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Blood Responses of Broilers to Cassava Peel Meal–Palm Oil Sludge Diets

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Abstract

The increasing cost and competition for conventional energy feedstuffs such as maize have intensified the search for locally available agro-industrial by-products for poultry feeding. This study evaluated the effects of graded dietary inclusion of an enzyme-supplemented cassava peel meal–palm oil sludge mixture (CPMPOS+E) on haematological indices and serum lipid profile of broiler chickens. Ninety-six broiler chickens were allotted to three dietary treatments containing 0%, 22.5% and 25.0% CPMPOS+E, respectively, in a completely randomised design. Each treatment was replicated four times with eight birds per replicate. The feeding trial lasted 56 days. At the end of the experiment, blood samples were collected from two birds per replicate for determination of haematological indices and serum lipid profile. Data were analysed using one-way analysis of variance, and treatment means were separated using Duncan's multiple range test at the 5% probability level. Dietary treatment significantly affected packed cell volume, haemoglobin concentration, red blood cell count, white blood cell count, mean corpuscular volume, mean corpuscular haemoglobin concentration, heterophil percentage, total cholesterol, low-density lipoprotein cholesterol and very-low-density lipoprotein cholesterol ($p < 0.05$). Mean corpuscular haemoglobin, lymphocyte, monocyte, eosinophil and basophil percentages, triglycerides and high-density lipoprotein cholesterol were not significantly affected ($p > 0.05$). Total cholesterol decreased from 96.26 mg/dL in the control diet to 92.83 and 93.21 mg/dL in the 22.5% and 25.0% CPMPOS+E diets, respectively. Similarly, LDL-C declined from 17.20 to 15.09 and 13.20 mg/dL. These findings suggest that inclusion of CPMPOS+E at the evaluated levels did not produce broad adverse alterations in the measured blood indices and was associated with lower serum total cholesterol and LDL-C relative to the control. However, the decline in dietary crude protein and metabolisable energy across the experimental diets warrants consideration when interpreting the physiological responses. Further studies using nutritionally isoenergetic and isonitrogenous diets, together with direct determination of residual hydrogen cyanide and nutrient digestibility, are recommended.

Keywords: broiler chickens; cassava peel meal; palm oil sludge; haematology; serum lipid profile; cholesterol; alternative feedstuffs.

INTRODUCTION

The rapid expansion of poultry production in developing countries has increased demand for energy- and protein-rich feed ingredients. Feed cost remains one of the major constraints to profitable poultry production because conventional ingredients, particularly maize and soybean meal, are also required for human consumption and industrial purposes. Consequently, the identification and effective utilisation of locally available agricultural and agro-industrial

by-products have become important strategies for reducing feed costs and improving the sustainability of poultry production.

Cassava (*Manihot esculenta* Crantz) is an important tropical root crop whose processing generates substantial quantities of peels. Cassava peel constitutes an important proportion of the root and is frequently discarded or inadequately utilised. Cassava by-products contain substantial amounts of carbohydrate and can therefore contribute energy to animal diets. However, their use in poultry diets is constrained by

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relatively high fibre content, low protein concentration, nutrient imbalance and the presence of cyanogenic glycosides, particularly linamarin and lotaustralin, which can release hydrogen cyanide (HCN) when plant tissues are disrupted.

Processing is therefore central to the safe utilisation of cassava by-products. Sun-drying, fermentation, ensiling and other treatments can reduce cyanogenic compounds and improve the feeding value of cassava-derived feed ingredients. Recent evidence indicates that processing method, cassava cultivar, inclusion level, diet composition and enzyme supplementation can substantially influence the response of broilers to cassava peel meal.

Palm oil sludge (POS) is another agro-industrial by-product with potential as an energy feed ingredient. It is generated during palm-oil processing and contains appreciable amounts of residual oil, although its relatively high fibre content and limitations in nutrient digestibility may restrict its direct use in poultry diets. Processing or fermentation has been investigated as a means of improving its nutritional value. Studies involving broilers have demonstrated that palm oil sludge can replace a proportion of conventional energy sources under appropriate dietary formulations.

Blood characteristics are useful indicators of the physiological and health responses of poultry to dietary treatments. Haematological variables such as packed cell volume (PCV), haemoglobin (Hb), red blood cell (RBC) count and white blood cell (WBC) count provide information about erythropoietic status, oxygen transport and immune function. Similarly, serum lipid variables provide information about lipid metabolism and may respond to differences in dietary energy sources and fatty-acid composition.

Previous research has demonstrated that cassava-derived feed ingredients can influence haematological characteristics of broilers, although responses vary according to processing method and dietary inclusion level. For example, studies on cassava peel meal have reported changes in selected haematological and serum biochemical parameters, while recent reviews indicate that high inclusion levels may adversely affect blood indices when residual HCN, fibre and other antinutritional factors are not adequately controlled.

Palm oil sludge has likewise attracted attention as a potential alternative energy source. Onibi et al. reported that replacing part of the maize-derived energy with palm oil sludge influenced haematological indices and serum cholesterol in broilers, demonstrating the relevance of POS to blood physiological responses. More recently, studies have specifically examined CPMPOS mixtures in broiler diets, although reported responses have not always been consistent.

Despite these studies, there remains a need for additional evidence on the physiological consequences of relatively high dietary inclusion of a cassava peel meal–palm oil sludge mixture, particularly when the mixture is enzyme supplemented. The present study therefore evaluated the effects of graded inclusion of CPMPOS+E on selected

haematological indices and serum lipid profile of broiler chickens.

Materials and Methods

Experimental site

The experiment was conducted at the Poultry Unit of the Teaching and Research Farm of Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. The experimental location lies within the humid rainforest zone of southeastern Nigeria at approximately 05°29'N latitude and 07°33'E longitude and approximately 122 m above sea level. The area is characterised by a warm, humid tropical climate.

Experimental birds and management

Ninety-six broiler chickens were used for the 56-day feeding trial. The birds were obtained from a reputable commercial source and transported to the experimental facility during the cooler period of the day to minimise transportation-associated stress.

The birds were randomly allocated to three dietary treatments, each replicated four times with eight birds per replicate, giving 32 birds per treatment. The experimental design was completely randomised.

Birds were provided feed and drinking water ad libitum throughout the experimental period. Standard brooding and routine management practices were adopted throughout the study.

Processing of cassava peel meal

Cassava peels obtained from a local cassava-processing facility were washed and sun-dried to reduce moisture and cyanogenic compounds. The dried peels were subsequently milled and stored in airtight bags until incorporation into the experimental diets.

The use of drying as a processing strategy is particularly important because cassava cyanogenic glycosides can release HCN, and appropriate processing is therefore necessary before incorporation into poultry diets.

Palm oil sludge

Palm oil sludge was obtained from a local palm oil processing mill and stored appropriately before incorporation into the experimental diets.

Experimental diets

Three experimental diets were formulated for the broiler starter and finisher phases. The control diet contained no CPMPOS+E, whereas the experimental diets contained 22.5% and 25.0% CPMPOS+E, respectively.

The composition of the diets supplied in the thesis is presented in Tables 1 and 2.

Table 1. Composition and calculated nutrient content of broiler starter diets

Ingredient (%)	T1	T2	T3

Ingredient (%)	T1	T2	T3
Maize	55.50	32.50	30.00
Palm kernel cake	3.00	3.00	3.00
Soybean meal	29.00	29.00	29.00
CPMPOS+E	0.00	22.50	25.00
Wheat offal	2.00	2.00	2.00
Brewer's grain	4.00	4.00	4.00
Fish meal	5.00	5.00	5.00
Bone meal	3.00	3.00	3.00
Lysine	0.25	0.25	0.25
Methionine	0.25	0.25	0.25
Salt	0.25	0.25	0.25
Vitamin premix	0.25	0.25	0.25
Total	100	100	100
Crude protein (%)	22.26	20.40	20.16
ME (kcal/kg)	2977.1	2661.2	2626.1

CPMPOS+E = enzyme-supplemented cassava peel meal blended with palm oil sludge; ME = metabolisable energy.

Table 2. Composition and calculated nutrient content of broiler finisher diets

Ingredient (%)	T1	T2	T3
Maize	60.00	37.50	35.00
Palm kernel cake	3.00	3.00	3.00
Soybean meal	22.00	22.00	22.00
CPMPOS+E	0.00	22.50	25.00

Ingredient (%)	T1	T2	T3
Wheat offal	2.00	2.00	2.00
Brewer's grain	4.00	4.00	4.00
Fish meal	5.00	5.00	5.00
Bone meal	3.50	3.50	3.50
Lysine	0.25	0.25	0.25
Methionine	0.25	0.25	0.25
Salt	0.25	0.25	0.25
Vitamin premix	0.25	0.25	0.25
Total	100	100	100
Crude protein (%)	22.26	20.40	20.16
ME (kcal/kg)	2977.1	2661.2	2626.1

Blood collection

At the end of the 56-day feeding period, blood samples were collected from two birds selected from each replicate. Samples intended for haematological analysis were collected into appropriate anticoagulant-containing tubes, while samples for serum biochemical analysis were processed to obtain serum.

The samples were transported to the designated laboratory for determination of haematological indices and serum lipid profile.

Haematological analysis

The following haematological parameters were determined:

- packed cell volume (PCV);
- haemoglobin concentration (Hb);
- red blood cell count (RBC);
- white blood cell count (WBC);
- mean corpuscular volume (MCV);
- mean corpuscular haemoglobin (MCH);
- mean corpuscular haemoglobin concentration (MCHC);
- lymphocytes;
- heterophils;
- monocytes;
- eosinophils; and
- basophils.

The procedures were based on established haematological methods described by Mitruka and Rawnsley.

Serum lipid profile

Serum samples were analysed for:

- total cholesterol;
- triglycerides;
- high-density lipoprotein cholesterol (HDL-C);
- low-density lipoprotein cholesterol (LDL-C); and
- very-low-density lipoprotein cholesterol (VLDL-C).

Statistical analysis

Data were analysed using one-way analysis of variance (ANOVA) appropriate for a completely randomised design.

Where significant treatment effects were detected, treatment means were separated using Duncan's multiple range test at $p < 0.05$. Duncan's multiple-range procedure was originally described by Duncan (1955). Statistical analyses were performed using IBM SPSS Statistics.

The general statistical model was:

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

Results

Haematological responses

The effects of dietary CPMPOS+E on the haematological indices of broiler chickens are presented in Table 3.

Table 3. Haematological indices of broiler chickens fed graded levels of CPMPOS+E

Parameter	T1 (0%)	T2 (22.5%)	T3 (25.0%)	SEM
PCV (%)	28.00 ^a	25.33 ^b	27.00 ^a	0.43
Hb (g/dL)	10.90 ^{ab}	10.33 ^b	11.06 ^a	0.15
RBC ($\times 10^6$ /dL)	3.20 ^a	3.03 ^b	3.20 ^a	0.03
WBC ($\times 10^6$ /mm ³)*	20.71 ^b	21.15 ^b	22.55 ^a	0.03
MCV (fL)	87.49 ^a	83.42 ^b	84.21 ^b	0.72
MCH (pg)	34.06	34.03	33.88	0.07
MCHC (g/dL)	38.93 ^b	40.80 ^a	40.24 ^{ab}	0.34
Lymphocytes (%)	60.33	60.00	61.33	0.29
Heterophils (%)	31.00 ^{ab}	32.00 ^a	29.33 ^b	0.46
Monocytes (%)	6.33	5.67	6.00	0.24
Eosinophils (%)	2.00	2.33	3.33	0.29
Basophils (%)	0.33	0.00	0.00	0.11

Different superscripts within a row indicate significant differences at $p < 0.05$.

Dietary treatment significantly affected PCV, Hb, RBC, WBC, MCV, MCHC and heterophil percentage ($p < 0.05$). PCV was highest in T1 (28.00%) and T3 (27.00%), whereas T2 had the lowest value (25.33%). Haemoglobin concentration was highest in T3 (11.06 g/dL), intermediate in T1 (10.90 g/dL), and lowest in T2 (10.33 g/dL). RBC count followed a similar pattern, with T1 and T3 recording comparable values that exceeded that of T2.

WBC count was highest in T3 (22.55) and differed significantly from T1 and T2. MCV was highest in the control group (87.49 fL), whereas T2 and T3 recorded lower values. MCH was not significantly affected. MCHC differed significantly among treatments, with the highest numerical value recorded in T2.

The differential leukocyte counts showed that heterophil percentage was significantly affected, whereas lymphocyte, monocyte, eosinophil and basophil percentages were not significantly affected.

Serum lipid profile

The serum lipid responses are shown in Table 4.

Table 4. Serum lipid profile of broiler chickens fed graded levels of CPMPOS+E

Parameter	T1 (0%)	T2 (22.5%)	T3 (25.0%)	SEM
Total cholesterol (mg/dL)	96.26 ^a	92.83 ^b	93.21 ^b	0.56
Triglycerides (mg/dL)	7.247	70.70	71.63	0.37
HDL-C (mg/dL)	64.17	64.75	65.05	0.29

Parameter	T1 (0%)	T2 (22.5%)	T3 (25.0%)	SEM
LDL-C (mg/dL)	17.20 ^a	15.09 ^b	13.20 ^b	0.58
VLDL-C (mg/dL)	14.52 ^a	14.13 ^b	14.29 ^{ab}	0.07

Total cholesterol, LDL-C and VLDL-C were significantly affected by dietary treatment ($p < 0.05$). Total cholesterol decreased from 96.26 mg/dL in T1 to 92.83 and 93.21 mg/dL in T2 and T3, respectively. LDL-C similarly declined from 17.20 mg/dL in the control group to 15.09 and 13.20 mg/dL in T2 and T3. VLDL-C was highest in T1 and lowest in T2, while T2 and T3 did not differ significantly.

Triglyceride and HDL-C concentrations were not significantly affected by dietary treatment.

Discussion

Haematological responses

Haematological measurements provide useful indicators of the physiological condition of poultry and can assist in evaluating whether a dietary treatment imposes adverse or beneficial effects on erythropoiesis, oxygen transport and immune status. In the present study, dietary inclusion of CPMPOS+E significantly affected PCV, Hb, RBC, WBC, MCV, MCHC and heterophil percentage, whereas MCH and most differential leukocyte parameters were unaffected.

The reduction in PCV and RBC count observed in T2 relative to the control is noteworthy. Nevertheless, the response was not progressive because birds receiving 25% CPMPOS+E recorded PCV and RBC values comparable to the control. This suggests that the physiological response was not simply a linear consequence of increasing CPMPOS+E inclusion. Such variation may arise from differences in nutrient density, nutrient availability, processing efficiency and interactions among the ingredients (Akapo et al., 2014).

Cassava by-products are attractive energy resources but contain nutritional limitations that include relatively high fibre, low protein concentration and potentially residual cyanogenic compounds. These limitations can influence nutrient utilisation when inclusion levels are high. Recent evidence suggests that inclusion levels exceeding approximately 20% CPM may be associated with poorer physiological or performance responses in some broiler studies, although the response varies substantially with processing and dietary formulation. (Bakare et al., 2021).

The relatively high inclusion levels used in the present experiment therefore warrant careful interpretation. Importantly, the experimental diets were not nutritionally equivalent: calculated crude protein declined from 22.26% in the control diet to 20.40% and 20.16% in the experimental diets, while metabolisable energy declined from 2977.1 to 2661.2 and 2626.1 kcal/kg. Consequently, some of the observed blood responses may reflect changes in overall nutrient density rather than the biological effect of CPMPOS+E alone.

The WBC response, which was highest at 25% CPMPOS+E, may indicate an alteration in immune or inflammatory status. However, WBC counts should not be interpreted in isolation, because leukocyte responses are influenced by age, stress, environmental conditions, infection and nutritional status. The absence of significant differences in lymphocytes, monocytes, eosinophils and basophils provides some evidence that the dietary treatments did not cause broad disruption of the differential leukocyte profile.

The findings are broadly consistent with evidence that processed cassava by-products can be incorporated into poultry diets without necessarily producing pathological changes in blood indices. Previous Nigerian studies have reported measurable haematological responses to cassava peel meal diets, although the magnitude and direction of effects have varied among experiments. (Ilo et al., 2024).

Palm oil sludge may also contribute energy to poultry diets. Previous work has shown that POS can replace a proportion of maize-derived energy without necessarily producing detrimental effects on broiler performance or carcass characteristics, although its high fibre content and relatively low digestibility can limit its utilisation. (Ogbuokiri, et al., 2018).

Thus, the present findings indicate that CPMPOS+E at the tested levels did not cause uniform deterioration of the measured haematological profile. However, the results should be described as evidence of physiological tolerance under the experimental conditions, rather than definitive proof that the ingredients are completely free of adverse effects.

Serum lipid responses

Dietary CPMPOS+E significantly affected total cholesterol, LDL-C and VLDL-C, whereas triglycerides and HDL-C were unaffected.

An important observation was the reduction in total cholesterol in both CPMPOS+E diets relative to the control. Total cholesterol decreased by approximately 3.6% in T2 and 3.2% in T3 relative to T1. LDL-C showed a more pronounced reduction, declining by approximately 12.3% in T2 and 23.3% in T3 relative to the control. This pattern suggests that inclusion of the CPMPOS+E mixture was associated with a modest reduction in circulating cholesterol, particularly LDL-C.

The reduction in serum cholesterol is biologically interesting because dietary lipid composition and energy supply can influence lipid metabolism in poultry. Palm oil sludge contains residual oil and therefore contributes lipid to the diet, while cassava peel provides substantial carbohydrate. The combined dietary matrix may consequently alter lipid absorption, hepatic lipid metabolism and lipoprotein transport.

Previous research has specifically demonstrated that palm oil sludge inclusion can influence serum cholesterol in broilers. Onibi et al 2021. investigated diets in which palm oil sludge substituted maize-derived energy and evaluated haematological indices, serum cholesterol and meat quality.

(Kehinde, 2024). This provides a useful comparative basis for the present findings.

A recent study specifically examining CPMPOS diets likewise investigated serum lipid and biochemical indices in broilers, indicating continued interest in the mixture as a potential maize replacement. (Nwokolo, et al., 2025). However, differences in ingredient processing, inclusion level, breed, basal diet and nutrient equivalence make direct comparison among studies difficult.

The reduction in cholesterol should not, however, be interpreted as proof that CPMPOS+E necessarily produces healthier broiler meat. Serum cholesterol and meat lipid composition are related but distinct outcomes. A dietary treatment should only be described as producing lower-cholesterol meat if cholesterol concentration in the edible tissue is directly measured.

Similarly, the present data do not establish the mechanism responsible for the lower cholesterol concentration. The original thesis attributed the response partly to antinutritional factors; however, such a mechanistic explanation cannot be established from the present experiment because specific antinutritional factors, lipid digestibility, hepatic lipid metabolism and cholesterol synthesis were not measured.

Practical Implications

The findings have potential implications for poultry production in regions where cassava-processing and palm-oil-processing by-products are readily available. Both materials are locally obtainable and can potentially contribute to reducing dependence on maize.

Cassava peel meal is particularly attractive because it is an abundant processing by-product. However, its safe use depends on appropriate processing and careful diet formulation because cassava by-products may contain residual cyanogenic compounds and substantial fibre.

Palm oil sludge also represents a potentially useful energy source. Evidence from previous broiler studies suggests that its incorporation is feasible when diets are appropriately formulated.

The present study therefore supports further investigation of CPMPOS+E as an alternative feed resource, but practical recommendations should be based on nutritionally balanced diets and economic evaluation, rather than blood parameters alone.

Conclusion

Graded dietary inclusion of enzyme-supplemented cassava peel meal blended with palm oil sludge significantly influenced several haematological indices and selected serum lipid variables of broiler chickens. Inclusion of 22.5% and 25.0% CPMPOS+E was associated with lower total cholesterol and LDL-C compared with the control diet, while triglycerides and HDL-C were not significantly affected.

The haematological findings did not demonstrate a consistent pattern of adverse physiological response across the evaluated

inclusion levels. However, because the experimental diets differed in crude protein and metabolisable energy, the observed effects cannot be attributed solely to CPMPOS+E.

Under the conditions of this study, CPMPOS+E shows potential as an alternative feed ingredient for broiler chickens. Nevertheless, future studies should employ nutritionally equivalent diets, quantify residual HCN and other antinutritional factors, determine nutrient digestibility, and evaluate growth performance, carcass characteristics, meat quality and economic returns before recommending high-level commercial inclusion.

Recommendations for Further Research

Future research should:

1. determine the proximate composition and amino-acid profile of CPMPOS+E;
2. quantify residual hydrogen cyanide, phytate, tannins and other antinutritional factors;

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