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Carcass yield and haemato-biochemical indices of broiler chickens as affected by dietary replacement of yellow maize with *gayamba* pearl millet (*Pennisetum glaucum* L.) variety

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Abstract

The consumer price for poultry products in Nigeria and the expansion of the commercial poultry industry are negatively affected by the utilization of competitive and costly ingredients in making poultry diets. Consequently, the identification and utilization of locally available alternatives would greatly reduce cost of poultry production and products. In this regard, a study was undertaken to examine the effects of replacement of yellow maize (YM) with gayamba pearl millet variety as dietary energy source on carcass yield and blood parameters of broiler chickens. Three hundred (300) Ross 308 broiler chicks weighing 167.94 – 173.07g were randomly assigned to four dietary treatments of 75 birds each. Each treatment was replicated thrice with 25 birds in a completely randomized design. The experimental diets contained 0, 33.33, 66.67 and 100% gayamba millet as replacement for YM designated as diets 1, 2, 3 and 4 respectively. Full-fat soya bean and groundnut cake meal were the main vegetable protein sources used in the diets. Feed and water were provided ad libitum and the experiment lasted for 49 days. Results for carcass yield indicated a significant (P<0.05) influence of diet on live weight (1828.33 – 2316.66 g), plucked weight (1622.83 – 2132.83 g), eviscerated weight (1429.50 – 1883.47 g) and carcass weight (1277.66 – 1680.33 g) in favour of diet 3. However, dressing percentage (69.00 – 72.50%) did not differ among treatments. In the same way, most of the relative weights of organs were also not significantly affected by diet. Except for the packed cell volume (29.81 – 35.04%), none of the haematological parameters showed significant difference among the treatments. Similarly, most of the serum biochemical indices apart from total proteins, albumin and globulin, did not differ significantly among treatments. It was therefore concluded that gayamba pearl millet can completely replace yellow maize in broiler chickens' diets with no adverse effect on carcass yield and blood constituents.

Keywords: Broiler chickens, carcass yield, haemato-biochemical indices, *gayamba* pearl millet, yellow maize.

Introduction

Broiler chicken is an important protein source for human consumption. Its production is also a formidable enterprise that creates employment opportunities and helps in poverty alleviation (Parveen *et al.,* 2017). However, a threat posed by higher prices and availability of maize which constitutes the main energy source in poultry diets has been negatively affecting the poultry industry in Nigeria. This predicament may not be unconnected with the effect of climate change and higher prices of inorganic fertilizer (Adamu *et al.,* 2012). Against this backdrop therefore, there is a need to explore the use of

alternative energy sources in broiler diets formulation. Previous research works with pearl millet (Niranjan and Yadav, 2009; Tok *et al.,* 2018) have shown that maize can be substituted with pearl millet in poultry diets without negatively affecting growth performance and haemato-biochemical indices. However, available data on the utilization of *Gayamba* pearl millet (GPM) by broiler chickens remained scanty. Like other pearl millet varieties, GPM does well on marginal soils with low fertility and moisture levels. The variety is usually grown around Tafawa Balewa, Dass and Bogoro Local Government Areas of Bauchi State and in some parts of Northern Plateau State, Nigeria. The objective of this study was therefore to evaluate the carcass yield and haemato-biochemical parameters of broiler chickens as affected by the dietary replacement of *gayamba* pearl millet for yellow maize.

Materials and methods

The study site

The study was conducted at the Poultry Unit, Teaching and Research Farm, Abubakar Tafawa Balewa University, Bauchi, Nigeria. The area is located within the geographic coordinates of 10°18' 37.2'' N and 9°50' 38.0'' E. It is 616 metres above sea level, characterized by two well-defined rainy (May-October) and dry (November-April) seasons. It has an average annual rainfall of 1009mm with the highest relative humidity of 94% in August and lowest (35%) in February. Ambient temperatures are between 13 - 17°C (December – February) and 36 – 37°C (March – April) (OnlineNigeria, 2018; Weather Atlas, 2019).

Procurement and processing of feed ingredients

Gayamba pearl millet and yellow maize were procured from local markets at Tafawa Balewa and Dass in Bauchi State. The two cereals were ground to the same particle size (2.0 mm) and incorporated into the diets at the specified levels. Soya bean was cleaned of impurities and boiled using jute bags for 30 -40 minutes, sundried for 3 -4 days to reduce the level of anti-nutritional factors present in the raw beans. Thereafter, the dried beans were crushed in a hammer mill and included in the diets.

Proximate analysis

Samples of *gayamba* millet and yellow maize were ground into approximately 1 mm size using a laboratory hammer mill. Thereafter, one (1) gram each of GPM and YM, in three replicates, were used for proximate analysis as described by AOAC (2011). The metabolizable energy content was calculated according to Pauzenga (1985) (Table 1).

Experimental diets

Four experimental diets were formulated using *gayamba* millet to replace yellow maize at 0, 33.33, 66.67 and 100% levels designated as diets 1, 2, 3 and 4, respectively. The main protein sources were full fat soya bean meal and groundnut cake. The starter diets contained 23% CP while the finisher had 20% CP (Tables 2 and 3).

Table 1: Proximate composition of gayamba millet and yellow maize

Nutrient (%)	Yellow maize	*Gayamba* millet
Dry Matter	94.89	86.47
Crude protein	10.23	13.10
Crude fibre	3.23	1.96
Ether extract	2.97	4.43
Ash	1.36	2.31
Nitrogen-Free-Extract	77.10	64.67
Metabolizable energy (Kcal/kg)	3356.13	3139.32
Tannin (% C.E)	0	1.46
Phytate (mg/100g)	92.14	238.05

Pauzenga (1985).ME (kcal/kg) = {(37 x % CP) + (81 x % EE) + (35.5 x % NFE)}
C.E.= Catechin equivalent.

Table 2: Ingredients and Composition (%) of Dietary Levels of Gayamba Millet as Replacement for Yello w Maize Fed to Starter Broilers (1-4 weeks)

	Diets			
Ingredient	**1**	**2**	**3**	**4**
Yellow Maize	45.50	30.33	15.17	0.00
Gayamba Millet	0.00	15.17	30.33	45.50
Full-Fat Soya bean	18.00	18.00	18.00	18.00
Groundnut cake	15.00	15.00	15.00	15.00
Wheat offal	10.00	10.00	10.00	10.00
Fish Meal	5.00	5.00	5.00	5.00
Palm oil	2.00	2.00	2.00	2.00
Bone Meal	2.50	2.50	2.50	2.50
Limestone	1.00	1.00	1.00	1.00
Salt	0.25	0.25	0.25	0.25
Premix*(Starter)	0.25	0.25	0.25	0.25
Methionine	0.30	0.30	0.30	0.30
Lysine	0.20	0.20	0.20	0.20
Total	**100**	**100**	**100**	**100**
Calculated Analysis (%)				
ME (Kcal/kg)	2868.54	2860.14	2853.44	2846.76
Crude Protein	23.00	23.00	23.00	23.00
Crude Fibre	4.11	3.90	3.73	3.53
Ether Extract	6.07	6.37	6.51	6.73
Calcium	1.79	1.79	1.79	1.79
Phosphorus	0.73	0.73	0.74	0.74
Methionine	0.67	0.68	0.69	0.70
Lysine	1.31	1.33	1.36	1.39

ME; Metabolizable energy

*Vit/mineral premix supplied/Kg of Diet: Vit. A, 12,500 IU; Vit. D_3, 2,500 IU; Vit. E, 30 IU; Vit. K, 2.5mg; Riboflavin, 6mg; Pantothenic acid, 10mg; Vit. B, 2mg; Niacin, 30mg; Vit. B_{12}, 22mg; Biotin, 0.05mg; Folic acid, 1mg; Chlorine chloride, 0.3mg; Anti oxidant, 0.125mg; Iron, 100mg; Manganese, 100mg; Zinc, 100mg; Iodine, 1.5mg; Cobalt, 0.5mg; Selenium, 0.1mg and Copper 10mg.

Experimental birds and management

Three hundred unsexed broiler chickens of the *cobb* strain were used for the study which lasted for seven (7) weeks. The birds were brooded for a period of 11 days during which they were given a commercial chick mash. At the end of the 11th day, the chicks were weighed and allotted to four (4) dietary treatments of three replicates each containing 25 birds each in a completely randomized design (CRD). Feed and clean drinking water were served *ad libitum* throughout the study period. All recommended vaccines were also administered as and when due. Similarly, necessary sanitary measures to guarantee the biosafety of the experimental pens, drinkers and feeders, were adhered to.

Data collection

At the end of the experiment, two (2) birds were randomly selected per replicate for blood sample collection and subsequent carcass analysis. The birds were fasted overnight before samples collection and subsequent slaughter the next morning. The blood samples were collected in EDTA and EDTA-free vacuum tubes for haematological and biochemical indices determination, respectively. For carcass measurements, the birds selected and starved were weighed individually before slaughter. Live weights, plucked weights, eviscerated weights and carcass weights (dressed weights) were determined.

Table 3: Ingredients and composition (%) of dietary levels of gayamba millet as replacement for yellow maize fed to finisher broilers (5-7 weeks)

	Diets			
Ingredient	**1**	**2**	**3**	**4**
Yellow Maize	48.00	32.01	15.99	0.00
Gayamba Millet	0.00	15.99	32.01	48.00
Full-Fat Soya bean	13.50	13.50	13.50	13.50
Groundnut cake	10.00	10.00	10.00	10.00
Wheat offal	15.00	15.00	15.00	15.00
Fish meal	5.00	5.00	5.00	5.00
Palm Oil	4.00	4.00	4.00	4.00
Bone Meal	2.50	2.50	2.50	2.50
Limestone	1.00	1.00	1.00	1.00
Salt	0.25	0.25	0.25	0.25
Premix*(Finisher)	0.25	0.25	0.25	0.25
Methionine	0.30	0.30	0.30	0.30
Lysine	0.20	0.20	0.20	0.20
Total	**100**	**100**	**100**	**100**
Calculated Analysis (%)				
ME (Kcal/kg)	2977.16	2968.08	2959.55	2950.22
Crude Protein	20.00	20.00	20.00	20.00
Ether Extract	5.20	5.43	5.72	5.91
Crude fibre	4.12	3.92	3.70	3.50
Calcium	1.89	1.90	1.90	1.90
Phosphorus	0.71	0.72	0.72	0.72
Methionine	0.64	0.65	0.66	0.67
Lysine	1.17	1.20	1.23	1.26

ME; Metabolizable Energy

*Vit/mineral premix supplied/Kg of Diet: Vit. A, 8,500IU; Vit. D_{3}, 2,000IU; Vit. E, 10mg; Vit. K_{3}, 1.5mg; Vit. B_1, 1.6mg; Vit. B_2, 4mg; Niacin, 20mg; Pantothenic acid, 5mg; Vit. B_6, 1.5mg; Vit. B_{12}, 0.01mg; Folic acid, 0.5mg; Biotin, 0.75mg; Chlorine chloride, 175mg; Cobalt, 0.2mg; Copper, 3mg; Iodine, 1mg; Iron, 20mg; Manganese, 40mg; Selenium, 0.2mg; Zinc, 30mg and Antioxidant, 1.25mg.

Dressing percentage was also calculated. Organ measurements (weights) were expressed as percentages of live weights.

Experimental design

The birds were allotted to the different experimental diets in three replicates each in a completely randomized design (CRD).

Data analysis

Data collected were subjected to one-way analysis of variance (ANOVA) using the SPSS version 23. Where significant differences between treatment means were observed, Duncan's Multiple Range Test (Duncan, 1955), was used to separate them.

Results and discussion

The chemical composition of *Gayamba* pearl millet (GPM) and yellow maize used in the study were as presented in Table 3. The results showed that the CP of GPM (13.10%) is slightly higher than 12.00% reported by Batal and Dale (2011) in other pearl millet varieties. However, the crude fibre content (1.96%), was lower than 3.00% (NRC,1994). The metabolizable energy of *gayamba* pearl millet(3139.32kcal/kg) was slightly lower than 3280 kcal/kg (Ibe *et al.,* 2014) but higher than 3093 kcal/kg (Baurhoo *et al.,* 2011). The level of antinutritional factors, tannin (1.46% C. E) and phytic acid (238.05 mg/100 g) in GPM was lower than 2.25 – 2.32% (kulthe *et al.,* 2016) and 943 – 1076 mg/100g (El-Hag *et al.,* 2002), respectively. The carcass and organ characteristics of broiler chickens fed

Table 4: Carcass and organs character istics of broiler chickens fed gayamba millet as replacement for yellow maize

	Diets				
Parameter	**1**	**2**	**3**	**4**	**SEM**
Live weight (g)	1828.33^{c}	1980.00^{bc}	2316.66^{a}	2116.67^{ab}	175.89*
Plucked weight (g)	1622.83^{b}	1747.83^{b}	2132.83^{a}	1841.66^{b}	183.18*
Eviscerated weight (g)	1429.50^{b}	1507.50^{b}	1883.47^{a}	1591.60^{b}	156.60*
Carcass weight (g)	1277.66^{c}	1405.83^{bc}	1680.33^{a}	1458.33^{b}	130.32*
Dressing percentage (%)	69.80	71.10	72.50	69.00	2.83^{NS}
Head, shank and visceral organs expressed as a percentage of liveweight					
Head	2.36	2.39	2.18	2.26	0.25^{NS}
Shanks	3.87	3.87	3.51	3.58	0.55^{NS}
Lungs	0.51	0.60	0.50	0.53	0.12^{NS}
Small intestine	4.53^{a}	4.20^{ab}	4.13^{ab}	3.40^{b}	0.80*
Kidney	0.14	0.17	0.14	0.15	0.05^{NS}
Liver	1.56	1.69	1.60	1.74	0.24^{NS}
Abdominal fat	1.02	0.87	0.76	0.93	0.39^{NS}
Heart	0.41^{ab}	0.45^{a}	0.34^{b}	0.37^{ab}	0.06*
Gizzard	2.05^{a}	2.02^{a}	1.77^{ab}	1.62^{b}	0.30*
Caeca	0.48	0.49	0.49	0.46	0.12^{NS}
Large intestine	0.22	0.21	0.17	0.14	0.07^{NS}
Pancreas	0.26	0.24	0.26	0.17	0.07^{NS}
Spleen	0.07	0.06	0.05	0.09	0.03^{NS}

^{abc}Means bearing different superscripts within the same row differ; * = (P<0.05); NS= Not significant; SEM = Standard Error of Means

Table 5: Haematological values of broiler chickens fed graded levels of gayamba millet as replacement for yellow maize

	Diets				
Parameter	**1**	**2**	**3**	**4**	**SEM**
PCV (%)	32.15^{ab}	32.55^{ab}	29.81^{b}	35.04^{a}	1.49*
RBC (x 10^{6}/µL)	3.87	3.98	3.76	4.11	0.20^{NS}
Hb (g/dl)	9.07	8.45	8.05	8.86	0.82^{NS}
MCV (fl)	83.03	81.91	79.30	85.34	5.28^{NS}
MCH (pg)	23.52	21.27	21.36	21.54	2.31^{NS}
MCHC (g/dl)	28.32	25.99	27.04	25.27	2.89^{NS}
WBC (x 10^{3}/µL)	2.69	3.08	3.04	3.97	0.71^{NS}
Platelets (x 10^{3}/µL)	2.66	2.72	2.57	2.80	0.33^{NS}

NS= Not significant, SEM= Standard Error of the Mean, ^{abc}Means bearing different superscripts within the same row differ; * = (P<0.05), PCV= Packed Cell Volume, RBC= Red Blood Cells, Hb= Haemoglobin, MCV= Mean Corpuscular Volume, MCH= Mean Corpuscular Haemoglobin, MCHC= Mean Corpuscular Haemoglobin Concentration, WBC =White Blood Cells.

Table 6: Serum biochemical parameters of broiler chickens fed dietary levels of gayamba millet as replacement for yellow maize

	Diets				
Parameter	**1**	**2**	**3**	**4**	**SEM**
Total protein (g/dl)	3.64^{b}	3.41^{b}	4.23^{a}	4.49^{a}	0.28*
Albumin (g/dl)	2.18^{b}	2.15^{b}	2.44^{ab}	2.51^{a}	0.15*
Globulin (g/dl)	1.46^{bc}	1.25^{c}	1.79^{ab}	1.98^{a}	0.23*
A/G ratio	1.55	1.73	1.37	1.26	0.24^{NS}
Glucose (mg/dl)	182.03	184.25	180.45	178.79	7.67^{NS}
Total Cholesterol (mg/dl)	170.61	170.84	168.09	164.07	3.98^{NS}
Triglycerides (mg/dl)	3.80	3.72	3.84	4.20	0.43^{NS}
Creatinine (mg/dl)	0.59	0.64	0.57	0.49	0.12^{NS}
Uric acid (mg/dl)	2.87	2.65	2.07	2.41	0.58^{NS}
Sodium (mmol/dl)	137.08	139.45	139.41	140.39	7.00^{NS}
Potassium (mmol/dl)	1.77	1.56	1.45	1.68	0.20^{NS}
Calcium (mmol/dl)	7.85	7.88	7.83	7.51	0.37^{NS}
ALT (iul)	33.34	31.91	34.75	32.63	2.68^{NS}
AST (iul)	140.77	142.81	147.69	139.18	5.05^{NS}

NS= Not significant, SEM= Standard Error of the Mean, ^{abc}Means bearing different superscripts within the same row differ; * = (P<0.05), ALT= Alanine aminotransferase, AST= Aspartate aminotransferase

dietary levels of *gayamba* millet as a replacement for yellow maize is presented in Table 4. Except for dressing percentage, all carcass parameters were significantly (P<0.05) affected by dietary treatments. Live weight was higher (P<0.05) in birds fed diet 3 (2316.66g) which did not differ from diet 4 (2116.67g), and lower on diet 1 (1828.33g) which was similar to diet 2 (1980.00g). This agrees with reports of Rama Rao *et al.* (2004) and Kawu *et al.* (2016). Plucked weight was also higher (P<0.05) on diet 3 (2132.83g) than diets 1 (1622.83g), 2 (1747.83g) and 4 (1841.66g) which were similar. Eviscerated weight too, assumed the same trend as plucked weight. Diet 3 (1883.47g) had a higher (P<0.05) mean value than diets 1 (1429.50g), 2 (1507.50g) and 4 (1591.60g) which were the same. Carcass weight was highest (P<0.05) on diet 3 (1680.33g), followed by diet 4 (1458.33g) and lowest (P<0.05) on diet 1 (1277.66g) which compared favourably with diet 2 (1405.83g). However, diet 4 (1458.33g) did not differ from diet 2. Dressing percentage, 69.00 – 72.50% on diets 4 and 3 respectively, was not significantly affected by treatment. These values were similar to 70.77% reported by Salami *et al.* (2004) for well-finished broiler chickens. Except for small intestine, heart and gizzard relative weights, no organ studied in this work was significantly (P<0.05) influenced by dietary inclusion of *gayamba* millet. This is at variance with Rama Rao *et al.* (2004) who recorded no significant difference in all organs weights when yellow maize was substituted with pearl millet in broiler chicken diets. The relative weight of small intestine was higher (P<0.05) on diet 1 (4.53%), which was similar to diets 2 (4.20%) and 3 (4.13%), and lower (P<0.05) on diet 4 (3.40%). Values for heart weight were also higher (P<0.05) on diet 2 (0.45%) which was the same with diets 1 (0.41%) and 4 (0.37%), and lower (P<0.05) on diet 3 (0.34%). Similarly, gizzard weight was higher (P<0.05) on diets 1 (2.05%) and 2 (2.02%) which did not differ from diet 3 (1.77%), and lower (P<0.05) on diet 4 (1.62%) which was similar to diet 3. Head

weight as a percentage of live weight, ranged between2.36% on diet 1 and 2.39% on diet 2. Relative weight of shanks, from 3.51% on diet 3 to 3.87% on diets 1 and 2. Numerical values for lungs weight were from 0.59% on diet 3 to 0.60% on diet 2. In the same way, values for kidney weight ranged from 0.14% on diets 1 and 3 to 0.17% on diet 2. Liver weight, from 1.56% on diet 1 to 1.74% on diet 4. Abdominal fat ranged from 0.93% on diet 4 to 1.02% on diet 1. Caecal weight, from 0.46% on diet 4 to 0.49% on diets 2 and 3. The weight of large intestine also ranged from 0.14% on diet 4 to 0.22% on diet 1. Weight of pancreas from 0.17% on diet 4 to 0.24% on diets 1 and 3. Relative weight of spleen ranged from 0.05% on diet 3 to 0.09% on diet 4. Haematological and serum biochemical indices of broiler chickens fed *gayamba* millet as replacement for yellow maize in broiler chickens' diets are presented in Tables 5 and 6. Except for packed cell volume (PCV), there was no significant ($P<0.05$) influence of diet observed on haematological parameters. The PCV was higher ($P<0.05$) on diet 4 (35.04%) which did not differ from diets 1 (32.15%) and 2 (32.55%) but lower ($P<0.05$) on diet 3 (29.81%) which was comparable to diets 2 (32.55%) and 1 (32.15%). Values obtained for RBC ranged from $3.76 \times 10^6/\mu/l$ on diet 3 to $4.11 \times 10^6/\mu/l$ on diet 4 while that of haemoglobin was from 8.05 to 9.07g/dl on diets 3 and 1 respectively. Mean corpuscular volume was between 79.30fl on diet 3 to 85.34fl on diet 4. Numerical values for MCH ranged from 21.27pg on diet 2 to 23.52pg on diet 1 while that for MCHC was between 25.27g/dl on diet 4 to 28.32g/dl on diet 1. White blood cell count, which was also not significantly influenced, ranged between $2.69 \times 10^3/\mu/l$ on diet 1 to $3.97 \times 10^3/\mu/l$ on diet 4 whereas platelets count was 2.66 – $2.80 \times 10^3/\mu/l$ on the control and diet 4 respectively. However, all values obtained in this study were within the normal ranges reported by Jain (1993). Analysis for serum biochemical parameters revealed that apart from total protein, albumin and globulin levels, no other parameter was significantly ($P<0.05$) influenced. This contravenes Bala *et al.* (2017) who did not observe any significant difference in serum biochemical parameters when broiler chickens were fed pearl millet as replacement for maize. Total protein was higher ($P<0.05$) on diets 4 (4.49g/dl) and 3 (4.23 g/dl) which were the same, and lower($P<0.5$) on diets1 (3.64g/dl) and 2 (3.41g/dl) which were also comparable. Since total protein is a reflection of quality of protein fed (Eggum, 1970), it could be said that the protein quality of GPM based diets were superior to maize. Similarly, serum albumin was higher ($P<0.05$) on diet 4 (2.51g/dl) which was similar to diet 3 (2.44g/dl), and lower ($P<0.05$) on diets 1 (2.18g/dl) and 2 (2.15g/dl) which did not differ. However, diet 3 was the same with diets 1 and 2. Serum globulin was highest ($P<0.05$) on diet 4 (1.98g/dl) which was similar to diet 3 (1.79g/dl), and lowest ($P<0.05$) on diet 2 which was the same with diet 1. This could be attributed to the challenge on the birds' immune system as a result of increased tannin content of the diets. Globulins have been reported to play a key role in the body's immune system (Rothschild *et al.,* 1975). The albumin/globulin ratio did not differ among treatments and ranged from 1.26 on diet 4 to 1.73 on diet 2. Serum glucose was also not significantly affected, and values obtained were within the range of 178.79 – 184.25 mg/dl on diets 4 and 2 respectively. Similarly, total cholesterol ranged from 164.07mg/dl on diet 3 to 170.84 mg/dl on diet 2 while that of triglycerides was between 3.72 mg/dl on diet 2, to 4.20 mg/dl on diet 4. The kidney biomarkers, creatinine, and uric acid ranged from : 0.49 – 0.64 mg/dl creatinine on diets 4 and 2 and 2.07 – 2.87 mg/dl uric

acid on diets 3 and 1 respectively. Be that as it may, all values recorded were within the normal ranges reported by Thrall (2007) and Wikivet (2012). The concentration of serum electrolytes, sodium and potassium, were also not significantly influenced by diet. Mean values of 137.08 – 140.39 mmol/dl sodium were obtained on diets 3 and 1 respectively. Values for potassium were between 1.45 – 1.77 mmol/dl on diets 3 and 1 while that for calcium ranged from 7.51 – 7.88 mmol/dl on diets 4 and 2 respectively. The hepatic enzyme, ALT , was also not significantly influenced, and values obtained ranged from 31.91 IU/l on diet 2 to 34.75 IU/l on diet 3, whereas that for AST ranged from 139.18 IU/l on diet 4 to 147.69 IU/l on diet 3.

Conclusion

Based on the results obtained in this study, it was concluded that the complete replacement of yellow maize *with gayamba* pearl millet in broiler chicken diets did not infer any deleterious effect on carcass yield and haemato-biochemical properties of broiler chickens. Therefore, GPM was recommended as an alternative to yellow maize as energy source in broiler chickens' diets

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