Evaluating whole grain millet feeding in broiler-starter chicks at 0-21days post hatch

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Abstract

A 21-d investigation was conducted to ascertain the effect of 50% whole millet grain replacement for milled millet on growth performance, gastrointestinal conditions and development in broiler chickens. Eighty-four one-day-old unsexed broiler chicks were randomly allotted to two treatment groups with 7 replicates of 6 chicks per replicate. Two diets; whole millet diet (WM), consisting of 50% of the millet provided as whole grain, and the ground millet diet (GM), as the control, were formulated and fed ad-libitum throughout the study period. Performance data: feed intake, daily live weight gain and feed conversion ratio were recorded weekly, i.e. at 7, 14 and 21d, while gastrointestinal assessment: jejunal, digesta pH, relative weights of the proventriculus, gizzard, pancreas and liver; and jejunal and ileal morphometry were conducted on 21d. Similarities ($p > 0.05$) were observed in the growth performance, digesta pH and relative weight and length of duodenum, jejunum, ileum and caeca for chickens in both treatments. A 25.7% increase in gizzard weight was observed in chickens on WM, as well as significant ($p < 0.05$) increases in jejunal and ileal height and jejunal villus width were recorded on the chickens. A significant reduction in flock uniformity was observed in chickens fed the whole millet diet at 14d. It could therefore be concluded that 50% whole millet grain replacement for milled millet resulted in similar growth performance and improved gastrointestinal function and activity in 21-d post hatch chickens.

Keywords: Whole grain feeding; *Pennisetum glaucum*; gastrointestinal function; gizzard development; alternative feeds and feeding

Introduction

Incorporation of cereal grains in the diets of poultry without prior milling, is hailed for its ability to improve performance (Plavnik *et al.*, 2002), starch digestibility (Svihus and Hetland, 2001), health and gastrointestinal function with specific reference to gizzard integrity and functionality (Abdollahi *et al.*, 2019; Fernandes *et al.*, 2013; Pacheco *et al.*, 2015), modify gut microbial diversity (Santos *et al.*, 2007), proliferation of beneficial microflora with attendant reduction in coliform bacteria counts, as well as lower intestinal salmonella prevalence (Bjerrum *et al.*, 2006; Gabriel *et al.*, 2008; Santos *et al.*, 2008) and *Clostridium perfringens* counts (Bjerrum *et al.*, 2005). Whole grain feeding has also been implicated in improved skeletal health, reflected in improved gait score in 3

week-old broiler chickens with up to 30% dietary whole wheat (Knowles *et al.*, 2008). Whole grains are commonly incorporated in poultry diets using the mixed feeding strategy which consists of substitution of whole grain for a part of the ground grain, or as a diluent in a complete diet (Singh *et al.*, 2014), with the latter resulting in a diet with lower nutrient density. Choice of whole grain delivery strategy influence diet costs, as a larger reduction in cost of production is obtained for diluted diets owing to the reduced ratio of complete diet to whole grain plus reduction in milling and pelleting costs. Dilution of diets with whole wheat grains is also implicated in decreased skeletal integrity in ducks (Kokoszynski *et al.*, 2019).

However, the majority of research into whole grain feeding of poultry is focused on

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whole wheat (Singh *et al.*, 2014), and this could be consequent on its small-grain size and predominant use as the primary energy source for poultry diets in parts of Europe, Canada, Australia and New Zealand (FAO, 2011). On the other hand, maize (corn), which is the predominant cereal used in the United States, Brazil and most countries in Asia and Africa, has relatively large grain size, which hampers its use in whole grain feeding (Singh *et al.*, 2014), and limits its use in the feed of larger poultry species and adult chickens (Oso *et al.*, 2014; Arroyo *et al.*, 2019). There exists relatively few publications reporting research into whole feeding of alternative small grain cereals including pearl millet (Garcia and Dale, 2006; Torres *et al.*, 2013; Mabelebele *et al.*, 2018). Pearl millet (*Pennisetum glaucum*), so named for its ovoid shape, is the most commonly grown type of millet, and compares favorably with maize for poultry feeding (Davis *et al.*, 2003). However, little is known about the effect of whole grain millet feeding on growth performance, flock uniformity, gastrointestinal conditions and development in broiler-starter chicks, hence preliminary investigations into whole grain millet feeding at 50% of millet in broiler starter diet was conducted. This was aimed at inducing improvement in performance and gastrointestinal development in broiler-starter chickens by whole millet grain inclusion at 50% replacement of ground millet in their diet.

Materials and methods

Experimental site, housing and animals

This research work was conducted at the poultry unit of the Teaching and Research Farm, University of Ibadan (7°26'30"N 3°54'00"E), Ibadan, Nigeria. A total of 84 one-d-old, unsexed broiler chicks (Arbor Acres) was sourced from a reputable commercial hatchery and raised on wood shavings in a deep litter housing system.

Deep litter house was partitioned into 0.8 m × 0.8 m pens using wire mesh, and chicks were neck-tagged, weighed (using an electronic scale with accuracy of 1.0 g) and randomly allocated to either the whole millet (WM) or ground millet (GM) treatments in 7 replicates, 6 chicks per replicate. Randomization was based on weight equalization using the Experimental Animal Allotment Program (Kim and Lindemann, 2007). Temperature within the building maintained at 32°C from 0-7d, while ambient temperature (24-29°C) was maintained during the rest of the study period. The lighting programme observed in the poultry house was 24L:0D and 14L:10D (natural illumination) at 0-7d and 8-21d, respectively.

Dietary treatment

The chicks were raised on a semi-purified diet in order to limit variations in particle size of the diets to the presence of whole grain pearl millet. Diets were formulated to meet the nutritional needs of 0-21d old broiler chickens (NRC, 1994) and fed as a mash. The whole millet diet (WM) had 50% of its millet component presented as whole grain, while the ground millet diet (GM) had all of its millet in ground/milled form. The diets were fed as a mash, while, the feed and water were provided *ad libitum*. Particle size spectra of the experimental diets and millet grains were determined by passing samples through a geometric series of sieves on an electric shaker. The amount of sample retained on each sieve was subsequently weighed.

Sample and data collection

Growth performance and flock uniformity

Data was collected for individual chick weight and feed intake per pen on 7, 14 and 21d, while body weight gain, feed conversion ratio (FCR) and flock uniformity were estimated weekly and for the overall study period.

Gastrointestinal evaluation

At 21d, 14 chickens per treatment were weighed, euthanized, and gastrointestinal tract were removed for analysis. The proventriculus, gizzard, pancreas and liver were excised, content of the proventriculus and gizzard were carefully emptied and the organs weighed. The small intestine was separated into its composite sections: the duodenum, jejunum and ileum, emptied of digesta and their empty weight and length were recorded using a laboratory analytical balance (0.01g accuracy) and measuring tape respectively. Subsequently, the relative lengths (g/kg LBW) and weights (cm/kg LBW) of the duodenum, jejunum and ileum were calculated. Sections of the ileum and jejunum were rinsed with sterile buffered saline and fixed in 10% formalin solution. Slides of ileal and jejunal tissues were prepared by methods described earlier (Adeleye *et al.*, 2019), and the villus height (μm : distance from apex of villus to the junction of the villus and crypt), villus width (μm : basal width of the intestinal villus), and crypt depth (μm : distance from the junction to the basement membrane of the epithelial cell at the bottom of the crypt) were measured. Ingesta/digesta from the proventriculus, gizzard, duodenum, jejunum and ileum were diluted in distilled water (1:10) in a sterile beaker, stirred manually for ~ 30 secs and the pH recorded using a digital handheld pH meter (PH20, Apera Instruments, LLC, Columbus, Ohio, USA).

Statistical analysis

Pen means served as the experimental unit for statistical analysis, data was subjected to *Studentized T*-test of independent samples in JASP (version 0.11.0) (JASP Team, 2019) and means were considered significantly different when $p < 0.05$.

Results and discussion

Improved growth performance, gastrointestinal function and health in

poultry species have been attributed to whole grain feeding (Singh *et al.*, 2014). This experiment was aimed at inducing improvement in performance and gastrointestinal development in broiler-starter chickens by whole millet grain inclusion at 50% replacement of ground millet in their diet. Ingredient composition and particle size distribution of the experimental diets and whole millet are shown in Table 1. Whole millet inclusion at 50% of ground millet in the control diet resulted in minimal variation in particle size spectra, %; particles $> 1\text{mm}$ (67.19 vs 66.39), particle ranging from 0.5-1.0mm (19.39 vs 19.05) and particles $< 0.5\text{mm}$ (13.62 vs 14.56). The minimal variation in particle size spectra between the experimental vs control diets could be attributable to the particle size spectra of the millet grain used in this study ($> 1\text{mm} = 75.4\%$, $0.5 - 1.0\text{mm} = 21.1\%$ and $< 0.5\text{mm} = 3.5\%$).

The diets were well received by the chickens with no visible signs of feed selection or rejection. The influence of whole grain millet inclusion in the diets of chickens at 0-7d, 8-14d, 15-21d and 0-21d on growth performance is shown in Table 2. Feed intake, body weight gain and feed conversion ratio were not negatively influenced when 50% of millet in the diet was presented as whole grain. The trend in growth performance indices observed in the current study, was in agreement with findings from similar studies involving whole grain millet, rice and maize feeding (Singh and Ravindran, 2019; Sittiya *et al.*, 2016; Torres *et al.*, 2013). Conversely, 25% whole sorghum inclusion increased feed intake and body weight by 14.5 and 13.0% respectively, without influencing feed conversion efficiency when provided in mash or pellet form to broiler chickens aged 1-24 days (Mabelebele *et al.*, 2018), while whole grain wheat at 20% replacement of ground wheat significantly reduced ($p <$

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0.001) weight gain and feed intake in broiler chickens 11-35 days post hatch (Singh *et al.*, 2019). However, 5-35% dilution of a complete diet with whole wheat grain significantly increased body weight and decreased feed conversion efficiency without affecting feed intake of 35-d old Peking ducks (Kokoszyński *et al.*,

2019). From reported findings, variations in response of birds to whole grain feeding in existing literature could be linked to differences in experimental conditions such as the age and species of poultry used, whole grain delivery strategy used and the presence/absence of other cereals and energy sources in the diet.

Table 1: Ingredient composition, calculated analysis (g/1000g) and particle size distribution of whole grain millet and experimental diets (as fed basis)

Ingredient	Whole grain millet (%)	Whole millet diet	Ground millet diet
Pearl millet (Whole grain)		275.0	-
Pearl millet (Milled)		275.0	550.0
Soybean meal		140.0	140.0
Wheat gluten		110.0	110.0
Maize starch		100.0	100.0
Soybean oil		40.0	40.0
Fish meal (72% CP)		25.0	25.0
Dicalcium phosphate		14.2	14.2
Limestone		10.0	10.0
Lysine		3.8	3.8
DL – methionine		2.0	2.0
Vitamin-mineral premix ^a		2.0	2.0
Sodium Chloride		2.0	2.0
Anticoccidial premix ^b		1.0	1.0
Calculated Analysis ^c			
Metabolizable energy (kCal/kg ME)		3184.79	
Crude Protein (%)		23.10	
Calcium (%)		1.20	
Phosphorus (%)		0.90	
Methionine (%)		0.59	
Lysine (%)		1.22	
Crude Fibre (%)		4.77	
Particle size distribution (%) ^d			
> 1.0 mm		67.19	66.39
0.5 -1.0 mm		19.39	19.05
0.1- 0.49 mm		13.62	14.56
Whole grain millet			
> 1.0 mm	75.40		
0.5 -1.0 mm	21.10		
< 0.5 mm	3.50		

^a Optimix poultry chick nourisher, Animal Care, Nigeria. Provided the following per kg/diet: vitamin A, 20,000 IU; vitamin D3, 4,000 IU; vitamin E, 20 mg; vitamin K3, 4 mg, vitamin B1, 3 mg; vitamin B2, 10 mg; niacin 16 mg; calpan 16 mg; vitamin B6, 6 mg; vitamin B12, 0.03 mg; choline chloride, 200 mg; folic acid, 2 mg; biotin, 0.1 mg; manganese, 120 mg; iron, 40 mg; zinc, 100 mg; copper, 10 mg; iodine, 2 mg; cobalt, 0.4 mg; selenium, 0.4 mg; antioxidant, 250 mg

^b Amprolium 20S; VM.D Livestock Pharma, Arendock, Belgium

^c Calculated analysis based on nutritional values of feed ingredients (NRC, 1994; Feedipedia)

^d Adeleye *et al.*, 2019

Table 2: Feed intake (g), body weight gain (g) and feed conversion ratio of chickens fed whole vs ground millet-based diet for 21 days

	Period (days)			
	0-7	8-14	15-21	0-21
<i>Feed Intake (g)</i>				
Whole millet diet	89.88	175.94	236.24	502.06
Ground millet diet	87.45	180.06	246.76	514.27
Pooled SEM	3.16	5.21	6.94	13.96
P- value	0.63	0.47	0.59	0.36
<i>Body weight gain (g)</i>				
Whole millet diet	107.86	214.92	367.14	689.92
Ground millet diet	110.63	216.67	358.29	685.59
Pooled SEM	1.29	4.86	8.05	13.08
P- value	0.50	0.25	0.06	0.73
<i>Feed conversion ratio</i>				
Whole millet diet	1.20	1.22	1.55	1.37
Ground millet diet	1.27	1.20	1.45	1.28
Pooled SEM	0.14	0.15	0.18	0.24
P- value	0.27	0.31	0.23	0.46

Flock uniformity, in lay terms, refers to the spread in live weights above and below the flock average, hence the wider the spread, the lower the value for flock uniformity. Flock uniformity is a key performance indicator of any commercial poultry practice as it drives profitability and it is influenced by genetic, nutritional and environmental variations (Gous, 2017). Flock uniformity (Table 3) at 14 days post hatch was lowered by 40.65% when 50% of millet in the diet was presented as whole grain (39.0 vs 65.71, $p = 0.02$), but at 7 and 21 days post hatch, flock uniformity was not influenced by whole millet. While little is documented about the relationship between whole grain feeding and flock uniformity, the observed reduction in flock uniformity in this study agreed with the findings of Gous (2017) and Hughes *et al.* (2017) that feed form was a contributor to reduced flock uniformity. However, whole sorghum inclusion at 25-75% in a sorghum-based broiler diet did not influence flock uniformity in both starter and grower phases (Mabelebele *et al.*, 2018) and neither did whole grain millet inclusion at 20-100% replacement of millet in broiler chickens in

both starter and grower phases (Adeleye *et al.*, 2019).

Influence of whole millet grain inclusion on relative organ weights, such as proventriculus, gizzard, pancreas and liver of chickens on whole millet vs ground millet diets is presented in Table 4. Relative weights of the proventriculus, pancreas and liver of chickens were not affected by whole millet inclusion, but relative gizzard weight was increased by 25.7% when compared to the control group (6.35g vs 5.05g, $p = 0.04$). Also, no effect of whole grain millet feeding was observed on intestinal development with regards to relative length and weight of the duodenum, jejunum, ileum and caeca (Table 5), however, whole millet inclusion affected the histological structure of the small intestine of chickens (Table 6) such as jejunal villus height (2027.90µm vs 1684.93 µm, $p = 0.04$), jejunal villus width (488.17µm vs 122.59µm, $p = 0.03$) and ileal villus height (2013.89µm vs 1576.43µm, $p = 0.02$). Ileal villus width and crypt depth in both jejunum and ileum were not significantly ($p > 0.05$) affected by whole millet feeding, as well as pH conditions in

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the gizzard and intestinal sections; duodenum, jejunum, ileum and caeca (Table 7). Improved gastrointestinal function is often highlighted as a consequence of whole grain feeding, especially with regard to gizzard function. Similar to the findings in this study, whole grain feeding seemed to have no effect on length and weight of intestinal segments and digestive organs such as the proventriculus, liver and pancreas in studies assessing whole corn, sorghum and wheat, as reported by Torres *et al.* (2013), Sittiya *et al.* (2016), Mabelebele *et al.* (2018), Kokoszyński *et al.* (2019) and Singh and Ravindran (2019). Other contrary reports of the effect of whole grain feeding on intestinal histomorphology have also been documented (Gabriel *et al.*, 2008;

Sittiya *et al.*, 2016; Adeleye *et al.*, 2019). On the other hand, up to 70% increase in gizzard weight have been reported as a result of whole grain feeding in poultry flocks (Svihus *et al.*, 2005 ; Sittiya *et al.*, 2016; Mabelebele *et al.*, 2018; Rodrigues and Choct, 2018; Singh and Ravindran, 2019; Singh *et al.*, 2019; Abdollahi *et al.*, 2019), emphasizing that whole grains primarily induce development of gizzard musculature by eliciting more intense grinding activity within the gizzard. While the inability of whole grain feeding to influence gastrointestinal pH has been reported (Adeleye *et al.*, 2019; Mabelebele *et al.*, 2018; Singh and Ravindran, 2019), some studies have also reported significant reduction in gizzard pH, arising from whole grain feeding (Singh *et al.*, 2014; Sittiya *et al.*, 2016; Singh *et al.*, 2019).

Table 3: Flock uniformity of chickens fed a whole vs ground millet-based diet for 21 days

	Age (days)		
	7	14	21
Whole millet diet	63.71	39.00 ^b	30.29
Ground millet diet	71.43	65.71 ^a	49.29
Pooled SEM	5.91	6.01	5.03
P- value	0.54	0.02	0.06

Superscripts in the same column that differ from one another are significantly different at $p < 0.05$

Table 4: Relative organ weight (g/kg live body weight (LBW)) of chickens fed a whole vs ground millet-based diet for 21 days

	Organs			
	Proventriculus	Gizzard	Pancreas	Liver
Whole millet diet	1.32	6.35 ^a	0.78	5.41
Ground millet diet	1.32	5.05 ^b	0.84	5.02
Pooled SEM	0.07	0.32	0.03	0.20
P- value	0.99	0.04	0.36	0.40

Superscripts in the same column that differ from one another are significantly different at $p < 0.05$

Table 5: Relative length (cm/kg live body weight (LBW)) and weight (g/kg LBW) of small intestinal segments of chickens fed a whole vs ground millet-based diet for 21 days

	Small intestinal segments			
	Duodenum	Jejunum	Ileum	Caeca
Relative length (cm/kg LBW)				
Whole millet diet	10.35	10.35	5.59	2.22
Ground millet diet	10.03	10.25	5.00	2.09
Pooled SEM	0.34	0.33	0.33	0.06
P- value	0.19	0.65	0.65	0.24
Relative weight (g/kg LBW)				
Whole millet diet	3.60	4.59	3.43	1.56
Ground millet diet	3.69	4.97	3.01	1.99
Pooled SEM	0.15	0.24	0.13	0.23
P- value	0.79	0.44	0.11	0.37

Table 6: Histological structure of the small intestine - jejunum and ileum- of chickens fed a whole vs ground millet-based diet for 21 days

			Villus width (µm)		Crypt depth (µm)	
	Jejunum	Ileum	Jejunum	Ileum	Jejunum	Ileum
Whole millet diet	2027.90 ^a	2013.89 ^a	488.17 ^a	271.09	209.18	190.17
Ground millet diet	1684.93 ^b	1576.43 ^b	122.59 ^b	228.75	193.56	187.60
Pooled SEM	276.36	262.95	67.58	41.99	4.09	3.19
P- value	0.04	0.02	0.03	0.64	0.42	0.30

Superscripts in the same column that differ from one another are significantly different at $p < 0.05$

Table 7: pH of digesta in the gizzard, duodenum, jejunum, ileum and caeca of chickens fed a whole vs ground millet-based diet for 21 days

	Gastrointestinal segment				
	Gizzard	Duodenum	Jejunum	Ileum	Caeca
Whole millet diet	3.15	6.11	6.05	6.23	6.27
Ground millet diet	3.36	6.06	5.79	6.34	6.18
Pooled SEM	0.23	0.10	0.11	0.23	0.08
P- value	0.30	0.42	0.50	0.38	0.65

Conclusion

In conclusion, the present study proved that 225g/kg inclusion of whole grain millet as replacement of 50% ground millet-based diet in the diet of broiler-starter chickens could produce similar growth performance compared to chickens fed sole ground millet-based diet, whilst improving gastrointestinal function. However, further research into the effect of whole millet feeding on flock uniformity is recommended.

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