2026 SCIENCELINE

Online Journal of Animal and Feed Research

Volume 16, Issue 4: 252-260; July 30, 2026

ISSN 2228-7701

DOI: https://dx.doi.org/10.51227/ojafr.2026.30

ASSESSMENT OF NUTRITIONAL POTENTIALS OF PALM KERNEL CAKE/RICE HUSK-BASED DIETS SUPPLEMENTED WITH FIBROLYTIC ENZYME ON PERFORMANCE, CARCASS CHARACTERISTICS AND ORGAN WEIGHT OF CHICKEN BROILERS

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Supporting Information

RESEARCH ARTICLE
PII: S222877012600030-16
Received: February 25, 2026
Revised: July 24, 2026
Accepted: July 26, 2026

ABSTRACT: The prohibitive costs of conventional feedstuffs have necessitated the search for other alternatives. Palm kernel cake (PKC) and rice husk (RH) are potential feed resources. PKC contains about 20% crude protein and about 50% nitrogen free extractives (NFE), whilst RH contains about 38% NFE. The use of these ingredients is limited in monogastric diets due to their high content of crude fibre, particularly non starch polysaccharides. The main objective of this study was to evaluate the nutritional potential of PKC/ RH based diets, supplemented with exogenous fibrolytic enzymes on performance and carcass/organ weight characteristics of Cobb strain broiler chickens. Six experimental diets were formulated such that diets 1 and 2 contained 0% PKC/RH, and 0% oil palm slurry (OPS), whilst diets 3 and 4 contained 25% PKC/RH, and diets 5 and 6 incorporated PKC/RH at 50%, respectively. The OPS was also included in the diets 3 – 6 at 4% level to boost their primary energy levels, whilst the feed enzyme was added to the diets 2, 4, and 6 at 1% inclusion level. A total of 108, one-day-old chickens were randomly distributed to the six dietary groups, in a 3 × 2 factorial arrangement. At the end of trial, results showed that all performance parameters in enzyme-treated factorial sets were significantly (P < 0.05) better than those of zero enzyme-treated groups. Similarly, all carcass/organ weight parameters, except weights of thigh/drumstick were also significantly (P < 0.05) better in the enzyme treated groups. The results suggest that PKC/RH based diets supplemented with feed enzymes at 1% inclusion level, could replace 50% of maize in chicken broilers diets without any deleterious effect on performance, carcass/organ weight characteristics.

Keywords: Broiler chicken, Feed enzyme, Nutritional potentials, Palm kernel cake, Rice husk.

INTRODUCTION

Intensive broiler chicken production has the potential of mitigating the short supply of animal protein in Nigeria. This is because of the birds' fast growth, livability, and excellent ability to convert feed to meat. With good holistic management, a day-old broiler of about 40g can reach a live weight of 1.8kg to 2.5kg within 7 – 8 weeks.

Apart from beef, chicken is the most widely consumed meat product in the country. Its extensive acceptability is due largely to the complete nonexistence of traditional or religious restrictions regarding its marketing and consumption (Bashar et al., 2010). The fundamental constraint to intensive poultry farming in Nigeria is feeding cost, which constitutes over 70% of production cost (Ukorebi, 2022). Poultry feed manufacture is dependent on availability of feed ingredients, the major proportion of which are energy and protein sources. For broilers to convert feed into profitable products there must be adequate calorie intake, sufficient supply of amino acids in suitable proportion, and the provision of necessary vitamins and minerals (Ogunnusi et al., 2023; Alabi and Adedokun, 2025). In recent times, the major energy and protein sources for poultry diets formulation such as corn, soybean and groundnut are in competitive demand for human consumption and industrial uses (Erdaw et al., 2016; Hijati, 2010). Consequently, the cost of finished feed and the poultry products they support have become prohibitive. This underscores the need for animal- nutritionists to search for alternative non-conventional feed resources, which are cheap, and of little or zero demand for direct human consumption (Onyimanyi and Onukwafor, 2003).

A readily available potential feedstuff for compounding chicken broilers diets is palm kernel cake (PKC), a by-product of palm kernel oil extraction. Research report by Ramin et al. (2010) showed that CP content of PKC varies between 10 – 19%. Onuh et al. (2012) observed that the proximate content of PKC varies considerably, which variability is traceable to: its source, method of oil removal, the proportion of endocarp remaining, and efficiency of oil extraction from the kernel (Adesehinwa, 2007). Broilers can tolerate up to 20% PKC in their diets without affecting their growth performance and feed efficiency (Anaeto et al., 2009).

Citation: Ukorebi BA (2026). Assessment of nutritional potentials of palm kernel cake/rice husk-based diets supplemented with fibrolytic enzyme on performance, carcass characteristics and organ weight of chicken broilers. *Online J. Anim. Feed Res.*, 16(4): 252-260. DOI: https://dx.doi.org/10.51227/ojafr.2026.30

The digestion of non-starch polysaccharides (NSPs) of the cell wall of PKC in poultry is variable due to the low digestive enzymes activity and their tendency to create a viscous environment in the intestinal lumen (Yuan et al., 2017; Nguyen et al., 2021). However, it can be broken down with the help of enzymes produced by the caecal microflora or by supplementation of poultry diets with specific enzymes (Jozefiak et al., 2004; Yamsakul et al., 2025). There is a wide variation in optimum inclusion level of PKC in poultry diets. More research is needed to standardize this.

Another potential feed resource for chicken broilers production is rice husk (RH). Rice husk is a by-product of rice milling. Bassey et al. (2022) indicated that during milling of paddy, about 78% of weight is received as rice, broken rice, and bran, the rest (22% of paddy) is received as husk. The researchers pointed out that Nigeria produces around 4.3 million tons of paddy per year, giving rise to around 1.1 million tons of RH per year.

The proximate composition of RH can vary based on variety, soil conditions, fertilizer use, and processing methods. However, general ranges for key components have been established. Uzoamaka et al. (2023) reported the following percentage levels: Ash, 23.39 ± 0.19; Carbohydrate, 37.04 ± 0.82; Crude fibre, 25.74 ± 0.42; Crude lipid, 3.76 ± 0.42; Moisture, 7.93 ± 0.02; Crude protein, 1.85 ± 0.10; Energy (Kcal/100g), 189.40. There is paucity of data on RH research.

Most alternative feed ingredients proposed for compounding poultry diets contain Non-Starch Polysaccharides, NSPs which cannot be hydrolyzed by endogenous digestive enzymes of poultry. This is a major limiting factor in the utilization of NSPs in chicken broilers feed manufacture, as birds require quite a moderate amount of fibre in their diets for proper functioning of their gastro-intestinal tract. However, utilization by monogastric livestock has recently gained interest for various reasons, primarily to promote constant passage of materials through the gut, and to stimulate growth (Grieshop et al., 2001).

Addition of exogenous enzymes in poultry diets has become widely acceptable strategy to address the fibre component of diets particularly NSP viscosity, improve gut health, feed efficiency, and faecal quality, this makes it easier and a lot more beneficial to use non-conventional feedstuffs in the formulation of poultry diets (Bedford et al., 2024; Bedford and Apajalahti, 2024). Faniyi (2006) reported that enzyme supplementation of poultry diets resulted in hydrolysis of NSP into its component monosaccharides and disaccharides, which can be digested, absorbed, metabolized and utilized.

Exogenous fibrolytic enzyme (Nutrizyme) is an enzyme designed to improve the digestibility of pigs and poultry diets which are rich in fibre. It is a multi-enzyme complex which contains hemicellulase, phytase, arabinose, pectinase, amylase, β-glucanases, cellobiase, xylanase, pentosanase, and lipase. Information on enzyme treatment of chicken broiler diets PKC/RH to facilitate the liberation of their nutrients in the diets such that they will be efficiently utilized to enhance performance of birds is unavailable. This research was therefore designed to evaluate the effects of enzyme supplementation of PKC/RH based diets on performance of chicken broilers, and to provide reference data on the same.

MATERIALS AND METHODS

This study was carried out in the Animal Science unit of the Teaching and Research Farm of the Faculty of Agriculture and Forestry, Cross River University of Technology, Obubra Campus. The location lies along longitude 8° – 9°E, and latitude 6° – 7° N of the Equator, with a warm weather and ambient temperature of about 21 – 30°C, and has an annual rainfall of 500 – 1070 mm (Mfam, 2002).

Animal care

This study was duly reviewed and approved by the Institutional Animal Care and use Committee of the University of Cross River State (UNICROSS8289). The animal experiment was performed in accordance with the National Institute of Health Guidelines for the Care and Use of Laboratory.

Sources of feed ingredients

Rice husk (RH) was collected from a rice milling plant, whilst oil palm slurry (OPS) was sourced from an oil palm mill in Ofodua, Obubra Local Government Area, all of Cross River State, Nigeria. Palm kernel cake and the commercial feed enzyme (Nutrizyme®) were purchased from a certified feed merchant in Calabar, Cross River State, and Uyo, Akwa Ibom State, respectively. All other feed ingredients were procured from Calabar.

Processing of some feed ingredients/ration formulation

PKC and RH were mixed in the ratio of 1:1, homogenized, and sun-dried for 3 – 4 days, thereafter, the percentage requirement of PKC/RH combo for each treatment diet was measured out and mixed with the quantity of OPS required for each diet. This strategy was adopted in order to use the PKC/RH as absorbent for OPS. The combo was dried again for another 3 – 5 days before other ingredients were subsequently incorporated according to the respective inclusion levels required in the diets (broiler starter and finisher diets). Apart from conditioning the feedstuffs to a safe moisture level for the final compound diets, the second sun-drying process also benefited from the sterilization properties of the ultra-violet radiation of the sun to destroy pathogenic organisms associated with oil palm slurry.

Six experimental diets were formulated such that diets 1 and 2 contained zero percent PKC/RH and OPS, while diets 3 and 4; 5 and 6 incorporated PKC/RH at 25% and 50%, respectively. OPS was also included in the test diets (diets 3 - 6) at 4% level to boost their energy levels, while the feed enzyme was added to diets 2, 4, and 6 at 1% inclusion level. A similar feed formula was used in compounding both starter and finisher diets. However, the finisher contained percentages of key ingredients as required in chicken finisher broilers diets (Tables 1 and 2).

Table 1 - Gross composition of experimental broiler starter diets (g/100g)

Ingredients \ Treatment/Enzyme level	T_1,0.00E	T_1,1.00E	T_2,0.00E	T_2,1.00E	T_3,0.00E	T_3,1.00E
Maize	50.00	50.00	37.50	37.50	25.00	25.00
PKC/RH	-	-	12.50	12.50	25.00	25.00
Soybean meal	36.03	36.65	37.12	37.76	36.29	36.91
Wheat offal	7.57	5.95	2.48	0.84	3.31	1.69
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00
Bone meal	3.00	3.00	3.00	3.00	3.00	3.00
NaCl	0.30	0.30	0.30	0.30	0.30	0.30
L- Lysine	0.30	0.30	0.30	0.30	0.30	0.30
DL- Methionine	0.30	0.30	0.30	0.30	0.30	0.30
Vit/Tm premix*	0.50	0.50	0.50	0.50	0.50	0.50
Oil palm slurry	-	-	4.00	4.00	4.00	4.00
Nutrizyme®	-	1.00	-	1.00	-	1.00
Calculated nutrient composition						
Crude protein (%)	23.00	23.00	23.00	23.00	23.00	23.00
Crude fibre (%)	4.35	4.35	6.37	6.29	8.70	8.60
ME (kcal/kg Diet)	2888.59	2888.59	2758.77	2678.34	2479.11	2464.67

*To provide the following per kg of diet: Vit A, 10,000iu; Vit D_3, 2000iu; Vit E, 5iu; Vit K, 2mg; Riboflavin, 4.20mg; Folic acid, 0.5mg; Choline, 3mg; Mg, 56mg; Fe, 20mg; Cu, 10mg; Zn, 50mg; Co, 125mg.

Table 2 - Gross composition of experimental broiler finisher diets (g/100g)

Ingredients \ Treatment/Enzyme level	T_1,0.00E	T_1,1.00E	T_2,0.00E	T_2,1.00E	T_3,0.00E	T_3,1.00E
Maize	56.00	56.00	42.00	42.00	28.00	28.00
PKC/RH (1:1)	-	-	14.00	14.00	28.00	28.00
Full-fat soybean meal	31.28	32.03	32.45	32.04	31.34	32.08
Wheat offal	6.31	4.57	1.15	0.56	2.26	0.52
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00
Bone meal	3.00	3.00	3.00	3.00	3.00	3.00
NaCl	0.30	0.30	0.30	0.30	0.30	0.30
L- Lysine	0.30	0.30	0.30	0.30	0.30	0.30
DL- Methionine	0.30	0.30	0.30	0.30	0.30	0.30
Vit/Tm premix*	0.50	0.50	0.50	0.50	0.50	0.50
Oil palm slurry	-	-	4.00	4.00	4.00	4.00
Nutrizyme®	-	1.00	1.00	1.00	1.00	1.00
Calculated nutrient composition						
Crude protein (%)	20.00	20.00	20.00	20.00	20.00	20.00
Crude fibre (%)	4.00	4.00	6.98	6.81	8.94	8.24
ME (kcal/kg Diet)	3130.48	3130.48	2917.89	2892.32	2670.50	2662.38

*To provide the following per kg of diet: Vit A, 10,000iu; Vit D_3, 2,000iu; Vit E, 5iu; Vit K, 2mg; Riboflavin, 4.20mg, Folic acid, 0.5mg; Choline, 3mg; Mg, 56mg; Fe, 20mg; Cu, 10mg; Zn, 50mg; Co, 125mg.

Experimental birds and design

A total of one hundred and eight (108) one day old broiler chicks of Cobb strain used for the trial were purchased from a reputable distributor in Calabar. The birds were randomly distributed into six groups of eighteen (18) birds each. In the starter phase of the experiment, the groups were randomly assigned to six dietary energy and single dietary protein rations in a 3x2 factorial arrangement involving 0, 25 and 50% inclusion of PKC/RH combo and two enzyme levels (0% and 1%). Each treatment was replicated three times with six (6) birds per replicate. Each replicate was housed in a separate pen in a Deep litter system. A similar arrangement was used in the finisher phase of the trial.

Management of experimental Birds

Brooding of birds was carried out until they were three weeks old, after which period, the brooding equipment were withdrawn feed and clean drinking water were provided ad libitum for all treatments throughout the experimental term of eight weeks. In addition, adequate prophylactic medications and vaccinations were carried out during the experiment.

Data collection

Performance data

All birds were weighed at the beginning of the trial, and subsequently on weekly bases. Daily feed intake was calculated as the difference between weight of feed offered from the beginning of a day, and the left over at the beginning of a new day. In all, data collected included average initial live weights, weekly average live weight and live weight gain, average daily feed intake, total average live weight and live weight gain, feed-to-gain ratio and mortality (Table 3).

Carcass/organ weight evaluation data

At the end of the trial, six birds per treatment were picked for carcass/organ weight analyses. These included two birds per replicate (one with the highest live weight, and another with the lowest). They were starved for twelve hours, of feed only, whilst being allowed access to clean drinking water free choice, this was to decongest their alimentary system. Thereafter, the birds were weighed and slaughtered by cervical bone dislocation, after which their jugular veins were severed, and the carcasses thoroughly bled. Before subsequent defeathering, the carcasses were scaled in hot water of about 80°C for about one minute. Defeathering of the carcasses was followed by their evisceration by cutting through the vents, and the viscera removed. The dressed carcasses were thereafter weighed. Major parts of the dressed carcasses including the breasts, thighs/drumsticks were sectioned out and accurately weighed using a sensitive electronic scale, and the weights expressed as percentages of respective live weights of birds used. Also, weights of internal organs including crop, proventriculus/gizzard, liver and pancreas were taken. These and the dressed carcass weights were similarly expressed as percentages of their respective live weights (Table 4).

Statistical analyses

All experimental data were subjected to a two-way analysis of variance as described by Snedecor and Cochran (1978). Where F-tests indicated significant treatment mean effects, the means were separated using the new Duncan's multiple range test as outlined Steel and Torrie (1990).

RESULTS

Performance

Performance characteristics of chicken broilers fed PKC/RH diets supplemented with exogenous enzyme (Nutrizyme) is shown on Table 3. Average body weight gain obtained for T_1, T_2, and T_3 factorial sets not supplemented with Nutrizyme® ranged from 1801.89g to 1941.11g whilst the treatment sets with treatment diets supplemented with 1% exogenous enzyme recorded 1955.55g to 2031.22g. There were significant ($P < 0.05$) treatment effects. Average daily weight gain data for the factorial set with zero enzyme supplementation ranged from 32.18g to 34.66g, whereas the set treated with Nutrizyme ranged from 34.92g to 36.27g. The results were significantly ($P < 0.05$) different among the treatment means. Average daily feed intake for zero enzyme factorial set were 82.18g (T_1), 93.81g (T_2), and 104.01g (T_3), and those of the enzyme treated counterpart were 71.89g, 76.37g, and 79.63g, respectively for T_1, T_2, and T_3; the data showed significant ($P < 0.05$) treatment effects. Feed-to-gain ratios recorded for zero enzyme factorial set ranged from 2.37 to 3.32 whilst the set supplemented with the feed enzyme ranged from 1.98 to 2.28; there were significant ($P < 0.05$) treatment effects.

Carcass and organ weights analysis

These are summarized in Table 4. Apart from weight of thigh/drumstick, all other carcass and organ weight parameters including live weights, dressed weights, dressing percentages, weights of breasts, crop, proventriculus/gizzard, weights liver, and pancreas showed significant ($P < 0.05$) differences among treatment means.

Table 3 - Effects of dietary levels of PKC/RH supplemented with feed enzyme on chicken broilers performance

Parameters	Treatment/Enzyme level						SEM	P. Value
	T_1, 0.00E	T_1,1.00E	T_2, 0.00E	$T_2$1.00E	T_3, 0.00E	T_3, 1.00		
Average initial weight (g)	38.89	38.89	38.89	38.89	38.89	38.89	0.00	p>0.05
Average final weight (g)	1980.00^{b}	2070.11^{a}	1962.78^{c}	2065.83^{a}	1840.78^{d}	1994.44^{b}	61.59	P<0.05
Average weight gain (g)	1941.11^{b}	2031.22^{a}	1923.89^{bc}	2026.94^{a}	1801.89^{d}	1955.55^{b}	61.59	P<0.05
Average daily wt. gain (g)	34.66^{b}	36.27^{a}	34.36^{bc}	36.20^{a}	32.18^{c}	34.92^{b}	1.10	P<0.05
Average feed intake (g)	4602.05^{c}	4025.59^{f}	5253.43^{b}	4276.47^{e}	5824.76^{a}	4459.49^{d}	197.91	P<0.05
Average daily feed intake (g)	82.18^{c}	71.89^{cd}	93.81^{b}	76.37^{c}	104.01^{a}	79.63^{c}	3.36	P<0.05
Feed conversion ratio	2.37^{b}	1.98^{c}	2.73^{b}	2.11^{c}	3.23^{a}	2.28^{b}	0.11	P<0.05

$^{a\,b\,c...}$Means on the same row, with different superscripts are significantly different (p<0.05).

Table 4 - Effects of dietary levels of PKC/RH supplemented with feed enzyme on carcass and organ weight characteristics of chicken broilers

Parameters	Treatment/Enzyme level						SEM	P. Value
	T_1, 0.00E	T_1,1.00E	T_2, 0.00E	$T_2$1.00E	T_3, 0.00E	T_3, 1.00		
Live weight (g)	2100.00^{c}	2466.67^{a}	2066.67^{d}	2266.67^{b}	2050.00^{d}	2166.67^{c}	25.78	P<0.05
Dressed weight (g)	1450.00^{c}	1750.00^{a}	1283.33^{d}	1683.33^{b}	1150.00^{e}	1500.00^{c}	18.23	P<0.05
Dressing %	69.05^{bc}	70.95^{b}	62.10^{c}	74.26^{a}	56.10^{d}	69.23^{b}	1.87	P<0.05
Weight of thigh/drumstick (% Of live weight)	24.01	24.41	23.40	24.72	23.28	24.10	0.89	p>0.05
Weight of breast (% of live weight)	28.62^{b}	30.82^{a}	26.10^{c}	28.95^{b}	26.01^{c}	28.21^{b}	0.95	P<0.05
Weight of crop (% of live weight)	0.59^{b}	0.44^{c}	0.70^{a}	0.46^{c}	0.74^{a}	0.48^{c}	0.07	P<0.05
Weight of proventriculus/gizzard (% of live weight)	2.79^{b}	2.78^{b}	4.30^{a}	2.79^{b}	4.33^{a}	2.81^{b}	0.09	P<0.05
Weight of pancreas (% of live weight)	0.26^{b}	0.15^{c}	0.33^{a}	0.25^{b}	0.34^{a}	0.26^{b}	0.01	P<0.05
Weight of liver (% of live weight)	1.84^{b}	1.74^{c}	2.94^{a}	1.76^{c}	2.97^{a}	1.78^{c}	0.02	P<0.05

$^{a\,b\,c...}$ Means on the same row, with different superscripts are significantly different (p<0.05).

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DISCUSSION

Performance characteristics

There were no significant differences ($P > 0.05$) across the treatment groups for average initial body weights. Experimental birds were homogenous in age, and average body weights, a fundamental requirement for the application of the Completely Randomized Design (CRD) in Animal experimentation

Birds in treatment groups whose' diets were supplemented with Nutrizyme recorded the highest final body weights, whilst the least body weight gain was in a treatment group without enzyme supplementation (T_3, 0%E). It was observed that average body weight gain, and average daily body weight gain followed a similar trend as observed in average final body weight gain. In general, PKC/RH treatment groups supplemented with Nutrizyme performed better with respect to the performance parameters so far discussed. It is suggested that this trend is traceable to the complementary role played by the exogenous enzyme in facilitating digestion, absorption and metabolism of NSPs in the test diets. This observation is corroborated by research reports (Douglas et al; 2000; Enberg et al; 2004), which stated that dietary inclusion of exogenous enzymes could compensate for the deficiencies of endogenous enzymes to speed up their catalytic and hydrolytic activities for increasing digestion of feed.

Sogbesan et al. (2006) posited that ability of an organism to utilize nutrients will positively influence its growth performance; also, the work of Ukorebi (2022) has shown that supplementation of feeds reduce digesta viscosity, enhance digestion of and absorption of nutrients especially fats and protein, improve metabolizable energy value of the diet, as well as alter microbial population in the tract, all of which are believed to enhance weight gain. This is in agreement with the reports of Alabi et al (2014): the researchers pointed out that addition of enzymes to address NSP viscosity can improve gut health, feed efficiency, improve fecal quality, and facilitate the use of low cost ingredients; they maintained that the benefits of using livestock feed enzymes is to increase availability of starches and proteins which are enclosed within the fibre-rich cell wall and to increase availability of phosphorous from phytate.

Average daily feed intake was significantly ($P < 0.05$) higher in the factorial set with zero enzyme dietary supplementation ($T_1$0% E, $T_2$0% E, and $T_3$0% E). This is attributable to the lower metabolizable contents of diets of these treatments, as birds would normally continue in feed intake until their energy requirements are met.

Feed-to gain ratio was significantly ($P < 0.05$) low in T_1, 1%E (1.98), followed by T_2, 1%E (2.11), whilst in contrast, it was significantly ($P < 0.05$) higher in T_3, 0%E (3.23). This trend further indicates better performance of birds placed on enzyme supplemented diets. Feed conversion ratio (FCR) of 2.20 is considered good in chicken broiler production; feed conversion ratios greater than 2.50 would suggest either feed wastage, low dietary energy, or poor-quality feed, among others.

In general, the relatively lower performance characteristics of birds in factorial sets without feed enzyme supplementation suggests that endogenous enzymes of the birds were incapable of hydrolyzing the dietary NSPs to liberate the nutrients they contain for the birds. Research reports (Kanengoni et al., 2002; Partenen et al., 2007) have shown that as the level of fibre in monogastric diets increase, digestibility of energy and Nitrogen decrease. In broilers, endogenous enzymes cannot adequately digest NSPs, therefore ingestion of high levels of soluble leads to digesta viscosity, low nutrient digestibility and absorption (Hijati, 2010; El-Wahab et al., 2024). Agreeably however, one may not also rule out the potential of certain anti-nutritional factors in NSPs to negatively impact performance of bird receiving diets containing them. Atasie and Akinhanmi (2009) reported that Palm kernel Meal (PKM) contain anti-nutritional properties such as β-mannan, galactomannan, Xylan, and arabino-Xylan which limit its inclusion in poultry diets. The aforementioned inhibitors can be dismantled by Nutryzyme the multi-enzyme complex of which contains hemicellulase, phytase, arabinases, pectinases, amylases, β-glucanases, cellobiase, Xylanase, pentosanase, lipase, among others.

Carcass and Organ weight characteristics

All carcass and organ weight characteristics excepting weights of thigh/drumstick were significantly ($p<0.05$) affected by treatments. Live weights were highest in enzyme supplemented treatments (T_1, 1%E; T_2, 1%E; T_3, 1%E), followed by T_1, 0%E (conventional diet with zero enzyme inclusion). The dressed weights, dressing percentage and breast weights followed a trend similar to live weights. From the results obtained, it would seem that enzyme supplementation facilitated the breakdown of NSPs and anti-nutritional factors contained in them, thus making the feed safe and richer in nutrients than the factorial set without enzyme supplementation, thus making way for the desirable carcass/organ weight characteristics observed.

The weights of proventriculus and pancreas were highest in factorial sets with zero percent enzyme supplementation and lower in treatment groups where diets were supplemented with exogenous enzyme. This might have been consequent on the challenge on these organs to increase their activities in order to acclimate themselves to the bulky feeds they received. It is also suggested that: the crop increased in weight as a result of the need to increase its storage capacity cope with increased storage of the feed; increase in the weight of the proventriculus could be traceable to its increased activity to produce more enzymes to deal with the bulky feed; similarly, the increased grinding activity of the gizzard needed to attack the bulky feed led to increased muscular development of the organ. The challenge posed by intact PKC/RH based diets could negatively impact the pancreas due to its dual role as an exocrine gland and an endocrine gland. As an exocrine gland, it produces pancreatic juices containing amylase, lipase and protease to hydrolyze

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carbohydrates, lipids and proteins; as an endocrine gland, the pancreas secretes hormones like insulin and glucagon that function in the regulation of glucose. With enzyme supplementation of PKC/RH based diets, the requirements for the digestion of NSPs are supplied thus reducing the workload on the pancreas. On the other hand, the structural increase in the size of the pancreas can be due to the 'struggle' to meet the enzyme requirement for dismantling the NSPs.

The significantly ($P < 0.05$) increased weights of livers in test diets with zero enzyme supplementation can also be associated with increased demand on it for its total "performance". The liver performs numerous functions, some of which include producing bile for digestion of lipids, metabolism of nutrients, filtering toxins, making essential proteins like clotting factors, and albumen, storing glucose and glycogen, fighting infections, and removing bacteria, detoxifying harmful and safely removing them, regulating blood chemistry, among others. To perform all its statutory functions coupled with antinutritional inadvertently present in dietary NSPs, as inhibitors in the diets, the liver has to increase its activities to match the demands on it, hence the increase in its size. The detailed interactions between the inclusion levels of PKC/RH and enzyme supplementation are shown in Tables 3 and 4.

CONCLUSION

The experiment showed that PKC/RH diets supplemented with exogenous fibrolytic enzyme (Nutrizyme) can replace up to 50% of maize in the diets of chicken broilers, both at starter and finisher phases. The diets were found to sufficiently support production without any deleterious effect on performance and carcass characteristics. The test diets not supplemented with the feed enzyme adversely affected weight gain, feed conversion ratio, and internal organs (crop, proventriculus/gizzard, pancreas and liver) of the birds. This has demonstrated that the use of commercial feed enzymes is beneficial in the utilization of high NSPs in chicken diets. In practical diets of chicken broilers therefore, Farmers could replace 50% of maize with PKC/RH (1:1 ratio), when the feed is supplemented with 1% Nutrizyme supplement (a kind of fibrolytic enzyme).

DECLARATIONS

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Data availability

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Ethical approval

This study was duly reviewed and approved by the Institutional Animal Care and use Committee of the University of Cross River State (UNICROSS8289). The animal experiment was performed in accordance with the National Institute of Health Guidelines for the Care and Use of Laboratory Animals; and the ARRIVE (Anima Research: Report of *In vivo* Experiments) guidelines.

Funding

The author declares that no funds/grants were received during the research and for the preparation and publication of this manuscript.

Consent to publish

The author gives full consent for the publication of this manuscript by Online Journal of Animal and feed research.

Competing interests

Author declares that there are no competing interests.

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