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# Evaluation of maize–sorghum mixture based diets supplemented with exogenous enzyme on growth response, haematology and serum biochemical indices of starter broiler chickens

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**Abstract**

*Poultry diets are largely composed of plant based materials that hold non-starch polysaccharides (NSP). The inclusion of NSP rich ingredients often reduces feed cost, but hampers a proper digestion due to anti-nutritional factors (ANF). Against this background, potency of exogenous enzymes was evaluated to upgrade dietary energy and total protein. A total of 180 broiler chickens were used in 28 days feeding trial. Six experimental diets were formulated in which maize based diet served as control (T1). Maize in the control diet was replaced by sorghum at the levels of 20% (T2), 40% (T3), 60% (T4), 80% (T5), and 100% (T6), respectively. Besides the control diet every other dietary groups were supplemented with enzyme at the rate of 50g/100kg. The broiler chicks were weighed and allotted to six dietary treatments of 30 birds each. The groups were replicated three times with 10 birds per replicate. The parameters determined for growth performance include: Final weight (g), Weight gain (g/bird), Daily weight gain (g/bird), Feed intake (g/bird), Daily feed intake (g/bird) and Feed conversion ratio (FCR). The result showed significant ($p<0.05$) effect on total feed intake and daily feed intake. Final weight, daily weight gain and feed conversion ratio (FCR) were not significantly ($p>0.05$) influenced by dietary treatments. Birds fed 60% (T4), 80% (T5) and 100% sorghum (T6) with enzyme supplementation showed higher similar statistical values 1365.00g, 1373.33g and 1373.66g, respectively for total feed intake. Haematological parameters were not significantly ($p>0.05$) affected by dietary treatments. Maize-sorghum based diet with enzyme supplementation had significant ($p<0.05$) effect on total protein, albumin and uric acid. Birds fed diets with 80% (T5) and 100% T6 sorghum levels with enzyme supplementation showed higher ($p<0.05$) statistical values 4.10 and 3.66 g/dl for total protein. Inclusion of sorghum up to 100% replacement level for maize with enzyme supplementation could be fed to starter broiler chicks for improved growth performance without adverse effect.*

**Keywords:** Maize-sorghum, enzyme, performance, haematology, serum biochemistry, broiler chickens.

## Introduction

Cereal grains account for about 50-60% of a typical broiler diet where this feed serve as a principal carbohydrate energy source for poultry. Yellow corn has remained the chief energy source in compounded diets and constitutes about 50% of poultry diet (Ajaja *et al*., 2002). However, the dependence on yellow corn grain becomes a problem in feed formulations when it is unavailable, expensive or of poor quality and competition between human beings and poultry over the consumption of cereal grains has compelled the nutritionists and led them to explore new and non-conventional feedstuff. With regards to the nutritive value, cost and availability, sorghum grain is probably the next alternative to maize in poultry feed (Hancock, 2000). However, sorghum contains a high level of tannins, variable amounts of phytate, kafirin and possibly

polyphenols in the sorghum grain may act as anti-nutritional factors (Selle *et al*., 2010a). These factors can negatively influence the nutritive properties of sorghum and therefore cause negative effects on feed intake, palatability, digestibility of nutrients and growth performance (Hassan *et al*., 2003; Kim and Miller, 2005). Poultry diets are largely composed of plant based materials that hold non-starch polysaccharides (NSP). The inclusion of NSP rich ingredients often reduces feed cost, but hampers a proper digestion due to anti-nutritional factors (ANF). Soluble NSP for instance increases digesta viscosity (Veldman and Vahl, 1994) where insoluble NSP in plant cell walls encapsulate nutrients and render them unavailable for digestion (Meng and Slominski, 2005). Non-ruminants are physiologically unable to hydrolyze NSP in their small intestine. Hence, supplementation of NSP enzymes to broiler diets can improve digestibility, whilst economizing the formula using cheaper NSP rich ingredients. Another way to moderate broiler feed expenses is to increase the protein digestibility of the various ingredients used in the formula. Endogenous proteases do not digest all dietary protein in the small intestine (Lemme *et al*., 2004). Therefore, exogenous counterparts can strengthen the bird's own protease community and as such increase protein and amino acid digestibility (Angel *et al*., 2011; Freitas *et al*., 2011). Also, combinations of proteases and NSP enzymes have been studied, where the former enhanced the digestion of amino acids and the latter of energy (Romero *et al*., 2013). Nevertheless, effects of protease on protein digestibility are not always consistent (Antipartis *et al*., 2013). Interestingly, however, NSP enzymes as such also showed a potential to increase protein digestibility in a corn- and wheat-based diet in broilers (Romero *et al*., 2011). Indeed, enzyme combinations at high concentration, targeting arabinoxylan, glucan, and pectic substances are potent blends to depolymerize NSP and hydrolyze NSP-protein complexes (Meng *et al*., 2005). Therefore, the potency of exogenous enzymes was evaluated to upgrade dietary energy as well as total protein and amino acid digestibility of maize-sorghum based diet with a view to assess growth response, haematology and serum biochemical indices of starter broiler chickens.

## Materials and methods

### *Experimental site*

The experiment was conducted at the Poultry unit of the Teaching and Research Farm of the Taraba State University Jalingo located between latitude 6° 30< and 9° 30<N and longitude 9°00< and 12°00<E in Guinea Savannah Zone of Northern Nigeria (Kefas *et al*., 2020). It has an annual rainfall range of 1000mm – 1500mm, the ambient temperature of the area ranges between 30 – 38°C with an average of 29°C.

### *Experimental birds and management*

A total number of 180 d-old unsexed broiler chicks of commercial strain (arbor acre) were purchased from a reputable hatchery. The chicks were weighed and allotted to six dietary treatment groups of three replicates each in a completely randomized design. Each replicate consists of 10 chicks, to have a total of 30 birds per treatment group. Birds were reared on deep litter housing system for 28 days. Routine vaccinations and medications were strictly followed and feed and water were provided *ad libitum*.

### *Source of test ingredients*

Sorghum was purchased from local market in Jalingo. The additive used in this study is a commercial multi-enzyme called Zympex. Zympex was sourced from Novus International USA and it contains alpha-amylase, acid protease, alpha-glucosidase, beta-mannanase, xylanase and beta-

glucanase. The inclusion rate is 500g/tonne of feed.

***Experimental diets***

The experimental diets were formulated to meet NRC (1994) minimum nutrient requirement. The diets consist of maize based diet (control T1), 20%, 40%, 60%, 80%, and 100% varying levels of sorghum as replacement for maize in the control diet denoted by T2, T3 T4, T5 and T6 respectively. Zympex multi-enzyme 50g/100kg diet was supplemented across dietary levels as presented in Table 1.

**Table 1: Percentage composition of broiler chicken starter diets (1- 28th days)**

| | Sorghum inclusion levels | | | | | |
|---|---|---|---|---|---|---|
| | **0%** | **20%** | **40%** | **60%** | **80%** | **100%** |
| **Ingredients:** | | | | | | |
| Maize | 52.00 | 41.60 | 31.20 | 20.80 | 10.40 | 0.00 |
| Sorghum | 0.00 | 10.40 | 20.80 | 31.20 | 41.60 | 52.00 |
| Soya bean meal | 18.50 | 18.50 | 18.50 | 18.50 | 18.50 | 18.50 |
| Groundnut cake | 16.20 | 16.20 | 16.20 | 16.20 | 16.20 | 16.20 |
| Fish meal | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Rice offal | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| Bone meal | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Oyster shell | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| Salt | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| *Premix | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| DL-Methionine | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| L-Lysine | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Total | **100.00** | **100.00** | **100.00** | **100.00** | **100.00** | **100.00** |
| **Supplementation** | | | | | | |
| Phytase 50g/100kg | - | + | + | + | + | + |
| **Calculated analysis:** | | | | | | |
| ME (kcal/kg) | 2842.79 | 2820.95 | 2799.11 | 2777.27 | 2755.43 | 2733.59 |
| Crude protein (%) | 22.87 | 23.06 | 23.26 | 23.46 | 23.66 | 23.85 |
| Crude fibre (%) | 3.54 | 3.54 | 3.54 | 3.54 | 3.54 | 3.54 |
| Ether extract (%) | 4.18 | 4.07 | 3.97 | 3.87 | 3.76 | 3.66 |
| Ca (%) | 1.25 | 1.25 | 1.26 | 1.26 | 1.26 | 1.27 |
| P (%) | 0.47 | 0.49 | 0.51 | 0.54 | 0.56 | 0.59 |
| L-Lysine (%) | 1.12 | 1.13 | 1.14 | 1.15 | 1.16 | 1.17 |
| DL-Methionine (%) | 0.58 | 0.58 | 0.57 | 0.56 | 0.55 | 0.54 |

- \- No enzyme supplementation
- \+ Enzyme supplementation

## Data collection

***Growth performance characteristics***

The initial weights of the birds were taken on arrival. The live weights of the birds as well as the feed consumption of each replicate were measured weekly. Feed conversion ratio for each replicate was determined by dividing the feed intake by the weight gain.

Feed intake/bird (g)=

$$\frac{\text{Quantity of feed fed} - \text{Quantity of feed left over}}{\text{Number of birds} \times 28 \text{ days}}$$

Daily weight gain (g) =

$$\frac{\text{Final live weight} - \text{Initial weight}}{\text{Number of birds} \times 28}$$

Feed conversion ratio =

$$\frac{\text{Quantity of feed consumed}}{\text{Weight gain}}$$

***Blood analysis***

At the end of 28$^{th}$ day, blood samples were

drawn from the wing vein of 3 birds per treatments that is one from each replicates. 2ml of blood sample was transferred into a bottle containing Ethylene Diamine Tetra Acetic Acid (EDTA) anticoagulant for haematological analyses. The parameters determined include Packed Cell Volume (PCV), White Blood Cell (WBC), **Haemoglobin** (Hb), Red Blood Cell (RBC), **Mean Cell Haemoglobin Concentration** (MCHC), **Mean Cell Haemoglobin** (MCH) and **Mean Cell Volume (MCV). 2**m1 of blood was collected into a clean syringe and put in plane bottle for serum biochemical analyses. The blood samples were allowed to clot; they were refrigerated for 6 hours and then spun in a centrifuge at 900 rpm for 20 minutes. The separated serum was stored in the freezer at -2°C prior to analysis for serum metabolites such as serum total protein, albumin, globulin, creatinine, uric acid and cholesterol.

**Statistical Analysis**

Data collected were subjected to one–way analysis of variance (ANOVA) in a completely randomized design using SAS (2000) while significant means was separated using Duncan's Multiple Range Test at 5% level of significance.

**Results and discussion**

***Growth performance***

The result of growth performance of starter broiler chicken fed maize-sorghum based diets with enzyme supplementation is presented in Table 2. Dietary treatments had significant ($p<0.05$) influence on growth performance characteristic of starter broiler chicken. Maize-sorghum based diet with enzyme supplementation showed significant ($p<0.05$) effect on total feed intake and daily feed intake. Final weight, daily weight gain and feed conversion ratio (FCR) were not significantly ($p>0.05$) influenced by dietary treatments. Though not significant ($P>0.05$), birds fed maize-sorghum based diet revealed higher numerical values for final weight and weight gain at comparative level to the control diet (TI). Birds showed range values 660.33g-773.33g and 624.59-736.87 for final weight and total weight gain responsively. Values recorded for daily weight gain followed similar pattern with total weight gain. This improved performance could be attributed to degradation effect of enzyme on non-starch polysaccharides (NSP) in the cell wall matrix of the sorghum with the release of encapsulated nutrients and lowered viscosity of digesta caused by soluble NSP and improved rate of diffusion between enzymes and digestion end products (Bedford and Schulze 1998). Improved final weight and weight gain as observed in this study agreed with literature (Pasquali *et al.,* 2016) who reported that inclusion of protease, xylanase and phytase enzyme improved broiler body weight gain when fed maize-sorghum based diets at starter phase.

Birds fed 60% (T4), 80% (T5) and 100% sorghum (T6) with enzyme supplementation showed higher similar statistical values 1365.00g, 1373.33g and 1373.66g, respectively for total feed intake. Birds fed 0%, 20% and 40% sorghum levels reveal least ($p<0.05$) statistical values 1356.009, 1356.33g and 1355.00g respectively for total feed intake. Daily feed intake followed similar trend with total feed intake. FCR was not significantly ($p>0.05$) affected by dietary treatments. Close range value 1.87-2.09 was recorded for FCR. The observations in this study in term of growth performance were at variance with Torres *et al*. (2013) who reported no significant ($p>0.05$) difference among performance parameters when broiler chicken were fed sorghum based diets. Values report from this finding on feed intake disagreed with

Ibitoye *et al*. (2012) who reported that replacing maize with sorghum or millet had no effect on feed intake. This report was at variance with literature (Ibrahim *et al*., 2012) who reported that inclusion of β-glucanase enzyme in sorghum-based diets decreased feed intake in broiler chickens. From the report of this findings, feed intake improved with enzyme supplementation contrary to the report of Mabelebele *et al*. (2017) who reported no effect of enzyme inclusion on feed intake, weight gain and FCR at all ages when broiler chickens were fed sorghum based diets. The observation in this study corroborated Selle *et al*. (2010) who reported increased feed intake and weight gain when xylanase enzyme was supplemented to sorghum-based diet fed to broiler chickens.

**Table 2 : Effect of maize-sorghum based diets with enzyme supplementation on growth response of starter broiler chickens (1 – 28 days)**

| | Sorghum inclusion levels | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameters | 0% T1 | 20% T2 | 40% T3 | 60% T4 | 80% T5 | 100% T6 | SEM |
| Initial weight (g) | 35.74 | 35.50 | 35.85 | 35.79 | 36.46 | 35.97 | 0.11 |
| Final weight (g) | 660.33 | 716.67 | 683.00 | 716.67 | 773.33 | 750.00 | 12.73 |
| Weight gain (g/bird) | 624.59 | 675.16 | 647.15 | 680.88 | 736.87 | 714.02 | 12.33 |
| Daily weight gain (g/bird) | 25.32 | 24.32 | 23.11 | 24.31 | 26.31 | 25.50 | 0.60 |
| Feed intake (g/bird) | 1356.00b | $1356.33^{b}$ | $1355.00^{b}$ | $1365.00^{ab}$ | $1373.33^{a}$ | $1373.66^{a}$ | 2.46 |
| Daily feed intake (g/bird) | $48.42^{b}$ | $48.44^{b}$ | $48.39^{b}$ | $48.74^{ab}$ | $49.04^{a}$ | $49.05^{a}$ | 0.09 |
| Feed conversion ratio | 1.96 | 2.01 | 2.09 | 2.01 | 1.87 | 1.92 | 0.04 |

$^{ab}$ Mean on the same row having different superscripts were significantly ($P<0.05$) different.

***Haematological parameters***

The result of haematological parameters of starter broiler chickens fed maize-sorghum based diets with enzyme supplementation is shown in Table 3. Dietary treatments had no significant ($p>0.05$) effect on all the parameters determined. Ranged values 31.00% - 35.33% and 11.52-12.33 g/dL were recorded for packed cell volume (PCV) and haemoglobin (Hb) respectively. Numerical values 31.00 - 35.33 % recorded for PCV in this study were higher than 24.00 - 28.00 % reported for broiler chickens (Onimisi *et al*., 2017). Improved ranged value recorded for PCV in this study could be an indication that the bone marrow of the birds functioned properly and showed absence of hypochronic anemia. PCV is a descriptor of the function and concentration of red blood cell (kenedy, 2011). Ranged values of 11.53 - 12.33g/dL recorded for Hb in this study compared favourably with 7-13 g/dL reported by Banerjee (2009). High concentration of haemoglobin in the cytoplasm of red blood cell gives an indication of effective oxygen carrying capacity, thus healthy living. White blood cell and red blood showed close range values 9.80-11.93 $x10^{3}$/mL and 4.300-4.86$x10^{6}$/L respectively. Range values 33.23 - 38.10 g/dL obtain for MCHC in this study were closer to mean value of 33.20 g/dL reported in literature (Owosibo *et al*., 2017) when broiler chickens were fed corn bran meal supplemented with enzyme. Haematology refers to the study of number and morphology of the cellular element of the blood such as RBC, WBC and platelet and the use of these results in the diagnosis and monitoring of disease. Hematological parameters are used to determine health status of animals and stress due to environment, nutrition and pathological factors (Afolabi *et al*., 2010). Invariably, normal range reported for hematological parameters in this study indicated that the birds were healthy.

**Table 3: Effect of maize -sorghum based diets with enzyme supplementation on haematological parameters of starter broiler chickens (1 – 28 days)**

| | Sorghum inlusion levels | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameters | 0% T1 | 20% T2 | 40% T3 | 60% T4 | 80% T5 | 100% T6 | SEM |
| Packed cell volume (%) | 31.00 | 35.00 | 33.66 | 34.66 | 35.33 | 33.00 | 0.71 |
| Haemoglobin (g/dL) | 11.76 | 11.63 | 11.53 | 12.30 | 11.96 | 12.33 | 0.34 |
| White blood cell ($\times10^3$/L) | 9.80 | 11.36 | 10.86 | 11.26 | 11.93 | 11.30 | 0.39 |
| Red blood cell ($\times10^6$/L) | 4.33 | 4.86 | 4.63 | 4.70 | 4.97 | 4.30 | 0.30 |
| Mean cell volume (fl) | 74.78 | 78.05 | 77.36 | 79.25 | 76.18 | 80.96 | 4.76 |
| Mean cell haemoglobin concentration (g/dL) | 38.10 | 33.23 | 34.28 | 35.66 | 33.93 | 36.87 | 0.82 |
| Mean corpuscular haemoglobin (pg) | 28.72 | 25.95 | 26.81 | 28.94 | 26.22 | 29.68 | 2.03 |

***Serum biochemical indices***

The result of serum biochemical indices of starter broiler chickens is presented in Table 4. Maize-sorghum based diet with enzyme supplementation had significant ($p<0.05$) effect on total protein, albumin and uric acid. Globulin, glucose, creatinine and cholesterol were not significantly ($p>0.05$) affected. Birds fed diets with 80% (T5) and 100% T6 sorghum levels with enzyme supplementation showed higher ($p<0.05$) statistical values 4.10 and 3.66 g/dL for total protein. Least ($p<0.05$) value of 2.65 g/dL was recorded for total protein in the birds fed 40% sorghum (T3). Albumin followed similar pattern with birds fed 40% sorghum with enzyme supplementation (T3) revealed least ($P<0.05$) value of 2.34 g/dL. Range values 2.34 - 3.56 g/dL recorded in this study close to the normal range 2.7-3.7 g/dL reported in literature (Oyeyemi *et al*., 2014). Improved significant ($P<0.05$) values recorded for total protein and albumin in this study suggested adequacy of the diets in supplying protein needed by the birds. Total serum protein had been reported to depend on quality and quantity of protein supplied in the diet (Awosanya *et al*., 1999). The observation in this study supported the report in literature (Mabelebele *et al*., 2017) who reported an improved protein digestibility in sorghum based diets with enzyme supplementation. Improved total protein and albumin record in this study corroborated report of Pasquali *et al*. (2016) who reported improved nitrogen retention in birds fed protease, xylanase and phytase supplemented maize-sorghum based diets. With the exception of birds fed 20% (T2) and 40% (T3) sorghum levels, similar ($P<0.05$) statistical values were recorded across dietary treatments for uric acid. Range values 2.30 -3.80 mmol/L were within the normal range. This suggested that no impairment in the balance of amino acid which are required as a major precursor for biosynthesis of protein. Elevated uric acid is an indication of imbalance amino acid in the diet and consequently energy wastage (Nworgu *et al*., 2017).

**Table 4 : Effect of maize-sorghum based diets with enzyme supplementation on serum biochemical indices of starter broiler chickens (1 – 28 days)**

| | Sorghum inclusion levels | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0% | 20% | 40% | 60% | 80% | 100% | |
| Parameters | T1 | T2 | T3 | T4 | T5 | T6 | SEM |
| Total protein (g/dL) | $3.03^{bc}$ | $3.17^{bc}$ | $2.65^{c}$ | $3.29^{abc}$ | $4.10^{a}$ | $3.66^{ab}$ | 0.12 |
| Albumin (g/dL) | $2.67^{ab}$ | $2.86^{ab}$ | $2.34^{b}$ | $3.02^{ab}$ | $3.56^{a}$ | $3.10^{ab}$ | 0.11 |
| Globulin (g/dL) | 0.36 | 0.31 | 0.31 | 0.27 | 0.53 | 0.56 | 0.04 |
| Glucose (mg/dL) | 175.00 | 172.33 | 174.66 | 175.33 | 178.33 | 180.33 | 1.94 |
| Creatinine (mg/dL) | 0.64 | 0.58 | 0.65 | 0.71 | 0.75 | 0.69 | 0.01 |
| Uric acid (mg/dL) | $3.40^{ab}$ | $2.35^{b}$ | $2.30^{b}$ | $3.00^{ab}$ | $3.80^{a}$ | $3.05^{ab}$ | 0.16 |
| Cholesterol (mg/dL) | 124.00 | 125.00 | 124.66 | 129.66 | 126.33 | 128.33 | 0.83 |

$^{abc}$ Mean on the same row having different superscripts were significantly ($P<0.05$) different.

## Conclusion

The study showed that maize-sorghum based diet with enzyme supplementation had effect on total feed intake and daily feed intake among growth response parameters. Inclusion of sorghum up to 100% with enzyme supplementation had effect on total protein and albumin which indicated quality of the diet. Sorghum with enzyme supplementation could replace maize completely without any adverse effect on starter broiler chickens.

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## References

**Afolabi, S. B. 2010**. Haematological parameters of the Nigerian local grower chickens fed varying dietary level of palm kernel cake. Proceeding of the 35th annual conference of Nigeria society for Animal Production held at University of Ibadan Oyo State Nigeria. 247 - 252.

**Ajaja, K., Agbede, J. O. and Aletor, V. A. 2002**. Replacement value of sorghum dust for maize in diets for broiler chicks. Proceedings of the 27th Annual Conference of the Nigerian Society for Animal Production, March 17-21, 2002, Akure, Nigeria, 109-112.

**Angel, C. R., Saylor, W., Vieira, S. L. and Ward, N. 2011**. Effects of a monocomponent protease on performance and protein utilization in 7- to 22-day-old broiler chickens. *Journal of Poultry Science*, 90: 2281 – 2286.

**Antipatis, C., Knap, I., Pontoppidan, K., Valientes, R. A. and Angel, R. 2013**. Exogenous proteases and their interaction with dietary ingredients. Proceeding 24th Australian Poultry Science Symposium. Sydney, New South Wales, Australia. 31 – 40.

**Awosanya, B. J., Joseph, K., Akpata, D. F. and Ayoola, M. A 1999**. Performance, blood chemistry and carcass quality attributed of rabbit fed raw and processed pwerarra seed meal. *Tropical Journal of Animal Science,* 2: 89 – 96.

**Banerjee, G. C. 2009**. A Texbook of Animal Husbandry 8th ed. Oxford and IBH Publishing Co. PVT. Ltd. New delhi India. 2009. 118 – 139.

**Bedford, M. R. and Schulz, H. 1998**. Exogenous enzymes for pigs and poultry. *Nutrition Research*, 11: 91-114.

**Freitas, D. M., Vieira, S. L., Angel, C. R., Favero, A. and Maiorka, A. 2011**. Performance and nutrient utilization of broilers fed diets supplemented with a novel mono-component protease. *Journal of Applied Poultry Research*, 20: 322 – 334.

**Hancock, J. D. 2000**. Value of Sorghum and Sorghum Co-Products in Diets for Livestock. In: Sorghum Origin, History, Technology and Production, Smith, W. and R.A. Fredericksen (Eds.). Wiley Series Crop Science, New York, pp: 731-751.

**Hassan, I. A. G., Elzubeir, E. A. and El Tinay, A. H. 2003**. Growth and apparent absorption of minerals in broiler chicks fed diets with low or high tannin contents. *Tropical Anim. Health Production*, 35: 189-196.

**Ibitoye, E. B., Olorode, B. R., Jimoh, A. A. and Abubakar, H. 2012**. Comparative performance and organ relative weight of broiler chickens fed three sources of energy diet. *Journal of Animal Production Advances*, 2(5): 233 – 238.

**Ibrahim, B., Abass, K. and Mudawi, H. 2012**. The effect of β-glucanaseinclution in sorghum based diet on performance of broiler chicks. *Proceedings of the Conference on International Research on Food Security, Natural Resource Management and Rural Development*, September 19-21, 2012, Georg-August Universitat Gottingen and University of Kassel-Witzenhausen, Gottingen, Germany, 1-4.

**Kefas, P. K., Ali, S., Ofem, K. I. and Umeugokwe, C. P. 2020**. Genesis and classification of soil along a toposequence in the Teaching and Research Farm of Taraba State University, Jalingo, Nigeria. *Global Journal of Agricultural Science*, 19: 33 – 43.

***Kenedy, R. 2011***. *CBC (Complet*e Blood Count) Interpretation. The medical doctors' library. http:// www. medical-library. net/cbc red blood cells. html.

**Kim, H. S. and Miller, D. D. 2005**. Proline-rich proteins moderate the inhibitory effect of tea on iron absorption in rats. *Journal of Nutrition*, 135: 532-537.

**Lemme, A., Ravindran, V. and Bryden, W. L. 2004**. Ileal digestibility of amino acids in feed ingredients for broilers. *Worlds Poultry Science*, 60: 423 – 438.

**Meng, X. and Slominski, B. A. 2005**. Nutritive values of corn, soybean meal, canola meal, and peas for broiler chickens as affected by a multicarbohydrase preparation of cell wall degrading enzymes. *Poultry Science*, 84: 1242 – 1251.

**NRC. 1994**. Nutrient Requirements of Poultry, Ninth ed.; National Academy Press: Washington, DC.

**Nyachoti, C. M., Campbell, L. D. and Guenter, W. 2005**. Degradation of cell wall polysaccharides by combinations of carbohydrase enzymes and their effect on nutrient utilization and broiler chicken performance. *Poultry Science*, 84: 37 – 47.

**Nworgu, F. C., Ogungbenro, S. A. and Solesi, K. S. 2007**. Performance and some blood chemistry indices of broiler chicken served fluted pumpkin (*Telfaria occidentalis*) leaves extract supplement. *American-Eurasian Journal of Agriculture and Environment Science*, 2(1): 90 – 98.

**Onimisi, P. A., Moses, O. and Jegede, J. O. 2017**. Evaluation of optimum inclusion level of Biostrong® 510 as replacement for antibiotics growth promoter in broiler chickens production under field condition in Nigeria. *Nigerian Journal of Animal Science*, 19(1): 203 – 214.

**Owosibo, A. O., Odesola, O. M., Okere, I. A. and Odejide, J. O. 2017**. Growth performance, blood parameters and carcass characteristics of broiler chicken fed corn bran based diets with or without enzyme (Maxigrain®) supplementation. *Nigerian Journal of Animal Science,* 19 (1): 135 -143.

**Oyeyemi, M. O., Ekanade, A. O. and Ogunsemoyin, A. 2014**. Haematology, Serum chemistry and

Hormonal assay of Yankasa ewe fed concentrate upplementation. Proceeding of 39th Annual Conference of Nigerian Society of Animal Production held at Babcock University Ilishan-Remo. March 16th – 19th 2014. 68-71.

**Pasquali, G. A. M., Fascina, V. B., Silva, A. L., Aoyagi, M. M., Muro, E. M., Serpa, P. G., Berto, D. A., Saldanha, E. S. P. B. and Sartori, J. R. 2017**. Maize replacement with sorghum and a combination of protease, xylanase, and phytase on performance, nutrient utilization, litter moisture, and digestive organ size in broiler chicken. *Canadian Journal of Animal Science*, 97: 328 – 337.

**Romero, L. F., Parsons, C. M., Utterback, P. L., Plumstead, P. W. and Ravindran, V. 2013**. Comparative effects of dietary carbohydrases without or with protease on the ileal digestibility of energy and amino acids and AMEn in young broilers. *Animal Feed Science Technology*, 181: 35 – 44.

**Romero, L. F., Sands, J. S., Indrakumar, S. E., Plumstead, P. W., Dalsgaard, S. and Ravindran, V. 2011**. Contribution of protein, starch, and fat to the apparent ileal digestible energy of corn- and wheat-based broiler diets in response to exogenous xylanase and amylase without or with protease. *Poultry Science*, 93: 2501 – 2513.

**SAS 2000**. SAS/STAT User's Guide: Statistics. Version 6. For Windows. SAS Institute Inc. Cary, N.C. USA.

**Selle, P. H., Cadogan, D. G., Ru, Y. J. and Partridge, G. G. 2010**. Impact of exogenous enzymes in sorghum-or wheat-based broiler diets on nutrient utilization and growth performance. *Poultry Science*, 9: 53-58.

**Torres, K. A. A., Pizauro, J. M., Soares, C. P., Silva, T. G. A. and Nogueira, W. C. L. 2013**. Effects of corn replacement by sorghum in broiler diets on performance and intestinal mucosa integrity. *Poultry Science*, 92: 1564-1571.

**Veldman, A. and Vahl, H. A. 1994**. Xylanase in broiler diets with differences in characteristics and content of wheat. *British Poultry Science,* 35: 537 – 550.

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