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NUTRITIONAL COMPOSITION OF ROSELLE SEED CAKE (*HIBISCUS SABDARIFFA*) AND ITS EFFECT ON BROILER CHICKENS

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ABSTRACT

Roselle seeds are usually processed or treated with enzymes before feeding to broilers and in smaller quantities. Recently, there has been a growing demand for roselle seed oil, which has resulted in the creation of large quantities of cake, but it is not widely use. The aim of this study was to determine the nutritional composition of roselle seed cake (*Hibiscus sabdariffa* L.) and its effect on broiler chickens. 100 kg of roselle seed cake was collected from households that extract roselle seed oil. Chemical analyzes were performed on RSC to determine the proximate, mineral and amino acid components. Five isonitrogenic and isoocaloric starter and finisher diets each were formulated, which included the following: CONT: soybean meal-based basal diet, RSC25: basal diet added with 25 % roselle seed cake, RSC50: basal diet added with 50 % roselle seed cake, RSC75: basal diet added with 75 % roselle seed cake and RSC100: basal diet added with 100 % roselle seed cake. Two hundred (250) day old Arbor Acre AA breed were assigned to the five dietary treatments and each treatment consisted of 5 replicates, and each replicate included 10 birds. The design used was a completely randomized design (CRD). The birds received feed and water *ad libitum* for 56 days. The results showed that the roselle seed cake was high in crude protein, nitrogen-free extract, potassium, phosphorus, iron leucine and arginine, but low in sodium, copper, selenium and methionine. The inclusion of RSC25 and RSC50 in the feed promoted a high growth rate and effective feed conversion. Furthermore, RSC25 and RSC50 as control diet promoted high carcass yield, packed cell volume and high red blood cells count. Internal organs, hemoglobin, erythrocyte indices, white blood cells and their differentials, and the entire serum biochemical indices were similar in all treatments. It can be concluded that RSC is rich in proteins and energy and it can be included up to 50 % in the diet of broilers without negative effects on growth rate and carcass performance.

Key words: Roselle seeds; oilseeds; cakes; soybean meal; broilers; feed cost

INTRODUCTION

Soybeans are known to be the main source of plant proteins (USITC, 2003) and are critically needed in poultry diets and their combination with human demand increases their cost and scarcity, especially in a low-income country like Nigeria. Overreliance on soybeans makes poultry feed production more expensive and exceeds the purchasing power of the low-income farmers who dominate the poultry industry in Nigeria. To remedy the situation, Animal Nutritionists are looking for alternative protein sources to replace soy. Mohammed *et al.* (2022) and Owosibo *et al.* (2018) stated that the use of low-cost ingredients provides more hope for effective and sustainable poultry production.

Peanut cake, palm kernel cake, sunflower meal and cottonseed cake are readily available alternative sources, but their proportion in poultry feed does not exceed 15 % due to their high fiber content and therefore cannot significantly reduce feed costs. There are plant-based materials that are considered as minor oilseeds (USITC, 2003) and are often used as whole seeds in feed production. One of these oilseeds is roselle (*Hibiscus sabdariffa*). Roselle belongs to the Malvaceae family. It is an annual herbaceous shrub that

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grows throughout Nigeria (Fasoyiro, 2005). Roselle is known for the production of zobo from its calyxes (Abu-Tarboush *et al.* 1997; Beshir & Babiker, 2009). The seeds have been used to feed ruminants and rabbits (Aliyu *et al.*, 2020) and less commonly used to feed birds due to the high content of protease inhibitors, total phenol, tannins, phytic acid and gossypol (Diarra *et al.*, 2011; Obadire *et al.*, 2022). To overcome the challenge of nutritional inhibitory factors, seeds are cooked, fermented, roasted or treated with enzymes (Mohammed *et al.*, 2022; Obadire *et al.*, 2022; Ocholongwa, 2017). However, despite the diverse processing method where roselle seeds are melted to reduce the nutritional inhibitory factors (Soetan and Oyewole, 2009), the level of inclusion in the birds' diet is still low. From an economic perspective, only a large proportion of unconventional feed ingredients would ensure a reduction in feed costs (Owosibo *et al.*, 2017). Recently, the demand for roselle seed oil is increasing, creating large quantities of roselle seed cakes, which are then wasted. The aim of this study was to determine the nutritional composition of roselle seed cake (*Hibiscus sabdariffa*) and its effect on broiler chickens.

MATERIALS AND METHODS

Ethical Consideration

This study was conducted in accordance with the guidelines of the Ethics Committee of the Federal University, Gashua, Yobe State, Nigeria on the use of animals in biomedical research (Approval number: 04/2023).

Experimental location

The experiment was carried out in the Teaching and Research Farm, Department of Animal Sciences, Federal University Gashua, Yobe State, Nigeria. Gashua is located at latitude of 12°26' N and longitude of 7°29' E. The average annual temperature is between 32.78 °C (91.0 °F) and the rainfall is about 50.77 mm (2.0 inches) (Ovimaps 2014).

Feed raw materials and formulation

100 kg of roselle seed cake was collected from households that extract roselle seed oil. Chemical analyzes were performed on RSC to determine the proximate and minerals content (AOAC, 2005), and amino acid profile (Benitez, 1989).

Five starter and finisher diets were formulated with similar levels of protein and calories. The diets included the following: CONTROL: soybean meal-based basal diet, RSC25: basal diet added with 25 % roselle seed cake, RSC50: basal diet added with 50 % roselle seed cake, RSC75: basal diet added with 75 % roselle seed cake, RSC100: basal diet added with 100 % roselle seed cake (Tables 1 and 2).

Experimental birds and management

Two hundred and fifty (250) one-day-old chicks of the Arbor Acre AA breed were purchased from Agric. International Technology and Trade (Nigeria) Limited (AGRITED), Ibadan, Nigeria from its distributor in Jos, Plateau State, Nigeria. They were allowed to acclimatize for three days. At the end of the acclimation, the chicks were weighed in groups of 10 chicks and assigned to the five dietary treatments based on the group weight in a completely randomized design (CRD), with each treatment comprising five replicates. They were provided with feed and water a*d libitum* for 56 days.

The Gumboro vaccine was administered on days 7 and 21, while the Newcastle disease vaccine was administered on days 1 and 28. Coccidiostats and broad-spectrum antibiotics were occasionally administered as prophylaxis. A sheet of thick paper was used as bedding material throughout the experiment and was replaced weekly. Mortality was recorded at the time of the event.

Data collection and analyses

Body weight, feed intake and feed conversion ratio (FCR) were determined weekly.

On days 14, 28, 42 and 56, blood samples were collected from the humeral wing vein of 6 birds per replicate using a needle and a 5-ml syringe. Some blood samples were transferred to vials containing the anticoagulant ethylendediaminetetraacetic acid (EDTA) to determine the hematological parameters, while others transferred to plain vials without anticoagulant were used for serum analysis. Blood for serum was centrifuged at 3,000 rpm for 5 minutes and serum was aliquoted into microcontainers. The Packed cell volume was determined using the microhematocrit method described by Dacie and Lewis (1991).

Hemoglobin concentration was determined with a spectrophotometer using the cyanmethemoglobin

Table 1. Gross composition of starter feed for broilers with different levels of roselle seed cake content

Ingredients (%)	CONTROL	RSC25	RSC50	RSC75	RSC100
Maize	53.04	52.25	52.00	52.50	52.50
Soybean meal	25.41	19.06	12.71	6.35	0.00
Roselle seed meal	0.00	6.35	12.71	19.06	25.41
Wheat offal	5.60	5.10	5.00	5.50	5.50
Groundnut cake	6.00	7.04	7.23	6.24	6.44
Fish meal	3.00	3.20	3.30	3.30	3.50
Bone meal	3.00	3.00	3.00	3.00	3.00
Limestone	3.00	3.00	3.00	3.00	3.00
Premix	0.25	0.25	0.25	0.25	0.15
Methionine	0.25	0.25	0.25	0.25	0.15
Lysine	0.20	0.20	0.25	0.25	0.20
Salt	0.25	0.30	0.30	0.30	0.15
Total	100.00	100.00	100.00	100.00	100.00
Nutrients					
Crude protein	22.73	22.70	22.68	22.71	22.69
Energy (kcal/kg)	2951.13	2953.25	2950.45	2955.47	2958.55
Lysine	1.26	1.26	1.26	1.26	1.25
Methionine	0.51	0.51	0.51	0.52	0.52
Calcium	1.04	1.04	1.04	1.03	1.03
Phosphorus	0.48	0.48	0.48	0.48	0.48
Crude fiber	3.61	3.62	3.64	3.65	3.66

CONTROL: soybean meal-based basal diet, RSC25: basal diet added with 25 % roselle seed cake, RSC50: basal diet added with 50 % roselle seed cake, RSC75: basal diet added with 75 % roselle seed cake, RSC100: basal diet added with 100 % roselle seed cake.

method described by Kelly (1979). Red blood cell and white blood cell counts and their "differentials" were determined using the Neubauer hemocytometer method as described by Feldman *et al.* (2000). The erythrocyte indices, mean corpuscular volume, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration were determined using the method described by Bain *et al.* (2006).

For carcass analysis, 6 birds were randomly selected and sacrificed on the last day (56 days) of each replicate. Birds were immobilized by placing them in a desiccator containing chloroform for 5 seconds. After each bird was killed, it was immersed in warm water at approximately 50-55 °C for 1–3 minutes. Then the feathers were then removed with hands and the carcass was then opened. The head and neck, legs and the internal organs (liver, heart, kidneys, lungs, intestines, spleen, gizzard, proventriculus) were removed. Each carcass was weighed to determine weight and the dressing percentage was calculated as follows:

$$\% \text{ Dressing} = \frac{\textit{Carcas weight}}{\textit{Live weight}} \times 100$$

Each organ was expressed as a percentage of the carcass weight.

The mortality rate was calculated as follows:

$$\text{Mortality } (\%) = \frac{\textit{Number of birds present}}{\textit{Number of birds stocked}} \times 100$$

Table 2. Gross composition of finisher diets for broilers with varied levels of roselle seed cake content

Ingredients (%)	CONTROL	RSC25	RSC50	RSC75	RSC100
Maize	55.50	55.50	55.45	55.55	55.00
Soybean meal	19.15	14.36	9.58	4.79	0.00
Roselle seed meal	0.00	4.79	9.58	14.36	19.15
Wheat offal	8.20	8.00	8.48	8.20	8.20
Groundnut cake	7.30	7.50	7.56	7.70	8.45
Fish meal	3.20	3.20	3.20	3.25	3.20
Bone meal	2.50	2.50	2.50	2.50	2.50
Limestone	2.00	2.00	2.00	2.00	2.00
Premix	0.15	0.15	0.15	0.15	0.15
Methionine	0.15	0.15	0.15	0.15	0.15
Lysine	0.20	0.20	0.20	0.20	0.20
Salt	0.15	0.15	0.15	0.15	0.15
Soy oil	1.50	1.50	1.00	1.00	0.85
Total	100.00	100.00	100.00	100.00	100.00
Nutrients					
Crude protein	19.37	19.33	19.33	19.28	19.41
Energy	3128.06	3128.72	3130.33	3131.57	3132.32
Lysine	1.17	1.17	1.16	1.17	1.17
Methionine	0.46	0.46	0.46	0.46	0.46
Calcium	0.98	0.98	0.98	0.97	0.97
Phosphorus	0.43	0.3	0.43	0.43	0.43
Crude fiber	4.09	4.10	4.20	4.30	4.40

CONTROL: soybean meal-based basal diet, RSC25: basal diet added with 25 % roselle seed cake, RSC50: basal diet added with 50 % roselle seed cake, RSC75: basal diet added with 75 % roselle seed cake, RSC100: basal diet added with 100 % roselle seed cake.

Statistical methods

The data obtained were subjected to one-way analysis of variance (ANOVA) using the linear model of the experiment was as follows:

$Y_{ij} = \mu + T_i + e_{ij}$

Where:
Y_{ij} = individual observation
μ = Overall mean
T_i = Treatment Effect
e_{ij} = Random error

The means with a significant difference were separated using the Duncan multiple range test (DMRT) with a probability of 5 %, using SPSS software (IBM, Version 25, Chicago, USA).

RESULTS

Table 3 shows the proximate composition of roselle seed cake. The content of crude protein and nitrogen-free extract was the highest, followed by crude fiber and ether extract, while the total ash was the lowest.

Table 3. Proximate composition of roselle seed cake

Items	% DM
Crude Protein	47.50
Crude Fiber	11.62
Ether Extract	6.14
Total ash	5.22
Nitrogen free extract	29.52
*Energy (MJ.kg^{-1})	1380.64

*Energy = (Crude protein x 17 + Ether extract x 37 + Nitrogen free extract x 17) (Kwari *et al.*, 2011).

Table 4. Mineral compositions of roselle seed cake

Macro-mineral	g/kg DM
Calcium	1.93
Phosphorus	6.67
Magnesium	2.97
Sodium	0.26
Potassium	9.48
Chlorine	0.75
Sulfur	3.07
Micro-mineral	**mg/kg DM**
Iron	231.82
Manganese	47.14
Copper	13.86
Zinc	54.82
Selenium	0.53

Table 4 shows the mineral composition of roselle seed cake. Among the macrominerals, potassium was the highest, followed by phosphorus, while sulfur, magnesium, calcium, chlorine and sodium were lowest, in that order. Among microminerals, iron had the highest value, followed by zinc and manganese, while copper and selenium had the lowest value.

Table 5 shows the amino acid profile of roselle seed cake. Leucine had the highest values, followed by arginine, while methionine had the lowest value.

Table 5. Amino acid profile (% / protein) of roselle seed cake

Amino acids	% of protein
Alanine	3.26
Arginine	7.99
Cysteine	1.10
Glycine	3.94
Histidine	2.03
Isoleucine	2.32
Leucine	9.90
Lysine	1.95
Methionine	0.43
Phenylalanine	3.20
Threonine	2.35
Tyrosine	2.85
Valine	3.64

Table 6 shows the effect of feeding roselle seed cake on the performance of broilers at 28 days of age. Birds fed RSC25 and RSC50 had similar final weight (FW), total weight gain (TWG), and daily weight gain DWG) as birds fed the control diet, while birds fed RSC75 and RSC100 ($p < 0.05$) had lower values. Total feed intake (TFI) and daily feed intake (DFI) were higher in RSC75 and RSC100 ($p < 0.05$) than in the control diet, while RSC25 and RSC50 had similar TFI and DFI as the control diet. Moreover, RSC25 and RSC50 showed similar feed conversion ratio (FCR) to the control diet and better than RSC75 and RSC100, while RSC100 showed the worst. The mortality rate with RSC25 and RSC75 was similar to that of the control diet, while RSC50 and RSC100 were lower.

Table 7 shows the effect of feeding roselle seed cake on the performance of broilers at 56 days of age. Birds fed RSC25 and RSC50 had similar final weight and FCR to those fed the control diet, as observed at 28 days of age, as birds fed the control diet, while RSC75 and RSC100 ($p < 0.05$) had lower values than those in the control diet, but RSC100 was the lowest. Daily weight gain was different, RSC25 and RSC100 ($p < 0.05$) had higher values than in the control diet, RSC75 had similar values than in the control diet, while RSC50 had the lowest DFI. As shown in Table 6, RSC75 and RSC100 ($p < 0.05$) had higher TFI and DFI than the control diet, while birds fed RSC25 and RSC50 achieved similar results to the control diet. The mortality rate in RSC25-75 was the same as in the control diet, while it was lower in RSC100.

Table 8 shows the effect of feeding roselle seed cake on the carcass and organ performance of broilers at 56 days of age. Slaughtered weight and flucked weight in RSC25 were similar to those in the control diet and decreased with increasing RSC in the diet. Dressed weight and dressing percentage were higher in RSC25 and RSC50 ($p < 0.05$) than in the control diet. Dressed weight decreases from RSC75, while dressing percentage was lower in RSC75 and RSC100. Abdominal fat and all internal organs were similar across treatments.

Table 9 shows the effect of feeding roselle seed cake on the hematological parameters of broiler chickens at 56 days of age. Only packed cell volume (PCV) and red blood cell (RBC) count differed ($p < 0.05$). They were similar to those of the control diet and those of RSC25 and RSC50, but lower for RSC75 and RSC100. Hemoglobin, the erythrocyte indices, white

Table 6. Effect of feeding roselle seed cake on the performance of broilers at 28 days of age

Items	CONTROL	RSC25	RSC50	RSC75	RSC100	SE	*p*-value
Initial weight (g)	49.12	49.12	49.22	49.12	49.23	0.06	0.986
Final weight (g)	1109.12^{a}	1110.46^{a}	1106.78^{a}	914.72^{b}	789.63^{c}	147.35	0.012
Total weight gain (g)	1060.00^{a}	1061.34^{a}	1057.56^{a}	865.60^{b}	740.40^{c}	147.38	0.010
Daily weight gain (g)	37.86^{a}	37.91^{a}	37.77^{a}	30.91^{b}	26.44^{c}	5.26	0.000
Total feed intake (g)	1687.00^{b}	1684.76^{b}	1708.56^{b}	1865.36^{a}	1899.52^{a}	104.64	0.039
Daily feed intake (g)	60.25^{b}	60.17^{b}	61.02^{b}	66.62^{a}	67.84^{a}	3.74	0.004
Feed conversion ratio	1.59^{c}	1.59^{c}	1.62^{c}	2.15^{b}	2.57^{a}	0.44	0.000
Mortality (%)	4	4	2	4	2	-	-

^{a,b,c}Means in the same row with different letters show significant differences (p < 0.05) among dietary treatments. CONTROL: soybean meal-based basal diet, RSC25: basal diet added with 25 % roselle seed cake, RSC50: basal diet added with 50 % roselle seed cake, RSC75: basal diet added with 75 % roselle seed cake, RSC100: basal diet added with 100 % roselle seed cake.

Table 7. Effect of feeding roselle seed cake on performance of broilers at 56 days of age

Items	CONTROL	RSC25	RSC50	RSC75	RSC100	SE	*p*-value
Initial weight (g)	1109.12	1110.46	1106.78	914.72	789.63	147.35	0.012
Final weight (g)	2657.00^{a}	2676.00^{a}	2621.00^{a}	2461.27^{b}	2358.49^{c}	138.57	0.006
Total weight gain (g)	1547.88^{b}	1565.54^{a}	1514.22^{c}	1546.55^{b}	1568.86^{a}	21.70	0.071
Daily weight gain (g)	55.28	55.91	54.08	55.23	56.03	0.78	0.057
Total feed intake (g)	2369.64^{b}	2359.28^{b}	2336.60^{b}	2538.76^{a}	2589.16^{a}	116.35	0.005
Daily feed intake (g)	84.63^{b}	84.26^{b}	83.45^{b}	90.67^{a}	92.47^{a}	4.16	0.078
Feed conversion ratio	1.53^{b}	1.51^{b}	1.54^{b}	1.64^{b}	1.65^{a}	0.07	0.002
Mortality (%)	4	4	4	4	2	-	-

^{a,b,c}Means in the same row with different letters show significant differences (p < 0.05) among dietary treatments. CONTROL: soybean meal-based basal diet, RSC25: basal diet added with 25 % roselle seed cake, RSC50: basal diet added with 50 % roselle seed cake, RSC75: basal diet added with 75 % roselle seed cake, RSC100: basal diet added with 100 % roselle seed cake.

Table 8. Effect of feeding roselle seed cake on the carcass and organ performance of broilers at 56 days of age

Items	CONTROL	RSC25	RSC50	RSC75	RSC100	SE	*p*-value
Slaughtered weight (%)	2510.87^{a}	2528.82^{a}	2476.85^{ab}	2325.90^{b}	2228.77^{c}	130.94	0.003
Flucked weight (g)	2429.01^{a}	2448.91^{a}	2398.58^{ab}	2253.56^{b}	2157.23^{c}	126.55	0.004
dressed weight (g)	1755.69^{a}	1777.42^{a}	1717.86^{a}	1543.02^{b}	1439.95^{c}	147.92	0.027
Dressing (%)	72.28^{a}	72.58^{a}	71.62^{a}	68.47^{b}	66.75^{b}	2.59	0.037
Abdominal fat (%)	0.99	0.95	0.96	0.91	0.90	0.04	0.998
Heart (%)	0.64	0.66	0.65	0.62	0.64	0.01	0.831
Liver (%)	1.97	1.98	1.95	1.89	1.90	0.04	0.776
Lungs (%)	1.01	1.02	0.92	1.11	1.03	0.07	0.598
Gizzard (%)	5.45	5.16	5.33	5.35	5.28	0.11	0.628
Kidneys (%)	0.93	0.93	0.91	0.92	0.92	0.01	0.711
Proventiculus (%)	2.23	2.17	2.06	2.25	2.38	0.12	0.677
Spleen (%)	0.33	0.34	0.33	0.33	0.34	0.01	0.585

^{a,b,c}Means in the same row with different letters show significant differences (p < 0.05) among dietary treatments. CONTROL: soybean meal-based basal diet, RSC25: basal diet added with 25 % roselle seed cake, RSC50: basal diet added with 50 % roselle seed cake, RSC75: basal diet added with 75 % roselle seed cake, RSC100: basal diet added with 100 % roselle seed cake.

Table 9. Effect of feeding roselle seed cake on the hematological parameters of broiler chickens at 56 days of age

Items	CONTROL	RSC25	RSC50	RSC75	RSC100	SE	*p*-value
PCV (%)	36.67[a]	36.22[a]	36.71[a]	34.37[b]	34.18[b]	1.04	0.000
Hb (g/L)	11.68	12.00	12.10	12.11	11.74	0.20	0.521
RBC (x10^6/mm^3)	3.58[a]	3.67[a]	3.61[a]	3.21[b]	3.19[b]	0.23	0.039
MCV	80.36	77.38	77.07	75.24	77.10	1.85	0.997
MCH	31.83	31.83	31.83	31.83	31.83	0.00	0.866
MCHC	26.47	26.47	26.47	26.47	26.47	0.00	0.571
WBC (x10^3/mm^3)	17.74	17.74	17.74	17.74	17.74	0.00	0.398
Neutrophils (%)	58.00	57.25	57.09	58.41	57.95	0.55	0.765
Lymphocytes (%)	40.65	40.77	40.53	40.58	40.54	0.10	0.388
Monocytes (%)	2.00	2.01	2.01	2.00	2.00	0.01	0.531
Eosinophils (%)	2.00	2.00	2.00	2.00	2.00	0.00	0.830
Basophils (%)	1.00	1.00	1.00	1.00	1.00	0.00	0.605

[a,b]Means in the same row with different letters show significant differences ($p < 0.05$) among dietary treatments. CONTROL: soybean meal-based basal diet, RSC25: basal diet added with 25 % roselle seed cake, RSC50: basal diet added with 50 % roselle seed cake, RSC75: basal diet added with 75 % roselle seed cake, RSC100: basal diet added with 100 % roselle seed cake. PCV = packed cell volume, Hb = hemoglobin, RBC = red blood cells, MCV = mean corpuscular volume, MCH = mean corpuscular hemoglobin, MCHC = mean corpuscular hemoglobin concentration, WBC = white blood cells counts.

Table 10. Effect of feeding roselle seed cake on serum biochemical of broilers at 56 days of age

Items	CONTROL	RSC25	RSC50	RSC75	RSC100	SE	*p*-value
Total protein (g/dl)	35.98	35.11	35.26	35.08	34.17	0.64	0.358
Albumin (g/dl)	12.18	12.22	11.72	11.27	11.04	0.53	0.527
Globulin (g/dl)	23.8	22.89	23.54	23.81	23.13	0.41	0.381
ALP (µ/l)	247.26	248.11	247.08	248.62	249.19	0.89	0.262
ALT (µ/l)	151.46	150.67	150.38	149.42	149.07	0.97	0.149
AST (µ/l)	237.33	237.33	237.33	237.33	237.33	0.00	0.333
Creatinine (µmol/l)	26.37	26.03	26.00	25.81	25.17	0.44	0.251
Uric acid (mmol/l)	544.33	543.72	541.75	511.23	505.39	19.28	0.123

CONTROL: soybean meal-based basal diet, RSC25: basal diet added with 25 % roselle seed cake, RSC50: basal diet added with 50 % roselle seed cake, RSC75: basal diet added with 75 % roselle seed cake, RSC100: basal diet added with 100 % roselle seed cake. ALP = alkaline phosphatase, ALT= alkaline aminotransferase, AST= aspartic aminotransferase.

blood cell counts and their differentials were similar in all the treatments.

Table 10 shows the effect of feeding roselle seed cake on the serum biochemistry of broilers at 56 days of age. All serum biochemical parameters were similar across treatments.

DISCUSSION

The crude protein content is above the range of 21.40 to 38.75 % reported by (Dashak and Nwanegbo, 2002; Hainida *et al.*, 2008; Ismail *et al.*, 2008; Kwari *et al.*, 2011) in whole seeds support Arrutia *et al.* (2020). Removing the oil from the oilseeds improved the protein content in the residue. Nyam *et al.* (2014) acknowledged that roselle seeds are rich in dietary fiber. However, this study found that the fiber content decreased when the seeds were processed into cakes, as illustrated in Table 3. The fiber content is lower than in the whole seeds, which contain between 15 and 17 % (Dashak and Nwanegbo, 2002; Kwari *et al.*, 2011) and 18.3 % (Hainida *et al.* 2008). The protein content of roselle seed cake is comparable to some highly quality protein sources used in Nigeria such as soybean cake with 44 % CP, soybean meal with 42 %

CP and peanut meal with 42 % CP; and is higher than the protein content of cotton seed cake (25 %), palm kernel cake (16 %) and palm kernel meal (12 %). The energy value is more than 2500 kcal/kg for soybean meal, 2950 kcal/kg for soybean cake, 2640 kcal/kg for peanut Cake, 2550 kcal/kg for peanut meal, and similar to 3100.00 kcal/kg for roasted and micronized full fat soybean (NIAS, 2021). The higher content of phosphorus and iron in roselle seed cake would make up for the deficiency of others protein sources. Due to its lower methionine content, RSC may need to be used in conjunction with dense methionine sources.

The similarity of gains and feed conversion ratio in RSC25 and RSC50 to the control diet during the growth period suggests that RSC can replace soybean meal by up to 50 % without adverse effects on growing birds. This was evident because birds fed RSC25 and RSC50 had similar feed consumption rates, explaining that RSC25 and RSC50 have similar nutritional values to the control diet. Decreased performance above RSC50 means that younger birds cannot tolerate increased dietary intake of RSC. Again, the similarity of final weight and feed conversion ratio in birds fed RSC25 and RSC50 to those fed the control diet during the fattening phase confirms the potential of RSC to replace soybean meal by up to 50 % without negative effects on performance. However, RSC100 showed better daily weight gain than control, but higher feed intake in RSC100 diet increased the higher value of feed conversion ratio. The decrease above RSC50 may be due to the fact that the fiber content of roselle is more than 4.5 % for soybean meal, and also its lysine and methionine content is less than 2.8 % and 0.59 % for soybean meal respectively (NIAS, 2021). However, the RSC value of 25–50 % is higher than the 15% value of roselle whole seeds reported in broiler chickens (Mohammed *et al.*, 2022), providing more information about the use of the cake than as a whole seed. Furthermore, the 25 to 50 % RSC inclusion values in this study are higher than the 5 to 15 % inclusion values of peanut meal, cottonseed cake, palm kernel cake, and safflower (El-Boushy and Ratherink, 1989; Chong *et al.*, 2008; Iyayi *et al.*, 2005; Juskiewicz *et al.*, 2010). This is probably due to its lower fiber content than 8.0 % in peanut cake, 25 % in cottonseed cake, 15 % in palm kernel cake and 12 % in sunflower cake (NIAS, 2021). The similarity in the mortality between RSC25-75 and control and the lower mortality in RSC100 in most cases suggests that the cause of death may not be due to dietary treatment but is likely due to management failure.

The similarity of dressed weight and dressing percentage in RSC25 and RSC50 compared to the control diet indicates the ability of RSC25 and RSC50 to produce high-quality chicken meat, and also confirms that soybean meal can be replaced by RSC25 and RSC50 with high meat performance. The insignificant difference in the organs between the control diet and the RSC-based diet means that RSC cannot negatively affect the growth of internal organs.

The high quality of RSC25 and RSC50 as compared to the control diet was evidenced by the higher PCV and RBC values than the RSC75 and the RSC100. In addition, the similarity of hemoglobin, the erythrocyte indices, white blood cell counts and their differentials as well as all serum biochemical parameters between the control diet and the RSC-based diet means that RSC has no deleterious effects on the formation blood levels. It also shows that the inclusion of RSC in the diet of broilers has no effect on nutrient requirements. This was evident by the observation of insignificant differences in serum protein between treatments. The safety of RSC was also demonstrated by the similarity of ALP, ALT and AST as well as creatinine and the uric acid between the control diet and the RSC-based diet, which explains that the kidney, liver and the muscle were not negatively affected because abnormal of ALP, ALT and AST values are indicators of liver and kidney damage (Campbell, 2013). All the blood parameters are within the international reference values (Hochleithner, 2013). Obadire *et al.* (2022) argued that normal blood values indicate a healthy state and efficient nutrient metabolism and that the introduced diet had no effect on health status as shown by the low mortality rate in RSC100 compared to the control diet.

CONCLUSION

An investigation was conducted to analyze the nutritional content of roselle seed cake (RSC) and its effects on the development and well-being of broiler chickens at various stages. The research revealed that RSC is packed with crude protein, nitrogen-free fiber, potassium, and iron, with leucine being the most abundant essential amino acid. Birds that were given diets containing 25 % and 30 % RSC exhibited improved weight gain and feed intake in the initial phase, while those consuming 25 % and 50 % RSC performed well in the later phase. Although there were some alterations in carcass characteristics and hematological parameters, RSC can promote enhanced growth rates in broiler chickens without any adverse impacts on internal organs and blood profile.

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CONFLICT OF INTEREST

I declare that there was no conflict in this research.

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