredients and Diets

Fresh cocoa bean shells (CBS) were sourced from cocoa bean processors in Ondo State, while bovine rumen content was collected from four randomly selected slaughtered cattle at Gwagwalada's abattoir in the Federal Capital Territory, Abuja. The CBS and rumen content were combined in a 1:1 ratio with potable water, stirred, and sieved to produce rumen filtrate (RF). The resulting RF was then mixed with CBS at a 5:5 ratio. The manual mixing was followed by packing the mixture into polythene bags, securing the open end with ties, and allowing it to be fermented for 24 hours under the shade of a tree according to the procedure of Odunlade et al. [9]. Subsequently, the fermented mixture was sun-dried within 48 hours to achieve a moisture content of less than 10%, following the procedure outlined by previous researchers which was originally described for fermenting sweet orange (*Citrus sinensis*) peels with bovine rumen filtrate for use in broilers, pullets, and rabbits. The resulting dried fermented cocoa bean shell (FCBS) was then incorporated into the experimental diets at varying levels: 0%, 5%, 10%, 15%, and 20%, as outlined in Table 1. Additional ingredients included in the diets as presented in Table 1.

2.3 Experimental Animals and their Management

A total of 150 birds (day-old) chicks were purchased and used for this study. Prior to the arrival of the experimental birds, the pen and facilities (equipment's and metabolic cages) were prepared ahead the arrival of the birds. It was cleaned, thoroughly washed and disinfected. The chicks were brooded for 2 weeks, all necessary routine vaccination and medications were administered. Feed and water were supplied *ad-libitum* A total of one hundred and fifty birds (day-old) chicks were purchased and used for this study. Prior to the arrival of the experimental birds, the pen and facilities (equipment's and metabolic cages) were prepared ahead the arrival of the birds. It was cleaned, thoroughly washed and disinfected. The chicks were brooded for 2 weeks, all necessary routine vaccination and medications were administered. Feed and water were supplied *ad-libitum.* Other daily management operations were carried out as outlined according to Olumide and Hamzat [10]. The birds will be were weighed on group basis and individual weight was obtained and randomly allotted to five treatment groups with thirty (30) birds per treatment and three replicates containing ten birds each in a completely randomized design.

2.4 Data Collection

Performance characteristics: Initial weight of the experimental birds was recorded at the onset of the experiment with sensitive scale of 5kg capacity on weekly basis before early morning feeding. Feed intake was determined by deducting the remnant obtained from the feed offered or given on daily basis measured and recorded weekly. Mortality was recorded, weight gain, average daily weight gain, feed intake and average daily feed intake. Feed conversion ratio (FCR) was calculated thus; as follows:

a. $\text{Average weight}\,\frac{\text{gain}}{\text{bird}} = \frac{\text{Final weight gain} - \text{Initial Weight gain}}{\text{Total number of birds}}$

b. $\text{Daily weight gain/bird} = \frac{\text{Average weight gain}}{\text{Number of days}}$

c. $\text{Average feed}\,\frac{\text{intake}}{\text{birds}} = \frac{\text{Feed Supplied} - \text{Leftover feed}}{\text{Total Number of birds}}$

d. $\text{Daily feed intake} = \frac{\text{Total Feed Consumed}}{\text{Number of days}}$

e. $\text{Feed Conversion Ratio (FCR)} = \frac{\text{Feed Consumed}}{\text{Weight gain}}$

2.5 Carcass Evaluation

The birds were fasted for 12 hours overnight to ensure that their digestive tracts were empty. Three birds from each replicate group were selected for evaluation. Each chicken was weighed using a digital weighing scale with a 5kg capacity. Following established humane slaughter practices, the birds were euthanized by neck slitting. After proper bleeding, the birds were plucked to remove feathers. The birds were then eviscerated, removing the internal organs. The weight of the entire carcass (including skin) was recorded. The weights of individual cuts were also measured, including drumsticks, thighs, breasts, wings, and backs. The abdominal fat was separated and weighed. Edible viscera (heart, gizzard, and liver,) were weighed together. Non-edible viscera (intestines and proventriculus) were weighed together. The bursa and spleen, essential organs of the immune system, were weighed individually. The carcass weight and weights of the different cuts were expressed as a percentage of the live weight for each bird within a treatment group. This allows for comparison of body composition across different dietary treatments.

Table 1. Gross Composition of Experimental Diets at Starter and Finisher phase

Ingredients	Starter					Finisher				
	T_1 (Control)	T_2 (5%)	T_3 (10%)	T_4 (15%)	T_5 (20%)	T_1 (Control)	T_2 (5%)	T_3 (10%)	T_4 (15%)	T_5 (20%)
Maize	54.40	51.68	48.96	46.24	43.52	57.00	54.15	51.30	48.45	45.60
FCBS	0	2.72	5.54	8.16	10.88	0	2.85	5.70	8.55	11.40
SBM	38.40	38.40	38.40	38.40	38.40	35.00	35.00	35.00	35.00	35.00
Fish meal	1.40	1.40	1.40	1.40	1.40	0.50	0.50	0.50	0.50	0.50
BDG	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Palm oil	0						1.00	1.00	1.00	1.00
Limestone	1.00	1.00	1.00	1.00	1.00	1.00	1.20	1.20	1.20	1.20
Bone meal	1.70	1.70	1.70	1.70	1.70	1.20	1.80	1.80	1.80	1.80
Methionine	0.30	0.30	0.30	0.30	0.30	1.80	0.30	0.30	0.30	0.30
Lysine	0.20	0.20	0.20	0.20	0.20	0.30	0.20	0.20	0.20	0.20
Premix	0.25	0.25	0.25	0.25	0.25	0.20	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100	100	100	100	100	100
Calculated Analysis										
CP (%)	23.14	23.11	23.07	23.03	23.00	21.49	21.45	21.41	21.37	21.34
CF (%)	4.25	4.48	4.71	4.94	5.16	4.11	4.35	4.59	4.83	5.07
ME (Kcal/kg)	2889.78	2874.06	2858.34	2824.62	2826.89	2962.32	2945.84	2929.37	2912.90	2896.42

FCBS: Fermented Cocoa bean shell, SBM: Soybean meal, BDG: Brewer dry grain, CP: Crude Protein, CF: Crude Fibre, ME: Metabolizable Energy

The dressing percentage was calculated as follows;

$$Dressing\ \% = \frac{Carcass\ Weight}{Live\ weight} \times 100$$

2.6 Sensory Evaluation

The sensory evaluation of cooked part of broiler chickens' breast minced meat from three (3) birds per replicate was carried out by ten (10) evaluators. The parameters that were evaluated are; colour, juiciness, flavour, tenderness, and acceptability. Each meat was coded and presented one after the other to each member of the panel. Each member rinsed his or her mouth with warm water after accessing each meat sample per treatment to avoid carry over effect. The panelists was awarded scores using a nine (9) point hedonic scale of

i. Dislike extremely
ii. Dislike very much
iii. Dislike slightly
iv. Intermediate
v. Like
vi. Like moderately
vii. Like very much
viii. Like extremely (Ogunwole et al., 2003)

2.7 Nutrient Digestibility Trial

This was conducted at the last week of the feeding trial using total collection technique according to the procedure of previous researchers (Aduku and Olukosi, 1990) [11]. Three birds were randomly chosen from each replicate group at the end of the feeding trial. These birds were housed in specially designed metabolic cages for a period of seven days. The birds were allowed three days to acclimatize to the metabolic cages and their new environment. Following the acclimatization period, the birds were fed a known quantity of feed each day. Faecal samples were collected from each replicate group for four consecutive days. Collected faeces were meticulously combined and thoroughly mixed to ensure a representative sample. A sub-sample was taken from the bulked faecal collection at the end of the four-day period. The fresh faecal sub-sample was weighed and then oven-dried at 85°C until it reached a constant weight. The dried faecal sample was subsequently ground to a fine consistency that could pass through a 2 mm sieve. The proximate composition (moisture, protein, fat, fiber, ash) of the ground faecal sample was analyzed following the methods outlined by the AOAC [12]. The difference between the nutrient's intake obtained from feed consumed and nutrient output obtained from faecal sample multiply by 100 gives gave the apparent digestibility coefficient of the feed.

The Apparent Digestibility was calculated using the formula;

$$\text{Dry Matter Digestibility} = \frac{\text{Weight of Feed Intake} - \text{Weight of Droppings (DM)}}{\text{Weight of Feed Intake}} \times \frac{100}{1}$$

$$= \frac{\text{(DM) Weight of Feed Intake} - \text{(DM) Weight of Droppings x 100}}{\text{(DM) Weight of Feed Intake}}$$

Also, the Digestible Crude Protein was calculated from the result of proximate composition of both the feed and feacal samples as follows;

$$\text{Digestible Crude Protein (DCP)} = \frac{\text{(DM) Feed Intake x \%CP in diet} - \text{Droppings (DM) x \%CP in Droppings}}{\text{(DM) Feed Intake x \%CP in diet}} \times \frac{100}{1}$$

Statistical Analysis: Data obtained was subjected to analysis of variance using statistical package of SAS [13]. The means among the variable were separated using Duncan (1955) multiple range test of the same statistical package

3. RESULTS

Chemical Composition of Fermented Cocoa Bean shell (FCBS) and non-fermented Cocoa Bean Shell Table 2 shows the chemical composition of Fermented Cocoa Bean Shell (FCBS) and non-Fermented Cocoa Bean Shell. Fermentation method employed had significant (P<0.05) effect on the Cocoa Bean Shell used in this study. The crude protein, ash, nitrogen free extract, flavonoids, tannins, saponin, terpenoides, steroids and theobromine content of the Cocoa Bean Shell reduced (CBS: 8.18% – FCBS: 5.10%), (CBS: 10.40% - FCBS: 9.08%), (CBS: 57.64% - 57.07%) (CBS: 10.52-RFCBS: 8.52%), (CBS: 8.03% – RFCBS: 7.97%), (CBS: 1.73% - RFCBS: 1.61%), (CBS:4.11% - RFCBS: 2.17%), (CBS: 1.73 – RFCBS:1.40%) and (CBS:14.19 – RFCBS: 10.83%) after being fermented but increased the crude fibre content, phytate and oxalate of the test ingredients from 10.27% to 15.26%, 0.10 -0.20% and 1.06 -1.20% respectively.

Table 2. Chemical composition of Fermented Cocoa Bean shell (FCBS) and non-Fermented Cocoa Bean Shell (CBS)

Parameters (%)	CBS	FCBS	SEM
Dry matter	89.10	89.11	0.00
Crude Protein	8.18^a	5.10^b	0.69
Ether extract	2.61	2.60	0.00
Crude fibre	10.27^b	15.26^a	1.12
Ash	10.40^a	9.08^b	0.30
NFE	57.64^a	57.07^b	0.13
Phytate	0.10^b	0.20^a	0.22
Oxalate	1.06^b	1.20^a	0.03
Flavonoids	10.52^a	8.52^b	0.44
Tannins	8.03^a	7.97^b	0.01
Saponin	1.73^a	1.61^b	0.03
Terpenoides	4.11^a	2.17^b	0.43
Steroids	1.73^a	1.40^b	0.07
Theobromine	14.19^a	10.83^b	0.75

^{a,b} Means along the same row with different superscripts are significantly different (P<0.05)
NFE: Nitrogen Free Extract, FCBS: fermented Cocoa Beans Shell

Table 3. Effect of dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell (BRFFCBS) on the Performance characteristics of broiler chickens

Parameters	Inclusion levels of BRFFCBS					
	0	5	10	15	20	SEM
Initial Body Weight (g/b)	90.53	90.52	90.54	90.53	90.53	0.00
Final Body Weight (g/b)	2430.00^{a}	2350.00^{a}	2490.00^{a}	2020.00^{b}	1916.70^{b}	67.84
Body Weight gain (g/b)	2339.50^{a}	2259.50^{a}	2399.50^{a}	1929.50^{b}	1826.10^{b}	67.84
ADWG (g/b/d)	41.78^{a}	40.35^{a}	42.84^{a}	34.46^{b}	32.61^{b}	1.21
TFI (g/b)	4725.27^{b}	4730.72^{b}	4802.60^{a}	4831.95^{a}	4846.50^{a}	15.60
ADFI (g/b/d)	84.38^{b}	84.48^{b}	85.76^{a}	86.28^{a}	86.54^{a}	0.28
FCR	2.02^{b}	2.09^{b}	2.01^{b}	2.51^{a}	2.66^{a}	0.08

^{ab} Means along the same row with different superscripts are significantly different (P<0.05). ADWG: Average daily weight gain, TFI: Total Feed Intake, ADFI: Average Daily feed intake, FCR: Feed Conversion ratio

3.1 Effect of Dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell (BRFFCBS) on the Performance Characteristics of Broiler Chickens

Presented in Table 3 is the effect of dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell (BRFFCBS) on the performance characteristics of broiler chickens. Dietary BRFFCBS significantly influenced (P<0.05) all the parameters of interest investigated in this study. Birds fed 0% (2430.00g/b, 23390.50g/b and 41.78g/b/d), 5% (2350.00g/b, 2259.50g/b and 40.35g/b/d) and 10 % (2490.00g/b, 2399.50g/b and 42.84g/b/d) BRFFCBS had similar (P>0.05) final body weight, weight gain, and average daily weight gain values. but However, they had significantly (P<0.05) higher body weight than those fed 15% (2020.00g/b, 1929.50g/b and 34.46g/b/d) and 20% (1916.70g/b, 1826.10g/b and 32.61g/b/d) BRFFCBS having similar values. The total feed intake (4725.27 - 4846.50g/b) and average daily feed intake (84.38 – 86.54 g/b/d) of the experimental chickens increased across the treatments as BRFFCBS increased. Birds fed 10% (85.76g/b/d), 15% (86.28g/b/d), 20% (86.54g/b/d) BRFFCBS recorded similar (P>0.05) average daily feed intake but significantly (P<0.05) higher than those on 0 (84.38g/b/d) and 5 % (84.48g/b/d) BRFFCBS having similar values. Similar (P>0.05) feed conversion ratio was obtained in birds fed 0% (2.02), 5% (2.09) and 10% (2.01) BRFFCBS which was significantly lower to than those on 15% (2.51) and 20% (2.66) BRFFCBS.

3.2 Effect of Dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell on the Nutrient Digestibility of Broiler Chickens

Presented in Table 4 is the effect of dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell on the nutrient digestibility of broiler chickens. Dietary BRFFCBS significantly (P<0.05) affected all the nutrient digestibility parameters. The dry matter values obtained in this study varied significantly across the dietary treatments in which birds fed 0% (89.49%), 10% (89.56%) and 20% (89.59%) BRFFCBS had similar (P>0.05) dry matter values but significantly higher (P<0.05) than those on 15% (88.56%) and 5% (88.21%). Birds fed 0(84.22%) and 10% (83.22%) BRFFCBS had statistically similar crude protein values but recorded the highest value compared with other dietary treatments. The ether extract digestibility values (48.74-65.91%) ranged significantly (P<0.05) across the treatment groups. The ash digestibility content of the experimental broiler chicken varied significantly across the dietary treatment in which birds fed 10% BRFFCBS (66.38%) had the highest value while the lowest value was obtained with birds fed 20% BRFFCBS (40.83%). The crude fibre (65.66 – 71.46%) and nitrogen free extract (NFE: 72.59 – 79.17%) values obtained in this study varied significantly (P<0.05) across the treatment groups. Birds fed 20 % BRFFCBS recorded highest crude fibre (71.46%) and NFE (79.17 %) value.

3.3 Effect of Dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell (BRFFCBS) on the Carcass characteristics of broiler chickens

The effect of dietary bovine rumen filtrate fermented cocoa bean shell on the Carcass characteristics of broiler chickens is presented in Table 5. There were significant (P<0.05) difference in all the parameters measured except the breast. Birds on control diet had the highest live (2450.00% g/b) and bled (2344 g/b) weight. The dressed weight of birds on 0% (2088.89 g/b), 5% (2011.44 g/b) and 10% (1944.44 g/b) BRFFCBS were similar but significantly higher those fed 15% (1722.22 g/b) and 20% (1533.33 g/b) BRFFCBS respectively. The eviscerated weight (1433.33 – 1972.22 g/b) and bled weight expressed as percentage of live weight (94.53 – 95.68%) decreased across the dietary treatment as the inclusion levels of BRFFCBS increased. Birds fed 0% (1972.22g/b, 95.68%) and 5% (1944.44g/b, 95.72%) BRFFCBS had similar (P>0.05) eviscerated weight and bled weight expressed as % of live weight values but significantly (P<0.05) recorded the highest value while lowest value was obtained in birds fed 20% (1433.33g/b, 94.53%) BRFFCBS. The dressed weight of the experimental birds expressed as percentage of live weight varied significantly (P<0.05) across the dietary treatments in which birds fed 5% BRFFCBS (87.20%) recorded the highest value while the lowest value was obtained in birds fed 20% BRFFCBS (83.59%). The highest relative weight of neck (3.64%) and thigh (14.07%). The back of the experimental birds varied significantly (P<0.05) across the treatment groups in which birds fed 0% (16.31%) and 5% (16.32%) BRFFCBS had similar (P>0.05) values but significantly (P<0.05) recorded the highest when compared with other dietary treatment.

Table 4. Effect of dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell on the Nutrient Digestibility of broiler chickens

Parameters (%)	Inclusion levels of BRFFCBS					
	0	5	10	15	20	SEM
Dry matter	89.49^{a}	88.21^{c}	89.58^{a}	88.56^{b}	89.59^{a}	0.16
Crude Protein	84.22^{a}	82.23^{b}	83.22^{a}	81.88^{c}	80.53^{d}	0.33
Ether extract	48.74^{e}	61.73^{b}	65.91^{a}	56.97^{c}	54.22^{d}	1.59
Ash	43.28^{d}	49.36^{b}	66.38^{a}	45.77^{c}	40.83^{e}	2.43
Crude fibre	65.66^{d}	65.66^{d}	68.29^{b}	66.35^{c}	71.46^{a}	0.61
NFE	75.14^{c}	72.59^{e}	77.74^{b}	74.43^{d}	79.17^{a}	0.63

^{abcde} Means along the same row with different superscripts are significantly different (P<0.05) NFE: Nitrogen Free Extract

Table 5. Effect of dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell BRFFCBS) on the Carcass characteristics of broiler chickens

Parameters	Inclusion levels of BRFFCBS					
	0	5	10	15	20	SEM
Live Weight (g/b)	2450.00^{a}	2344.44^{ab}	2277.78^{b}	2011.11^{c}	1833.33^{d}	41.98
Bled Weight (g/b)	2344.44^{a}	2244.44^{ab}	2161.11^{b}	1911.11^{c}	1733.33^{d}	41.70
Dressed Weight (g/b)	2088.89^{a}	2044.44^{a}	1944.44^{a}	1722.22^{b}	1533.33^{c}	40.20
Eviscerated Wt (g/b)	1972.22^{a}	1944.44^{a}	1761.11^{b}	1622.22^{b}	1433.33^{c}	40.62
Bled Weight (%)	95.68^{a}	95.72^{a}	94.85^{ab}	94.94^{ab}	94.53^{b}	0.14
Dressing (%)	83.59^{b}	87.20^{a}	85.31^{ab}	85.36^{ab}	83.59^{b}	0.42
Eviscerated Wt (%)	80.39^{ab}	83.00^{a}	77.28^{b}	80.30^{ab}	78.12^{b}	0.69
Cut Parts (Expressed as % of DW)						
Head (%)	2.53^{a}	2.40^{ab}	2.19^{b}	2.50^{a}	2.40^{a}	0.04
Neck (%)	3.31^{ab}	3.64^{a}	3.08^{b}	3.31^{ab}	3.39^{ab}	0.08
Breast (%)	23.95	24.13	22.12	23.80	21.84	0.35
Thigh (%)	13.79^{ab}	14.07^{a}	13.55^{abc}	12.02^{c}	12.18^{bc}	0.26
Drumstick (%)	11.80^{b}	12.22^{b}	11.21^{b}	14.38^{a}	11.72^{b}	0.33
Wings (%)	6.64^{c}	7.08^{abc}	6.78^{bc}	8.17^{a}	7.95^{ab}	0.20
Back (%)	16.31^{a}	16.32^{a}	12.88^{b}	14.55^{ab}	14.62^{ab}	0.35
Legs (%)	4.12^{ab}	3.63^{bc}	3.29^{c}	4.75^{a}	4.45^{a}	0.13
Organs (Expressed as % of LW)						
Spleen (%)	0.54^{c}	0.55^{bc}	0.58^{bc}	0.63^{ab}	0.70^{a}	0.02
Heart (%)	0.45^{a}	0.35^{bc}	0.31^{c}	0.38^{b}	0.36^{bc}	0.01
Liver (%)	1.39	1.32	1.32	1.49	1.45	0.04
Gizzard (%)	1.56^{b}	1.50^{b}	1.46^{b}	3.30^{a}	3.38^{a}	0.14
Kidney (%)	0.11^{a}	0.08^{b}	0.09^{b}	0.11^{a}	0.11^{a}	0.00

^{abcde} Means along the same row with different superscripts are significantly different (P<0.05)

Table 6. Effect of dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell on the sensory evaluation of broiler chickens

Parameters	Inclusion levels of BRFFCBS					
	0	5	10	15	20	SEM
Tenderness	7.97^{ab}	8.03^{ab}	8.33^{a}	8.07^{ab}	7.60^{b}	0.08
Juiciness	7.63^{bc}	7.93^{abc}	8.37^{a}	8.03^{ab}	7.40^{c}	0.09
Flavour	7.37^{c}	8.10^{ab}	8.43^{a}	8.03^{ab}	7.67^{bc}	0.09
Colour	7.53^{b}	8.00^{ab}	8.30^{a}	7.80^{ab}	7.80^{ab}	0.09
Aroma	7.57^{b}	8.03^{ab}	8.37^{a}	7.90^{ab}	7.53^{b}	0.09
Taste	7.10^{b}	8.13^{a}	8.00^{a}	7.90^{a}	7.07^{b}	0.11

^{abc} Means along the same row with different superscripts are significantly different (P<0.05)

Discussion

3.4 Effect of Dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell on the Sensory Evaluation of Broiler Chickens

Table 6 shows the effect of dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell on the sensory evaluation of broiler chickens. Dietary treatment had significant effect (P<0.05) on all the parameters investigated. The tenderness (7.60 – 8.33), juiciness (7.40 – 8.73), flavour (7.37 – 8.43), colour (7.53 – 8.30) and aroma (7.53 – 8.37) of meat from the broiler chicken used in this study varied significantly across the dietary treatments in which the highest values (8.33, 8.37, 8.43, 8.30 and 8.37) respectively were obtained in birds fed 10% BRFFCBS. The taste (7.07 – 8.13) of the meat sample from the experimental broiler chicken were similar (P>0.05) in birds fed 5% (8.13), 10% (8.00) and 15% (7.90) BRFFCBS but significantly (P<0.05) greater when compared with those on 0% (7.10) and 20% (7.07) BRFFCBS having statistically similar (P>0.05) values.

3.5 Determination of the Proximate Composition and Phytochemical Analysis of the Fermented Cocoa Bean Shell (FCBS) and Non-Fermented CBS

The crude protein values obtained in both Fermented Cocoa Bean Shell (FCBS) and raw Cocoa Bean Shell (CBS) were lower than the range of values (15.20-19.80%) reported by Afoakwa et al. [14]. This variation could be related to the type or variety of cocoa beans used, as well as environmental circumstances such as climate, soil quality, possible illnesses, and seasonal fluctuations. The chemical composition of CBS is known to be influenced by environmental conditions as well as individual cocoa bean varietal [15].

In this investigation, FCBS had a lower crude protein content when compared with non-fermented CBS, which is consistent with the findings of Ndife et al. [16] and Crouzillat et al. (1999). The observed decrease in crude protein content after fermentation could be attributed to breakdown processes during curing, such as hydrolysis into amino acids and peptides, polyphenol conversion into insoluble forms, and diffusion losses [14,17]. However, this study contradicted the observation of Aremu et al. [18] who showed a considerable increase in protein content of CBS after fermentation. This disparity could be attributed to differences in fermentation methods or durations. In respect to ether extract (fat) content, no significant difference was found between CBS and FCBS in this study, which contradicted the findings of Aremu et al. [18], who reported a considerable decrease in fat content of CBS during fermentation. This variance could be related to variations in fermentation times. The crude fibre content was much higher in fermented CBS than in unfermented samples, most likely because of water loss during fermentation and drying, resulting in a higher crude fibre concentration. This finding was consistent with observation of Ndife et al. [16]. The ash level of CBS reduced significantly during fermentation, which was consistent with the findings of Aremu et al. [18]. Ash concentration is an indicator of mineral content in feeds, and the decrease found after fermentation reflects changes in mineral composition during the process. The fermentation methods used in this study were recommended to improve the nutritive content of the test ingredients by neutralizing the negative impacts of anti-nutritional elements found in cocoa beans, which supports prior claims made by Adamafio et al. [19]. Overall, this analysis highlights the changes in several chemical elements of cocoa bean shells caused by fermentation, with some variations observed when compared to previous studies, most likely due to variances in cocoa bean varieties, fermentation processes, and environmental circumstances.

3.6 Dietary Effect of Rumen Bovine Filtrate Fermented Cocoa Bean Shell on the Growth Performance of broiler chickens

The most popular approach for assessing the overall nutritional condition or health of broiler chickens was found to be total weight increase (Parvin et al*.,* 2010). Gohl [20] reported that the Cocoa Bean Shell has a great nutritional potential when properly prepared. Birds fed 5 and 10% FCBS had comparable body weight and average daily weight gain to birds fed the control diet. This could be attributed to the fact that those birds on 5 and 10 % FCBS based diet were able to degrade and utilize what being ingested. The decreased body weight growth reported in birds fed 15 and 20% FCBS-based diets could be attributed to inadequate nutrient absorption, nutritional unavailability, and altered digestive and metabolic processes (Egbewande and Olorede, 2003). The increase in feed intake of experimental birds across treatment groups as FCBS increased could be related to fermentation's effect on CBS, which influences the acceptability of the experimental diets. However, the higher feed intake seen in this study did not lead to improved growth performance. This could be due to the residual effects of the phytochemicals included in FCBS.

According to Gemede and Ratta's (2014) observations, tannin has the potential to alter animal growth rate and feed efficiency. Thus, the mean voluntary feed intake values found in birds fed 0, 5, and 10% FCBS were consistent with the suggested values for broiler chickens [21]. However, Tion et al. (2005) found that broiler feed intake increased when dietary protein levels declined. The average weight increase of birds fed 15 and 20% FCBS-based diets was significantly reduced, which could be attributed to the presence of residual anti-nutritional components in the FCBS-based diet. The birds' increased average weight gain on the control, 5 and 10% FCBS-based diets compared to other dietary treatments could be attributed to the comparatively low crude fibre (CF) level. In addition to the effect of the CF, which increased across the dietary treatments as FBS increased, it is possible that anti-nutritional variables contributed to weight gain. Nonetheless, as compared to the control group, the experimental birds fed 5 and 10% FCBS-based diets maintained their body weight gain and feed conversion ratio values, demonstrating that FCBS is as nutritious as conventional diets and promotes broiler chickens' normal growth. A lower feed conversion ratio (FCR) indicates higher performance, as it shows the rate at which feed is converted to flesh. There were considerable fluctuations in FCR values reported in this investigation; thus, the FCR of birds fed 5 and 10% FCBS-based diets were equivalent to those fed control. The FCR of the experimental birds obtained in this investigation were lower than the values (3.27–4.03) reported by Oyewola et al. [22].

3.7 Nutrients' Digestibility of Broiler Chickens fed Dietary Bovine Rumen Filtrate Fermented Cocoa Bean Shell

The digestibility coefficients obtained in this study were moderate in all parameters, indicating that the broiler chickens could utilize nutrients in the diets to a reasonable extent for their growth. In the fermented cocoa bean shell (FCBS) group, crude protein digestibility varied significantly among dietary treatments but did not follow a clear pattern. The decline in crude protein digestibility in the FCBS-based diet could be attributed to the residue effect of theobromine content in cocoa bean shell, which had been shown to limit its utilization in animals [23], as well as the increasing level of fibre in the FCBS-based diet. The decrease in protein digestibility supports the unfavourable impact of fibrous substances on nutrient digestibility in farm animals [24,25]. Reduced digestibility could be ascribed to a shorter average retention duration of feed in the alimentary canal [24]. The digestible crude fibre values found in this investigation increased across the dietary treatments as FCBS increased. Meffeja et al. [26] showed that high fibre concentrations cause abundant mucus production, which serves to preserve the digestive tract lining and so reduces the action of digestive enzymes in the colon [27]. The nutritional digestibility coefficients in this study were higher than those reported for cocoa shell meal by Meffeja et al. [26]. However, cocoa shell meal has fewer nutrients than cocoa pod husk meal, and because the nutrients in cocoa shell meal are less digestible, it is recommended for animals in the finishing phase rather than those in rapid growth [26]. The digestibility of nutrients obtained in this study for dry matter (88.21-89.59%), crude fibre (65.66-71.46%), ether extract (48.74-65.91%), and ash (40.83-66.38%) are higher than the range of values reported by Adedire et al. [28] for digestible dry matter (63.63-69.37%), crude fibre (55.61-62.88%), ether extract (62.14-64.15%), and ash (51.75-58.05%) who fed crop-based residues fermented with Rhizopus oligosporus to experimental rabbits. The crude protein digestibility values obtained in this study (80.53 - 84.22%) were within the range reported by Adedire et al. [28]. The observed difference in nutritional digestibility values could be attributed to the various feeding materials used as test ingredients, the processing methods used, and the associated fibre levels.

3.8 Dietary Effect of Bovine Rumen Filtrate Fermented Cocoa Bean Shell on the Carcass Characteristics of Broiler Chickens

Birds fed dietary 5 and 10% FCBS exhibited comparable dressed and eviscerated weights as control birds. The dressing percentage values recorded in this study ranged between 83.59 and 87.20%. Birds fed a 5% FCBS diet had the greatest dressing percentage (87.20%). The study's findings exceeded the ranges (77.33-83.00%) and (60.30-74.65%) recommended for broiler chickens by Akpodiete et al. [29] and Bamgbose and Niba [30], respectively. Variations in gut's size have been connected to the amount of fibre consumed by birds in the process of meeting their energy needs. The observed increase in gizzard size across dietary treatments as FCBS increased could be attributed to an increase in dietary fibre, as higher the crude fibre, the lower the digestibility of a diet [31]. The results of this study were similar to those of Olumide et al. [32], who fed broiler chickens graded levels of raw cocoa bean shell. Previous studies [33,34] found that increasing fibre consumption led to an increase in gut and gizzard size in cockerels fed a 30% melon husk-based diet. However, the percentage weights of gizzards in birds fed FCBS-based diets were higher than the range of values (2.40-2.46%) reported by Akpodiete et al. [29] for broilers fed maggot meal-based diets. This variations observed in the gizzard percentage could be attributed to the fibrous nature of FCBS used in this study. The larger gizzards of birds fed FCBS-based diets might be related to the GIT's functional adaptation to the CBS-based diet [35].

3.9 Sensory Evaluation of Meat from Broiler Chickens fed Bovine Rumen Filtrate Fermented Cocoa Bean Shell

Dietary FCBS had a substantial effect on the tenderness, juiciness, flavour, colour, and aroma of breast samples in all treatment groups. The meat breast samples from broiler chickens fed 10% FCBS were ranked highest overall best. Meat tenderness has been described as the most important feature in meat acceptance [36]. This is due to the amount of connective tissue present, which influences sensory properties [37]. This clearly indicates that FCBS contains phytochemicals that can improve meat quality. The results were consistent with previous researchers' findings (Musa et al., 2020; Oluwafemi et al., 2020) when different mixtures were fed to broiler chicks, but contradicted the reports of Symeon et al. (2009) and Burt et al. (2000) who fed broilers a diet supplemented with 250 mg/kg oregano essential oil. More so tenderness of meat is also determined by muscle type [38], and the more tender the meat, the more appealing it is to consumers [39]. The highest scent found in this investigation could be related to a high total cholesterol and high HDL content, which most likely influenced aroma in broiler breast meat [40]. This actually corroborated level of blood cholesterol obtained in this study. Increasing fermented cocoa bean shell levels by up to 10% appeared to have a good effect on fatty tissue accretion in the breast, mostly in the intramuscular fat depot (since there was little abdominal fat), resulting in an enhanced scent and juiciness. Cholesterol is an important chemical that plays a role in membrane development and serves as a precursor for the creation of vitamin D, bile acids compound and steroid hormones. It should be noted that throughout the sensory examination, the panelists showed a considerable preference for the meat samples from birds fed a 10% FCBS-based diet. The findings of this study opposed those of Waskar et al. [39], who stated that the medicinal plants utilized had no effect on meat quality in terms of aroma, initial perception of juiciness, or connective tissue.

4. CONCLUSION

Based on the results on obtained in this study It, it can be concluded that;

- The fermentation process utilized in this study had a considerable impact on the chemical composition of cocoa bean shell, increasing crude fibre and decreasing theobromine values of the CBS.
- Dietary at 5 and 10 % Fermented Cocoa Bean Shell (FCBS) had comparable weight gain, feed intake and the best feed conversion ratio with those on control
- Broiler chickens on dietary 10% FCBS had comparable nutrient digestibility values with those on control in terms of dry matter and crude protein.
- Dietary 5% FCBS had improved carcass characteristics as it increased the dressed weight and thigh of broiler chickens
- Meat sample on 10% FCBS based diet recorded highest level of preference across the dietary treatments.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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