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Dietary Effect of Different Drying Methods and Graded Inclusion Levels of Ginger (*Zingiber officinale*) on the Performance and Gut Morphology of Broilers

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Authors' contributions

This work was carried out in collaboration between all authors. Author GOA designed the study, wrote the protocol, reviewed the experimental design and read all drafts of the manuscript. Author EOO wrote the first draft of the manuscript, managed the analyses of the study and performed the statistical analysis. Author OGL gave the idea that led to this study. All authors read and approved the final manuscript.

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ABSTRACT

The effect of processing methods and varying dietary inclusion levels of ginger on performance and gut morphology of broilers was studied. Ten experimental diets designated as diet 1 (control 0% ginger inclusion), diet 2 (sundried ginger at 1%), diet 3 (sundried ginger at 1.5%), diet 4 (sundried ginger at 2%), diet 5 (air-dried ginger at 1%), diet 6 (air-dried ginger at 1.5%), diet 7 (air-dried ginger at 2%), diet 8 (oven-dried ginger at 1%), diet 9 (oven-dried ginger at 1.5%) and diet 10 (oven-dried ginger at 2%) were fed to the broilers *ad-libitum*. The experimental design was a 3 by 3 factorial arrangement in a completely randomized design. Three hundred broilers were used for the experiment; they were randomly allotted to the ten dietary treatments with 5 replicates per treatment and 6 birds per replicate. The birds were weighed weekly to determine their weight gain,

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body weight and feed conversion ratio. Thirty finisher birds were sacrificed and the ileum and duodenum removed for gut histo-morphometry.

Results showed that drying methods influenced performance. This was observed for the average body weight gained per bird per day while the effect of the inclusion level was observed on the feed conversion ratio. Factor interaction was observed for weight gained/bird per day and feed conversion ratio. However, only numerical differences were observed for average final body weight/bird and average feed intake /bird/day.

Duodenal and ilea, villous height showed significant effect ($P<0.05$) of drying method, inclusion levels and treatment interaction with the control having the highest mean values.

It can be concluded that supplementing broiler feed with air-dried ginger at 1.5% inclusion level can be effective as it led to an increase in the final body weight, average body weight gained per day per bird and average feed intake. No effect of drying methods and inclusion levels were observed for the histo-morphometry.

Keywords: Broilers; drying methods; ginger; gut morphology; performance.

1. INTRODUCTION

Phyto-biotics or botanicals are plant-derived products used in feed to potentially improve performance. Aside from having antimicrobial activity, these products potentially provide anti-oxidative effects, enhance palatability, improve gut functions, or promote growth. Phyto-genics comprise a wide range of substances and thus have been further classified according to botanical origin, processing, and composition. Phytogenic feed additives include herbs, which are non-woody flowering plants known to have medicinal properties; spices, which are herbs with intensive smell or taste, commonly added to human food; essential oils, which are aromatic oily liquids derived from plant materials such as flowers, leaves, fruits, and roots; and oleoresins, which are extracts derived by non-aqueous solvents from plant material [1].

The rhizome of *Zingiber officinale* is one of the most widely used species of the ginger family and is a common condiment for various foods and beverages. Ginger is now widely cultivated in warm climatic regions of the world such as Nigeria, Bangladesh, Taiwan, India, Jamaica and the United States of America. Ginger rhizome contains several active compounds including gingerol, shogaols, gingerdiol, and gingerdione which have biological activities such as antioxidation, antimicrobial and pharmacological effects [2,3].

Drying is the most common and fundamental method for post-harvest preservation of medicinal plants. It is essentially important for preservation of agricultural crops for future use as it preserves crops by removing enough moisture from it to avoid decay and spoilage because it is a simple method for the quick conservation of the medicinal qualities of the plant material. The implication of the improper handling and drying method employed for ginger produced in Nigeria is far reaching because the quality of fresh ginger produced in Nigeria is adjudged the best in the world hence it is highly valued for its aroma, pungency, high oil and oleroresin content [4]. However, the quality of its dried Nigerian ginger attracts the cheapest price in the world market due to loss of some important ginger qualities [5]. The effects of solar drying on the appearance, aroma/flavour, pungency and the ginger oil/oleoresin yield of dried ginger and analysis of the ginger oil/oleoresin contents are essential for processing of ginger. Therefore, a suitable method of drying and storage of powder of *ginger* rhizome tubers is needed [6].

2. MATERIALS AND METHODS

2.1 Ginger Purchase and Processing

The experiment was carried out in May, 2014. Ginger rhizomes were purchased from Bodija market in Ibadan, Nigeria. The ginger used was observed for any physical defect, surface cleaned and washed in running tap water to remove adhering debris, sliced to increase the surface area to aid the process of drying after which it was divided into 3 parts, the first part was sun dried for 2 weeks at an average temperature of 32.4°C, second part was shed dried for 5 weeks at an average temperature of 30.9°C while the third part was oven dried at 60°C for 72 h, all to constant weight and ground to fine powder using a commercial blender. The powder obtained was stored in airtight plastic containers until needed for further use. All dried ginger samples were analyzed for chemical composition at the University of Ibadan, Oyo-state, Nigeria.

2.2 Experimental Animals

300 day old arbor acre strains of broiler chickens with average weights of 44.48±1.27 g were used. The chickens were divided into 10 groups and each group sub-divided into 5 groups of 6 birds each.

2.3 Diets Formulation

Ten (10) experimental diets were formulated in which diet 1 served as the control and contained 0% of powdered ginger; Diet 2-4 contained sun dried ginger at 1%, 1.5% and 2% respectively, Diet 5-7 contained air-dried ginger at 1%, 1.5% and 2% respectively, Diet 8-10 contained oven dried ginger at 1%, 1.5% and 2% respectively of powdered ginger. The feeds and drinking water were given *ad libitum*. The composition of the experimental diets is shown in Table 2.

2.4 Data Collection

The birds were offered experimental diets and water *ad libitum*. Daily feed intake was measured as the difference between the quantity of feed offered and the left over. Weight gain was measured weekly. Daily weight gains and feed conversion ratios were calculated.

2.5 Gut Morphology

On the 52nd day of the experiment, 3 birds per treatment were randomly selected and slaughtered for gut histo-morphometry. After slaughtering, the small intestine was removed and washed with sterile phosphate buffered saline (PBS), then middle sections (3-4 cm) of duodenum and ileum of 3 birds from each treatment were cut and prepared for histological indices assay. The histological indices were measured according to Iji et al. [7]. Intestinal tissue samples were fixed in buffered formalin and dehydrated, cleared and impregnated with paraffin. The processed tissues were then embedded in paraffin wax. Tissue sections, 6 µm thick (3 cross-sections from each sample), were cut from the waxed tissue by a microtome, cleared of wrinkles by floating on warm water (55-60℃) and were fixed on slides. A routine staining procedure was carried out using a combination of the periodic acid-Schiff method (PAS staining) with the basophilic dyes alcian blue (AB staining). Histological indices were determined by use of a light microscope (Olympus Corporation, Tokyo, Japan). The villous height (VH) and crypt depth (CD) were measured, Villus height was measured from the tip of the villus to the top of the lamina propria and the crypt depth was measured from the base up to the region of transition between the crypt and villus. Ten measurements were taken per bird for each variable. The average of these values was used for statistical analysis.

2.6 Experimental Design and Statistical Analysis

The experimental design was 3 x 3 factorial arrangements in a completely randomized design (CRD) and the data generated were subjected to analysis of variance (ANOVA) using the SAS [8] package and means were separated using SAS MICRO of the same software at 5% level ($P<0.05$) of significance.

3. RESULTS

The report of the performance indices measured in Table 3 showed that the method of drying of ginger had no significant effect ($P>0.05$) except for the average body weight gained per day which was significantly influenced. The control diet had the highest mean values for the average body weight gained per bird per day and lowest feed conversion ratio (FCR). The effect of the inclusion levels significantly influenced the FCR with the 0% inclusion having the lowest mean value of 2.43 and the 1.5% having the highest value of 2.63.

Table 1. Proximate composition of the test ingredient (%)

Parameters	Sun dried ginger	Air dried ginger	Oven dried ginger
Crude protein	11.53	13.33	11.01
Crude fibre	15.35	9.88	14.87
Ether extract	4.12	4.46	3.97
Dry matter	88.90	89.36	92.42
Ash	6.80	7.20	6.51
Gross energy	3.38	3.39	3.38

Table 2. Gross composition of experimental basal diets

Ingredients	Starter (kg/100 kg)	Finisher (kg/100 kg)
Maize	55.00	56.50
Soybean	33.00	---
Wheat offal	---	10.00
Fish meal (72 %)	0.50	0.30
Groundnut cake	4.60	9.50
Full fat soya (38%)	3.00	20.00
Oyster shell	0.50	1.00
L-lysine	0.15	0.10
Dl-methionine	0.25	0.15
Broiler premix	0.25	0.25
Salt	0.25	0.25
Dicalcium phosphate	2.50	1.95
Total	**100.00**	**100.00**
Analysed nutrients		
Crude protein (%)	24.25	22.07
Metabolizable Energy (Kcal/kg)	3005.31	3000.39
Crude fibre (%)	5.00	5.00
Ether extracts (%)	7.00	6.11
Calcium (%)	1.02	1.12
Available phosphorus (%)	0.55	0.45

The interaction effect in Table 4 showed significant differences (P<0.05) in the average body weight gained per bird per day and feed conversion ratio. The birds fed the air-dried ginger diet at 1.5% had the highest mean values for the Average final body weight, Average daily feed intake and Average body weight gained per bird per day.

Table 5 showed the effects of drying methods and levels of ginger inclusion on the gut morphology of the broilers. Significant differences (P<0.05) in the duodenum villi height between the control and the other methods were observed. The control had the highest mean value of 1817.67 µm while the oven dried had the lowest mean value of 1271.6 µm. No significant differences (P>0.05) occurs in the effect of the methods on the duodenal crypt depth across all the treatments however an increase in the mean value were observed from the sundried to the air-dried to the oven-dried respectively. The effect of drying methods on the duodenal villi width did not show any significant difference (P>0.05) however the control method had the highest mean values of 130.00 µm. Significant differences (P<0.05) were observed in the effect of the drying methods on the ileum villous height with the control having the highest mean value. However no significant differences (P<0.05) were observed for the crypt depth and villi width of the ileum.

The effect of the inclusion level on the duodenal villi height showed significant differences (P<0.05) between the 0% inclusion level and the 1.5% and 2% inclusion level but no significant differences (P>0.05) with the 1% inclusion level. No significant differences (P>0.05) occur in the effect of the inclusion levels on the duodenal crypt depth and villi width. The 2% inclusion level however had the highest mean value of 116.63 µm for the crypt depth which is higher than the value of 116.00 µm for the 0% inclusion level while the 1.5% had the lowest mean value of 110.97 µm. The 0% inclusion level had the highest mean value for the villi width while the 1.5% also had the lowest mean value.

The effect of the inclusion levels on the ileum villous height showed significant differences (P<0.05) between the 0% inclusion level and the 1.5% and 2% levels but no significant differences (P>0.05) between the 1% and 2% inclusion levels. The ilea crypt depth and villous width showed no significant differences (P>0.05) due to the inclusion levels.

The interaction of drying methods and levels of ginger inclusion on the gut morphology of the broilers is shown in Table 6. Significant differences (P<0.05) between the duodenal villi height across the interactions were recorded. The control had the highest mean value of 1817.67 µm while the lowest mean value of 1048.66 µm was recorded for oven dried ginger at 1.5% inclusion level. Data obtained indicate that there were no significant differences (P>0.05) observed in the duodenum crypt depth of the birds irrespective of the diet and the inclusion level. Although the birds fed air-dried ginger at 2% inclusion level and oven dried ginger at 1% inclusion level were not significantly different from each other, their mean values of 116.57 µm and 117.33 µm respectively were higher than the value of 116.00 µm for the control birds which were fed 0% inclusion levels of ginger.

Table 3. Main effect of drying methods and levels of ginger inclusion on the performance of broilers

Parameters	Methods				% Inclusion level				SEM
	Control	Sun dried ginger	Air dried ginger	Oven dried ginger	0	1	1.5	2	
AIBW/bird (g)	38.62	44.44	43.33	47.63	38.62	47.16	42.22	46.03	1.02
AFBW/bird (g)	1941.43	1801.11	1893.33	1862.06	1941.43	1876.19	1837.78	1842.54	70.06
ADFI/bird/day (g)	94.07	93.18	95.13	93.25	94.07	94.66	95.35	91.54	1.38
ABWG/bird/day(g)	38.80^{a}	35.85^{b}	37.76^{ab}	37.01^{ab}	38.80	37.31	36.64	36.65	1.42
FCR/bird/day	2.43	2.61	2.54	2.53	2.43^{b}	2.55^{ab}	2.63^{a}	2.51^{ab}	0.10

Means with different superscript are significantly different from each other (P<0.05)

AIBW: Average Initial Body Weight, AFBW: Average Final Body Weight, ADFI: Average Daily Feed Intake, ABWG: Average Body Weight Gained, FCR: Feed Conversion Ratio

Table 4. Interaction effect of drying methods and levels of ginger inclusion on performance of broilers

Parameters	Methods										SEM
	Control		Sundried			Air-dried			Oven-dried		
	0%	1%	1.5%	2%	1%	1.5%	2%	1%	1.5%	2%	
AIBW/bird (g)	38.62	46.66	40.00	46.66	43.33	40.00	46.66	51.48	46.66	44.76	1.02
AFBW/bird (g)	1941.43	1860.00	1693.37	1850.00	1886.67	1973.33	1820.00	1881.91	1846.67	1857.62	70.06
ADFI/bird/day(g)	94.07	95.85	91.36	92.31	96.33	97.62	91.23	91.61	97.06	91.09	1.38
ABWG/bird/day(g)	38.80^{a}	37.01^{ab}	33.74^{b}	36.80^{ab}	37.62^{ab}	39.46^{a}	36.19^{ab}	37.32^{ab}	36.73^{ab}	36.96^{ab}	1.42
FCR/bird/day	2.43^{b}	2.60^{ab}	2.73^{a}	2.52^{ab}	2.58^{ab}	2.51^{ab}	2.54^{ab}	2.47^{ab}	2.66^{ab}	2.47^{ab}	0.10

Means with different superscript are significantly different from each other (P<0.05)

AIBW: Average Initial Body Weight, AFBW: Average Final Body Weight, ADFI: Average Daily Feed Intake, ABWG: Average Body Weight Gained, FCR: Feed Conversion Ratio

Significant differences (P<0.05) were observed in the mean values of the ileum villi height between the control and sundried ginger at 1.5% inclusion level, air-dried at 1.5% inclusion level and oven dried at 1% inclusion level. The mean value ranges from 1879 µm for oven dried ginger at 2% to 1150.00 µm for sundried at 1% inclusion level. No significant differences occurred in the (P>0.05) mean values of the crypt depth and villi width.

4. DISCUSSION

The findings in this study showed that the inclusion levels and methods of drying did not have any significant effect on the average final body weights of birds which is in accordance with the work of Doley et al. [9] who reported no significance differences in the weight of broilers fed with ginger for six weeks and contrary to the report of Arkan et al. [10] who reported higher final body weights than the control by the addition of ginger at 0.1 and 0.2% respectively. Although the mean values for birds on the control diet were the highest for the measured average final body weight gain, birds fed air-dried method ginger compared favorably with the control. This may be due to the preservation of the active ingredients in the ginger by the air dried method as it was hypothesized that the active ingredients in ginger are preserved by this method and this active ingredients are known growth promoters. The control birds gained more weight per birds per day than any other drying methods or inclusion levels, this is in disagreement with the report of Minh et al. [11] who reported that average daily weight gains (ADG) were lower for control treatment (23.4 g) than for antibiotic treatment (26.9 g) (P<0.01), supplemented garlic treatment (26.5 g) and supplemented ginger treatment (25.2 g) (P<0.001).

The feed intake for the birds showed that the air dried ginger fed birds consumed more feed than the control; this may be due to the preservation of the essential oils which gives ginger its sweet aroma which are destroyed at higher temperature in other drying methods which caused the birds to eat more. The results observed for the FCR for the drying methods and inclusion levels were in disagreement with the report of Herati and Marjuki [12] who revealed that broilers fed on ration with red ginger showed significantly lower (P<0.05) feed conversion than those on control treatment.

The results of the interaction for the final body weight of the birds at 1.5% for the air-dried method showed that the inclusion of air-dried ginger at 1.5% led to an increase in the final bodyweight, average daily feed intake per bird per day and average body weight gained per bird per day of broilers which gave higher means than the control. This may be due to the effect of the low drying temperature used in the process which preserves the phytogenic qualities of ginger. The FCR which showed significant differences disagrees with the results of Wafaa et al. [13] who reported that no significant differences were observed for FCR among chicks fed 0.5%, 1% and 1.5% ginger root powder supplemented diets.

The manipulation of gut functions and microbial habitat of domestic animals with feed additives has been recognized as an important tool for improving growth and feed efficiency. Mucosa status and their microscopic structure can be good indicators of the response of the intestinal tract to active substance in feeds [14]. The gastro-intestinal tract (GIT) is the first organ to come in contact with food and such will be affected with greater potency as compared to other organs [15]. The morphological structure of the gastrointestinal tract (GIT) offers key information to evaluate gut health. Longer, thinner villi are considered to indicate that the bird will have a better ability to absorb nutrients, due to increased surface area [16]. Shorter villi height (VH) and deeper crypt depth (CD) are associated with decreased digestibility of nutrients [17].

Main effect showed significant differences (P<0.05) for the duodenum and ilea villi heights between the control and the other methods with the control having the highest mean values. This is however contrary to the findings of Thayalini et al. [18] who observed no significant difference when dried ginger was fed up to 2%, Incharoen and Yamauchi [19] who reported that the villus height, surface in the intestinal segment had higher values in ginger-fed laying hens compared to the control birds and Purwanti et al. [20] who also observed higher villi height when curcumin, garlic and their combination were fed to broilers. The control birds had the highest duodenal and ilea villous heights and widths which may be responsible for the reduced feed conversion ratio recorded for the control at the end of the experiment. No significant differences were observed for the crypt depth and villous width for both the duodenum and the ileum.

Table 5. Main effect of drying methods and levels of ginger inclusion on gut morphology of broilers (µm)

Parameters	Methods				Inclusion level				SEM
	Control	Sun dried ginger	Air dried ginger	Oven dried ginger	0	1	1.5	2	
Duodenum villus height	1817.67^{a}	1375.60^{b}	1395.30^{b}	1271.60^{b}	1817.67^{a}	1512.50^{ab}	1226.90^{b}	1303.20^{b}	150.66
Duodenum crypt depth	116.00	109.10	114.19	117.56	116.00	113.24	110.97	116.63	10.12
Duodenum villus width	130.00	122.83	124.08	117.00	130.00	125.64	117.97	120.30	8.40
Ileum villus height	1736.43^{a}	1335.20^{b}	1369.90^{ab}	1475.30^{ab}	1736.43^{a}	1331.50^{bc}	1224.40^{c}	1624.40^{ab}	176.06
Ileum crypt depth	99.67	104.67	99.41	106.13	99.67	99.16	105.78	105.28	8.09
Ileum villus width	131.50	112.53	123.78	121.99	131.50	128.13	117.11	113.06	10.61

Means with the same superscript are not significantly different from each other. (P>0.05).Means with different superscript are significantly different from each other (P<0.05)
SEM = standard error means

Table 6. Interaction effect of drying methods and levels of ginger inclusion on gut morphology of broilers (µm)

Level of inclusion parameters	Methods										SEM
	Control	Sun dried ginger			Air dried ginger			Oven dried ginger			
	0	1	1.5	2	1	1.5	2	1	1.5	2	
Duodenum villus height	1817.67^{a}	1665.43^{ab}	1377.33^{abc}	1084.17^{c}	1540.17^{ab}	1254.83^{bc}	1391.00^{abc}	1331.83^{bc}	1048.66^{c}	1434.30^{abc}	150.66
Duodenum crypt depth	116.00	111.73	110.40	105.17	110.67	115.33	116.57	117.33	107.17	128.17	10.12
Duodenum villus width	130.00	132.27	134.07	102.17	121.67	111.50	139.07	123.00	108.33	119.67	8.40
Ileum villus height	1736.43^{ab}	1255.83^{bc}	1150.00^{c}	1569.83^{abc}	1519.40^{abc}	1166.67^{c}	1423.67^{abc}	1189.30^{c}	1356.67^{bc}	1879.83^{a}	176.06
Ileum crypt depth	99.67	89.17	112.17	112.67	95.23	104.67	98.33	113.07	100.50	104.83	8.09
Ileum villus width	131.50	127.93	112.00	97.67	121.67	119.67	130.00	134.80	119.67	111.50	10.61

Mean values from birds on control showed a good correlation between crypt depth and villi height for duodenum and ileum as its crypt value translated into a higher villi height. This is because the crypt is known to be important in the formation of villi. Also the crypt depth determines the degree of exigency of cells (enterocytes) of the intestinal mucosa which leads to the formation and elongation of the villi [21]. It appeared that supplementation of *Zingiber officinale* rhizome dried using different methods and inclusion levels did not alter the digestive capacity of the birds. The interactions effect showed that there were significant differences in the duodenal and ileum villi heights with the control at 0% inclusion and oven dried method at 2% having the highest interaction means for the duodenal and ileum villi height respectively.

The variations in gut morphology of broilers in the present study compared to those reported in earlier works may be due to possible differences in the nutrient and chemical composition, source of the ginger, preparation process, inclusion levels, the overall diet composition, feed quality and breed/strain of bird used in the study.

5. CONCLUSION

This study demonstrated that drying methods and/or inclusion levels of ginger in broiler diets had effect on their performance as it led to an differences in the final body weight, average weight gained per day per bird and average feed intake of the birds. Although longer, thinner villi are considered to indicate that the bird will have a better ability to absorb nutrients, due to increased surface area while shorter villi height (VH) and deeper crypt depth (CD) are associated with decreased digestibility of nutrients, the effect of drying methods and/or inclusion levels on the gut morphology showed that the control had longer villus height than the other diets, ginger inclusion particularly the air dried ginger compares favorably with the control.

From the results obtained in this study, the inclusion of air-dried ginger up to 1.5% gave higher mean values or compare favourably with the control for the performance and gut morphology of broilers for most of the parameters measured than any other methods and inclusion levels.

ETHICAL APPROVAL

The authors declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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