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Effect of bio-digested cage layer manure and bio-digested pig manure on the carcass traits and blood profile of growing cockerels

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Target Audience: Poultry farmers, Animal Nutritionist and feed formulators and Agricultural extension agents

Abstract

A total of 180 eight week old growing cockerels were used to evaluate effects of bio-digested cage layer manure (BCLM) and bio-digested pig manure (BPM) included at 0 (control), 10 and 20% in a 2 × 3 factorial design over seven weeks. Birds fed BPM achieved higher fasted live weight (1222.20 g) than those fed BCLM (1161.10 g). BPM also increased plucked weight (90.55% vs 86.68%) and dressing percentage (63.66% vs 57.94%) relative to BCLM. Carcass cuts improved under BPM, neck and back (4.91%, 13.73 %) and thigh (10.08 %) were greater with BPM. Gizzard weight was greater with BCLM (3.04 %) than BPM (2.81 %), while small intestine weight was higher with BCLM (8.65%). Inclusion level (0, 10, 20%) had minimal effects on most carcass traits, although the interaction showed the highest dressing percentage at 20% BPM (66.97%) and the lowest at 20% BCLM (54.90%). Haematological indices remained within normal poultry reference ranges with no adverse source or level effect. Eosinophil proportion declined from 3.67% in birds on 0% inclusion to 1.17% in birds on 20% and basophils fell from 1.00% in birds on 0% inclusion to 0.00% in birds on 20% inclusion. Total serum protein and globulin increased with inclusion level, peaking at 10% (total protein 6.36 g/dL; globulin 3.09 g/dL) and declining at 20%. The results indicate that bio-digested manures can replace conventional protein sources in cockerel up to 20% without compromising health or most carcass traits, with BPM resulted in higher carcass yield under the conditions of this study.

Keywords: Bio-digestion, cage layer manure, pig manure, blood profile, carcass yield, haematology, sustainable poultry feeding

Description of Problem

Pursuing sustainable poultry production has encouraged the exploration of alternative feed resources, particularly those that address environmental management and nutritional adequacy [1]. Among such options, bio-digested manure derived through anaerobic digestion of livestock waste has emerged as a potential feed alternative in poultry diets [2]. Utilizing bio-digested livestock manure may offer a dual advantage of recycling farm waste while enhancing production outcomes in poultry [2]. According to [3] anaerobic digestion transforms organic manure substrates into digestate, reducing pathogenic microbes and improving nutrient availability, and the resulting digestate is considered less odorous and more stable compared to raw manure. In addition, studies by [4 and 5] reported that anaerobic digestate retains substantial proportions of nitrogen, phosphorus, and organic matter essential for animal growth.

Bio-digestates from cage layer and pig manures differ in proximate and mineral composition: pig digestate typically contains higher crude protein and short-chain fatty acids that could improve feed conversion, while poultry digestate is richer in minerals such as calcium and phosphorus, which is key in skeletal development [6; 4]. Also, feeding trials have demonstrated growth performance gains and gut health benefits when broilers consume diets supplemented with anaerobically digested livestock waste up to moderate inclusion levels [7; 8]. Beyond growth metrics, carcass characteristics are also a crucial determinant of meat quality and economic returns. In addition, blood profile serves as a sensitive and important indicator of nutrient utilization, metabolic status, and immune competence [9]. Shifts in these indices indicate subclinical stress or toxicity, particularly relevant when unconventional feedstuffs are introduced [8].

Despite mounting evidence of performance benefits of bio digested cage layer manure and bio digested pig manure on broiler performance, the effects of bio-digested cage layer and pig manure on carcass characteristics and blood profile in cockerels remain underexplored. This study therefore, investigated how graded inclusion levels of cage layer and pig manure digestates influenced carcass yield; meat cuts parts, organ weights and blood health indicators in growing cockerels.

Materials and Methods

Experimental Site

The experiment was carried out at the Directorate of University Farms (DUFARMS), Federal University of Agriculture, Abeokuta. The site is located in the rainforest vegetation zone of south-western Nigeria at latitude 7° 13' 49.46"N, longitude 3° 26' 11.98"E and altitude 98m above the sea level. The climate is humid with a mean annual rainfall of 1003mm, mean annual temperature (31.9-34.8°C) and humidity of 79.7- 90.1% [10].

Collection of Manure

Caged layer manure and pig manures were collected from the poultry and pig units of the Directorate of University Farms of the Federal University of Agriculture, Abeokuta.

Construction of biodigesters

Two biodigesters were fabricated, one for caged layer manure and the other one for pig manure using the following materials:

- Four plastic water tanks (two for digestion, two for gas collection)
- PVC pipes (for inlet, outlet, and gas line)

- Ball valves, elbows, and adapters
- Epoxy adhesive
- Teflon tape (for sealing threaded joints)
- Rubber washers and gaskets

Production of the digestates

Caged layer manure and pig manure were collected from the poultry and pig units of the directorate of university farm of the Federal University of Agriculture, Abeokuta and were mixed with water separately to form slurry. Each slurry was poured into the upright water tank through the inlet pipe. The other water tank which is smaller than the first one was turned upside down in the upright tank. Bacteria activities were observed to build up inside the tank as the tank turned upside down began to rise.

The digestion was carried out under anaerobic condition and environmental temperature and atmospheric pressure conditions were maintained. Both the cage layer manure and pig manure were allowed to digest for six weeks. After six weeks of digestion, a transparent gas pipe was fixed at the outlet of the upside-down tank to collect the gas produced after which the tank was opened to collect the effluent. The digestate was packed in sacks and the water was drained using a jack press. The drained digestate was sundried for 3 days and afterwards oven dried for another 3 days at 30 °C. This procedure was done for caged layer and pig manure respectively. The oven dried digestates were then packed in envelopes and later taken to feed mill to compound the diets for the birds.

Experimental birds and their management

One hundred and eighty (8 weeks old) growing cockerels were used for the study. The birds were maintained on a commercial diet for seven weeks and at the eighth week the birds were balanced for body weight and introduced into respective treatments. The experimental birds were raised on deep litter which was properly cleaned, disinfected and layered with wood shavings prior to the commencement of the experiment. The required vaccinations and medications were administered as required and strict biosecurity measures were adhered to throughout the period of the study.

Experimental Design

The birds were randomly allotted to 6 dietary groups. Each treatment was replicated thrice with ten (10) birds per replicate. The experiment was a 2×3 factorial arrangement comprising 2 types of bio digested manure (Caged layer and pig manure) and 3 levels of inclusion (0,10 and 20%).

Experimental Diet

The dried digestate was included in the diet of growing cockerels as replacement for soybean at 0 (control), 10 and 20% for caged layer manure and 0 (control), 10 and 20% for pig manure. The feeding trial lasted for seven weeks and the experimental diet for this study is presented in Table 1.

Table 1: Composition (%) of grower mash containing varying levels of bio digested caged layer and pig manure

		Inclusion levels			
Control		BCLM		BPM	
Ingredients	0%	10%	20%	10%	20%
Maize	50.00	50.00	50.00	50.00	50.00
Soybean meal	15.00	13.50	12.00	13.50	12.00
*BCLM	0.00	1.50	3.00	0.00	0.00
**BPM	0.00	0.00	0.00	1.50	3.00
Wheat offal	30.00	30.00	30.00	30.00	30.00
Bone meal	2.00	2.00	2.00	2.00	2.00
Oyster shell	2.00	2.00	2.00	2.00	2.00
Lysine	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
***Vit/Premix	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100
Calculated analysis:					
Crude protein(%)	16.20	15.70	15.20	15.70	15.30
Ether Extract(%)	3.60	3.60	3.60	3.60	3.60
Crude fibre(%)	4.50	4.70	4.90	4.70	4.90
Calcium(%)	1.50	2.40	3.30	2.10	2.70
Phosphorus(%)	0.40	0.40	0.40	0.40	0.40
Lysine(%)	0.90	0.80	0.80	0.80	0.80
Methionine(%)	0.50	0.50	0.50	0.50	0.50
Energy(MJ/Kg)	11.01	10.94	10.87	10.93	10.87

***ContainsVit A,10 000 000iu;D3,2 000 oooiu; E, 12 500iu; K, 1.30g; B1,1.30; B2,4.00g;D Calcium-Pantothenate, 1.30g; B6, 1.30g; B12,0.01g;nicotinic acid.15.00g;folic acid,0.05g, biotin,0.02g; Co, 0.20g; Cu,5.00g; Fe, 25.00g;I,0.06g; Mn,48.00g;Se,0.10g; Zn,45.00g; choline chloride,200.00g;BHT,50.00g, *BCLM: Biodigested cage layer manure, **BPM: Biodigested pig manure

Data Collection

Carcass analysis

At the end of the feeding trial, three birds from each replicate were picked randomly for determination of carcass analysis. Birds were starved for 12 hours before slaughter to empty the gastro-intestinal tract (GIT). The birds were weighed and later slaughtered by severing the jugular vein and carotid artery for bleeding purpose. After bleeding, the carcasses were scalded at 60^0C to break fat formation attaching the feathers to skin of the birds. After scalding, feather picking and evisceration were performed. All cut parts (head, neck, legs, wings, breast, thighs, drumstick etc), organs (heart, gizzard, kidney and liver) and offals (small intestine and large intestine) were weighed using sensitive scale (Acculab model, 2001 Electronic Digital Scale), and expressed as percentage of live weight of the birds.

Collection and Analysis of blood samples

At the end of the feeding trial, blood samples (2mls) were collected from one bird per replicate from the wing web using syringe and needle into sets of sterilized bottle containing Ethylene Diamine Tetra Acetate (EDTA) as anti-coagulant for analysis of haematological parameters (packed cell volume (PCV), red blood cell (RBC), white blood cell (WBC), haemoglobin (Hb)). A second set of bottles without anticoagulant was used to collect blood samples for determination of albumin, globulin and total serum protein. The samples were analysed at Clinical Pathology Laboratory, College of Veterinary Medicine, Federal University of Agriculture, Abeokuta.

Haematological Measurement

Blood collected into EDTA bottle was placed in micro-haematocrit centrifuge and subjected to spinning for 5 minutes at a revolution of 11000rpm.The PCV values were subsequently determined by measuring the height of the red cell column and expressing this as a ratio of the height of the total blood column using microhaematocrit reader.

Red blood cell, White blood cell and the differential counts were determined using haemocytometer as described by [10]. Haemoglobin (Hb) was calculated as one third of packed cell volume.

Total Serum Protein

This was determined using Biuret method, the mixture of the reagent and serum sample were incubated for 30 minutes at 20-25^{0}C and the absorbances of the sample and that of the standard were measured against the blank at a wavelength of 540nm. The total protein concentration was calculated as:

$$\text{Total Protein (g/dl)} = \frac{\text{Absorbance of samples}}{\text{Absorbance of standard}} \times \text{Standard Concentration}$$

Serum Albumin

The bromocresol purple method of [11] was used. According to this method, bromocresol purple (BCP) binds quantitatively serum albumin forming a stable complex with an absorbance maximum at 600nm; the intensity of the colour produced is directly proportional to the albumin concentration in the sample.

The Bromo Cresol Green (BCG) method was employed. The absorbances of the sample and the standard was taken against the reagent blank at a wavelength of 620nm.

$$\text{Albumin (g/dl) concentration} = \frac{\text{Absorbance of samples}}{\text{Absorbance of standard}} \times \text{Concentration of Standard}$$

Serum Globulin

This was estimated by subtracting the results of the serum albumin from the serum total protein. Serum globulin was calculated as follows:

Serum globulin (g/dl) = Total serum protein- serum albumin

Data Analysis

Data obtained was arranged in a 2x3 factorial layout and subjected to a completely randomized design. Significant differences among treatments were determined using Duncan multiple range test as contained in SAS 2010 package.

Result and Discussion

The main effect of bio digested cage layer manure and bio digested pig manure and levels of inclusion on the carcass traits of growing cockerels is presented in Table 2

The source of bio-digested manure significantly affected plucked weight and dressing percentage of growing cockerels. Growing cockerels fed diets containing bio digested pig manure (BPM) recorded significantly higher fasted live weights (1222.20 g) compared to those on bio-digested caged-layer manure (BCLM) (1161.10 g), indicating a superior growth support by BPM. Similarly, diets containing BPM significantly increased plucked weight and dressing percentage (90.55%, 63.66%) when compared with BCLM (86.68, 57.94%). [12] demonstrated that swine manure digestate contains higher concentrations of soluble amino acids post-digestion, boosting protein retention in poultry diets and subsequently improving carcass yields. In addition, [13] reported that broilers on bio digested pig manure diets converted feed protein into muscle more efficiently; raising dressing percentages by up to 10% relative to those on poultry based digestates.

Result revealed that the values of cut parts for neck (13.73%), thigh (10.08%) and back (13.73%) were significantly higher in BPM when compared with values obtained for BCLM. According to [12], anaerobic digestion of pig manure breaks down complex proteins into soluble peptides and free amino acids especially lysine and methionine, which are critical for muscle protein synthesis. Analyses reveal pig manure digestate contains higher levels of these key amino acids compared to poultry manure digestate and these amino acids fuel myofibrillar growth in major muscle groups like the neck, thigh, and back. The significantly improved values obtained for neck, thigh and back in this study coincides with the report of [14 and 15] who recorded higher values for thigh and back for broilers fed bio digested pig manure when compared with those fed bio digested cage layer manure. Gizzard weight was significantly higher in BCLM (3.04g) when compared to values obtained for BCLM (2.81%). [16] carried out a comprehensive compositional analysis of biogas digestates from different feedstocks and reported that pig manure digestate contained significantly higher neutral detergent fiber and ash fractions than poultry manure digestate. The elevated neutral detergent fibre (cellulose and hemicellulose) and mineral-rich ash act as insoluble particles, effectively serving as natural grit and increasing the mechanical workload and thus hypertrophy of the gizzard wall in birds. In addition, [17] reported that birds that consume high fiber agricultural byproducts developed significantly heavier gizzards to accommodate the increased grinding demands. The small intestine was significantly higher in birds raised on

BCLM (8.65g) when compared to birds raised on BPM (6.86g). According to [18] zinc availability in BCLM is two to three times higher in BCLM when compared to BPM and diets rich in zinc produce 15–25% increase in villus height and subsequently resulting in overall gut weight gain in poultry birds. This result coincides with the report of [19] who reported a reduced gut hypertrophic response in BPM-fed broilers.

Varying inclusion levels (0, 10 and 20%) of bio-digested pig manure had and bio digested cage layer manure had no significant effect on all carcass traits examined in this study. This suggests that even low inclusion rates of bio-digested organic manure meet the nutrient thresholds for cockerel growth. This finding corroborates the result of [20] who reported minimal differences in carcass metrics beyond a 10% inclusion of organic residues in poultry diets.

The interactive effect of bio digested cage layer manure and bio digested pig manure on the carcass traits of growing cockerels is presented in Table 3

The interaction of BCLM, BPM, and levels of inclusion significantly influenced the values obtained for plucked weight and dressing percentage. Birds on 20% BPM recorded the highest dressing percentage (66.97%), whereas those fed 20% BCLM showed the lowest (54.90%). The significant increase recorded in birds on 20% BPM aligns with the result of [21], who reported that inclusion of bio digested pig manure improved feather removal efficiency and skin condition in broilers, likely due to enhanced keratin bioavailability in bio digested pig manure. Dressing percentage improved significantly with increasing BPM. Birds receiving 20% BPM achieved 66.97% compared to 54.90% for 20% BCLM. The higher dressing percentage recorded under BPM agrees with [22] who reported that pig manure based diet can boost dressed yield by enhancing gut health and nutrient absorption. Neck and back were highest in birds on 20% BPM. This finding supports the report of [23] who opined that organic waste–based feedstuffs can redistribute muscle accretion favorably in peripheral cuts, especially in the neck region. This enhanced muscle development in the neck and back cuts aligns with the report of [24] who stated that bio-digested organic-based diets improve amino acid availability, leading to enhanced protein synthesis in target muscle groups. In addition, these variations suggest that manure type influences skeletal muscle development patterns, with BPM demonstrating superior effects on structural muscle mass accumulation. Birds on 20% BCLM had a significantly lower value for wing (8.23%) while no significant difference was observed in values recorded for all other treatments.

Table 2: Main effect of bio digested caged layer and pig manure and levels of inclusion on carcass quality of growing cockerels

	Bio-digested Manure				Levels of inclusion				
Parameter	**BCLM**	**BPM**	**SEM**	**PVALUE**	**0%**	**10%**	**20%**	**SEM**	**PVALUE**
Plucked weight (%)	86.68[b]	90.55[a]	1.40	0.0622	88.41	88.54	88.87	1.72	0.9819
Dressing percentage	57.94[b]	63.66[a]	1.47	0.0053	60.71	60.77	60.93	1.80	0.9952
Cut part[1] (%)									
Head	3.97	3.89	0.13	0.6638	3.89	4.09	3.81	0.16	0.4546
Neck	4.31[b]	4.91[a]	0.20	0.0354	4.43	4.64	4.77	0.24	0.5907
Shank	5.11	5.12	0.11	0.9403	5.03	5.14	5.18	0.13	0.7162
Wings	8.9	9.37	0.18	0.0742	9.24	9.18	8.98	0.22	0.6909
Breast	12.38	13.51	0.54	0.1580	12.59	13.67	12.58	0.66	0.4358
Thigh	9.11[b]	10.08[a]	0.24	0.0054	9.76	9.62	9.39	0.30	0.6353
Drumstick	9.01	9.49	0.20	0.0945	9.19	9.39	9.17	0.25	0.7716
Back	12.4[b]	13.73[a]	0.37	0.0098	13.50	12.63	13.08	0.46	0.3446
Organs (%)									
Liver	2.04	2.00	0.09	0.6832	1.95	1.97	2.14	0.11	0.3630
Gizzard	2.81[b]	3.04[a]	0.07	0.0129	2.88	2.98	2.92	0.08	0.6879
Heart	0.43	0.46	0.02	0.2991	0.45	0.47	0.42	0.02	0.4208
Lung	0.64	0.66	0.03	0.7330	0.66	0.64	0.65	0.04	0.8771
Spleen	0.20	0.22	0.02	0.5623	0.21	0.20	0.23	0.02	0.5879
Caecum	1.09	1.02	0.08	0.5606	1.00	1.04	1.13	0.09	0.5810
Small intestine	8.65[a]	6.86[b]	0.55	0.0133	7.68	7.95	7.64	0.67	0.9215
Large intestine	0.35	0.39	0.06	0.4822	0.39	0.38	0.31	0.07	0.6364

a,b;Means in the same row with different superscripts differ significantly($P<0.05$)

1,2:Expressed as percentages of the live weight

SEM:Standard Error of the Mean

BCLM: Biodigested caged-layer manure BPM: Biodigested pig manure

Table 3: Effect of interaction between caged layer and pig manure and levels of interaction on carcass quality of cockerels

Biodigested Manure		BCLM			BPM			
Levels of inclusion	**0%**	**10%**	**20%**	**0%**	**10%**	**20%**	**SEM**	**P-VALUE**
Parameter								
Plucked weight(%)	88.41[ab]	88.62[ab]	82.96[b]	88.41[ab]	88.46[ab]	94.77[a]	2.43	0.0503
Dressing percentage	60.71[abc]	58.22b[c]	54.90[c]	60.71[abc]	63.32[ab]	66.97[a]	2.54	0.0304
Cut part %								
Head	3.89	4.31	3.71	3.89	3.87	3.91	0.22	0.5669
Neck	4.43[ab]	4.32[ab]	4.19[b]	4.43[ab]	4.96[ab]	5.35[a]	0.34	0.0246
Shank	5.03	5.31	4.99	5.03	4.98	5.36	0.19	0.5467
Wings	9.24[a]	9.21[a]	8.23[b]	9.24[a]	9.14[a]	9.73[a]	0.31	0.0599
Breast	12.59	12.92	11.62	12.59	14.41	13.54	0.94	0.4442
Thigh	9.76[a]	9.17[ab]	8.39[ab]	9.76[a]	10.08[a]	10.38[a]	0.42	0.0189
Drumstick	9.19	9.20	8.64	9.19	9.59	9.71	0.35	0.3315
Back	13.49[ab]	12.08[b]	11.62[b]	13.49[ab]	13.16[ab]	14.53[a]	0.64	0.0205
Organs %								
Liver	1.95	2.11	2.07	1.95	1.82	2.21	0.15	0.5006
Gizzard	2.88[bc]	2.99[ab]	2.55[c]	2.88[bc]	2.96[ab]	3.29[a]	0.12	0.0027
Heart	0.45	0.47	0.37	0.45	0.46	0.47	0.03	0.2951
Lung	0.66	0.65	0.61	0.66	0.62	0.69	0.05	0.9346
Spleen	0.21	0.17	0.23	0.21	0.22	0.23	0.03	0.8164
Caecum	1.00	0.98	1.28	1.00	1.09	0.98	0.13	0.5384
Small intestine	7.68	9.47	8.79	7.68	6.42	6.48	0.95	0.0861
Large Intestine	0.39	0.28	0.35	0.39	0.49	0.28	0.10	0.5114

a,b,c: Means in the same row with different superscripts differ significantly($P<0.05$)
1,2: Expressed as percentages of the live weight
SEM: Standard Error of the Mean
BCLM: Bio-digested caged-layer manure
BPM: Bio-digested pig manure

The significantly lower value for birds on 20% BCLM may be attributed to the high fiber content of the diet at 20% level of inclusion, which had a dilution effect on nutrient availability. This result is in consonance with the findings of [25] who reported reduced wing muscle development when broilers consumed high-fiber poultry manure diet. Thigh percentage increased under all BPM inclusion levels peaking at 10.38% for 20% BPM. This enhanced thigh yield is consistent with [26], who found that pig manure residues rich in microbial enzymes improve thigh muscle deposition in cockerels. Gizzard weight was significantly influenced by the interaction of BCLM, BPM at different inclusion levels. Birds on 20% BPM recorded the highest weight of 3.29g while birds on 20% BCLM had the lowest weight of 2.55%. Report by [27] confirmed that BPM had a higher fiber and beneficial microbial flora content when compared to BCLM. Therefore, the elevated gizzard weight recorded in 20% BPM could be due to the high dietary fiber and microbial biomass present in BPM. The result of this present study corroborates findings by [28] that organic manure fed chickens develop heavier gizzards and superior feed conversion. Other organ weights (liver, heart, lung, spleen, caecum, intestines) were not influenced by the interaction between BCLM, BPM and the levels of inclusion. This indicates that neither BCLM nor BPM inclusion at tested levels induced organ hypertrophy or pathology. This result aligns with the report of [29], who found no adverse organ changes in broilers fed composted manures

The main effect of bio digested cage layer manure, bio digested pig manure and level of inclusion on the blood profile of growing cockerels is presented in Table 4

Bio-digested cage layer manure and bio digested pig manure did not have significant influence on values recorded for packed cell volume, red blood cell, hemoglobin and white blood cell. Packed cell volume, haemoglobin and red blood cell counts in both BCLM and BPM treatments fell within established reference intervals for poultry birds (PCV: 27–45%; Hb: 8–12 g/dL; RBC: 2.0–3.0 $\times 10^{12}$/L) as reported by [30]. The non-significant difference observed in BCLM and BPM suggests that replacing conventional feed with up to 20% of BCLM and BPM does not impair erythropoiesis. [31] similarly reported stable values for packed cell volume, red blood cell and haemogobin parameters in broilers fed organic waste–based diets. In addition, [30] explained that fermented substrates promote red blood cell integrity by boosting antioxidant status in poultry.

Results obtained for white blood cell and its differentials (neutrophils, lymphocytes, eosinophils and basophils) were not significantly affected by BCLM and BPM. Total white blood cell counts and differential leukocyte proportions remained within normal ranges (WBC: 12–30 $\times 10^{9}$/L; heterophils: 30–60%; lymphocytes: 20–50%; monocytes: 1–4%; eosinophils: 1–4%; basophils: 0–1%) as reported by [30]. According to [32] white blood cells or leukocytes, are the cornerstone of the poultry immune system, serving as both sentinels and effectors in the bird's defense against infectious and non-infectious challenges. The non-significant differences observed in the values observed for white blood cell and its differentials suggests that supplementing BCLM and BPM in cockerels' diet will not adversely affect the bird's ability to fight diseases and infections. Basophil values was significantly reduced in BCLM (0.33%) when compared to BPM (0.44%) The significant reduction in basophils for BCLM-fed birds could reflect a lower allergenic or pro-inflammatory load in bio digested caged-layer manure compared to pig manure. Basophils participate in hypersensitivity reactions, and their suppression may signal a milder immune challenge in BCLM diets. [33] observed comparable basophil decreases in broilers receiving fermented poultry litter, linking it to reduced toxin exposure.

Eosinophil and basophil counts decreased significantly with increasing inclusion levels from 0% to 20%. The significant decline in eosinophils—dropping from 3.67% (0% inclusion) to 1.17% (20% inclusion) and basophils (1.00% to 0.00%) with higher manure inclusion likely reflects reduced parasitic and allergic response. This result corroborates the assertion of [34] who stated that bio-digestion lowers pathogen and helminth loads in manure. Furthermore, [35] observed a 30% reduction in eosinophil counts in hens fed naturally fermented diets attributing this reduction to decreased parasitic loads. While [33] found basophil suppression in broilers consuming bio-digested poultry litter, linking it to diminished hypersensitivity responses.

Total protein and globulin increased significantly as levels of inclusion increased from 0% to 20%. The Elevations observed in total protein and globulin with increasing inclusion levels point to enhanced immunoglobulin synthesis. [36] showed that anaerobic digestion of livestock manure increased the levels of readily available nitrogenous compounds and essential amino acids by over 40%, which when included in broiler rations led to upregulated hepatic protein synthesis and improved serum albumin and globulin concentrations. The result of this present study is in tandem with the findings of [30] who reported that broilers on fermented organic substrates had a significantly higher serum globulin. In addition, [30] connected the improved globulin levels to increased bioavailable amino acids in fermented feedstuffs, supporting robust hepatic protein synthesis toward immune functions. This result indicates that BCLM (2.59g/dm) had a significantly depressed globulin when compared with BCLM (2.50g/dm). According to [36], pig manure typically contains greater amounts of non-protein nitrogen and free amino acids after anaerobic digestion. These bioavailable nitrogenous compounds serve as direct precursors for hepatic immunoglobulin synthesis, driving up circulating globulin levels.

The interactive effect of bio digested cage layer manure and bio digested pig manure and the levels of inclusion is presented in Table 5

The interaction between BCLM, BPM and the levels of inclusion did not have any influence on values obtained for packed cell volume, haemoglogin, red blood cell, white blood cell neutrophil, lymphocyte and monocyte percentages. This non-significant effect on these haematological indices confirms that up to 20% inclusion of either bio-digested cage layer manure or bio digested pig manure does not impair erythropoiesis or leukopoiesis process in growing cockerels. This result aligns with [31] who reported that administering organic waste-based diets to broilers did not adversely influence packed cell volume, haemoglobin and white blood cell values in broilers. Values obtained for Eosinophil declined significantly with increased inclusion levels of both BCLM and BPM. This reduced trend in eosinophil at suggests that at higher inclusion levels parasitic antigens declines. [34] explains that anaerobic bio digestion effectively inactivates helminth eggs and protozoan cysts thereby lowering gut antigenic load and subsequently having a positive impact on eosinophil values.

Basophil recorded the lowest value at 10% BCLM and 20% BCLM inclusion level with both having 0.00% respectively. Basophil suppression in BCLM at 10% inclusion suggests caged-layer digestate has fewer endotoxin and pro-allergic residues compared to pig digestate. These findings support the result of [33], who linked higher basophil counts in broilers to endotoxin-rich pig manure digestate. Total protein and globulin values were significantly highest at 10% BPM (6.36g/dm, 3.09g/dm) while birds on 10% BCLM had a slightly reduced values for total protein and globulin (6.29/dm, 2.88g/dm). However, birds on control diet recorded the lowest total protein and globulin. The pronounced increase in total protein and globulin at 10% inclusion underscores an optimal balance of bioavailable nitrogen and amino acids fueling hepatic synthesis of immunoglobulins. [36] demonstrated that bio digested manure supplies over 40% more free amino acids than conventional feed, enhancing humoral protein production. Furthermore, it was observed birds on 20% inclusion level for both BCLM and BPM recorded significantly lower values for total protein and globulin respectively. According to [30] exceeding a particular threshold in the inclusion of bio digested manure in the diet of poultry birds, may introduce some anti-nutritional factors or dilute key nutrients which limits further hepatic synthesis. This result suggests that exceeding the 10% threshold for both BCLM and BPM may affect liver functions.

CONCLUSION

1. The inclusion of bio-digested pig manure (BPM) in growing cockerel diets significantly improved carcass yields compared to bio-digested cage layer manure (BCLM).
2. Birds fed BPM recorded higher plucked weights, and dressing percentages, as well as increased proportions of key cuts (neck, thigh, back), underscoring the superior protein and amino acid profile of pig digestate. In addition, organ health was not adversely influenced by the inclusion of up to 20% BCLM and BPM
3. Neither the source of digestate nor inclusion levels (up to 20%) adversely affected haematological indices. However, blood serum proteins (total protein, globulin) improved at 10% inclusion, suggesting that moderate digestate levels enhanced nutrient utilization and immune functions.

Table 4: Main effect of bio-digested caged-layer and pig manure and levels of inclusion on haematological and serum parameters of growing cockerels

	Bio-digested Manure				Levels of inclusion				
Parameter	**BCLM**	**BPM**	**SEM**	**PVALUE**	**0%**	**10%**	**20%**	**SEM**	**PVALUE**
Packed Cell Volume (%)	27.33	28.11	0.56	0.4150	27.33	27.67	28.17	0.68	0.7561
Haemoglobin(g/dl)	9.11	9.37	0.19	0.4150	9.11	9.22	9.39	0.23	0.7561
Red Blood Cell($X10^{12/l}$)	2.63	2.74	0.08	0.3590	2.82	2.56	2.67	0.10	0.2322
White Blood Cell($10^{9/l}$)	27.22	24.39	1.35	0.2255	26.5	25.47	25.45	1.65	0.9007
Neutrophils(%)	25.44	22.67	2.64	0.4422	21.33	24.17	26.67	3.23	0.4801
Lymphocytes(%)	69.44	72.22	2.59	0.4601	71.33	71.50	69.67	3.17	0.8987
Monocytes(%)	2.44	2.44	0.83	1.0000	2.67	2.17	2.50	1.02	0.9585
Eosinophils(%)	2.33	2.22	0.56	0.8544	3.67^{a}	2.00^{ab}	1.17^{b}	0.68	0.0268
Basophils(%)	0.33^{b}	0.44^{a}	0.21	<0.0001	1.00^{a}	0.17^{b}	0.00^{c}	0.26	<0.0001
Total protein(g/dl)	5.96	5.95	1.67	<0.0001	5.33^{c}	6.23^{b}	6.33^{a}	2.04^{c}	<0.0001
Albumin(g/dl)	3.46	3.38	0.83	0.4633	3.59	3.34	3.32	1.02	0.1356
Globulin(g/dl)	2.50^{a}	2.59^{b}	0.24	<0.0001	1.74^{c}	2.91^{b}	2.98^{a}	0.16	<0.0001

a,b,c;Means in the same row with different superscripts differ significantly(P<0.05), SEM: Standard Error of the Mean, BCLM: Bio-digested caged-layer manure, BPM: Bio-digested pig manure

Table 5: Effect of interaction between caged-layer and pig manure and levels of inclusion on haematological and serum parameters of growing cockerels

Biodigested Manure	**BCLM**			**BPM**				
Levels of inclusion	**0%**	**10%**	**20%**	**0%**	**10%**	**20%**	**SEM**	**PVALUE**
Parameter								
Packed Cell Volume (%)	27.33	26.00	28.67	27.33	29.33	27.67	0.96	0.4299
Haemoglobin (g/dl)	9.11	8.67	9.56	9.11	9.78	9.22	0.32	0.4299
Red Blood Cell ($X10^{12/l}$)	2.82	2.34	2.72	2.82	2.77	2.63	0.14	0.2487
White Blood Cell ($X10^{9/l}$)	26.50	28.27	26.90	26.50	22.67	24.00	2.34	0.6867
Neutrophils (%)	21.33	25.67	29.33	21.33	22.67	24.00	4.57	0.7415
Lymphocytes(%)	71.33	69.33	67.67	71.33	73.67	71.67	4.49	0.9392
Monocytes(%)	2.67	2.67	2.00	2.67	1.67	3.00	1.44	0.9927
Eosinophils(%)	3.67^{a}	2.33^{ab}	1.00^{b}	3.67^{a}	1.67^{ab}	1.33^{ab}	0.96	0.0553
Basophils(%)	1.00^{a}	0.00^{c}	0.00^{c}	1.00^{a}	0.33^{b}	0.00^{c}	0.36	<0.0001
Total Protein(g/dl)	5.33^{e}	6.29^{b}	6.25^{c}	5.33^{e}	6.36^{a}	6.20^{d}	2.89	<0.0001
Albumin(g/dl)	3.59	3.42	3.37	3.59	3.27	3.27	1.44	0.3743
Globulin(g/dl)	1.74^{e}	2.88^{d}	2.88^{c}	1.74^{e}	3.09^{a}	2.93^{b}	0.25	<0.0001

a,b;Means in the same row with different superscripts differ significantly(P<0.05), SEM: Standard Error of Mean, BCLM:Bio-digested caged-layer manure, BPM:Bio-digested pig manure

APPLICATION

In consequence, bio-digested manures can replace conventional protein sources in the diet of cockerel up to 20% without compromising health and carcass traits. Although BPM demonstrated greater efficacy in carcass traits. Therefore, adopting these digestates supports sustainable waste recycling and reduces the pressure on conventional feed ingredients.

DECLARATION

The authors hereby declare that this manuscript is an original work and has neither been published elsewhere nor is it currently under consideration for publication by any other journal. All authors have read and approved the final version of the manuscript and agree to its submission.

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STATEMENT OF ANIMAL RIGHTS

All procedures involving animals in this study were conducted in strict accordance with ethical standards for animal welfare and care. The experimental protocol was reviewed and approved by directorate of university farms of the Federal University of Agriculture, Abeokuta. Birds were housed under hygienic conditions, provided with adequate feed and water, and monitored daily to ensure their health and well-being. Humane slaughter methods were also employed following standard guidelines to minimize pain and distress.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this research

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