

# Evaluation of Manure Nitrogen and Ammonia from Broiler Chickens fed with Different Protein Sources

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## Abstract

Manure Nitrogen (N) is volatile and lost in the form of ammonia (NH<sub>3</sub>) and N-containing compounds (NO<sub>x</sub>). Fraction of excreted N mineralized to NH<sub>3</sub> during storage depends on time and to a lesser extent temperature. The study was conducted to evaluate fresh and stored manure N and NH<sub>3</sub> levels from broiler chickens that fed different protein sources. Four hundred and twenty (420) broiler chickens were randomly selected and assigned into seven dietary treatments, each replicated three times with twenty chickens per replicate in a completely randomized design. Control diet (I) consisted of soy bean meal (SBM)-maize diet, diets II, III, IV and V composed of 20% SBM partially substituted with another source of protein; groundnut and roselle seed cakes (GNC and RSC) without multienzymes (E), GNC+E and RSC+E, diets VI and VII contained animal protein at 10%; grasshopper meal (GHM) and fish meal (FM). Body weight (BW), feed intake (FI) and feed conversion ratio (FCR) for all groups were recorded for 7 weeks. Data collected were analyzed and means were separated using Least significant difference (LSD). Results on BW showed that chickens fed FM, GHM and SBC were statistically (P>0.05) similar, GNC and GHM were not significant (P>0.05). Manure from group fed RSC+E had the least fresh manure N while those from GHM and FM had the least fresh and stored manure NH<sub>3</sub> levels. Multienzyme inclusion in diets (GNC+E and RSC+E) significantly (P<0.05) reduced N levels from litter. The levels were also significantly (P<0.05) affected by dietary inclusion of other protein sources without multienzymes supplementation. Farmers can add 20 % SBM with FM, GHM, SBC and GNC in their chicken diets for higher performance, more so GNC+E, RSC+E, GHM and FM can be added with 20% SBM to reduce manure N and NH<sub>3</sub> buildup in broiler chicken farms.

**Keywords:** ammonia, animal protein, body weight, fresh and stored manure, multienzymes, nitrogen

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## 1. Introduction<sup>1</sup>

Ammonia build up in poultry houses is common most especially in low ventilated poultry houses with wet litter. Either wet or dry, the environmental condition, type of feed, its quality (composition),

digestive efficiency and utilization, can affect the level of N and NH<sub>3</sub> in the manure. The amount of N that is excreted is a factor that increases ammonia escapes into the atmosphere. Moisture, consistency and output of the droppings during the starter and finisher phases differ and this can affect the amount of N excreted and ammonia that escapes at the

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different phases of growth. The fresh droppings (containing uric acid and undigested proteins) after excretion are degraded to form ammonia, which can be lost by volatilization [1, 2]. The process is aerobic, mediated by microbes and requires the presence of water and oxygen [1]. Therefore, it is very important to study different feed types and available N in manure to estimate and know the ammonia level of different kinds of litter from chickens fed with different kinds of protein ingredients. This will help to reduce the amount of ammonia that escapes from the manure which will eventually be converted to N<sub>2</sub>O, to mitigate NH<sub>3</sub> and N<sub>2</sub>O emissions. Ammonia emissions which result from the decomposition of nitrogen in manure [3] is the primary pollutant from poultry production. Excessive emissions can lead to air pollution and affect the health of both workers and the chickens causing health and environmental concerns [4]. The occurrence of respiratory disease, ascites, gastrointestinal irritation and higher chick mortality is jointly caused by ammonia and dust particles [5]. Wang et al. [6] in their studies used the mass balance method to predict NH<sub>3</sub> emissions from manure belt (MB) poultry layer facilities. This necessitates the need for effective manure management strategies to reduce emissions [7], depending on the manure management system. As a result of ammonia emission, N<sub>2</sub>O which is a greenhouse gas, can be emitted either directly or indirectly [8] from manure. Reliable information on the level of broiler chicken manures N and NH<sub>3</sub> will help to reduce any associated potential health and environmental problems.

Processed animal protein (PAP) like meat meal; FM and insect protein (IP) such as worm meal; GHM are termed as specialty protein ingredients (SPI) from animal origin; they are used in broiler chicken diets to lower the problem of poor nitrogen utilization and reduce excretion [9]. On the other hand, the conventional plant proteins have a well-balanced concentration of amino acid profile [10] with low antinutritional factors [3] compared to the non-conventional ones like roselle and baobab seed cakes.

The non-conventional proteins can be improved by several processing methods like enzyme treatment, fermentation, or heat treatment [11]. Therefore, the objective of this study was to test the effectiveness of PAP (FM), IP (GHM) and multienzymes addition to the non-conventional plant protein

(GNC and RSC) in improving performance and lowering level of manure N excretion into the droppings and NH<sub>3</sub> from fresh and stored manure.

## 2. Materials and methods

### *Experimental site*

The research was carried out at the Poultry House of the Poultry Research Programme, National Animal Production Research Institute, Ahmadu Bello University Shika (NAPRI/ABU), Zaria. The area is located in the Northern Guinea Savanna of Nigeria on latitude 11°12' 16.78' N and longitude 7° 33' 39.18' E [12]. Early-dry or cool season falls between the months of October and February, late-dry or hot season falls between March and May while cool wet season falls within June to September, at an elevation of 691 m above sea level with an average annual rainfall of about 1,107 mm. It has an ambient morning temperature ranging from 19–32°C while afternoon temperature ranges from 20–38°C [13].

### *Ethical Approval*

Before commencement of the study, ethical approval was obtained from Ahmadu Bello University Committee on Animal Welfare and Use.

### *Sources of Experimental Ingredients and Chickens*

Grasshopper was purchased from Main Market in Funtua Local Government, Katsina State, and crayfish was sourced at Sabon Gari market, multienzymes (protease 3,000,000 U, xylanase DS 5,000,000 U, phytase 1,450,000 IU and cellulase 1,000,000,000 IU, Beta-glucanase 700,000 U, Amylase 300,000 U, Pectinase 70,000 U, Lipase 10,000 U along with Arabinase, Alpha galactosidase and Hemicellulase) from Fresh Haam Global Farm, Zaria Kaduna, State. Other feed ingredients were purchased from Labar feed mill in Samaru, Zaria, birds were purchased from Elym Kwangila Zaria, Kaduna State.

### *Experimental Design and Management of Birds*

Four hundred and twenty (420) day old broiler Ross 308 chicks were allotted into seven dietary treatments, each replicated three times with 20 chicks in a completely randomized design (CRD). The birds were raised in deep-litter pens, wood shaving was used as bedding material. They were

brooded using charcoal and 100 watts electric bulb as source of heat, light was provided with feed and water *ad libitum* and all other routine management practices were adhered to.

The experiment lasted for 49 days.

*Experimental Diets*

Diets were formulated containing five different protein sources GNC, RSC with and without multienzymes supplementation (GNC, GNC+E, RSC and RSC+E) substituted with 20% SBM, with SBM as shown in Table 1A, while soya bean meal (SBM) served as protein source in the control diet.

**Table 1A.** Composition of Broiler Starter and Finisher Chicken Diets Containing Groundnut and Roselle Seed Cakes with and Without Multienzymes Supplementation Grasshopper Meal and Fish Meal

Ingredients	Diets						
	Starter						
	SBM	GNC	GNC + E	RSC	RSC + E	GHM	FM
Maize	56.00	56.00	56.00	48.00	48.00	56.00	60.00
Soybean Meal	39.00	20.00	20.00	20.00	20.00	27.00	23.00
Groundnut Cake	0.00	19.00	19.00	0.00	0.00	0.00	0.00
Roselle Seed Cake	0.00	0.00	0.00	28.00	28.00	0.00	0.00
Grasshopper Meal	0.00	0.00	0.00	0.00	0.00	10.00	0.00
Fish Meal	0.00	0.00	0.00	0.00	0.00	0.00	10.00
Maize offal	1.00	0.86	0.86	0.00	0.00	2.95	4.05
Bone Meal	3.00	3.00	3.00	3.00	3.00	3.00	2.21
Limestone	0.30	0.30	0.30	0.20	0.20	0.35	0.04
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.2	0.20	0.20	0.20	0.20	0.20	0.20
Lysine	0.00	0.14	0.14	0.13	0.13	0.00	0.00
Vit- min Premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Binder	0.15	0.15	0.15	0.15	0.15	0.15	0.15
+E	0.00	0.00	0.03	0.00	0.03	0.00	0.00
<b>TOTAL</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>
Ingredients	Finisher						
	SBM	GNC	GNC + E	RSC	RSC + E	GHM	FM
	Maize	60.00	58.00	58.00	57.00	57.00	56.00
Soybean Meal	30.00	20.00	20.00	20.00	20.00	18.00	14.00
Groundnut Cake	0.00	10.00	10.00	0.00	0.00	0.00	0.00
Roselle Seed Cake	0.00	0.00	0.00	15.00	15.00	0.00	0.00
Grasshopper Meal	0.00	0.00	0.00	0.00	0.00	10.00	0.00
Fish Meal	0.00	0.00	0.00	0.00	0.00	0.00	10.00
Maize offal	5.82	7.80	7.80	3.92	3.92	11.92	13.05
Bone Meal	3.00	3.00	3.00	3.00	3.00	3.00	2.16
Limestone	0.30	0.27	0.27	0.13	0.13	0.30	0.04
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Lysine	0.18	0.20	0.20	0.20	0.20	0.03	0.03
Vit- min Premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Binder	0.15	0.15	0.15	0.15	0.15	0.15	0.15
+E	0.00	0.00	0.03	0.00	0.03	0.00	0.00
<b>TOTAL</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

SBM=Soybean Meal, GNC=Groundnut Cake, RSC=Roselle Seed Cake, ME=Metabolizable Energy, +E=Multienzymes, GHM=Grasshopper Meal, FM=Fish Meal

The diets were formulated with 23% and 20% crude protein, 2800 and 3000 kcal/kg metabolizable energy for starter and finisher phases respectively, to meet the standard requirement of broiler chickens as recommended by NRC [14]. Multienzymes were added to GNC and RSC to

improve digestion; they were not incorporated in GHM, FM and SBM diets because they are highly digestible with high concentration and balanced essential amino acid profile. Table 1A and B showed the diet composition and calculated analysis for the experimental diets.

**Table 1B.** Calculated Analysis for Broiler Starter and Finisher Chicken Diets Containing Groundnut and Roselle Seed Cakes with and Without Multienzymes Supplementation Grasshopper Meal and Fish Meal

Parameters	Diets						
	Starter						
	SBM	GNC	GNC + E	RSC	RSC + E	GHM	FM
ME (kcal/kg)	2848	2883	2883	2835	2835	2898	2985
Crude Protein (%)	23.18	23.10	23.10	22.85	22.85	23.00	23.10
Ether Extract (%)	3.11	4.17	4.17	5.22	5.22	3.29	3.45
Crude Fibre (%)	2.88	4.45	4.45	5.19	5.19	4.12	2.73
Calcium (%)	1.25	1.25	1.25	1.27	1.27	1.25	1.12
Phosphorus (%)	0.78	0.78	0.78	0.70	0.70	0.71	0.83
Lysine (%)	1.12	1.12	1.12	1.13	1.13	1.26	1.24
Methionine (%)	0.52	0.48	0.48	0.51	0.51	0.67	0.62
Cost/kg (₦)	0.509	0.503	0.505	0.476	0.478	0.587	0.824

  

Parameters	Finisher						
	SBM	GNC	GNC + E	RSC	RSC + E	GHM	FM
ME (kcal/kg)	2918	2926	2926	2920	2920	2951	3039
Crude Protein (%)	20.22	20.17	20.17	20.05	20.05	20.00	20.07
Ether Extract (%)	3.09	3.54	3.54	4.27	4.27	3.12	3.28
Crude Fibre (%)	3.10	4.06	4.06	4.23	4.23	4.70	3.30
Calcium (%)	1.24	1.23	1.23	1.24	1.24	1.22	1.09
Phosphorus (%)	0.74	0.74	0.74	0.71	0.71	0.67	0.79
Lysine (%)	1.10	1.06	1.06	1.06	1.06	1.10	1.08
Methionine (%)	0.47	0.46	0.46	0.47	0.47	0.63	0.58
Cost/kg (₦)	0.490	0.474	0.477	0.478	0.481	0.576	0.78

SBM=Soybean Meal, GNC=Groundnut Cake, RSC=Roselle Seed Cake, ME=Metabolizable Energy, +E=Multienzymes, -E=without multienzymes, GHM=Grasshopper Meal, FM=Fish Meal, Dollar (\$) exchange rate to Naira (₦) in 2024=1(\$) equivalent 1650 (₦)

#### Growth Study

Feed intake, Initial and final body weights (BW) of chickens were taken at the beginning and end of both starter and finisher phases respectively. Feed intake was assessed weekly, feed conversion ratio (FCR) and feed cost were computed and recorded for each treatment group. Mortality was recorded as it occurred.

#### Manure Nitrogen and Ammonia Analysis

Collection of samples occurred on the days that manure was removed and after storing in a 100 kg sack for 2 weeks from each replicate (3), making a total of 21 samples, using a polyethylene leather at the end of starter and finisher phases (week 5, 6 and 7) respectively. The manure was stored in the sack in an empty ventilated room at room temperature, fresh and stored samples were analyzed for N and NH<sub>3</sub> in the Nitrogen Laboratory of the Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Zaria. Total N in fresh and stored manure samples were analysed using the modified Kjeldhal Method [15] as described by Thiex [16,

AOAC 990.03:17]. Ammonia was also analyzed using magnesium oxide in the digestion process using the same procedure for total N [13, 23].

#### Statistical Analysis

Data compiled from the work were analyzed using ANOVA procedure of Statistical Analysis System [19], treatment means were statistically separated using Least Significant Difference (LSD).

## Results and Discussion

#### Weekly Body Weight and mortality of Broiler Finisher Chicken Diets Containing Groundnut and Roselle Seed Cakes with and Without Multienzymes Supplementation Grasshopper Meal and Fish Meal

The weekly body weight of broiler chickens fed SBM, GNC and RSC with and without multienzymes supplementation GHM and FM are presented in Table 2.

**Table 2.** Body weight and mortality of broiler chickens from the experiment

Age in Weeks	Experimental Groups							
	SBM	GNC	GNC+E	RSC	RSC+E	GHM	FM	LSD
Initial Weight	44.67	44.75	44.67	44.67	44.67	44.67	44.67	0.26
Body weight (g/bird) Week 1	156.92 <sup>b</sup>	139.52 <sup>c</sup>	131.96 <sup>c</sup>	139.27 <sup>c</sup>	139.73 <sup>c</sup>	142.50 <sup>c</sup>	172.22 <sup>a</sup>	10.78
Body weight (g/bird) Week 2	389.97 <sup>b</sup>	296.70 <sup>c</sup>	279.56 <sup>c</sup>	307.90 <sup>c</sup>	313.38 <sup>c</sup>	375.00 <sup>b</sup>	429.92 <sup>a</sup>	39.5
Body weight (g/bird) Week 3	678.25 <sup>b</sup>	546.23 <sup>c</sup>	492.98 <sup>d</sup>	546.49 <sup>c</sup>	563.78 <sup>c</sup>	651.67 <sup>b</sup>	771.79 <sup>a</sup>	38.51
Body weight (g/bird) Week 4	1094.74 <sup>ab</sup>	817.13 <sup>c</sup>	758.24 <sup>cd</sup>	875.88 <sup>c</sup>	866.92 <sup>c</sup>	1028.33 <sup>b</sup>	1158.86 <sup>a</sup>	77.539
Body weight (g/bird) Week 5	1416.37 <sup>abc</sup>	1289.47 <sup>bc</sup>	1256.28 <sup>c</sup>	1250.55 <sup>c</sup>	1352.38 <sup>abc</sup>	1501.75 <sup>a</sup>	1467.86 <sup>ab</sup>	208.49
Body weight (g/bird) Week 6	1848.93 <sup>ab</sup>	1678.95 <sup>bc</sup>	1691.72 <sup>bc</sup>	1586.40 <sup>c</sup>	1648.71 <sup>c</sup>	1919.30 <sup>a</sup>	1986.82 <sup>a</sup>	185.46
Body weight (g/bird) Week 7	2366.10 <sup>a</sup>	2109.00 <sup>bc</sup>	2071.30 <sup>c</sup>	1927.40 <sup>c</sup>	2086.00 <sup>c</sup>	2339.30 <sup>ab</sup>	2434.70 <sup>a</sup>	244.03

<sup>abc</sup>=Means with different superscripts on the same row are significantly different  $P < 0.05$ , SBM=Soybean Meal, GNC=Groundnut Cake, RSC=Roselle Seed Cake, ME=Metabolizable Energy, +E=Multienzymes, -E=without multienzymes, GHM=Grasshopper Meal, FM=Fish Meal, LSD=Least Significant Difference

The weekly body weight of broiler chickens fed SBM, GNC and RSC with and without multienzymes supplementation GHM and FM are presented in Table 2. Multienzymes addition to plant protein; GNC and RSC have no significant ( $P > 0.05$ ) effect on the final weight of the treatment groups, the BW of birds fed FM, GHM and SBC were statistically ( $P > 0.05$ ) similar, GNC and GHM were also not significant ( $P > 0.05$ ) at week 7. At the starter phase (week 4), chickens fed FM and SBM had significantly ( $P < 0.05$ ) superior body weight of 1158.86 and 1094.74 g/bird respectively and BW of chickens on GHM and SBM diets were also not significant ( $P > 0.05$ ).

Both FM and SBM have excellent essential amino acid composition, low fiber and are readily digestible. The FM, SBM and GHM groups performed best at the finisher phase; the GNC group also showed acceptable final BW compared to GNC, GNC+E, RSC and RSC+E groups. The result was in line with the work of Attia et al. [20] who fed FM to broiler chickens throughout 1-14 and 15-42 days of age, at 3 and 5% and concluded that FM is the most effective for growth performance. It also agreed with Lee et al. (2024) [21], who stated that dietary supplementation of GHM from 5 to 10% serves as an alternative to protein sources for broiler chickens. Research by

Shehu (2021) [22], Onunkwo et al. (2020) [23] and Ojileh et al. (2017) [24] reported a similar result, that GNC and RSC can replace a significant portion of the conventional protein source like SBM at 20-24%, to maintain the health and performance of broiler chickens. They supported the idea that adding RSC and GNC to the diet can be beneficial, providing a sustainable option for poultry nutrition with no effect on the health status of the bird. Their results were also in line with the results for GNC and RSC obtained from this study. This suggests that the inclusion of FM, SBM, GHM and GNC in the broiler chickens' diet positively influenced their growth compared to other treatment groups.

*Weekly Feed Intake and Feed Conversion Ratio of Broiler Chickens Fed Groundnut and Roselle Seed Cakes with and Without Multienzymes Supplementation Grasshopper Meal and Fish Meal*  
The feed consumption pattern of broiler chickens fed SBC, GNC, GNC+E, RSC, RSC+E, GHM and FM from week 1-7 is shown in Table 3. Feed consumed was ( $P < 0.05$ ) significant across all the treatment groups from week 1-7, with the following feed intake pattern:  
GNC < GNC+E < RSC+E < SBM < GHM < RSC < F.

**Table 3.** Feed intake and feed conversion ratio of broiler finisher chickens from the experiment

Age in weeks	Experimental groups							
	SBM	GNC	GNC +E	RSC	RSC +E	GHM	FM	LSD
Feed Intake Week 1 (g/bird)	124.00 <sup>abc</sup>	115.86 <sup>a</sup>	134.68 <sup>bcd</sup>	140.96 <sup>dc</sup>	131.14 <sup>abcd</sup>	118.80 <sup>ab</sup>	144.58 <sup>d</sup>	17.14
FCR	1.10 <sup>a</sup>	1.24 <sup>b</sup>	1.54 <sup>d</sup>	1.48 <sup>d</sup>	1.37 <sup>c</sup>	1.20 <sup>b</sup>	1.13 <sup>a</sup>	0.06
Feed Intake Week 2 (g/bird)	335.30 <sup>dc</sup>	246.54 <sup>a</sup>	250.37 <sup>a</sup>	296.44 <sup>bc</sup>	287.60 <sup>ab</sup>	326.75 <sup>bcd</sup>	355.45 <sup>d</sup>	41.50
FCR	1.43 <sup>a</sup>	1.56 <sup>ab</sup>	1.70 <sup>bc</sup>	1.76 <sup>c</sup>	1.66 <sup>bc</sup>	1.40 <sup>a</sup>	1.38 <sup>a</sup>	0.18
Feed Intake Week 3 (g/bird)	502.76 <sup>b</sup>	450.41 <sup>a</sup>	421.32 <sup>a</sup>	498.33 <sup>b</sup>	489.15 <sup>b</sup>	495.00 <sup>b</sup>	568.38 <sup>c</sup>	29.74
FCR	1.75 <sup>ab</sup>	1.83 <sup>ab</sup>	1.98 <sup>bc</sup>	2.09 <sup>b</sup>	1.95 <sup>bc</sup>	1.79 <sup>ab</sup>	1.66 <sup>a</sup>	0.25
Feed Intake Week 4 (g/bird)	815.70 <sup>b</sup>	546.55 <sup>a</sup>	546.08 <sup>a</sup>	761.40 <sup>b</sup>	732.74 <sup>b</sup>	736.35 <sup>b</sup>	761.99 <sup>b</sup>	131.52
FCR	1.95	2.11	2.09	2.31	2.41	1.95	1.99	0.67
Feed Intake Week 5 (g/bird)	885.48 <sup>ab</sup>	838.60 <sup>ab</sup>	807.80 <sup>a</sup>	852.02 <sup>ab</sup>	891.98 <sup>ab</sup>	992.98 <sup>b</sup>	834.53 <sup>ab</sup>	178.02
FCR	2.26	2.10	1.90	2.31	1.84	2.41	2.48	0.67
Feed Intake Week 6 (g/bird)	1054.28 <sup>ab</sup>	1017.05 <sup>a</sup>	977.69 <sup>a</sup>	1004.59 <sup>a</sup>	994.11 <sup>a</sup>	1046.70 <sup>ab</sup>	1174.47 <sup>b</sup>	147.16
FCR	2.50 <sup>a</sup>	2.657 <sup>ab</sup>	2.13 <sup>a</sup>	3.12 <sup>ab</sup>	3.53 <sup>b</sup>	2.54 <sup>ab</sup>	2.32 <sup>a</sup>	0.99
Feed Intake Week 7 (g/bird)	1271.55 <sup>ab</sup>	1191.44 <sup>ab</sup>	1183.38 <sup>a</sup>	1180.46 <sup>a</sup>	1261.76 <sup>ab</sup>	1263.32 <sup>ab</sup>	1335.27 <sup>b</sup>	145.24
FCR	2.57	3.04	3.24	3.55	2.88	3.13	2.99	1.16
Total Feed Intake (g/bird)	4989.1 <sup>cd</sup>	4406.5 <sup>ab</sup>	4321.3 <sup>a</sup>	4734.2 <sup>abc</sup>	4788.5 <sup>bcd</sup>	4979.9 <sup>cd</sup>	5174.7 <sup>d</sup>	429.14
FCR	2.16 <sup>a</sup>	2.15 <sup>a</sup>	2.13 <sup>a</sup>	2.52 <sup>b</sup>	2.35 <sup>ab</sup>	2.17 <sup>a</sup>	2.16 <sup>a</sup>	0.24
Total Feed Cost/kg (\$)	0.999	0.977	0.982	0.954	0.959	1.163	1.604	

<sup>abc</sup>=Means with different superscripts on the same row are significantly different  $P<0.05$ , SBM=Soy Bean Meal, GNC=Groundnut Cake, RSC=Roselle Seed Cake, ME=Metabolizable Energy, +E=Multienzymes, -E=without multienzymes, GHM=Grasshopper Meal, FM=Fish Meal, LSD=Least Significant Difference, FCR=Feed conversion ratio, Dollar (\$) exchange rate to Naira (₦) in 2024=1(\$ equivalent 1650 (₦)).

Treatment group with birds fed FM consumed more feed and there was no significant ( $P>0.05$ ) difference with the results of birds fed GHM and SBM. Multienzymes addition to GNC and RSC has no significant ( $P>0.05$ ) effect on the amount of feed consumed. Feed conversion ratio was not significant ( $P>0.05$ ) across all treatment groups in week 4, 5 and 7 and among birds on FM, SBM, GNC and GHM diets.

The study found that replacing SBM with FM resulted in the best FCR among the groups tested. The amount of feed consumed by broiler chickens fed FM, GHM, SBC and GNC in terms of their body weights showed that the diets were palatable and that the birds likely consumed adequate amounts of feed. The better performance of birds in the treatment groups indicated that the birds had a favorable feed intake compared to other dietary groups. The findings of this study for birds in the FM group agreed with that of Attia et al. (2023) [20], who fed fish and black soldier fly meals at 3 and 5% to broiler chickens and suggested that FM encourages efficient feed intake and had the best feed conversion ratio (FCR) among all groups tested. Feed cost/kg was lower for RSC, RSC+E, GNC, SBM and GNC+E in both starter and finisher phases, but GHM and FM groups had the highest feed cost/kg diet in both phases. Result of this work agreed with the findings of Onunkwo et al. (2020) [23] and Shehu (2021) [22] that RSC (at 24 and

20% respectively) is a viable and cost-effective alternative protein source for broiler chickens, which could help address the challenges of feed scarcity and high costs in the poultry industry.

#### *Nitrogen and Ammonia Levels of Fresh and Stored Manure from Broiler Chickens Fed Different Protein Sources*

Fresh and stored manure nitrogen and ammonia from birds fed protein diets containing SBM, GNC, GNC+E, RSC, RSC+E, GHM and FM are presented in Table 4. Multienzymes inclusion in diets significantly ( $P<0.05$ ) reduced fresh manure N level, but did not significantly ( $P>0.05$ ) reduce  $\text{NH}_3$  level. The levels were also significantly ( $P<0.05$ ) affected with dietary inclusion of the other protein sources without multienzymes inclusion. Manure from group fed with RSC+E had the least total fresh manure N while those from GHM and FM had the least total fresh and stored manure  $\text{NH}_3$  levels. Low values ( $P>0.05$ ) for total fresh manure N level were observed in all groups except GNC, RSC and GHM. Storage significantly ( $P<0.05$ ) increased N for treatment groups SBM, GNC+E, RSC+E and decreased N for GNC, GHM and FM manure N except RSC which remained constant at 9.89%, it significantly ( $P<0.05$ ) decreased  $\text{NH}_3$  level across the treatment groups with low emission observed in RSC+E. Levels of stored and fresh  $\text{NH}_3$  were not significantly

( $P>0.05$ ) affected either by dietary or multienzymes inclusion in the diets, but storage significantly ( $P<0.05$ ) affected only stored N levels

at the starter phase, GHM and FM groups recorded the least values 1.82 and 1.31 respectively.

**Table 4.** Nitrogen and ammonia levels of fresh and stored manure from broiler chickens

Parameters	Experimental Groups							
	SBM	GNC	GNC+E	RSC	RSC+E	GHM	FM	LSD
Total Fresh litter Nitrogen (%)	8.17 <sup>ab</sup>	10.31 <sup>b</sup>	8.33 <sup>ab</sup>	9.89 <sup>b</sup>	6.76 <sup>a</sup>	9.10 <sup>b</sup>	8.41 <sup>ab</sup>	2.30
Total Fresh Manure Ammonia (%)	0.54 <sup>ab</sup>	0.60 <sup>ab</sup>	0.54 <sup>ab</sup>	0.81 <sup>b</sup>	0.54 <sup>ab</sup>	0.42 <sup>a</sup>	0.44 <sup>a</sup>	0.35
Total Manure Nitrogen after storage (%)	8.40 <sup>ab</sup>	9.81 <sup>bc</sup>	9.75 <sup>bc</sup>	9.89 <sup>bc</sup>	11.11 <sup>c</sup>	7.71 <sup>ab</sup>	6.82 <sup>a</sup>	2.53
Total Manure Ammonia after storage (%)	0.36 <sup>ab</sup>	0.37 <sup>ab</sup>	0.39 <sup>ab</sup>	0.36 <sup>ab</sup>	0.52 <sup>b</sup>	0.24 <sup>a</sup>	0.34 <sup>ab</sup>	0.23
Fresh Manure Nitrogen (Starter %)	2.23	3.60	3.29	3.52	2.31	2.94	2.49	1.40
Fresh Manure Ammonia (Starter %)	0.07	0.04	0.03	0.07	0.05	0.05	0.08	0.06
Manure Nitrogen after storage (Starter %)	1.92 <sup>ab</sup>	2.83 <sup>bc</sup>	2.17 <sup>ab</sup>	2.24 <sup>ab</sup>	3.49 <sup>c</sup>	1.82 <sup>a</sup>	1.31 <sup>a</sup>	0.99
Manure Ammonia after storage (Starter %)	0.10	0.09	0.11	0.09	0.10	0.11	0.08	0.07
Fresh Manure Nitrogen (Finisher %)	5.94 <sup>ab</sup>	6.71 <sup>b</sup>	5.03 <sup>ab</sup>	6.37 <sup>ab</sup>	4.448 <sup>a</sup>	6.16 <sup>ab</sup>	5.92 <sup>ab</sup>	1.96
Fresh Manure Ammonia (Finisher %)	0.47 <sup>ab</sup>	0.56 <sup>ab</sup>	0.51 <sup>ab</sup>	0.74 <sup>b</sup>	0.48 <sup>ab</sup>	0.34 <sup>a</sup>	0.357 <sup>a</sup>	0.36
Manure Nitrogen after storage (Finisher %)	6.47	6.98	7.58	7.65	7.62	5.89	5.51	2.62
Manure Ammonia after storage (Finisher %)	0.26 <sup>ab</sup>	0.28 <sup>ab</sup>	0.28 <sup>ab</sup>	0.26 <sup>ab</sup>	0.42 <sup>b</sup>	0.12 <sup>a</sup>	0.25 <sup>ab</sup>	0.21

<sup>abc</sup>=Means with different superscripts on the same row are significantly different  $P< 0.05$ , Fresh manure nitrogen and ammonia=manure N and NH<sub>3</sub> directly from pen, SBM=Soya Bean Meal, GNC=Groundnut Cake, RSC=Roselle Seed Cake, ME=Metabolizable Energy, +E=Multienzymes, -E=without multienzymes, GHM=Grasshopper Meal, FM=Fish Meal, LSD= Least Significant Difference

Manure N (stored) at finisher phase was not significant ( $P>0.05$ ) and followed the same trend as stored and fresh ammonia at starter phase across all the groups. A significant ( $P<0.05$ ) difference was observed for fresh manure N, NH<sub>3</sub> and stored NH<sub>3</sub> at finisher phase. Values for fresh manure N and NH<sub>3</sub> in this study (6-10.3%) fell within close range (5-6.5%) as reported by Mahimairaja et al. (1990) [15] who measured total N and forms of inorganic N in fresh sample of poultry manure. Variation could be due to difference in the type of feed consumed, type of poultry (species e.g. chicken, turkey, layer) manure and the type of treatment of fresh samples before analysis [15]. The result explained that the RSC+E group had lower fresh manure N and NH<sub>3</sub> levels, retained N and NH<sub>3</sub> more in stored form compared to other groups, where NH<sub>3</sub> levels significantly ( $P<0.05$ ) decreased with storage. It was observed that there was a high rate of volatilization of N in the form of NH<sub>3</sub> and possibly other oxidized forms of N like NO<sub>3</sub> and NO<sub>2</sub>, during storage in all other groups except RSC+E. The reason for lower levels of N and NH<sub>3</sub> in fresh manure could be because chickens fed with RSC and RSC+E diets had wet litter compared to other groups. High oxidation of ammonia N occurs in dryer than in moist manure, indicating higher levels of N and NH<sub>3</sub> in the stored manure for the RSC+E group. Onunkwu et al. (2020) [23],

reported that chickens fed with RSC in their diets produce wet litter due to its high lysine composition, which can lead to increased nitrogen excretion, contributing to wet litter conditions as excess nitrogen is converted to ammonia in the litter. Moisture and multienzymes treatment retained N, reduced the oxidation of ammonia N and its transformation into other oxidized N forms in the fresh RSC+E manure. Observations on stored N and NH<sub>3</sub> levels in this study agreed with Mahimairaja et al. (1990) [15], that drying of animal manures at room temperature caused a decrease in organic N and NH<sub>3</sub> especially in poultry manure. They added that most of the decrease in N content with drying was attributed to the volatilization loss of ammonia and concluded that air drying caused maximum loss of N as NH<sub>3</sub>.

### Conclusions

The performance of chickens fed the control diet SBM, SBM at 20% substituted with GNC, FM and GHM partly substituting SBM at 10% were superior in terms of body weight, and overall growth performance compared to those fed GNC+E, RSC and RSC+E, highlighting that FM is a beneficial dietary protein source for broiler chickens. Multienzymes addition to the RSC diet decreased N and NH<sub>3</sub> levels (6.76 and 0.54%) of

fresh manure, while storage increased N level (11.11%) but maintained NH<sub>3</sub> level at a relative value (0.52%). Farmers and feed millers can partly substitute 20 % SBM with GNC and GHM at 10%, to help address the challenges of feed scarcity, high costs of production and 20% SBM with RSC to reduce manure N and NH<sub>3</sub> levels in poultry farms.

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