Chapter 12
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Nutritional Value of Exogenous Enzyme Supplementation in the Utilization of Cassava Peel Meal-Based Diet by Broiler Finisher Chickens

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ABSTRACT

The utilization of exogenous enzymes is a prevalent nutritional strategy in the poultry industry. However, their effectiveness when used in diets formulated with non-traditional agro-byproducts like cassava peel remains uncertain. From a practical standpoint, assessing the efficacy of these enzymes in such contexts is vital to achieving competitive performance outcomes while maintaining low production costs. This study assessed the supplemental value of exo-enzyme (Maxigrain®) in the utilization of cassava peel meal (CPM) by broiler finisher chickens in a 28-day feeding trial. Two hundred and forty, 4 weeks old Arbor acre broiler birds were randomly allocated to four experimental diets tagged as T1, T2, T3 and T4, which were formulated to replace maize at 0, 25, 50, and 75% inclusion levels respectively with supplementary enzyme (Maxigrain®). The birds were further subdivided into four replicates of ten birds each in a completely randomized design arrangement. At the end of the 4 weeks feeding trial, performance and carcass attribute indices were measured, while feces and blood samples were collected for nutrient digestibility and blood biochemical evaluations, respectively. Data on feed cost analysis were calculated using the prevailing current market price of feed ingredients. The result showed that average weight gain and feed intake were significantly affected (P<0.05) by dietary treatments. Birds on a 50%

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CPM enzyme diet had a significant (P<0.05) higher weight gain and feed intake followed by those on a 75% CPM diet as compared to the control group. Feed cost/kg weight gain significantly (P<0.05) decreased with increasing levels of enzyme-supplemented CPM. Profit margins generated were higher (P<0.05) in bird fed enzyme-treated CPM diet group. The apparent nutrient digestibility of the birds revealed a significant (P<0.05) variation in all parameters evaluated and increased with increasing levels of enzyme-supplemented CPM diets. Also, all blood metabolites evaluated were significantly affected (p<0.05) by enzyme supplementation to CPM-based diseases except for WBC, globulin, creatinine and cholesterol. Enzyme supplementation produced no significant (p>0.05) effect on live weight, carcass weight and dress weight across the treatments, however, birds at 50% dietary level had the highest mean values compared to other treatment groups. The cut weights of the wing, breast, thigh, back, liver, GIT and kidney were significantly (P<0.05) affected by the dietary treatments. Therefore, enzyme supplementation improved performance, nutrient digestibility, and carcass characteristics of broiler finishers fed cassava peel meal-based diet without any adverse effect and 50% inclusion gave an optimum performance on carcass and organ traits.

Keywords: Broiler finishers; cassava peel; enzyme; performance; nutrient utilization.

1. INTRODUCTION

Globally, poultry farming has emerged as a highly favored livestock venture among small and medium-scale farmers in both rural and urban settings, owing to its rapid turnover rate and swift returns on investment. The poultry industry plays a crucial role in narrowing the gap between the supply and demand for high-quality protein sources like meat, essential for the ever-growing global population. However, its profitability has been undermined by the skyrocketing cost of feed, which comprises roughly 70-80% of the overall expenses in poultry farming [1,2,3]. Maize, the main energy-providing ingredient in poultry feed in many developing countries, has seen price hikes due to intense competition for its use among humans, animals, and industrial applications, particularly in broiler chicken diets [4]. This situation has resulted in a rise in the cost of finished feeds, subsequently increasing the expenses associated with intensive broiler production and thereby driving up the cost of animal protein [5,6]. This has particularly affected resource-poor citizens in developing countries, leading to lower animal protein intake. Consequently, animal nutritionists, scientists, and other related professionals are focused on finding alternative energy feed sources that can economically replace maize without negatively impacting the performance and physiological health of broilers.

Cassava (*Manihot esculenta* Crantz) is a tuber crop widely cultivated in Nigeria with an average annual production estimate of 45 million tonnes [7]. It is the highest supplier of carbohydrates among energy staple foodstuff and also, it offers a great potential as cheap, alternative energy feedstuff in rations for livestock [8,9,10,11]. Cassava peel is a cheaper and readily available agro-industrial by-product, farm waste or crop residue resulting from the processing of cassava roots for human consumption. Several studies have shown that cassava peel can be exploited as an alternative feed resource in the diets of monogastric animals in replacing high-energy cereals, particularly maize [12,13,10,14,15,16]. However, the use of cassava peel has largely remained underutilized as livestock feed due to its high level of cyanide, non-starch polysaccharides (10.0 - 38.4%) often designated as fiber, high phytate content and low protein content ranging between 2.10 and 8.20%, which often limit their utilization in monogastric diet [17,13,4,14]. The major problem encountered with the use of cassava products especially peels in poultry diets is the deleterious effects on animal physiology resulting from the activities of cyanogenic glycoside content in the product as well as its high fiber content [18,19,4]. Some studies have indicated that the presence of cyanogenic glucosides in cassava peel meal may be responsible for the poor performance of chickens, as higher levels of cassava peel meal in their diets have been linked to adverse effects [20,21].

To address these issues, various processing methods such as sun-drying, ensiling, and fermentation have been employed to improve the nutritional value of cassava peels [22,10,14,16]. Additionally, enzyme supplementation has been utilized to overcome the limitations posed by the high fiber content in cassava products [2,9,11,15]. Using multi-enzyme supplementation is recognized as a key technique to enhance the utilization of nontraditional feed ingredients, thereby reducing costs and nutrient emissions in poultry nutrition [23,24,25,3]. These enzyme complexes are formulated to complement the birds' digestive capacity not only to reduce the anti-nutritive effects of non-starch polysaccharides (NSPs) but also to release some nutrients which could be utilized by the birds [13,10,5,26,27]. Maxigrain® is an exogenous enzyme complex product that contains a blend of the most relevant digestive enzymes that work synergistically to break down complex carbohydrates into simpler sugar for easy digestion and absorption. The enzymatic profiles of Maxigrain® enzyme contain the activity of both non-starch polysaccharides (NSPs) enzymes and phytase that brings about efficient utilization of a wide range of untraditional feed ingredients and agro-industrial by-products. Therefore, this study was designed and conducted to evaluate the performance and physiological attributes of broiler finisher birds fed cassava peel meal-based diet with exogenous enzyme supplementation.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the Poultry Unit of the Teaching and Research Farm of theDepartment of Animal Production Technology, Federal College of Wildlife Management, New Bussa, Niger State, Nigeria. The college is geographically located on longitude 9° 81′ 95″ N and 9° 49′ 10″ N and latitude 4° 58′ 05″ N and 4° 34′ 49″ N, which covers an area of 2.5km^2 with its vegetation described as Northern Guinea savanna zone of Nigeria. The average temperature is 28ºC to 40ºC with a relative humidity of 60% and mean annual rainfall of 650mm-1300mm.

2.2 Preparation of Cassava Peel

Fresh cassava (*Manihot esculenta*) peels were collected from local cassava processing centers in NewBussa, Niger State [13]. The cassava peels were soaked in water inside a plastic drum for three (3) days, after which they were removed and drained with a basket and sun-dried for five (5) days before milling to fine particles of 2mm in diameter, using a hammer mill to produce cassava peel meal (CPM). The sun-dried CPM was analyzed for its proximate composition according to the procedures of [28].

2.3 Active Ingredient Composition of Maxigrain® Enzyme Product

Maxigrain® enzyme is an enzyme complex containing β-glucanase, amylase, cellulose, xylanase, pectinase, phytase, protease and lipase, which originates from the bacteria *Aspergillus oryae* and was incorporated at a level of 100mg/kg of the basal diet according to the manufacturer's recommendation.

2.4 Management of Experimental Birds and Design

A total of two hundred and forty (240), 4-week-old Arbor acre birds were used for the experiment. They were randomly sub-divided into 4 dietary treatments of four replicates, with ten birds each in a completely randomized design. Feed and water were given to the birds' *ad-libitum.* A lighting source was provided using electricity bulbs during the night [13]. The birds were administered anti-stress and vitamin/mineral premix orally at the recommended dosage after randomization before the commencement of the experiment. The birds were reared on deep litter in an open-sided wire mesh-constructed poultry house to allow for adequate ventilation. Medications, vaccinations and other routine management practices were strictly followed. The birds were offered experimental diets and cool, clean water *ad-libitum* throughout the four-week period of the experiment [13].

2.5 Experimental Diet and Treatment

Four experiment diets were formulated to contain Maxigrain® enzyme supplemented cassava peel meal to replace maize at 0, 25, 50 and 75% as T_1, T_2, T_3 and T_4 respectively. Treatment 1 was the control diet with no cassava peel meal and enzyme inclusion. Maxigrain® enzyme was supplemented at the rate of 100mg/kg. The experimental diet composition is presented in Table 1 [13].

2.6 Data Collection

2.6.1 Performance measurement

Birds were weighed at the beginning of the trial and weekly thereafter. Weight gain was computed by subtracting the initial weight from the final weight. Leftover feed was collected and weighed weekly, and subtracted from the quantity offered to obtain weekly feed intake per replicate. The feed conversion ratio was computed by dividing the average feed consumed per bird by the average weight gain per bird.

Table 1. ***Gross composition of experimental broiler finisher chicken diets***

Ingredients %	T_1 (0% CPM)	T_2 (25% CPM)	T_3 (50% CPM)	T_4 (75%CPM)
Maize	59.00	45.70	30.40	15.10
CPM	_	15.30	30.60	45.90
Soybean meal	28.00	28.00	28.00	28.00
Fish meal	3.00	3.00	3.00	3.00
Wheat offal	6.00	4.00	4.00	4.00
Bone meal	2.00	2.00	2.00	2.00
Limestone	1.00	1.00	1.00	1.00
*Premix	0.30	0.30	0.30	0.30
Lysine	0.2	0.2	0.20	0.20
Methionine	0.30	0.30	0.30	0.30
Salt	0.20	0.20	0.20	0.20
**Maxigrain®	0.00	0.01	0.01	0.01
Total	**100**	**100**	**100**	**100**
Calculated analysis				
CP %	**21.24**	**20.73**	**19.33**	**18.63**
ME kcal/kg	**296.81**	**2985.18**	**30.3341**	**3058.28**

**Premix contains the following: Vitamin A-15000000i.u; Vitamin D3- 3,000000i.u, Vitamin E-30,000i.u, Vitamin K- 2,500mgr, Thiamin B1- 2,000mgr, Riboflavin B2- 6,000mgr; Pyridxine B6- 4,000; Niacin- 4,000mgr; Vitamin B12- 20mgr; Pantothenic Acid- 10,000mgr; Biotin-80mgr; Cholin Chloride- 500mgr; Antioxidant- 125gr; Manganese- 96gr; Zinc- 60gr; Iron-24gr; Copper- 60gr; Iodine- 1.4gr; Selenim- 240gr; Cobalt- 120gr*
***Maxigrain® (Cellulase 10000 i.u, Beta glucanase 200 i.u,, Xylanase 10000 i.u, Phytase 2500FTU) added at 100mg/kg of feed*

2.6.2 Cost indices evaluation

The cost evaluation of broiler-chickens fed enzyme-supplemented cassava peel meal-based diets was determined using the procedure of Akinyele et al. [4]. The production cost of the processed cassava peel meals was determined with respect to the sum of expenditures incurred in the processing method employed. The cost of feed was calculated based on the prevailing market price of the feed ingredients at the time of this study. The cost of feed/kg was calculated by adding prevailing prices of the different ingredients per kilogram (at the time of the experiment) multiplied by their inclusion levels and divided by one hundred. The cost per kilogram weight gain was calculated as FCR x cost/kg of feed.

2.6.3 Evaluation of apparent nutrient digestibility (Metabolic cage trial)

At the end of 28 days, 2 birds per replicate making a total of 10 birds per treatment were randomly selected from the four (4) treatment groups for the metabolic cage study which lasted for 5 days after an adjustment period of two (2) days. A known quantity of feed was given and feces voided were collected daily for a period of 5 days. Dropping trays were covered with aluminum foil paper for total excreta collection. The feed intake over the 5-day trial was recorded. The fecal droppings from each replicate were sun-dried to remove the moisture content to bring the feces to a constant weight after the feather and contaminants were removed. The total collection of feces was pooled, weighed, and ground and representative samples were taken for proximate analysis [28]. Thereafter, the results obtained were used to calculate the coefficient of nutrient digestibility using the procedure of Aguihe et al. [9].

2.6.4 Evaluation of carcass and organ weight parameters

At the end of the 28-day feeding trial, two birds weighing closer to the pen mean were fasted overnight for carcass studies and organ measurements following the method of Diarra et al. [27]. The birds were killed by cervical dislocation, scalded at 60ºC for 30 seconds, manually plucked and eviscerated where the internal contents were neatly removed and weighed followed by the cutting of the carcass into prime-cut parts Thereafter, carcasses and different prime-cut parts as well as organs were weighed and expressed as percentages of the live weight.

2.6.5 Evaluation of blood biochemical parameters

At the end of the 4th week of the feeding trial, blood samples were randomly collected from four (4) birds per replicate. 2mls of blood was collected from the wing vein of randomly sampled birds into labeled sterile universal bottles containing anti-coagulant (Ethyl Diamine Tetra Acetic Acid, EDTA) to determine haematological indices within 2 hours of blood collection such as Packed Cell Volume (PCV) (%), Red blood cells (RBC), White blood cells (WBC) and Haemoglobin (Hb). Another 2mls of blood was collected without anticoagulant into the sterile test tube for determination of serum biochemical indices. The tube containing blood was placed in a slanting position at room temperature for clotting. Blood samples were centrifuged at 3000rpm for 10 minutes and thereafter stored at -20^{o}C to determine the concentration of serum total protein, globulin, albumin, creatinine, glucose and cholesterol. All analyses followed the procedure described by Ewuola and Egbunike [29].

2.7 Statistical Analysis

All data collected were subjected to one-way analysis of variance (ANOVA) of the General Linear Model (GLM) of the SPSS Statistical Package (SPSS for Windows 2013, version 22.0; IBM Corporation, Armonk, NY, USA) according to Steel et al. [30] with pen as the experimental unit. Treatment means were compared using the Duncan Multiple Range test option of the same statistical software and differences were considered significant at $p<0.05$ in all analyses.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of CPM and Experimental Diets

The result of the proximate composition of cassava peel and the experimental diets are presented in Tables 2 and 3. The analysis showed that cassava peel contained 5.75% crude protein, 14.83% crude fiber, 1.47% ether extract, 5.68% ash and

70.1% NFE (Table 2) [13]. The crude protein and NFE values obtained in this present study were similar within the range of 5.46 – 5.83% and 70.67 – 73.10% respectively as reported in previous investigations [31, 21, 11] but slightly higher than the values reported by Ehebha and Eguaoje [10] (4.80% CP and 61.36% NFE), Akinyele et al. [21] (3.95% CP and 68.56% NFE) and Nwuso et al. [32] (3.84% CP and 52.76% NFE). The crude fiber of 14.83% recorded in the current experiment was higher than the value (12.35%) reported by Obih and Amagwula [21], however lower than the values reported by Augustine et al [31], Ehebha and Eguaoje [10], Akinyele et al. [4] and Nwuso et al. [32] as 18.81%, 16.91%, 20.20% and 32.00% respectively. The differences observed could be due to differences in cassava varieties, peeling methods, soil types and processing methods adopted. The nutrient (proximate) compositions of the diets (Table 3) are adequate and within the recommended range for broiler finishers as reported by NRC [33] and Oluyemi and Robert [34].

Table 2. Proximate composition of cassava peel meal

Components	Composition
Dry mater %	92.66
Crude protein %	5.75
Crude fiber %	14.83
Ether Extract %	1.47
Ash %	5.68
NFE %	70.10
Energy (kcal/kg)	3720

Table 3. Proximate composition of experimental broiler finisher diet

Component	T_1	T_2	T_3	T_4
	0% CPM	25% CPM	50% CPM	75% CPM
Dry matter (%)	89.72	90.01	90.31	90.06
Crude Protein (%)	20.60	19.95	19.84	19.20
Crude Fiber (%)	4.54	5.89	7.55	9.13
Ether Extract (%)	3.80	3.64	2.98	2.57
Ash (%)	4.85	5.20	5.93	6.36
NFE (%)	55.97	55.33	54.01	52.80

**CPM: Cassava Peel Meal*

3.2 Performance of Experimental Birds

Data on the performance response and economics of production are presented in Table 4. The result revealed a significant ($P<0.05$) difference in average final body weight and average weight gain, while average feed intake and feed conversion ratio (FCR) were not significantly ($P>0.05$) affected among the birds fed experimental diets. Birds on T3 recorded the lowest value of FCR though not significantly ($p>0.05$) from other dietary groups. Average feed intake (g) values among the dietary treatment groups were statistically similar ($P>0.05$) and were higher in both T3 and T4. Feed intake increased numerically from T1 (0%) to T4 (75%) as the percentage inclusion level of enzyme-supplemented CPM increased. These findings align with the research conducted by Amagwula et al [15], which observed that feed intake increased as the levels of enzyme-supplemented cassava peel meal rose to 52% in the diets of laying hens. The relationship between voluntary feed intake and the caloric content of animal diets is such that animals consume more of a low-energy diet than a high-energy diet to compensate for the dietary energy deficit [21]. Birds on T3 recorded higher ($P<0.05$) average body weight and weight gain, though similar ($P>0.05$) to those on the T4 diet but differed significantly ($P<0.05$) from birds on the control and T2 groups. The enhanced performance of broiler finisher birds on diets containing enzyme-supplemented cassava peel meal at 50% and 75% inclusion levels in terms of body weight and weight gain is indicative of the enzyme complex's efficacy in improving nutrient availability from cassava peel meal-based diets. This is consistent with the findings of Ukorebi [14], who reported significantly higher final body weights and weight gains in groups treated with cassava peel meal and enzyme supplementation. These results are further supported by studies suggesting that the inclusion of exogenous enzymes in diets can effectively complement endogenous enzymes, thereby accelerating their catalytic and hydrolytic activities. This enhances the digestion, absorption, and metabolism rates of complex feed nutrients [35, 4, 32]. Previous studies have shown that the supplementation of feeds with exogenous enzymes reduces digesta viscosity, enhances nutrient digestion and absorption particularly fats and proteins, which improves the apparent metabolizable energy value of the diet, and alters the population of microorganisms in the digestive tract, all of which contribute to enhanced weight gain [36, 37, 38, 27]. Consistent with our findings, Mael et al. [39] and Diarra and Anand [25] also reported reduced weight gain in finishing broilers fed with commercial diets diluted with cassava meal per kilogram without enzyme supplementation; however, these effects were mitigated with enzyme addition. These authors attributed this improvement to the beneficial impact of enzyme products on cassava meal utilization. Similarly, enzyme supplementation has been shown to enhance the use of diets containing cassava leaf meal for growing pullets [40] and laying hens [15]. These observations suggest that the Maxigrain® enzyme cocktail improves the overall digestibility and utilization of cassava peel meal (CPM) diets by breaking down non-starch polysaccharides (NSPs) in the cassava peel, thereby reducing its fiber content, thus, leading to increased growth performance [9, 10, 5, 26, 41]. Accordingly, the current investigation is supported by some previous studies that reported the use of sun drying method to effectively reduce the cyanogenic glycoside and phytate content [20, 21, 10, 14] and enzyme supplementation [5, 27,3, 15] to cause the release of nutrients for efficient utilization.

3.3 Economics of Production

Likewise, Table 4 presented the result of economic indices revealed that Maxigrain® supplementation had a significant ($P<0.05$) effect on the economic parameters measured. It was observed that as the inclusion level of enzyme-supplemented CPM diets increased, the cost/kg feed and cost/kg weight gain decreased across the dietary treatments due to the wide margin between the market prices of maize and the cost of procuring cassava peel meal as at the time of this study. This has shown that dietary substitution of maize with CPM up to 75% optimized monetary returns with enzyme supplementation. Birds on 50 and 75% CPM-enzyme diets had similar (P>0.05) profit margins which were significantly (P<0.05) higher than those on the control diet. The inclusion of Maxigrain® in CPM-based diets yielded the highest profit, likely due to enhanced nutrient availability and utilization facilitated by the increased hydrolysis from enzyme supplementation. This result is in accordance with the reports of previous researchers [42, 9, 22, 4, 15] but contrary to the finding of Mael et al. [39], who found no effect of enzyme supplementation on feed cost per kilogram body gain in their study.

3.4 Apparent Nutrient Digestibility

Data obtained on apparent nutrient digestibility are presented in Table 5. Significant differences (P<0.05) occurred in all the parameters evaluated with the exception of dry matter. In all parameters measured, higher (P<0.05) values occurred in birds fed a 50% CPM-enzyme-supplemented diet as compared to the control group. The improved nutrient digestibility of birds with enzyme-supplemented cassava peel meal-based diets could be attributed to the multi-enzyme (Maxigrain®) complex adopted which is capable of degrading the feed anti-nutritional compounds and fiber components of the diets, which subsequently release trapped nutrients, thereby making more nutrients available for utilization by the birds [43, 31, 44, 12, 26]. The enhancement in nutrient digestibility observed in CPM diets supplemented with Maxigrain® can be attributed to the exogenous enzyme complex's ability to reduce the viscosity of digesta in the lumen [45, 3]. This reduction allows for a concomitant release of nutrients, making them more accessible for utilization by the birds, thereby leading to improved chicken performance [10, 45,46]. Romero et al. [47] and Liu et al. [45] reported that adding exogenous enzyme complexes containing amylase, xylanase, galactosidase, protease, and phytase to diets can improve nutrient digestibility. This improvement occurs because these enzymes provide better access for endogenous enzymes to the cellular content and facilitate the hydrolysis of NSPs in the cellular wall of ingredients. Additionally, Córdova-Noboa et al. [48] showed that dietary supplementation with amylase can enhance energy utilization, nutrient digestibility, and broiler performance by improving starch digestibility. Previous studies indicate that dietary enzyme supplementation positively influences nutrient digestibility and reduces variability in the energy value of diets formulated with poorly digestible ingredients [45, 15].

3.4.1 Carcass and organ characteristics

Table 6 shows the summary of the effect of Maxigrain® enzyme supplementation on the carcass and organ characteristics of broiler chickens fed cassava peel-based diets. The live weight, carcass weight and dress weight were not significantly varied (P>0.05) across the dietary treatment groups, except for dressing percentage, which was significantly (P>0.05) affected by the treatments [13]. The prime-cut parts weight that differs significantly (P>0.05) among the treatment groups were wings, breast, thigh and back, whereas leg, neck and head were compared (P>0.05) across the treatment groups. Assessment of visceral organs such as the gizzard, liver and gastrointestinal tract were significantly (p<0.05) influenced by the enzyme supplementation [13]. Worthy of note is the observation that the weights of the live bird as well as carcass and dress weights were similar (P>0.05) across the treatment groups. The weights of the group-fed enzyme-supplemented CPM diets compared favorably with those of treatments receiving maize-based diets. This suggests that the cassava peel meal diets did not negatively impact the carcass yield of broiler finisher chickens. These findings may be attributed to the exogenous enzymes promoting a balanced availability and utilization of nutrients present in the feed ingredients [49, 45, 3]. It has been shown that carbohydrates exhibit a protein-sparing effect and that amylase can enhance starch digestibility [50], thereby influencing carcass characteristics and increasing nitrogen retention. Furthermore, the starch source can affect the expression of genes that regulate glycogen synthesis (glycogen synthase) and fat synthesis (fatty acid synthase) [51]. Giacobbo et al. [45] posited that dietary enzymes could influence nutrient availability and the expression of enzymes related to carbohydrate and lipid metabolism, which in turn can impact carcass composition and yield. Additionally, the superior prime-cut attributes observed in broilers fed with Maxigrain® supplemented CPM diet at a 50% inclusion level (T3) compared to those in T4 and T2 groups were likely due to improved nutrient utilization, which was reflected in their higher body weights and, consequently, a greater degree of carcass meatiness [52, 32]. The increased gizzard weight observed in the T4 groups can be attributed to the high insoluble fiber content in the CPM-based diets [14]. Research by Mteos et al. [53] indicated that enzyme supplementation in

Table 4. Performance and economic indices of broiler finisher chickens fed graded levels of cassava peel meal (CPM) based diets with Maxigrain® enzyme supplementation

Indices	T1 0%CPM	T2 25% CPM	T3 50% CPM	T4 75% CPM	SEM
Ave. initial weight (g)	857.00	856.00	857.50	856.50	8.20
Ave final weight (g)	1812.50^{c}	1895.00^{b}	2001.50^{a}	1915.50^{ab}	4.82
Ave. weight gain (g)	955.50^{c}	1039.00^{b}	1144.00^{a}	1059.00^{ab}	3.67
Ave feed intake (g)	2745.00	2765.00	2880.00	2864.00	10.14
FCR	2.87	2.66	2.52	2.70	0.26
Cost/kg feed (₦/kg)	107.42^{a}	96.51^{ab}	85.03^{bc}	73.56^{c}	1.26
Cost/kg weight gain (₦/kg)	308.30^{a}	256.71^{b}	214.28^{c}	198.61^{b}	16.94
Profit margin (₦/kg)	490.08^{c}	656.76^{b}	984.08^{a}	986.43^{a}	6.22

^{abc} _Means with different superscripts within the same row are significantly different (P<0.05)_

Table 5. Apparent nutrient digestibility of broiler finishers fed graded levels of cassava peel meal (CPM) with enzyme (Maxigrain®) supplementation

Nutrient Digestibility %	T1 0% CPM	T2 25% CPM	T3 50% CPM	T4 75% CPM	SEM
Dry matter	75.89	74.84	75.86	74.17	3.81
Crude Protein	66.34^b	68.39^b	75.86^a	74.67^a	1.41
Crude Fiber	51.50^b	58.58^a	58.79^a	52.81^b	2.69
Ether Extract	63.85^b	68.58^b	75.33^a	71.14^a	0.76
Ash	53.00^b	52.54^b	68.67^a	53.14^b	0.82

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

Table 6. Carcass and organ characteristics of broiler finisher fed cassava peel meal-based diet supplementedwith Maxigrain® enzyme

Parameter	T_1(0% CPM)	T_2 (25% CPM)	T_3 (50% CPM)	T_4 (75% CPM)	SEM
Live weight	2100.00	2233.30	2300.00	2050.00	54.60
Carcass weight	1983.0	2016.70	2183.30	1916.70	48.14
Dress weight	1620.57	1619.14	1883.37	1551.85	14.50
Dress %	77.70	72.50	81.90	75.70	6.12
Prime cuts					
Wing	9.20	9.23	9.51	9.99	0.08
Breast	18.03^{ab}	17.92^{ab}	20.09^a	15.43^b	0.47
Thigh	18.87^b	20.19^b	25.53^a	17.82^b	0.83
Drumstick	17.56^b	18.67^b	24.75^a	16.98^b	0.92
Back	13.73	14.28	15.68	12.63	0.17
Organ Weights					
Heart	0.40	0.44	0.48	0.35	0.04
Gizzard	1.71^b	1.40^c	1.51^{cb}	1.90^a	0.04
Liver	1.68^{ab}	1.88^a	1.31^b	1.92^a	0.08
Spleen	0.40	0.60	0.6	0.24	0.04
Intestine	4.13^b	3.20^c	3.53^{bc}	5.70^a	0.09
Lung	0.52	0.47	0.87	1.16	0.08
Kidney	0.66^b	0.88^a	0.59^b	0.80^a	0.05

^{abc} Means in the same column without superscript in common are different at P<0.05

broiler diets generally reduces gizzard weight, whereas higher dietary fiber promotes the thickening of muscles, resulting in increased gizzard weight. Previous studies have demonstrated that elevated gizzard weight in broilers is often related to higher dietary fiber content and the gizzard's thickening response to this fiber, however, has a beneficial effect on the gizzard's development and function [53,14].

3.4.2 Haematological profile of experimental birds

The results of haematological indices are summarized in Table 7. The effect of dietary treatment on haematological examination showed that there were significant differences (P<0.05) among the treatment diets in the parameters evaluated. Blood serves as an important and reliable medium for evaluating the physiological and health status of individual animals [54]. The difference (P>0.05) recorded in the packed cell volume of broilers fed varying levels of cassava peel meal with Maxigrain® supplementation was in discordance with the findings of Ehebha and Eguaoje [10] who reported no significant difference in the PCV values of chickens fed Maxigrain® supplemented CPM based dies. There were significant (P<0.05) differences in the haemoglobin and red blood cells, and the values obtained were within the normal range for chickens as stated by [55]. These results indicate that the broilers effectively utilized the nutrients without any adverse effects, contributing to their overall health, lack of anemia, and resilience to stress. This aligns with the findings of Ehebha and Eguaoje [10] who incorporated cassava peel meal supplemented with Maxigrain® in broiler diets, but contrasts with the findings of Olajide [41], who reported no significant difference (P>0.05) in the blood haematological values of laying hens fed varying levels of Maxigrain enzyme supplemented beniseed hull meal for maize replacement. The white blood cell (WBC) counts were unaffected by the dietary treatments, suggesting that the enzyme-supplemented CPM inclusion did not induce any pathological effects, thus maintaining the birds' normal health status. The values for packed cell volume (PCV), Hb, WBC, and RBC of birds fed enzyme-supplemented CPM diets were significantly higher at 50% CPM inclusion level and were comparable to those on the control diet. This indicates that enzyme supplementation positively impacts all the hematological parameters investigated, subsequently enhancing the birds' health [56]. Hematology serves as an index reflecting the effects of dietary treatments on the animals, indicating the type and quantity of nutrients ingested and their availability to meet the physiological, biochemical, and metabolic requirements of the animals [57].

Table 7. ***Haematological indices of broiler finishers fed Maxigrain ® enzyme-supplemented cassava peel meal-based diets***

Parameters	T_1 (0%CPM)	T_2 (25%CPM)	T_3 (50%CPM)	T_4 (75%CPM)	SEM
PCV (%)	30.45^a	24.7^b	26.9^a	21.25^b	1.06
Hb (g/dl)	10.10^a	8.20^{ab}	8.95^a	7.10^b	1.39
WBC ($x10^9$/L)	9.65	10.25	9.88	8.06	4.97
RBC ($x 10^{12}$/L)	8.02^a	6.51^b	7.82^a	5.92^b	0.89

^{ab} Means with the same superscript in the same row are not significant (P>0.05)

3.5 Serum Biochemical Indices of Experimental Birds

The result of serum biochemistry (Table 8) revealed a significant variation ($p<0.05$) except for serum globulin, creatinine and cholesterol. The highest ($p<0.05$) value of total protein was obtained in the birds fed diet T3 (50% CPM) and this increment in blood protein as a result of enzyme supplementation confirms the report of Nwosu and Igugo [11] that the enzyme preparation increased nutrient metabolism, particularly protein anabolism of chickens therefore promoting the growth of chickens. The elevated total protein levels observed in birds fed a diet supplemented with 50% CPM and Maxigrain® may be attributed to the enzyme cocktail's ability to break down fibrous materials, thereby generating energy and protein that are readily available for the animal's use. Additionally, Maxigrain® can catalyze certain metabolic activities that improve blood quality [10]. The increased albumin levels in birds fed the T3 diet, coupled with an increase in total protein, indicate a good state of health, as albumin is a crucial component of hormones, co-enzymes, and phospholipids. The synthesis of serum proteins like albumin and globulin is linked to the availability of proteins and micronutrients [58]. Furthermore, creatinine serves as an indirect measure of protein utilization in poultry birds [59], and the non-significant differences in creatinine values among the broilers suggest that protein utilization was improved when enzyme-supplemented CPM replaced maize in their diet. A significant ($P<0.05$) reduction was observed in serum glucose as the levels of enzyme-supplemented CPM increased. This showed that serum glucose concentration decreased with increasing enzyme-supplemented CPM inclusion because the metabolizable energy value of CPM is lower than that of maize. The marked reduction in glucose levels observed in broilers-fed diets with increasing levels of Maxigrain®-supplemented CPM suggests that these birds are less likely to accumulate fat compared to those on control diets. This finding aligns with Ehebha and Eguaoje [10], who reported significant variations in glucose concentrations in broilers fed different levels of cassava peel meal supplemented with Maxigrain®. Consequently, the processing methods used coupled with

Table 8. Serum biochemistry of broiler finishers fed enzyme (Maxigrain®) supplemented cassava peel meal-based diets

Parameters	T_1 (0%CPM)	T_2 (25% CPM)	T_3 (50% CPM)	T_4 (75% CPM)	SEM
Globulin (g/dl)	2.35	2.35	2.75	2.35	0.1
Albumin (g/dl)	3.55^{b}	4.10^{b}	5.00^{a}	3.80^{b}	0.22
Total protein (g/dl)	5.90^{b}	6.45^{b}	7.75^{a}	6.15^{b}	0.20
Creatinine (mg/dl)	2.43	2.36	2.40	2.44	1.21
Glucose (mg/dl)	233.44^{a}	215.05^{ab}	208^{b}	206.50^{b}	0.54
Cholesterol (mg/dl)	78.00	78.88	75.78	74.68	0.94

^{ab} _Means with the same superscript in the same row are not significant ($P>0.05$)_

exogenous enzyme complex supplementation may have effectively reduced the levels of fiber, hydrogen cyanide, and other anti-nutritional factors commonly found in the cassava peel to tolerable limits. This reduction likely enhanced the concentrations of serum metabolites, thereby improving overall performance. The results of this study support previous findings that sun-dried cassava peel meal, when supplemented with enzymes, can effectively replace maize up to 50% in broiler diets, resulting in good performance and health status [22, 21, 32].

4. CONCLUSION AND RECOMMENDATION

The addition of Maxigrain® enzyme to CPM diets has underscored the beneficial impact of feed enzymes in poultry production. The results of this study indicate that broiler finisher chickens fed enzyme-supplemented CPM diets exhibited improved performance, nutrient digestibility, and carcass yield. Moreover, the findings demonstrate that a 75% inclusion level of CPM with Maxigrain® enzyme supplementation in broiler finisher diets can be tolerated without any adverse effects on health while also lowering production costs. Enhancing the digestibility of the high-fiber content and reducing the anti-nutritional effects of cassava peel meal through soaking and sun-drying, aided by an enzyme cocktail supplementation, can make it a superior feedstuff in the poultry diet. Consequently, the study recommends enzyme supplementation for diets containing 50% CPM in place of maize to achieve improved growth performance, providing valuable insight for poultry farmers. Future research should explore varying enzyme levels to determine the optimum dosage for maximizing growth performance in broilers.

DISCLAMER (ARTIFICIAL INTELLIGENCE)

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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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