



Effect of Different Grain-Based Diets on Performance and Gut Morphology of 8-Week-Old Turkeys

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Abstract

This research paper presents an investigation into the impact of different grain-based diets on the growth performance and gut morphology of 8-week-old turkeys. A total of 160 one-day-old turkey poults were randomly allotted to four treatments, five replicates of eight birds each and fed diets containing acha, wheat, maize, and sorghum respectively for 8 weeks. At the end of the eight-week experiment, performance parameters were calculated, and gut parameters were analysed. The analysis of growth performance revealed notable variations among the turkeys fed different grain-based diets. Turkeys fed the maize-based diet exhibited the highest body weight gain (409.61g) and average daily weight gain (6.08g/day), highlighting its potential for promoting rapid growth during the critical 8-week period. Conversely, those fed the Acha-based diet had the lowest feed intake (312.6g) and average daily weight gain (4.04g/day). The feed conversion ratio showed no significant differences between the treatment groups, indicating similar feed utilisation efficiencies. Analysis of the gut morphology revealed significant differences among the treatment groups for various parameters. Turkeys fed the wheat-based diet had the highest villus height (377.69µm) and muscular wall thickness (133.58µm). On the other hand, the sorghum-based diet resulted in the highest crypt depth (58.64µm), suggesting possible alterations in gut structure that could influence nutrient processing and gut health. The findings of this study emphasised the critical role of dietary composition in influencing growth performance and gut morphology in 8-week-old turkeys.

Keywords: Turkey, growth performance, gut morphology, grain-based diets

Introduction

The poultry industry plays a pivotal role in meeting the growing global demand for animal protein. Among poultry species, turkeys hold immense economic importance due to their significant contribution to meat production (Askerov *et al.*, 2021). Achieving optimal growth performance and maintaining intestinal health are crucial factors that directly impact the productivity and profitability of turkey production (Oviedo-Rondón, 2019). Grains, such as wheat, maize, and sorghum, are common ingredients in poultry diets, providing essential nutrients and energy for growth and development. However, these grains vary in their nutritional composition, leading to questions about their specific impact on young turkeys' growth and gut health. This is where acha (*Digitaria exilis*), an underutilised African grain, presents an exciting opportunity for exploration. Acha, also known as fonio, boasts a unique nutritional profile. Rich in protein, dietary fiber, essential amino acids, and minerals, it holds potential as a valuable addition to turkey diets. Although being one of the oldest indigenous cereals in West Africa,

acha has long been disregarded by scientific research and development initiatives (Ballogou *et al.*, 2013).

Understanding the relationship between dietary composition and growth performance is vital to maximising the efficiency of feed utilisation and promoting optimal weight gain in young turkeys. Furthermore, the intestinal health of turkeys is intricately linked to their nutrient absorption capacity, which, in turn, is influenced by gut morphology (Choct, 2008). Key parameters, such as villus height, crypt depth, muscular wall thickness, and epithelial thickness, are indicative of the gut's ability to assimilate nutrients effectively. Analysing these gut morphology parameters in relation to the grain-based diets will provide valuable insights into how specific diets may influence nutrient absorption and overall gut health.

The findings of this study hold practical implications for turkey producers and feed manufacturers, as the optimisation of growth performance and gut morphology is pivotal for achieving higher productivity and ensuring the



well-being of turkeys. By understanding the effects of different grain-based diets on 8-week-old turkeys, stakeholders can make informed decisions in formulating nutritionally balanced diets tailored to these young birds' specific needs.

Materials and Methods

Experimental site

The experiment was carried out at the Poultry Unit, Teaching and Research Farm, Oyo State College of Agriculture Igboora, Nigeria.

Procurement of the Test Ingridents

Maize, sorghum, and wheat were sourced at Bodija market in Ibadan, Oyo state, Nigeria

while acha was sourced from the National Cereal Research Institute (NCRI), Ibadan. They were sorted to remove stones and dirt and were stored pending the time to be used for the experiment.

Experimental diets and management of birds

160 one-day-old Nicholas turkey poultts were purchased from a reputable hatchery. The birds were tagged, weighed and mass brooded for two weeks and were fed standard commercial turkey diets. On day 15, the birds were randomly allotted to four treatments with five replicates of eight birds each and fed the experimental diet for six weeks. Feed and water were supplied *ad libitum*.

Table 1: Gross composition of experimental starter turkey poultts diets

Ingredients (g/kg)	Acha	Wheat	Maize	Sorghum
Acha	436.62	0.00	0.00	0.00
Wheat	0.00	436.62	0.00	0.00
Maize	0.00	0.00	436.62	0.00
Sorghum	0.00	0.00	0.00	436.62
Soybean meal	446.05	446.05	446.05	446.05
Fish meal	20.00	20.00	20.00	20.00
Soya oil	39.41	39.41	39.41	39.41
Dicalcium phosphate	35.42	35.42	35.42	35.42
Premix	2.50	2.50	2.50	2.50
Limestone	7.07	7.07	7.07	7.07
Methionine	3.75	3.75	3.75	3.75
Lysine	4.18	4.18	4.18	4.18
Salt	2.23	2.23	2.23	2.23
Sodium Bicarbonate	1.69	1.69	1.69	1.69
Phytase	0.10	0.10	0.10	0.10
Toxin Binder	1.00	1.00	1.00	1.00
Total	1000	1000	1000	1000
Analysed values				
Crude protein (g/kg)	249.00	265.02	260.00	262.00
Metabolisable energy (kcal/kg)	2910.00	2890.00	2900.00	2853.00
Crude fibre (g/kg)	35.63	36.65	37.52	37.52
Calcium (g/kg)	13.30	13.30	13.30	13.30
Phosphorus (g/kg)	9.89	9.89	9.89	9.89

Provided per kilogram of diet: vitamin A, 12,500 IU; vitamin D3, 3,500 IU; vitamin E (DL- α -tocopherol acetate), 20 IU; vitamin K3, 3 mg; thiamine hydrochloride, 0.01 mg; riboflavin, 8.00 mg; pyridoxine hydrochloride, 4.5 mg; vitamin B12, 0.02 mg; nicotinic acid, 34 mg; calcium pantothenate 12 mg; folic acid, 0.5 mg; biotin, 0.2 mg; Fe, 80 mg; Cu, 8 mg; Zn, 80 mg; Mn, 80 mg; I, 0.7 mg; Se 0.3 mg.

Gut Morphological parameters measurement

On day 55, feed was withdrawn for 24 hours, and two birds were selected per replicate. The

birds were slaughtered, and the gastrointestinal tract was removed for gut morphological parameters. Samples were taken from the junction between Merkel's diverticulum and ileo-caeco-colonic junction and placed into sample bottles containing 10% formalin solution. The samples were transported to the laboratory for further analysis.



The specimens underwent a preservation process, involving exposure to a mixture of acetic acid and ethanol (in a ratio of 25:75, v/v) for a duration of 24 hours. Subsequently, rehydration occurred in an ethanol-water bath (50:50, v/v), followed by immersion in distilled water. The Feulgen reaction was then employed for staining: this entailed subjecting the samples to hydrolysis in 1 Normal hydrochloric acid (1N HCL) at a temperature of 60 °C for a duration of 6 minutes. The samples underwent three rounds of rinsing with distilled water and were subsequently stained with Schiff reagent for a period of 30 minutes. Following staining, additional rinsing with distilled water was carried out, and the samples were conserved in acetic acid-water solution (in a ratio of 45:55, v/v) at a temperature of 4 °C until further examination.

For the analysis of intestinal villi alongside their crypts, an individual separation of these structures was performed using a dissecting microscope, employing the technique as outlined by Goodlad *et al.* (1991). Measurements of villi length and width were conducted utilising an optical microscope equipped with a camera, following the methodology described by Hampson (1986). The following parameters were assessed and recorded:

- i. Villus height
- ii. Villus width
- iii. Crypt depth
- iv. Crypt width
- v. Muscular Wall Thickness
- vi. Epithelial cells
- vii. Goblet cells

Performance parameters

The body weight and feed consumption were monitored and recorded for each replicate weekly to determine the average feed intake, average body weight gain and feed conversion ratio of the birds. The initial and final body weights of the birds were recorded and the difference in weight was the body weight gained. Feed was supplied daily, and the leftover feed was weighed daily to calculate the feed conversion data with equations as shown below:

Average feed intake / bird = (Feed offered – feed leftover) ÷ Number of birds

Feed conversion ratio = Feed intake ÷ Body weight gain

Body weight gained = Final weight – Initial weight

Statistical analysis

Data obtained were analysed using ANOVA of SAS (SAS, 2012). Significant level of P = 0.05 was used. The treatment was compared using Duncan's Multiple Range Test (Duncan, 1955).

Results

Chemical composition of acha, wheat, maize and sorghum

The chemical composition of acha, wheat, maize and sorghum are presented in Table 2. No significant differences were observed for the dry matter, ether extract, crude fibre and gross energy. The crude protein (CP) content exhibited significant variation ($p < 0.05$) among the cereals, with wheat having the highest CP content of 10.13% while acha had the lowest CP content of 6.99%. The ash content of the cereals exhibited significant variations ($p < 0.05$) across the different dietary treatments with values of 2.21%, 3.38%, 2.29%, and 2.84% for acha, wheat, maize, and sorghum respectively.

Table 2: Chemical composition of acha, wheat, maize and sorghum

Parameters	Acha	Wheat	Maize	Sorghum	SEM	p-value
Dry matter (%)	90.85	91.71	91.13	91.54	0.20	0.429
Crude protein (%)	6.99 ^c	10.13 ^a	9.15 ^b	9.23 ^b	0.67	0.000
Ether extract (%)	2.09	1.92	1.99	1.79	0.06	0.135
Ash (%)	2.21 ^c	3.38 ^a	2.29 ^{bc}	2.84 ^{ab}	0.27	0.005
Crude fibre (%)	1.19	1.74	1.99	2.54	0.28	0.067
NDF (%)	24.90 ^b	34.78 ^{ab}	39.46 ^a	20.55 ^b	4.36	0.005
ADF (%)	11.84 ^{ab}	14.06 ^a	10.23 ^{ab}	7.15 ^c	1.45	0.001
ADL (%)	4.61 ^b	6.63 ^a	4.98 ^b	3.36 ^c	0.67	0.001
Gross energy (kcal/kg)	3672.20	3613.96	3663.76	3544.88	29.25	0.219

a,b,c Means with different superscripts on the same row are significantly different ($P < 0.05$)

NDF = Neutral detergent fibre

ADF = Acid detergent fibre

ADL = Acid detergent lignin



Performance parameters of 8-week-old turkeys fed with experimental turkey starter diets

The performance parameters of 8-week-old turkeys fed with experimental turkey starter diets are presented in Table 3. There were no significant differences for the initial weight, final weight and body weight gain of turkeys; final weight and body weight gain were numerically highest in maize-fed birds, but differences were not statistically significant ($p > 0.05$). Feed intake was significantly higher ($p < 0.05$) in maize and sorghum groups (1892.67g and 1807.59g, respectively) compared to those fed with acha (1746.37g) and wheat (1848.56g) diets. No significant differences were observed in feed conversion ratio across diets ($p > 0.05$).

Table 3: Performance parameters of 8-week-old turkeys fed with experimental turkey starter diets

Parameters	Acha	Wheat	Maize	Sorghum	SEM	p-value
Initial weight (g/bird)	55.6	54.67	54.67	54.33	0.72	0.921
Final weight (g/bird)	570.33	573.33	590.00	571.67	4.60	0.846
BWG (g/bird)	514.73	518.66	535.33	517.34	4.82	0.857
ADWG (g/bird)	9.19	9.26	9.56	9.24	4.82	0.857
Feed intake (g/bird)	1746.37 ^b	1848.56 ^a	1892.67 ^a	1807.59 ^{ab}	31.11	0.004
Feed intake (g/b/d)	31.19 ^b	33.01 ^{ab}	33.80 ^a	32.28 ^b	2.22	0.004
FCR	3.39	3.56	3.54	3.49	0.14	0.960

a,b,c Means with different superscripts on the same row are significantly different ($P < 0.05$)

BWG = body weight gain

ADWG = Average daily weight gain

FCR = feed conversion ratio

Gut morphological parameters of 8-week-old turkey fed with experimental turkey starter diets

The gut morphological parameters of 8-week-old turkey fed with experimental turkey starter diets are presented in Table 4. Turkeys fed maize diet had the highest ($p < 0.05$) villus height (409.61 μm), followed by sorghum (382.72 μm) and wheat (377.69 μm) while the acha (312.60 μm) resulted in the shortest villi. No significant differences were observed in villus width or crypt depth. Acha, maize and sorghum-based diets yielded thicker ($p < 0.05$)

muscular walls (174.11, 196.86 and 174.62 μm respectively) compared to wheat diets (133.58 μm). Wheat and maize diets resulted in thicker ($p < 0.05$) epithelial layers (20.36 and 20.84 μm respectively) compared to acha (13.40 μm) and sorghum (10.84 μm) diets. Maize-based diet promoted the highest ($p < 0.05$) number of goblet cells, followed by sorghum and wheat, with acha having the lowest. The highest ($p < 0.05$) villus height: crypt depth ratio was observed in s fed wheat-based diets, followed by sorghum and maize while turkeys fed acha-based diets had the lowest ratio.

Table 4: Gut morphological parameters of 8-week-old turkey fed with experimental turkey starter diets.

Parameters	Acha	Wheat	Maize	Sorghum	SEM	p-value
Villus Height (μm)	312.60 ^b	377.69 ^{ab}	409.61 ^a	382.72 ^a	20.58	0.000
Villus Width (μm)	94.62	80.15	81.37	81.52	3.42	0.053
Crypt Depth (μm)	77.46 ^a	55.19 ^c	67.38 ^b	58.64 ^c	4.98	0.000
Crypt Width (μm)	32.00 ^c	58.83 ^a	38.72 ^b	38.61 ^b	5.81	0.001
Muscular Wall Thickness (μm)	174.11 ^a	133.58 ^b	196.86 ^a	174.62 ^a	13.19	0.000
Epithelial (μm)	13.40 ^b	20.36 ^a	20.84 ^a	10.84 ^b	2.51	0.000
Goblet Cells (μm)	110.82 ^d	156.04 ^b	184.57 ^a	124.58 ^c	16.50	0.000
Villus height: Crypt depth	4.04 ^c	6.84 ^a	6.08 ^b	6.53 ^a	0.630	0.000

a,b,c,d Means with different superscripts on the same row are significantly different ($P < 0.05$)

Discussion

The findings of this study underscore the importance of dietary composition in influencing the growth performance and gut morphology of 8-week-old turkeys.

Proximate analysis is used for the estimation of the quantitative composition of food and food substances including moisture, crude protein,

total fat, total carbohydrate, and dietary fiber (Ganogpichayagrai and Suksaard, 2020). Ochame *et al.* (2018) reported the proximate composition of wheat as follows; 14.70% CP, 1.93% fat, 0.70% ash, 0.84% CF and 90.9% DM, except for CP, all other values were lower than the values observed from this study. When compared to the figure of 3556.06 kcal/kg published by Ukim *et al.* (2013) and a range of



3098.10 – 3290.00 kcal/kg documented by Enyisi *et al.* (2014), the gross energy of acha from this study (3621.20–3672.21 kcal/kg) was greater. Rezaei *et al.* (2020) reported the chemical composition of maize as 7.86% CP, 2.18% CF, 3.76% EE, 1.14% ash, 89.62% DM and 3995.95 kcal/kg gross energy. The gross energy of sorghum from this study (3544.88 - 3573.59 kcal/kg) was less than the 4120 kcal/kg amount reported by Abubakar *et al.* (2006).

With the exception of feed intake, no significant differences were observed for the performance parameters, and this agreed with reports by Haladu and Sonaiya (2017) who evaluated the performance of broilers fed maize, sorghum, millet and acha at 2 weeks and 8 weeks, the report revealed no significant differences in the body weight gain (BWG) and average daily weight gain of broilers. These results indicated that all the dietary compositions supported similar avian growth rates. Turkeys fed the wheat and maize-based diet exhibited the highest feed intake, while those fed the acha-based diet showed the lowest feed intake. While turkeys fed the acha-based diet consumed less feed compared to other groups, they achieved comparable feed conversion ratios (FCR), suggesting efficient nutrient utilisation. The better feed conversion ratio recorded for turkeys on acha may be because of its rich methionine and cysteine content which are almost deficient in cereals like wheat, maize, and sorghum (Ballogou, 2013). The similarities observed in the BWG is an indication that all the cereals can be used to formulate feed for turkeys at the starter phase.

The variations in gut morphology parameters suggested that different grain-based diets can influence intestinal health and nutrient absorption capacity. The development of the gastrointestinal tract and nutrient utilisation are intricately related, and it is therefore essential to understand the morphological and functional changes that occur during gut development to optimise nutrient utilisation in poultry (Kiarie *et al.*, 2013). The villus height, crypt depth, muscular wall thickness, and epithelial thickness varied significantly among the treatment groups. Turkeys fed the wheat-based diet had the highest villus height and muscular wall thickness, indicating improved nutrient absorption capacity (Smulikowska, 1998). Wang *et al.* (2017) reported that the crypt depth in poultry birds is influenced by dietary

energy levels and sources, with higher energy diets resulting in deeper crypts, this may explain why the crypt depth of turkeys fed diets containing wheat was lower compared to the other cereals. On the other hand, the higher crypt depth in turkeys fed the sorghum-based diet warrants further investigation, as it may have implications for nutrient absorption and gut health in the long term.

Turkeys fed wheat and maize diets consumed significantly more than those fed acha and sorghum. This higher feed intake may have contributed to improved gut health and nutrient absorption, as suggested by their increased villus height (Chen *et al.*, 2019). Villus height reflects the surface area available for nutrient absorption, and studies have shown a positive correlation with feed intake (Pluske *et al.*, 2014). While body weight gain didn't differ significantly across diets, wheat and maize-fed turkeys displayed deeper crypts compared to acha and sorghum groups. Crypt depth indicates the rate of cell renewal in the epithelium, potentially influencing nutrient uptake and subsequent growth (Iwaniuk *et al.*, 2009). Although weight gain wasn't impacted in this study, deeper crypts suggest the potential for improved growth with longer feeding periods or different dietary conditions. Notably, the feed conversion ratio was similar across all groups, indicating efficient utilization of consumed nutrients regardless of diet. Additionally, goblet cell counts remained unchanged, suggesting the diets did not significantly affect mucus production and gut barrier function (Uni *et al.*, 2014). Mucus plays a crucial role in protecting the gut epithelium and aiding in nutrient absorption, but excessive production can hinder this process (Awaji *et al.*, 1994).

Conclusion

This study demonstrates that acha, wheat and sorghum are suitable substitutes for maize in the diet of 8-week-old turkeys. The findings of this research provide valuable insights for turkey producers and feed manufacturers to develop targeted nutritional strategies that can enhance turkey production efficiency and overall health.

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