Reproductive and Physiological Responses and Egg Quality Traits of Isa Brown Chickens fed Diets Supplemented with Ginger or Turmeric Powder

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Abstract

*The increasing demand for healthy and low fat poultry products by consumers has necessitated the use of natural growth promoters to enhance hens' laying performance. This study investigated the reproductive response and egg quality traits of pullet chickens fed dietary turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) powder. Five hundred and four pullets were assigned basal diet ($G_0 T_0$) or basal diet supplemented with 1.5 (G1.5) and 3% (G3) ginger or 1.5 (T1.5) and 3% (T3) turmeric to investigate the reproductive responses and egg quality traits of pullet chickens during a 60 week trial period. Data were collected on egg and laid out in a Completely Randomized Design in a 2 x 3 factorial arrangement. Hen-day and hen-housed egg production, egg mass, feed conversion ratio and age at first lay were significantly ($p < 0.05$) affected by phytobiotic type. The best ($p < 0.05$) hen-day, hen-housed, egg mass, FCR, earliest age at first lay and least weight at first lay were obtained in birds placed on 1.5% ginger ration. Percentage mortality was not significant except at the different inclusion levels and was least among birds fed 1.5% phytobiotic inclusion levels. The highest ($p < 0.05$) value for egg length, egg width, egg shape index, albumen weight and yolk colour were obtained in birds fed 3% turmeric diets. Internal egg qualities were most enhanced by turmeric inclusion while dietary ginger improved the external qualities. The study concluded that dietary ginger and turmeric enhanced reproductive performance and egg quality of egg-type chickens fed over their commercial production lifespan without impairing their overall well-being.*

Introduction

The ever-increasing global population and the increase in individual food consumption have continuously made the demand for animal products to be on the rise. The world's per capita consumption of eggs has now attained almost a double-fold of what obtained in the early 1960s, while poultry meat consumption has increased by 50% (FAO, 2020). Per capita demand for poultry meat between year 2000 and 2030 will increase by 271 % in South Asia, 116 % in Eastern Europe and Central Asia, 97 % in the Middle East and North Africa and 91% in East Asia and the Pacific (OECD/FAO, 2019). In Africa, Nigeria has the second largest chicken population after South Africa (USDA, 2013) with the poultry industry comprising about 180 million birds and producing 650, 000 tonnes of eggs and 300, 000 tonnes of poultry meat in 2013 (FAOSTAT, 2017).

The use of natural additives and medicinal plants such as ginger and turmeric are known to possess bioactive compounds (El-Bahr et al., 2007; Oke et al., 2017; Oke, 2018; Oke et al., 2021) having health-promoting functions, including gingerone and shogaol of ginger (Fuhrman et al., 2000) and curcuminoid compounds of turmeric plants (Chattopadhyay et al., 2004), having ability to lower egg yolk lipids. There has been a growing concern on the use of antibiotics as growth promoters due to the residues in animal tissues and the production of drug resistant bacteria (Zomrawi et al., 2013) that are zoonotic in nature. Hence, the use of phytobiotics is now increasingly gaining a global approval especially in the aspects of health and nutrition as a possible suitable alternative.

Ginger and turmeric powder may improve nutritive value of livestock diets, enhance animal performance by increasing their growth rate, better feed conversion efficiency, improved livability and lowered mortality in poultry birds (Devegowda, 1996).

Haematological studies are of ecological and physiological importance which aids the understanding of the relationship of blood characteristics to the environment (Ovuru and Ekweozor, 2004). It could also be useful in the animal selection, especially those that are genetically resistant to certain diseases and environmental conditions (Mmereole, 2008; Isaac et al., 2013). Haematological parameters are good indicators of the physiological status of animals and valuable in monitoring feed toxicity especially with feed constituents that affect the blood as well as the

health status of farm animals (Oyawoye and Ogunkunle, 2004). The safety of turmeric and its characteristic yellow colouration are endorsed by organizations and researchers (WHO, 1987; Hallagan et al., 1995; NCCAM, 2012). The active ingredient (curcumin) has hepatoprotective properties (Pal et al., 2001) and is claimed to enhance digestion and metabolism of nutrients. Ginger rhizome also contains a number of compounds that exert varying biological activities, including antioxidant, antimicrobial (Akoachere et al., 2002) and various pharmacological effects (Ali et al., 2008).

Generally speaking, herbs could serve as feed additives due to their suitability and preference, reduced risks of toxicity and minimum health problems (Devegowda, 1996). Several studies have been carried out to verify the efficacy of these feed additives (Mishra and Singh, 2000; Deepak et al., 2002; Jahan *et al.*, 2008). There is however conflicting results in the literature. Most studies have focused on a short term administration of the additives, mostly in broilers and layer chickens alike. Therefore, there is a need to further explore the potency and the impact of their extended use over the reproductive lifespan of egg-type chickens.

Materials And Methods

Processing of test ingredients

Ginger and turmeric rhizomes were obtained from a reputable local market in Lagos, Nigeria. Ginger rhizomes were washed and cleaned. The cleaned rhizomes were cut into slices and to air-dried until certain moisture content is reached; after which they were pulverised and stored away in an airtight container before being incorporated into the experimental diets. Turmeric rhizomes were also processed as described for ginger. Table 1 shows the composition (%) of the experimental layer diets.

Table 1: Composition of Experimental Layer Diets (Days 162-420)

Ingredients	Ginger (G) powder			Turmeric (T) powder		
	G ₀	G _{1.5}	G ₃	T ₀	T _{1.5}	T ₃
Maize	48.00	48.00	48.00	48.00	48.00	48.00
Wheat offal	26.00	24.50	23.00	26.00	24.50	23.00
Soyabean meal	7.00	7.00	7.00	7.00	7.00	7.00
Groundnut cake	14.00	14.00	14.00	14.00	14.00	14.00
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	2.00	2.00	2.00	2.00	2.00	2.00
Salt (NaCl)	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25	0.25
*Layer premix	0.25	0.25	0.25	0.25	0.25	0.25
Ginger	0.00	1.50	3.00	0.00	0.00	0.00
Turmeric	0.00	0.00	0.00	0.00	1.50	3.00
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis (%)						
Crude protein	17.21	17.14	17.06	17.21	17.14	17.06
Ether extract	4.76	4.74	4.64	4.76	4.72	4.59
Crude fibre	4.58	4.81	5.04	4.58	4.70	4.82
Ash	3.47	3.57	3.67	3.47	3.60	3.73
Calcium	3.89	3.89	3.89	3.89	3.89	3.89
Phosphorus	0.47	0.47	0.47	0.47	0.47	0.47
Lysine	0.85	0.85	0.85	0.85	0.85	0.85
Methionine	0.41	0.41	0.41	0.41	0.41	0.41
M. E (kcal/kg)	2497.46	2478.68	2459.84	2497.46	2478.68	2459.84

*Layer vitamin premix supplied the following vitamins and trace elements per kg diet: Vit A 6250 IU; VitD3 1250IU; VitE, 14.38 mg; Vitk3 1.25 mg, VitB, 1.88 mg Vit B2 3.75 mg; Niacin 31.25 mg; calcium pantothenate 6.25 mg; Vigt B6 3.8 mg, Vit B12 0.02 mg; Choline Chloride 250 mg; Folic acid 0.63 mg; Biotin 0.03 mg; Mn 75 mg; Fe 62.5 mg; Zn 50 mg; Cu 5.31 mg; I 0.94 mg; Co 0.019 mg; Se 0.08mg and Antioxidant 75 mg.

Note: G₀/ T₀ = Ginger/turmeric powder at 0% level of inclusion, G_{1.5%}/T_{1.5%} = Ginger /turmeric powder at 1.5% level of inclusion, G₃/T₃ = Ginger/turmeric powder at 3% level of inclusion; M.E = Metabolisable energy.

Experimental birds and management

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Five hundred and four day old pullet chicks were used for the study. The pullets were divided into two equal groups of two hundred and fifty two birds each. The first group of the birds was fed diets containing ginger powder (G) while the other was allocated to diets containing turmeric powder (T). The birds in each group were further divided into three treatment groups of four replicates per treatment with twenty one birds per replicate. The birds fed basal diets (G₀ and T₀) without ginger and turmeric powder served as the control groups. Pullets in experimental groups G_{1.5} and T_{1.5} were fed diets containing ginger and turmeric powder at 1.5% inclusion levels respectively, while those of G₃ and T₃ were fed diets containing ginger and turmeric powder respectively, at 3% inclusion levels.

Experimental diets

Layer mash containing ginger (G) and turmeric (T) powder supplemented at 0%, 1.5% and 3% levels were introduced to laying birds at 5% in lay. The diets were fed to the birds for a period of 37 weeks. The diets were formulated to meet the nutrient requirements of laying birds (NRC, 1994).

Data collection

Egg production parameters

Eggs laid per replicate were collected daily and the weights were determined using a Mettler top-loading weighing scale. Body weights of the birds at first lay were taken as the average weight of live birds over the number of birds per group while age at first lay was the number of days from day-old to the day the first egg was laid. The body weights at first lay and the weight of first egg were determined using a balance scale with sensitivity of 0.01g. Egg number per week was determined by the total number of eggs laid by individual pullet in each group per week.

Hen-day egg production: Egg production was calculated on hen-day basis per group as:

$$\frac{\text{Number of eggs laid}}{\text{Number of live birds}} \times 100$$

Hen-housed egg production: Egg production was determined on hen-housed basis per group as:

$$\frac{\text{Number of eggs laid during the laying period}}{\text{Total number of birds housed at the beginning of laying period}} \times 100$$

Egg mass: This was calculated per group as:

$$\frac{\text{Egg production} \times \text{egg weight}}{100}$$

Feed Conversion Ratio (FCR):

$$\frac{\text{Total feed intake (g)}}{\text{Egg mass (g)}}$$

Mortality: This was recorded as they occurred as:

$$\frac{\text{No of dead birds}}{\text{No of birds stocked}} \times 100$$

Egg quality evaluation

Eight (8) eggs per replicate were collected for the evaluation of egg quality traits on a monthly basis.

External quality of eggs

Individual egg was weighed using top-loading weighing balance and their shape indices were measured as egg width (mm) divided by egg length (mm). Egg shell was weighed using a sensitive scale and shell thickness was measured by digital caliper. Individual egg shell was air-dried in egg crates for a week and the relative shell weight was determined by relating the shell weight to the weight of the egg. Shell thickness was measured to the nearest 0.01mm using a micrometer screw gauge. The egg length was measured as the distance between the broad and narrow ends of the egg while the width was measured as the distance between two ends of the egg at the widest cross sectional region using vernier calipers.

Internal quality of eggs

Eggs were broken onto a glass-topped table; the albumen height (AH) was measured with a tripod micrometer at its widest part at a position halfway between the yolk and the outer margin. Albumen weight was taken as the difference between the egg weight and the sum of the weight of the yolk and dry egg shell while the percentage albumen weight was calculated as the percentage of the albumen weight to the egg weight. Yolk weight was measured using Mettler top-loading weighing balance while albumen weight was determined as the difference of the yolk to the egg weight. The Haugh unit (HU) was calculated from the weight and height of the albumen of the egg using the formula of Haugh (1937):

$$HU = 100 \log (H + 7.57 - 1.7W^{0.37})$$

Where:

HU = Haugh unit

H = height of the albumen in mm

W = weight of the egg in grams

Yolk colour

This was determined using Roche yolk fan (Roche Ltd., Basel, Switzerland), with scores varying between 1 and 15.

Blood Parameters

At 40 weeks of age, 1 ml of blood samples were collected via the jugular vein of the chickens using sterilized syringes, and was immediately emptied into an Ethylene diamine-tetra-acetic acid (EDTA) bottle in order to determine haematological (packed cell volume, haemoglobin, red blood cells (RBC), white blood cells (WBC) and WBC differentials, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) analysis. The blood samples were collected within one minute of capture to ensure that the levels of monitored parameters were not altered by stress induced by pre-sampling handling (Chloupek et al., 2009).

All data collected were subjected to One-way Analysis of Variance in a 2 x 3 factorial arrangement using SAS software (SAS, 2000) while significant ($p < 0.05$) means among variables were separated using Tukey's HSD.

Results

Main effects of phytobiotic type and inclusion levels on laying performance indices

The main effects of phytobiotic type and inclusion levels on laying performance indices are presented in Table 2. Hen-day egg production, hen-housed egg production, egg mass and feed conversion ratio were significantly ($p < 0.05$) influenced by phytobiotics type. Hen-day production and hen-housed production of laying hens fed dietary ginger were significantly ($p < 0.05$) higher than those fed turmeric powder rations. Birds placed on ginger powder ration had a higher ($p < 0.05$) egg mass of than those of turmeric powder. The FCR obtained for hens fed diets containing ginger powder (2.44) was better ($p < 0.05$) compared to those obtained in birds maintained on dietary turmeric diet. The feed intake and % mortality obtained in birds fed ginger powder diets did not differ ($p > 0.05$) from those fed dietary turmeric. Growing pullets fed dietary inclusion of ginger powder attained the age at first lay earlier ($p < 0.05$) than those on turmeric powder diets.

Table 2
Main effects of phytobiotic type and inclusion levels on laying performance indices

Parameters	Phytobiotic type			Inclusion levels			
	Ginger powder	Turmeric powder	p-value	0%	1.5%	3%	p-value
Egg production (% Hen-day)	60.64 ± 1.34 ^a	54.54 ± 1.35 ^b	0.0013	56.91 ± 1.63	57.94 ± 1.65	57.93 ± 1.68	0.8802
Egg production (% Hen-housed)	58.27 ± 1.28 ^a	52.75 ± 1.30 ^b	0.0026	51.89 ± 1.46 ^b	57.47 ± 1.64 ^a	57.17 ± 1.65 ^a	0.0203
Egg weight(g)	63.00 ± 1.07	63.32 ± 0.54	0.7967	62.19 ± 1.50	63.16 ± 0.78	64.15 ± 0.60	0.4163
Egg mass (g/hen/day)	48.14 ± 1.10 ^a	43.90 ± 1.09 ^b	0.0067	44.99 ± 1.52	46.45 ± 1.30	46.67 ± 1.27	0.6402
Feed intake (g/hen/day)	113.65 ± 0.50	113.13 ± 0.51	0.4637	113.34 ± 0.61	113.31 ± 0.62	113.51 ± 0.63	0.9703
Feed conversion ratio	2.44 ± 0.05 ^b	3.09 ± 0.18 ^a	0.0014	2.51 ± 0.12	2.37 ± 0.06	2.59 ± 0.06	0.2738
Age at first lay (days)	171.75 ± 3.37 ^b	188.46 ± 2.28 ^a	0.0007	181.13 ± 3.51	179.50 ± 6.14	179.13 ± 4.36	0.9522
Weight at first lay (g)	1635.83 ± 55.00	1577.50 ± 36.99	0.3883	1552.50 ± 50.49 ^b	1514.44 ± 42.54 ^b	1745.00 ± 46.87 ^a	0.0057
Mortality (%)	6.97 ± 2.21	5.36 ± 1.55	0.5573	12.23 ± 2.16 ^a	1.92 ± 1.26 ^b	4.35 ± 1.71 ^b	0.0137
^{a, b} , Means within the same row by factor with different superscripts differ significantly (p<0.05), $\frac{\text{varvec{F}}\text{varvec{C}}\text{varvec{R}}}{\text{varvec{e}}\text{varvec{g}}\text{varvec{g}}\text{varvec{m}}\text{varvec{a}}\text{varvec{s}}\text{varvec{s}}} = \frac{\text{varvec{f}}\text{varvec{e}}\text{varvec{e}}\text{varvec{d}}\text{varvec{i}}\text{varvec{n}}\text{varvec{t}}\text{varvec{a}}\text{varvec{k}}\text{varvec{e}}}{\text{varvec{e}}\text{varvec{g}}\text{varvec{g}}\text{varvec{m}}\text{varvec{a}}\text{varvec{s}}\text{varvec{s}}}$							

Inclusion levels of phytobiotics did not significantly (p>0.05) impact the hen-day production but hen-housed egg production was positively influenced (p<0.05) with birds on 1.5% and 3% inclusion levels higher than those on 0% inclusion levels. Percentage mortality of laying birds fed 1.5% inclusion levels were significantly lower compared to those on 0% inclusion level. The earliest age (p>0.05) at first lay (179.13days) and the highest weight (p<0.05) at first lay (1745.00g) were observed among birds fed 3% inclusion level of phytobiotics. Weight at first lay in pullets fed ginger diets was numerically higher than those offered turmeric powder.

Interactive effects of phytobiotic type and inclusion levels on laying performance indices

The interactive effects of phytobiotic type and inclusion levels on laying performance indices are presented in Table 3. The interaction between phytobiotics and inclusion levels influenced (p<0.05) hen-day egg production, hen-housed egg production, egg mass and FCR. Hen-day egg production of hens fed dietary inclusion levels of ginger powder at 0% (60.73%) and 1.5% (62.26%) were higher (p<0.05) compared to values obtained for hens fed diets containing 0% (52.97%) and 1.5% (53.62%) turmeric powder. Hen-housed was highest among birds placed on ginger powder diets at

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powder at 3%, while the lowest value of 49.53% was noted for those fed 0% turmeric powder diets. The highest value obtained for egg mass among birds fed 1.5% ginger powder diets was 46.14g/hen/day while those on dietary inclusion of turmeric powder diets recorded the least value of 36.11, 35.34 and 36.55g/hen/day. The least FCR value of 2.64 was obtained in hens fed gingerised diets at 5% dietary inclusion while hens maintained on 1.5% dietary turmeric recorded the highest values of 4.00. Egg weight and feed intake were not influenced ($p>0.05$) by the interaction between phytobiotic type and inclusion levels. Mortality was the highest ($p>0.05$) among birds supplied 0% ginger powder ration (14.63%), followed by birds on 0% turmeric powder ration while the least value of 1.92% was obtained each from birds fed 1.5% ginger and 1.5% turmeric powder diets. Birds offered 1.5% turmeric powder attained lay much later than the rest of the treatment groups (192.75days). Age at first lay was attained earliest ($p<0.05$) by pullet birds placed on 1.5% ginger powder diets recording 166.25 days while birds fed turmeric powder diets attained lay at later age of 192.75 days. The highest weight ($p<0.05$) at first lay was observed among those offered 3% ginger powder diets (1805.00g) while pullet birds which consumed the control diets (1595.00g; 1510.00g), those on 1.5% ginger (1507.50g) and 1.5% turmeric (1537.50g) powder rations recorded the lowest weight at first lay.

Table 3
Interactive effects of phytobiotic type and inclusion levels on laying performance indices of pullets

Parameters	Ginger powder			Turmeric powder			p-value
	0%	1.5%	3%	0%	1.5%	3%	
Egg production (Hen-day)	60.73 $\pm$ 2.42 ^a	62.26 $\pm$ 2.33 ^a	58.95 $\pm$ 2.21 ^{ab}	52.97 $\pm$ 2.16 ^b	53.62 $\pm$ 2.31 ^b	56.91 $\pm$ 2.52 ^{ab}	0.0232
Egg production (Hen-housed)	54.14 $\pm$ 2.12 ^{bc}	62.26 $\pm$ 2.33 ^a	58.40 $\pm$ 2.18 ^{ab}	49.53 $\pm$ 2.00 ^c	52.67 $\pm$ 2.26 ^{bc}	55.95 $\pm$ 2.48 ^{abc}	0.0014
Egg weight(g)	63.55 $\pm$ 1.88	64.62 $\pm$ 1.61	63.47 $\pm$ 1.20	63.43 $\pm$ 1.23	61.69 $\pm$ 1.49	64.83 $\pm$ 1.24	0.7145
Egg mass (g/hen/day)	40.14 $\pm$ 2.72 ^{ab}	46.14 $\pm$ 2.67 ^a	41.52 $\pm$ 2.16 ^{ab}	36.11 $\pm$ 2.30 ^b	35.34 $\pm$ 3.69 ^b	36.55 $\pm$ 3.49 ^b	0.0107
Feed intake (g/hen/day)	113.53 $\pm$ 0.86	113.52 $\pm$ 0.86	113.89 $\pm$ 0.89	113.16 $\pm$ 0.89	113.10 $\pm$ 0.88	113.13 $\pm$ 0.89	0.9862
Feed conversion ratio	3.04 $\pm$ 0.18 ^{ab}	2.64 $\pm$ 0.18 ^c	2.90 $\pm$ 0.17 ^{bc}	3.39 $\pm$ 0.23 ^{ab}	4.00 $\pm$ 0.71 ^a	3.50 $\pm$ 0.31 ^{abc}	0.0003
Age at first lay (days)	177.75 $\pm$ 6.70 ^{abc}	166.25 $\pm$ 6.60 ^c	171.25 $\pm$ 3.75 ^{bc}	184.50 $\pm$ 2.25 ^{ab}	192.75 $\pm$ 3.92 ^a	187.00 $\pm$ 5.76 ^{ab}	0.0149
Weight at first lay (g)	1595.00 $\pm$ 99.12 ^b	1507.50 $\pm$ 25.2 ^b	1805 $\pm$ 85.00 ^a	1510.00 $\pm$ 29.44 ^b	1537.50 $\pm$ 87.50 ^b	1685.00 $\pm$ 25.00 ^{ab}	0.0339
Mortality (%)	14.63 $\pm$ 3.67 ^a	1.92 $\pm$ 1.92 ^b	4.36 $\pm$ 2.52 ^b	9.82 $\pm$ 2.09 ^{ab}	1.92 $\pm$ 1.92 ^b	4.34 $\pm$ 2.70 ^b	0.0011
a, b, c Means within the same row with different superscripts differ significantly ($p<0.05$).							

Main effects of phytobiotic type and inclusion levels on egg quality traits of pullets

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Table 4 shows the main effects of phytobiotic type and inclusion levels on egg quality traits of pullets. The results showed that mean values of egg length, egg width, egg shape index (ESI), albumen weight (59.90%), yolk weight, % yolk weight, shell weight and % shell weight did not show significant ($p>0.05$) differences among the treatment groups fed ginger and turmeric powder diets. The values obtained for egg length (55.47mm), egg width (44.11mm) and egg shape index (0.79) were lower among birds fed diets containing ginger powder than those on turmeric powder diets which recorded 56.23mm, 44.97mm and 0.80 respectively. Albumen height (6.77mm), % albumen weight (66.37%), yolk colour (5.99) and Haugh unit (77.90) had significantly ($p<0.05$) lower values in birds fed ginger powder diet compared to the higher values of albumen height (8.60mm), % albumen weight (66.79%), yolk colour (6.35) and Haugh unit (91.54) noted for turmeric powder group. However, birds fed diets containing ginger powder had thicker shell ($p<0.05$) of 0.46mm in while a lower value of 0.44mm was observed in hens placed on turmeric powder diets.

Table 4
Main effects of phytobiotic type and inclusion levels on egg quality traits of pullets

Parameters	Phytobiotic type		p-value	Inclusion levels			
	Ginger powder	Turmeric powder		0%	1.5%	3%	p-value
Egg length (mm)	55.47 ± 0.80	56.23 ± 0.21	0.3651	55.12 ± 1.18	56.15 ± 0.30	56.30 ± 0.24	0.4558
Egg width (mm)	44.11 ± 0.63	44.97 ± 0.18	0.1971	43.90 ± 0.94	44.38 ± 0.18	45.34 ± 0.20	0.1937
Egg shape index	0.79 ± 0.01	0.80 ± 0.00	0.1946	0.78 ± 0.02	0.79 ± 0.00	0.81 ± 0.00	0.2044
Egg weight(g)	63.00 ± 1.07	63.32 ± 0.54	0.7967	62.19 ± 1.50	63.16 ± 0.78	64.15 ± 0.60	0.4163
Albumen height (mm)	6.77 ± 0.26 ^b	8.60 ± 0.11 ^a	0.0001	7.54 ± 0.33	7.84 ± 0.26	7.66 ± 0.23	0.7561
Albumen weight (g)	38.23 ± 0.69	39.55 ± 0.49	0.1248	37.97 ± 0.91	38.42 ± 0.61	40.29 ± 0.62	0.0620
% Albumen weight	66.37 ± 0.51	66.79 ± 0.57	0.5842	67.66 ± 0.63 ^a	66.75 ± 0.71 ^{ab}	65.33 ± 0.57 ^b	0.0401
Yolk weight (g)	14.36 ± 0.24	14.53 ± 0.13	0.5247	13.91 ± 0.18 ^c	14.55 ± 0.26 ^b	15.17 ± 0.17 ^a	0.0001
% Yolk weight	22.90 ± 0.40	23.06 ± 0.39	0.7571	21.58 ± 0.53 ^b	23.14 ± 0.32 ^a	23.77 ± 0.32 ^a	0.0220
Yolk colour	5.99 ± 0.14 ^b	6.35 ± 0.11 ^a	0.0477	5.88 ± 0.19 ^b	6.13 ± 0.11 ^{ab}	6.50 ± 0.15 ^a	0.0185
Haugh unit	77.90 ± 2.09 ^b	91.54 ± 0.62 ^a	0.0001	82.92 ± 2.73	86.11 ± 1.80	85.03 ± 1.70	0.5621
Shell weight (g)	6.70 ± 0.12	6.62 ± 0.07	0.5556	6.38 ± 0.16 ^b	6.67 ± 0.10 ^{ab}	6.92 ± 0.07 ^a	0.0052
Shell weight (%)	10.73 ± 0.17	10.15 ± 0.33	0.1208	10.31 ± 0.25	10.11 ± 0.47	10.90 ± 0.17	0.2115
Shell thickness (mm)	0.46 ± 0.01 ^a	0.44 ± 0.00 ^b	0.0282	0.43 ± 0.01 ^b	0.45 ± 0.00 ^{ab}	0.46 ± 0.00 ^a	0.0055

^{a, b, c} Means within the same row by factor with different superscripts differ significantly (p<0.05).

Yolk weight, % yolk weight, yolk colour and shell weight were significantly (p<0.05) influenced by inclusion levels of phytobiotics. All parameters measured increased with increasing inclusion levels of phytobiotics except albumen height and Haugh unit. The values recorded for egg length were 55.12, 56.15 and 56.30mm; 43.90, 44.38 and 45.34mm were obtained for egg width, and 0.78, 0.79 and 0.81 for ESI. Albumen height recorded 7.54, 7.84 and 7.66mm while 67.66, 66.75 and 65.33% were documented for % albumen weight. Birds offered 1.5 and 3% inclusion levels recorded the highest (p<0.05) values of % yolk weight (23.14 and 23.77%) while those birds on 0% inclusion recorded the lowest (p<0.05) values of % yolk weight (21.58%) and % yolk weight (21.58%). Shell weight and shell thickness had the

highest ($p<0.05$) values of 6.92g and 0.46mm for birds maintained on 3% inclusion levels while least values of 6.38g and 0.43mm were obtained among those on 0% inclusion level.

Interactive effects of phytobiotic type and inclusion levels on egg quality traits of pullets

The interactive effects of phytobiotic type and inclusion levels on egg quality traits of pullets are presented in Table 5. All parameters measured except egg length, egg width, ESI and % albumen weight were significantly ($p<0.05$) impacted by the interaction between the treatment factors. The highest ($p<0.05$) value for egg length (56.79mm), egg width (45.85mm) and ESI (0.81mm) were obtained from birds maintained on 3% turmeric powder ration while the least (54.13mm, 42.78mm and 0.76) values were obtained from birds fed diet with 0% ginger powder ration. Albumen height recorded least values of 6.56, 6.78 and 6.98mm for birds on ginger powder inclusion levels while birds supplied feed containing turmeric powder recorded higher albumen height values of 8.57, 8.89 and 8.34mm. Birds maintained on 3% turmeric powder ration had the highest ($p<0.05$) albumen weight of 42.05g while least values were obtained from those on diets containing 0% (36.88), 3% (38.53g) ginger powder and 1.5% turmeric powder recording 37.48g. % albumen weight recorded the highest ($p>0.05$) value of 64.99% for birds maintained on 3% turmeric powder diets while the lowest value was obtained from those fed 0% ginger powder diet. The highest yolk weight and % yolk weight were observed among birds fed 3% ginger powder diet recording 15.37g and 24.27% while the least were obtained from those fed 0% ginger powder with the value of 13.30g and 21.08% respectively. Yolk colour recorded the highest ($p<0.05$) value among birds fed 3% turmeric powder. Lower Haugh unit values were recorded for laying hens fed ginger powder inclusion levels while birds fed 0% (91.25), 1.5% (93.51) and 3% (89.86) turmeric powder recorded higher values. Birds fed 1.5% (6.95g) and 3% (7.00g) dietary ginger powder produced eggs with the highest shell weight while those on 0% ginger powder rations recorded the lowest value of (6.17g). % shell weight (11.06%) was the highest among birds on 3% ginger powder diet while the least was obtained from those fed 0% ginger powder ration. Laying birds on the control groups (0.43 and 0.44mm) and 1.5% dietary turmeric (0.43mm) laid eggs with lower shell thickness while those placed on 1.5 (0.47mm) and 3% (0.48mm) ginger powder diets 0.47 and 0.48mm).

Table 5
Interactive effects of phytobiotic type and inclusion levels on egg quality traits of pullets

Parameters	Ginger powder			Turmeric powder			p-value
	0%	1.5%	3%	0%	1.5%	3%	
Egg length (mm)	54.13 ± 2.29	56.54 ± 0.44	55.80 ± 0.36	56.14 ± 0.35	55.76 ± 0.41	56.79 ± 0.30	0.5115
Egg width (mm)	42.78 ± 1.80	44.78 ± 0.28	44.84 ± 0.23	45.07 ± 0.29	43.98 ± 0.19	45.85 ± 0.29	0.1232
Egg shape index	0.76 ± 0.03	0.79 ± 0.01	0.80 ± 0.01	0.80 ± 0.00	0.79 ± 0.00	0.81 ± 0.01	0.1515
Albumen height (mm)	6.56 ± 0.56 ^b	6.78 ± 0.39 ^b	6.98 ± 0.38 ^b	8.57 ± 0.23 ^a	8.89 ± 0.17 ^a	8.34 ± 0.16 ^a	0.0001
Albumen weight (g)	43.23 ± 1.87	43.18 ± 0.31	41.07 ± 1.24	42.91 ± 1.29	41.30 ± 1.62	42.93 ± 1.28	0.8093
% Albumen weight	67.80 ± 0.99	66.73 ± 0.53	64.57 ± 0.87	67.52 ± 0.81	66.76 ± 1.35	66.08 ± 0.71	0.1724
Yolk weight (g)	13.30 ± 0.59 ^c	14.49 ± 0.21 ^{ab}	15.34 ± 0.18 ^a	13.97 ± 0.14 ^{bc}	14.62 ± 0.30 ^{ab}	15.01 ± 0.16 ^a	0.0042
% Yolk weight	21.96 ± 0.98 ^b	22.48 ± 0.27 ^{ab}	24.27 ± 0.44 ^a	22.11 ± 0.35 ^b	23.81 ± 0.54 ^{ab}	23.28 ± 0.45 ^{ab}	0.0496
Yolk colour	5.68 ± 0.30 ^b	6.29 ± 0.18 ^b	6.00 ± 0.24 ^b	6.08 ± 0.24 ^b	5.96 ± 0.11 ^b	7.00 ± 0.11 ^a	0.0006
Haugh unit	74.92 ± 4.71 ^b	78.71 ± 2.77 ^b	80.19 ± 3.01 ^b	91.25 ± 1.27 ^a	93.51 ± 0.91 ^a	89.86 ± 0.89 ^a	0.0001
Shell weight (g)	6.17 ± 0.28 ^c	6.95 ± 0.10 ^a	7.00 ± 0.10 ^a	6.61 ± 0.12 ^{abc}	6.40 ± 0.15 ^{bc}	6.84 ± 0.09 ^{ab}	0.0010
% Shell weight	9.77 ± 0.46 ^c	10.78 ± 0.13 ^{ab}	11.06 ± 0.19 ^a	10.47 ± 0.25 ^{abc}	9.92 ± 0.48 ^{bc}	10.57 ± 0.14 ^{abc}	0.0332
Shell thickness (mm)	0.43 ± 0.02 ^b	0.47 ± 0.01 ^a	0.48 ± 0.01 ^a	0.44 ± 0.01 ^b	0.43 ± 0.01 ^b	0.45 ± 0.01 ^{ab}	0.0004
a, b, c Means within the same row with different superscripts differ significantly (p<0.05).							
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Main effects of phytobiotic type and inclusion levels on haematological indices of laying pullets

Table 6 shows the main effects of phytobiotic type and inclusion levels on haematological indices of pullets at layer phase. All parameters were not significantly impacted by phytobiotic type and levels of inclusion. Packed cell volume (29.31%), haemoglobin (9.79g/dl) and red blood cells count ($2.52 \times 10^{12}/L$), WBC ($10.42 \times 10^9/L$), lymphocytes (58.69%) and eosinophils (0.15%) were lower in birds fed ginger powder diets compared to those on turmeric powder diets which

recorded 34.75% for packed cell volume, 11.42% for haemoglobin, $2.96 \times 10^{12}/L$ for red blood cells, 10.76×10^9 for WBC, 68.17% for lymphocytes and 0.33% for basophils. Higher values of heterophils (32.32%), heterophils:lymphocytes ratio (0.51), eosinophils (0.38) and monocytes (0.85%) were obtained for birds fed ginger powder ration while lower values were recorded in those on turmeric powder diets. For MCV, MCH and MCHC, lower values of 107.86fL, 36.08pg and 30.65g/dl were documented respectively for birds on ginger powder ration compared to the corresponding values noted for those placed on turmeric powder diets (117.69fL, 38.69pg and 33.03g/dl).

Table 6
Main effects of phytobiotic type and inclusion levels on haematological indices of pullets at layer phase

Parameters	Phytobiotic type			Inclusion levels			
	Ginger powder	Turmeric powder	p-value	0%	1.5%	3%	p-value
Packed cell volume (%)	29.31 ± 2.71	34.75 ± 0.82	0.5376	28.44 ± 3.67	33.00 ± 1.71	34.75 ± 1.33	0.0760
Haemoglobin (g/dl)	9.79 ± 0.89	11.42 ± 0.30	0.4519	9.51 ± 1.22	10.85 ± 0.53	11.48 ± 0.46	0.1064
Red blood cells ($\times 10^{12}/L$)	2.52 ± 0.24	2.96 ± 0.08	0.3238	2.42 ± 0.31	2.83 ± 0.17	2.99 ± 0.13	0.1113
White blood cells ($\times 10^9/L$)	10.42 ± 0.97	10.76 ± 0.28	0.2842	10.07 ± 1.36	10.78 ± 0.40	10.96 ± 0.48	0.7463
Heterophils (%)	32.23 ± 3.00	30.50 ± 1.53	0.8513	28.67 ± 4.07	32.50 ± 1.83	33.38 ± 2.10	0.6214
Lymphocytes (%)	58.69 ± 5.08	68.17 ± 1.63	0.2438	59.33 ± 7.69	65.75 ± 2.12	65.13 ± 1.97	0.0997
Heterophils:lymphocytes	0.51 ± 0.05	0.46 ± 0.04	0.3818	0.44 ± 0.07	0.50 ± 0.04	0.52 ± 0.05	0.5563
Eosinophils (%)	0.38 ± 0.14	0.25 ± 0.13	0.0967	0.22 ± 0.15	0.38 ± 0.18	0.38 ± 0.18	0.4917
Basophils (%)	0.15 ± 0.10	0.33 ± 0.14	0.3813	0.22 ± 0.15	0.38 ± 0.18	0.13 ± 0.13	0.3138
Monocytes (%)	0.85 ± 0.24	0.83 ± 0.30	0.4950	0.44 ± 0.18	1.13 ± 0.44	1.00 ± 0.33	0.9738
MCV (fL)	107.86 ± 9.18	117.69 ± 1.76	0.6120	104.44 ± 13.09	117.36 ± 2.28	116.95 ± 3.24	0.3222
MCH (pg)	36.08 ± 3.09	38.69 ± 0.71	0.5148	34.98 ± 4.41	38.63 ± 0.67	38.70 ± 1.34	0.4369
MCHC (g/dl)	30.65 ± 2.57	33.08 ± 0.29	0.2718	29.76 ± 3.73	32.93 ± 0.30	33.03 ± 0.42	0.3748
MCV – Mean corpuscular volume, MCH – Mean corpuscular haemoglobin, MCHC – Mean corpuscular haemoglobin concentration							
fL – femtolitre, pg – pictogram, g/dl – gram per decilitre.							

Birds on 3% inclusion level recorded the highest PCV (34.75%), Hb (11.48g/dl), RBC ($2.99 \times 10^{12}/L$), WBC ($10.96 \times 10^9/L$), heterophils (33.38%) and heterophils:lymphocytes ratio (0.52) values while those on 0% inclusion level recorded the least values of 28.44%, 9.51g/dl, $2.42 \times 10^{12}/L$, 10.07×10^9 , 28.67% and 0.44, respectively).

Interactive effects of phytobiotic type and inclusion levels on haematological indices of laying pullets

The interactive effects of phytobiotic type and inclusion levels on haematological indices of laying pullets are presented in Table 7. All the parameters measured were not significantly ($p>0.05$) influenced by the interaction between phytobiotic type and levels of inclusion. PCV haemoglobin, WBC heterophils, MCV, MCH, and MCHC values increased as ginger powder inclusion level increased while the trend differed among birds fed turmeric powder diets. Birds on 3% turmeric powder diets recorded the highest values of PCV (36.26%), haemoglobin (11.85g/dl), RBC ($3.10 \times 10^{12}/L$) and monocytes (1.50%) while those supplied 0% ginger powder diets recorded the least PCV (23.60%), haemoglobin (8.08g/dl) and RBC ($2.00 \times 10^{12}/L$) values. However, monocytes recorded the lowest values among birds fed 0% turmeric ration. Heterophils:lymphocytes ratio, eosinophils and basophils values ranged from 0.49 - 0.56, 0.25 - 0.50% and 0.00 - 0.50% for those fed 0, 1.5 and 3% ginger powder while the values of those fed 0, 1.5 and 3% turmeric powder diets ranged from 27- 33.25, 0.37- 0.52% and 0.25 - 0.50%, respectively.

Table 7

Interactive effects of phytobiotic type and inclusion levels on haematological indices of pullets at layer phase

Parameters	Ginger powder			Turmeric powder			p-value
	0%	1.5%	3%	0%	1.5%	3%	
Packed cell volume (%)	23.60 ± 5.90	32.50 ± 3.38	33.25 ± 1.89	34.50 ± 0.87	33.50 ± 1.44	36.25 ± 1.80	0.1482
Haemoglobin (g/dl)	8.08 ± 2.02	10.60 ± 1.04	11.10 ± 0.58	11.30 ± 0.40	11.10 ± 0.44	11.85 ± 0.74	0.2528
Red blood cells (x10 ¹² /L)	2.00 ± 0.50	2.83 ± 0.33	2.88 ± 0.23	2.95 ± 0.03	2.83 ± 0.17	3.10 ± 0.15	0.1617
White blood cells (x10 ⁹ /L)	9.32 ± 2.47	10.88 ± 0.56	11.33 ± 0.96	11.00 ± 0.58	10.68 ± 0.66	10.60 ± 0.24	0.9121
Heterophils (%)	30.00 ± 7.52	31.75 ± 2.87	35.50 ± 2.96	27.00 ± 1.73	33.25 ± 2.66	31.25 ± 2.98	0.8361
Lymphocytes (%)	48.80 ± 12.21	66.00 ± 3.67	63.75 ± 2.59	72.50 ± 1.44	65.50 ± 2.72	66.50 ± 3.18	0.2012
Heterophils:lymphocytes	0.49 ± 0.03	0.49 ± 0.12	0.56 ± 0.07	0.37 ± 0.03	0.52 ± 0.06	0.48 ± 0.07	0.7403
Eosinophils (%)	0.40 ± 0.24	0.50 ± 0.29	0.25 ± 0.25	0.00 ± 0.00	0.25 ± 0.25	0.50 ± 0.29	0.7018
Basophils (%)	0.00 ± 0.00	0.50 ± 0.29	0.00 ± 0.00	0.50 ± 0.29	0.25 ± 0.25	0.25 ± 0.25	0.3687
Monocytes (%)	0.80 ± 0.20	1.25 ± 0.75	0.50 ± 0.29	0.00 ± 0.00	1.00 ± 0.58	1.50 ± 0.50	0.2621
MCV (fL)	94.48 ± 23.65	115.68 ± 2.39	116.78 ± 5.96	116.90 ± 1.79	119.05 ± 4.09	117.13 ± 3.65	0.6639
MCH (pg)	32.32 ± 1.63	37.83 ± 0.83	39.05 ± 2.19	38.30 ± 0.98	39.43 ± 0.94	38.35 ± 1.85	0.8199
MCHC (g/dl)	26.78 ± 6.71	32.70 ± 0.49	33.43 ± 0.58	33.48 ± 0.54	33.15 ± 0.39	32.63 ± 0.60	0.6527
MCV – Mean corpuscular volume, MCH – Mean corpuscular haemoglobin, MCHC – Mean corpuscular haemoglobin concentration							

Discussion

The feed intake recorded in this study was slightly lower compared to Petek (1999) who recorded 115g/bird/day in laying birds. Attia (2018) reported non-significant impact of feed intake which ranged from 115.00 to 115.70g/bird/day and 111.61 to 118.28g/bird/day for ISA Brown layers and White Lohmann LSL respectively. Contrariwise, Elwardany *et al.* (1998) reported a mean value of 102g while Moeini *et al.* (2011) reported 89.91; 93.63g/bird/day and 80.37; 86.84g/bird/day in 1 and 3% ginger and turmeric powder diets, respectively for single comb White Leghorns Hyline. The disparity obtained in feed intake from these previous works could be due to different strains and management of birds used in the various studies (Farooq *et al.* (2002). Feed intake is a variable

phenomenon affected by diverse factors which include strain of the birds (Farooq *et al.* (2002), stocking density (Carey *et al.* (1995) and environment (Zahir-ud-Din *et al.* (2001).

Generally, the action of phytobiotics is caused by primary and secondary compounds/ingredients (Wald, 2003). Primary compounds are major nutrients which include protein content and fats, while secondary compounds comprise volatile oils: curcuminoids (Toennesen, 1992), turmerone (Baik *et al.*, 1993) and arturmerone (Ferreira *et al.*, 1992); colorants such as demethoxycurcumin, bisdemethoxycurcumin (Huang *et al.*, 1995) and phenolic compounds such as flavonoids and chicoric acid (Grashorn, 2010). The crucial indispensable bioactive compound responsible for the biological action of turmeric is curcumin (Nouzarian *et al.*, 2011).

In laying birds, FCR is determined by the amount of feed consumed per kilogram of egg production (Gumus *et al.*, 2018). According to Ascard *et al.* (1995), a hen requires 2.5kg feed to produce 1kg eggs. Thus, feed consumption and efficient feed utilization is one of the main concerns for commercial egg enterprise because feed contributes 60 to 70% to the total cost of production in egg-type chickens (Mian, 1994 and Qunaibet *et al.*, 1992). The least ($p < 0.05$) value of FCR (2.64) obtained for birds on 1.5% ginger powder suggests that this inclusion percentage enhanced feed utilization and stimulated endogenous digestive enzymes for absorption of ingested nutrients resulting in optimum egg production (Incharoen and Yamauchi, 2009). This could probably be traced to the biological activities of gingerol, gingerdiol and gingerone contents of ginger powder for enhanced reproductive performance (Mansoub *et al.*, 2011).

The studies of Abdollah *et al.* (2011) and Moeini *et al.* (2011) agrees with the current work which demonstrated that laying birds consuming diet containing 1.5% of ginger powder had the highest value of egg mass (46.14g/bird/day); indicating that ginger enhanced egg production of laying hens at this level of inclusion. The effect of ginger powder on egg production (hen-day/hen-housed) coupled with the individual egg weights seemed to be responsible for the increase observed in egg mass. Zhao *et al.* (2011) partially attributed the increased egg mass to the enhanced antioxidant status by the addition of ginger powder. However, the authors reported that the mechanisms by which ginger powder elevated egg mass without impacting feed intake (as also obtained in this experiment) were not clear (Zhao *et al.*, 2011).

Lower mortality observed among the phytobiotic groups compared to the control groups (11.71 and 9.82%) was probably due to greater capacity of the supplied ginger and turmeric powder rations to reduce morbidity among the birds as a result of their medicinal functions (Chattopadhyay *et al.*, 2004), culminating in improved livability. Previous studies conducted using phytobiotics as feed additives have shown encouraging results with respect to lowered mortality and increased livability in poultry birds (Issa, 2012 and Oleforuh-Okoleh *et al.*, 2014). Hertog *et al.* (1993) and Knekt *et al.* 1996) reported that the phenolic flavonoids constituents of phytobiotics have been shown to have an inverse association with morbidity and mortality.

Besides this, turmeric has been noted to ameliorate the effects of aflatoxin, common in maize-based feed, causing hepatotoxic and hepatocarcinogenic effects, which poses serious challenge to poultry production (da Rocha *et al.*, 2014). According to Kumari *et al.* (2007), Faghani *et al.* (2014) and Qasem *et al.* (2015), turmeric powder inclusion could raise the immune response and antibody titer values of poultry after vaccination by its supplementation in feed. Such effect would be very useful when vaccinating against a highly contagious viral disease like Newcastle disease which causes high mortality and huge economic losses. Although, it is clear that vaccination could not prevent disease occurrence on the farm (Moomivand *et al.*, 2013), yet phytobiotics like ginger and turmeric have been proven to contain immuno-modulatory properties which play a very important role at the post-vaccination periods for avian infectious viruses, such as the infectious bronchitis virus (IBV) and Gumboro disease (IBD), thereby controlling mortality rate in the birds (Akhtar *et al.*, 2008; Ali *et al.*, 2008).

Conversely, high mortality rate experienced among the control groups (11.71 and 9.82%) in the present study could partly be due to the hot environmental conditions at some period (between January and March, 2018) of the experiment leading to heat stress in the laying birds. High ambient temperature or heat stress has been a major environmental stressor and thus a concern for the poultry industry, mostly in the hot regions of the world. Growth, feed intake and egg production are usually negatively influenced (Haruhiko *et al.*, 2015) during heat stress. Good management which includes good control of feeding timetable, lighting programme (ISA, 2009) as well as nutritional strategies aimed at eradicating the negative influence of heat stress through the use of medicinal herbs (such as ginger and turmeric), and micronutrients like vitamins and minerals to meet the requirements of birds during heat stress have proven to be of immense advantage (Lin *et al.*, 2006). According to Devegowda (1996), curcumin present in turmeric are included in feed for the enhancement of animal performance by improving livability and lowering mortality in poultry birds.

The attainment of lay at an earlier age among birds fed ginger powder rations (as opposed to a later age obtained for the turmeric groups) could possibly be connected to higher body weight at first lay among these groups. The earliest age at first lay observed among the birds placed on 1.5% ginger powder group is higher than those obtained by Islam *et al.* (2015) and Kabir and Haque (2010) who both recorded 141 days in Isa Brown pullets. Age at sexual maturity is a very vital trait from economic standpoint. The age at first oviposition is crucial, not only because it determines its first year production but also because the earlier a pullet comes to lay, the sooner revenue is generated (Jull, 1970). However, the least age at first lay obtained in this research was older than the recommended (126 days) for ISA Brown by Hendrix Genetic Company Limited (www.HendrixGenetics.com), and this variation may be due to environmental factors. In most domestic animals, reproductive functions are known to be considerably affected by nutrition (Armstrong and Benoit, 1996; Williams, 1998). Feed consumption, lighting schedule, length of daylight and environmental factors are major factors that determine age and weight at sexual maturity (Morris and Fox, 1960). The commercial layer usually comes to lay between 18 and 19 weeks (126-133 days) of age, egg production then rises sharply to a peak of 94-96% (www.HendrixGenetics.com) at 26-27 weeks of age and finally declines gradually (Rahman, 2003). Age at sexual maturity is also influenced by pronounced sexual effect (Eaton, 1961) which is characterized by egg lay. Therefore, the probable explanation for this delay may be due to the fact that a threshold of ovary and oviduct weights must be achieved before sexual maturity is attained; since these organs are responsive to feed allocation and influenced by body weight profile (Robbinson *et al.*, 2007). The impact of the bioactive compounds of turmeric powder on the reduction of adipocyte number which resulted in decreased fat accretion influencing body weight and in turn the age at first lay (Attia, 2018) may as well be responsible for this delayed sexual maturity.

Egg production is the most important index of performance of commercial layer and it accounts for 90% of the income from the enterprise (Oluyemi and Robert, 1979). The results obtained in this study depicted that hens maintained on 1.5% ginger powder diets had superior laying performance in terms of hen-day egg production, hen-housed egg production, egg mass and feed conversion ratio. Gingerol compounds contained in ginger powder may be responsible for the improvement in the digestive tract of laying hens which in turn boost egg production. This observation is comparable to those reported by Moeini *et al.* (2011) who discovered that the incorporation of 1% ginger rhizome powder increased the egg production and egg mass in white leghorn laying birds. Similar values obtained for hen-day and hen-housed production birds on 1.5% ginger powder diets indicated low mortality rate among these birds during the laying period. Abdollah *et al.* (2011) documented an increase in egg production with 0.5% dietary inclusion of ginger root with no negative effect on egg weight and feed conversion ratio of laying birds. The authors also found that egg production and egg mass in the groups fed diets containing turmeric powder were

higher than those of control groups. Samarasinghe *et al.* (2003) reported that 0.1, 0.2 and 0.3% turmeric treatments did not affect feed intake, egg production, egg weight and egg mass.

The incorporation of phytobiotics at varied inclusion levels did not impact egg weight among the dietary treatment groups. This could be due to the low levels or concentrations of the primary (protein content and fats) compounds and the volatility of the secondary compounds (volatile oils) in ginger and turmeric powder which may be required to enhance egg weight. The finding is similar to Samarasinghe *et al.* (2003) and Emadi and Kermanshahi (2007) but contrary to Pandian *et al.* (2013) and Kanagaraju *et al.* (2016). Malekizadeh *et al.* (2012) reported that turmeric powder at 1 or 3% inclusion level had no beneficial effect on egg weight and reduced egg production compared to the control groups. The ability to make significant changes to egg weight enables the egg producer to adapt to market demands (ISA, 2009), since most consumers tend to appreciate larger egg size. According to ISA (2009), it is possible to change egg size by 1 to 3g by changing the age at sexual maturity, or the body weight at start of lay.

The mean values obtained for egg width and egg shape index (ESI) in the current study differed from the findings of Attia (2018) who reported that the incorporation of 1.5 and 3% of turmeric powder in the layer diet did not show improvement on ESI among the groups. Nasiroleslami and Torki (2010) reported that addition of essential oil of ginger had no significant impact on ESI. The significantly higher values of albumen height, albumen weight, % albumen weight noted in hens maintained on 3% turmeric powder suggests that eggs produced by this group are of superior quality compared to the other treatment groups. Increase in albumen showed that the bioactive compounds in turmeric powder stimulated the growth of the epithelial cells and tubular gland cells in the magnum of the reproductive tract to synthesize and secrete substantial amount of albumen compared to the rest of the groups (Saraswati *et al.*, 2013).

Regarding yolk parameters, birds on 3% turmeric powder produced eggs with the best values of yolk weight and yolk colour which implies that turmeric had a major role to play in improving the yolk quality of eggs. Park *et al.* (2012) observed that the value of yolk colour in Lohmann Brown laying hens fed 0.50% turmeric powder was higher than those in control. Yolk colour is very vital feature which determines the acceptability of the egg and depends on the presence and profile of carotenoids in feed (Puvača *et al.*, 2018). Jacqueline *et al.* (1998) reported that the body system of laying hens cannot synthesize egg yolk pigments (Karaskova *et al.*, 2015) by their own biochemical processes. This suggests that the yellow orange pigment present in turmeric was deposited in the yolk. This may also have contributed to the higher yolk weight recorded for this group of birds. Thus, the natural yellow-orange substances in turmeric could be used to improve yolk colour in light-coloured feeds (Park *et al.*, 2012). According to Riasi *et al.* (2012), enhancement of yolk color could be as a result of curcumin, curcuminoids and its related compounds which are the yellowish pigment of turmeric.

Consumers give preference to deep yolk colour (Englmaierova *et al.*, 2014) as they are associated to healthier and more natural eggs. Therefore, some phytobiotic additives are commonly added to laying hen diets to enrich the yolk. Xanthophyll is attached to fat-soluble pigments in the feed (Yıldırım *et al.*, 2013). Carotenoids modify egg yolk colour and are a source of red and yellow (xanthophylls) pigments (Englmaierova *et al.*, 2014).

The higher Haugh unit of birds placed on 1.5% turmeric powder in the present study could mean that turmeric enhanced the internal quality of the eggs produced by this treatment group and thus may prolong the keeping quality during storage. Our result was higher than those obtained by Nasiroleslami and Torki (2010) who reported a value of 70.64. The Haugh unit is the most widely accepted measure of internal egg quality and tends to decrease with the time of storage (Williams, 1992). The quality of eggs and their stability during storage are largely determined by their physical structure and chemical composition (Seidler, 2003).

The results of shell weight (7.00g), % shell weight (11.06%) and shell thickness (0.48mm) obtained in 3% dietary ginger groups revealed that eggs produced were of superior external quality. These values are in agreement with those of Zomrawi *et al.* (2014) who observed higher values of shell weight and thickness in laying hens fed varying levels of ginger root powder. The use of ginger in layer diets might have caused an improved environment in the shell gland (uterus), which is a calcium deposition site, and thus enhanced shell weight and thickness (Radwan *et al.*, 2008). The observation in the present study is similar to the findings of Nasiroleslami and Torki (2010) who concluded that addition of the essential oil of ginger increased egg shell weight and thickness in laying hens. In contrast, Incharoen and Yamauchi (2009) reported there was no difference in shell thickness and shell ratio with 1 and 5% dietary dried fermented ginger. The relationship observed between egg shell thickness and ESI in the current study is in conformity with the findings of Altuntaş and Şekeroğlu (2008), who reported that the mean shell thickness increased as ESI increased.

Although, all haematological parameters measured in this current study were not significantly influenced by dietary ginger or turmeric, yet, the slight increase in PCV and Hb levels in birds placed on turmeric diets may indicate an enhanced oxygen carrying capacity of the blood (Larsson *et al.* 1985), and could be linked to the elevation observed in the red blood cells. Increased RBC depicts a better transportation of red blood components in response to erythropoietic system stimulation which may be associated with the effects of bioactive compounds in turmeric to improve the antioxidant status of the birds (Rababah *et al.*, 2004). Afolabi (2010) posited that haematological parameters of farm animals are affected by a number of factors: breed, climate, geographical location, season, day length, time of day, nutritional status, life habit of species, present status of individual among other factors. MCV, MCH and MCHC levels obtained in this study were in line with the normal range (90-140fL, 33-47pg and 26-35g/dl respectively) as reported by Patra *et al.* (2010). A low level of MCH and MCHC is an indication of anaemia (Aster, 2004) in farm animals and humans. It is noteworthy that the normal levels of these parameters among birds placed on turmeric powder diets could mean that turmeric inclusion in the diet did not negatively impair the transport of oxygen in the body tissues via the blood throughout their laying period. According to Oyawoye and Ogunkunle (2004), haematological components such as MCV, MCH and MCHC are valuable in monitoring feed toxicity especially with feed constituents that affect the blood as well as the health status of farm animals.

Conclusion

Based on the results of this study, it can be concluded that the effect of ginger and turmeric powder on the performance of pullets depends on their inclusion levels. Moreover, ginger powder enhanced sexual maturity and onset of egg lay in egg-type chickens. Egg-type chickens can be fed ginger and turmeric powder diets up to 3% inclusion levels over their commercial production lifespan in order to enhance their reproductive performance without impairing their overall growth. Laying birds which consumed diets with 1.5% of ginger powder had the best performance in terms of hen-day, hen-housed production, egg mass and FCR.

The external egg qualities (shell weight, % shell weight and egg shell thickness) were more enhanced by ginger powder inclusion while superior internal qualities (albumen height, albumen weight, % albumen weight, yolk colour, and Haugh unit) were obtained from eggs produced by birds raised on turmeric powder diets. The inclusion of 1.5% turmeric powder in layer feed may enhance egg quality due to higher Haugh unit values.

Both ginger and turmeric powder did not impair the health status of the laying birds by stimulating their immune response through increased lymphocytes count.

Declarations

Loading [MathJax]/jax/output/CommonHTML/jax.js

Funding

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Conflict of Interest

Authors declare they have no conflict of interest.

Ethics Approval

The procedure used in this study was approved by the Federal University of Agriculture, Abeokuta, using the guideline of the Nigerian Institute of Animal Science (NIAS).

Consent to Participate

Not applicable

Consent for Publication

All authors have given their consent to publish this study.

Availability of Data and Materials

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Code Availability

Not applicable.

Authors Contributions

All the authors have significant contributions to the different aspects (from conceptualization to manuscript preparation) of this study.

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