Reproductive and physiological responses and egg quality Traits of Isa Brown chickens fed diets supplemented with Zingiber officinale (Ginger) or Curcuma longa (turmeric) powder under the tropical hot environments of Nigeria

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Abstract: The increasing demand for healthy and low-fat poultry products by consumers has necessitated the search for 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. Four hundred and twenty egg-type chicks of Isa Brown at three weeks old were assigned to 5 treatments: basal diet (GT0); basal diet supplemented with 1.5 % (G1.5) or 3% (G3) ginger or 1.5 (T1.5) or 3% (T3) turmeric during a 60-week trial. A complete randomized design arrangement was applied. The results showed that the best ($p<0.05$) hen-day production, hen-housed production, egg mass, feed conversion ratio (FCR), age at first lay and weight at first lay were obtained in birds receiving the 1.5% ginger feed. A higher mortality rate was experienced among the control group (9.82%) while egg traits revealed significantly higher values of albumen height in hens placed on 1.5 and 3% turmeric powder compared to the other treatment groups. The study concluded that dietary ginger and turmeric enhanced the reproductive performance and egg quality of egg-type chickens over their commercial production lifespan without impairing their overall well-being.

Keywords: Phytobiotics; hen; eggs; production; welfare; tropics; food quality.

1. Introduction

The tropical environment is characterized by a persistent high ambient temperature and relative humidity (Oke et al., 2020; Lare et al., 2021), imposing thermal stress on the performance of livestock species, with its attendant poor performance and profitability (Sejian et al., 2011; Oni et al., 2024). Heat stress is a significant factor causing oxidative stress. Oxidative stress occurs when animals are exposed to heat stress (Oke et al., 2021; Kpomasse et al., 2021; Uyanga et al., 2022), resulting in impaired performance (Mujahid et al., 2007; Uyanga et al., 2023), poor meat quality and susceptibility to diseases (Kris-Etherton et al., 2004). Due to the inability of the body's antioxidant system to remove excessive reactive oxygen species during prolonged heat stress, supplementation with antioxidant additives may be beneficial to partially alleviate the effects of heat stress (Oni et al., 2023; Akosile et al., 2023a,b).

As the world's population continues to grow and individual food consumption increases, the demand for animal products has continued to rise. World per capita consumption of eggs has almost doubled since the early 1960s, while consumption of poultry meat has increased by 50% (FAO, 2020). Per capita demand for poultry meat between the years 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), Poultry is the second-biggest sector in Africa and a profitable business in Nigeria, where more than 180 million birds produce 3.8 million tons of eggs and 454 billion tons of meat annually (Poultry World, 2024).

The use of antioxidants has been reported as an alternative therapy to ameliorate the effect of oxidative or heat stress on birds (Oke, 2018; Adjei-Mensah et al., 2022; Oni et al., 2024). The use of phytogenic feed additives (PFA) such as *Zingiber officinale* (ginger) and *Curcuma longa* (turmeric) are known to possess bioactive compounds (El-Bahr et al., 2007; Oke et al., 2017; Oke, 2018). For instance, the findings of Oke (2018) revealed that dietary *Curcuma longa* improved the performance and antioxidant status of chickens. PFA possesses health-promoting functions, including gingerone, linalool, geraniol, neral, and shogaol in ginger (Fuhrman et al., 2000) and curcuminoid compounds in turmeric plants (Chattopadhyay et al., 2004), resulting in lower egg yolk lipids. There is a growing interest in the use of PFA because they are residue-free and are generally perceived as safe additives (Varel, 2002; Kpomasse et al., 2023). Most of these additives are also cheap and easily available to farmers, particularly in rural areas, in contrast to the use of synthetic growth promoters, which has been banned in different parts of the world as a result of their residues in animal tissues and the production of drug resistance (Zomrawi et al., 2013). Hence, the use of phytogenic feed additives is increasingly gaining global attention, especially in the aspects of health and nutrition as a possible suitable alternative.

The safety of turmeric and its characteristic yellow coloration are endorsed by organizations and researchers (WHO, 1987; NCCAM, 2012; Kpomasse et al., 2023). 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 several compounds, including shogaols, gingerdione, gingerol, gingerdiol, etc. that exert varying biological activities, including immunomodulatory, antioxidant, anti-inflammatory, antimicrobial, anti-tumorigenic and various pharmacological effects (Akoachere et al., 2002; Ali et al., 2008).

Phytogenic feed additives could be used as feed additives due to their suitability and preference, reduced risks of toxicity, and minimum health problems (Devegowda, 1996; Tokofai et al., 2020). Several interesting results have been documented on the efficacy of PFAs (Jahan et al., 2008; Tokofai et al., 2021 Tokofai et al., 2023). The beneficial effect of ginger and turmeric on the gut health (which has a nexus to performance) of animals has been documented (Platel & Srinivasan, 2000; Oke, 2018). There is, however, a scarcity of information on the evaluation of ginger and turmeric powder on the performance of egg-type chickens in the hot, humid tropics of Nigeria. Most studies have focused on a short-term administration of the additives, mostly in broilers and rarely in layer chickens (Oke, 2018; Dosu et al., 2023). Therefore, this study aimed to investigate the effect of the extended use of ginger and turmeric on the reproductive performance of egg-type chickens in hot humid tropics.

2. Materials and Methods

2.1. Processing of test ingredients

Fresh ginger and turmeric rhizomes were obtained from a reputable local market in October 2021 in Lagos, Nigeria. Ginger rhizomes were washed with clean water and air-dried. The cleaned rhizomes were cut into slices (about 1.0 g) and air-dried until they were crispy to the touch; after which they were pulverized using a 0.5-mm mesh sieve (Carl Roth GmbH + Co. KG) and stored in an airtight container before being incorporated into the experimental diets. Turmeric rhizomes were also processed as described for ginger. A maize-soybean-based basal diets supplemented with phytogenic additives were formulated to meet the needs of the chickens as presented in Table I (the composition (%) of the experimental layer diets).

Ingredients		Ginger (G) powder		Turmeric (T) powder	
	GT_0	**$G_{1.5}$**	**G_3**	**$T_{1.5}$**	**T_3**
Maize	48.00	48.00	48.00	48.00	48.00
Wheat offal	26.00	24.50	23.00	24.50	23.00
Soyabean meal	7.00	7.00	7.00	7.00	7.00
Groundnut cake	14.00	14.00	14.00	14.00	14.00
Bone meal	2.00	2.00	2.00	2.00	2.00
Limestone	2.00	2.00	2.00	2.00	2.00
Salt (NaCl)	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
*Layer premix	0.25	0.25	0.25	0.25	0.25
Ginger	0.00	1.50	3.00	0.00	0.00
Turmeric	0.00	0.00	0.00	1.50	3.00
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Crude protein	17.21	17.14	17.06	17.14	17.06
Ether extract	4.76	4.74	4.64	4.72	4.59
Crude fibre	4.58	4.81	5.04	4.70	4.82
Ash	3.47	3.57	3.67	3.60	3.73
Calcium	3.89	3.89	3.89	3.89	3.89
Phosphorus	0.47	0.47	0.47	0.47	0.47
Lysine	0.85	0.85	0.85	0.85	0.85
Methionine	0.41	0.41	0.41	0.41	0.41
M. E (kcal/kg)	2497.46	2478.68	2459.84	2478.68	2459.84

Table 1 – Composition (%) of layer diets between weeks 22 and 60.

*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: GT_0 = Ginger/turmeric powder at 0% level of inclusion, $G_{1.5\%}$ /$T_{1.5\%}$ = Ginger /turmeric powder at 1.5% level of inclusion, G_3/T_3 = Ginger/turmeric powder at 3% level of inclusion; M.E = Metabolisable energy.

2.2. Experimental birds and management

Four hundred and twenty one-day-old pullet chicks (Isa Brown breed) obtained from a reputable hatchery (Ibadan, Nigeria) were assigned to 5 treatments; GT0 basal diets (GT0); (T0) or basal diet supplemented with 1.5 % (G1.5) or 3% (G3) ginger or 1.5(T1.5) or 3% (T3) turmeric (Table 1). The birds in each group were further assigned to four replicates per treatment with 21 birds per replicate. The birds fed basal diets (GT0) without ginger and turmeric powder served as the control groups. The treatments were applied at three weeks of age and the birds were fed according to their production stages. The diets were isoenergetic and isoproteic.

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2.3. Data collection

2.3.1. Egg production parameters

Eggs laid per replicate were collected daily and the weights were determined using a Mettler top-loading weighing scale (Mettler Toledo GmbH, Giessen, Germany) with a sensitivity of 0.01 g. Body weights of the birds at first laying were taken as the total weight of live birds over the number (15) of birds per group, while age at first lay was the number of days from day old to the day when the first egg was laid. Egg number per week was determined by the total number of eggs laid by the hens in each group per week.

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

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

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

$$\frac{Number\ of\ eggs\ laid\ during\ the\ laying\ period\ (36\ weeks)}{Total\ number\ of\ birds\ housed\ at\ the\ beginning\ of\ laying\ period} \times 100$$

Egg mass: This was calculated per group as:

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

Feed Conversion Ratio (FCR): total feed intake over the laying period

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

Mortality: Mortality rate was calculated as:

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

2.4. Egg quality evaluation

Eight (8) eggs per replicate were collected for the evaluation of egg quality traits every month.

External quality of eggs: Individual eggs were weighed using a top-loading weighing balance and their shape indices were calculated as egg width (mm) divided by egg length (mm). 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 (Model JL-DZKC015, Realmote, Canada). The eggs were carefully broken and their contents were poured onto a sterile clean, flat plastic surface. Individual eggshell was air-dried in egg crates for a week the relative shell weight was determined by relating the shell weight to the weight of the egg. The Eggshell was weighed using a sensitive scale(Mettler Toledo GmbH, Giessen, Germany)), and shell thickness was measured by a digital caliper (Model JL-DZKC015, Realmote, Canada) to the nearest 0.01mm using a micrometer screw gauge.

The internal quality of eggs: The egg albumen height (AH) was measured with a tripod micrometer (B.C. Ames Co., Waltham, MA). 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 eggshell, while the percentage albumen weight was calculated as the percentage of the albumen weight to the egg weight. Yolk weight was measured using a Mettler top-loading weighing balance, while albumen weight was determined as the difference between the weight of the entire egg and the combined weight of the yolk and eggshell. The Haugh unit (HU) was calculated from the weight and height of the albumen of the egg using the formula of Haugh (1937):

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

Where HU is the Haugh unit, H is the height of the albumen in mm, and W is the weight of the egg in grams.

Yolk color: The yolk color was determined using a Roche yolk fan (Roche Ltd., Basel, Switzerland), with scores varying between 1 and 15, as described by Oke et al. (2014).

2.4.1. Blood parameters

At 40 weeks of age, 1 ml blood samples were collected via the jugular veins of four randomly selected chickens per replicate using sterilized syringes. These were immediately emptied into an ethylene diamine-tetra-acetic acid (EDTA) bottle tube to determine hematological parameters were determined using a hematology analyzer (Mindray BC-2800Vet). Parameters such as packed cell volume, hemoglobin, red blood cells (RBC), white blood cells (WBC) and WBC differentials, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC). 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).

3. Statistical analysis

3.1. Statistical methods

The data collected were subjected to a 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. The model is shown below:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where Y_{ij} is the mean value of the dependent variable; μ is the overall mean; T_i is the ith effect of phytobiotics; and e_{ij} is the error term.

4. Results

The effects of phytobiotic type and inclusion levels on laying performance indices are presented in Table 2. Hen-housed egg production, egg mass, and feed conversion ratio (FCR) were significantly ($p<0.05$) influenced by phytobiotics type. Laying hens fed both ginger diets Had better egg production, egg mass, and FCR ($p<0.05$) than those fed the turmeric powder diets. Birds on ginger powder diets recorded 56.8% hen-housed egg production, while those fed turmeric powder diets had 52.8%. The FCR for hens fed the ginger diets (2.98) was better ($p<0.05$) than that of birds fed the turmeric diets (3.63). Feed intake and mortality rate did not differ ($p>0.05$) between ginger and turmeric-supplemented groups. Pullets allocated to the ginger powder diets reached first laying at 174 days, 14 days earlier ($p<0.05$) than those raised on turmeric powder diets.

Inclusion levels of phytobiotics did not significantly ($p>0.05$) impact the hen-day production, whereas hen-housed egg production was positively influenced ($p<0.05$), with birds on 1.5% (57.47%) and 3% (57.17%) inclusion levels recording higher values than those on 0% (49.64%) inclusion levels. Birds on 1.5% inclusion levels of phytobiotics recorded lower percentage mortality compared to other treatment groups. The highest weight ($p<0.05$) at first lay (1745.0g) was found among birds fed a 3% inclusion level of phytobiotics.

Parameters	Control	Ginger powder		Turmeric powder		
	0%	1.5%	3%	1.5%	3%	p-value
Egg production (Hen-day)	53.09 ± 2.15^{b}	62.26 ± 2.33^{a}	58.95 ± 2.21^{ab}	53.62 ± 2.31^{b}	56.91 ± 2.52^{ab}	0.0232
Egg production (Hen-housed)	49.53 ± 2.00^{c}	55.73 ± 2.26^{a}	58.40 ± 2.18^{ab}	52.67 ± 2.26^{bc}	55.95 ± 2.48^{abc}	0.0014
Egg weight (g)	63.55 ± 1.88	64.62 ± 1.61	63.47 ± 1.20	61.69 ± 1.50	64.83 ± 1.24	0.7145
Egg mass (g/hen/day)	36.12 ± 2.32^{b}	46.14 ± 2.67^{a}	41.52 ± 2.16^{ab}	35.34 ± 3.69^{b}	36.55 ± 3.49^{b}	0.0107
Feed intake (g/hen/day)	113.14 ± 0.88	113.52 ± 0.86	113.89 ± 0.89	113.10 ± 0.88	113.13 ± 0.89	0.9862
Feed conversion ratio	3.13 ± 0.24^{ab}	2.46 ± 0.18^{c}	2.74 ± 0.17^{bc}	3.20 ± 0.71^{a}	3.09 ± 0.31^{abc}	0.0003
Age at first lay (days)	184.50 ± 2.25^{ab}	166.25 ± 6.60^{c}	171.25 ± 3.75^{bc}	192.75 ± 3.92^{a}	187.00 ± 5.76^{ab}	0.0149
Weight at first lay (g)	1510.00 ± 29.44^{b}	1507.50 ± 25.20^{b}	1805 ± 85.00^{a}	1537.50 ± 87.50^{b}	1685.00 ± 25.00^{ab}	0.0339
Mortality (%)	9.82 ± 2.09^{a}	1.92 ± 1.92^{b}	4.36 ± 2.52^{b}	1.92 ± 1.92^{b}	4.34 ± 2.70^{b}	0.0011

Table 2 – Effects of phytobiotic type and percentage inclusion levels on laying performance of hens.

[a, b, c] Means within the same row with different superscripts differ significantly ($p<0.05$).

4.1. 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 3. The mean values of egg width, albumen height, and yolk color were superior among the groups placed on 3% turmeric diets compared to those of the other treatment groups. Haugh units were the highest in 1.5 and 3% turmeric, while the heaviest shell weights were recorded for birds fed 3% ginger powder.

Parameters	Ginger powder			Turmeric powder		p-value
	0%	1.5%	3%	1.5%	3%	
Egg length (mm)	56.38 ± 0.59	56.54 ± 0.64	55.80 ± 0.52	55.76 ± 0.60	56.79 ± 0.44	0.7559
Egg width (mm)	44.56± 0.42^{ab}	44.78 ± 0.41^{ab}	44.84±0.34^{ab}	43.98 ± 0.28^{b}	45.85 ± 0.42^{a}	0.0388
Egg shape index	0.79 ± 0.00	0.79 ± 0.01	0.80 ± 0.01	0.79 ± 0.01	0.81 ± 0.01	0.2036
Egg weight (g)	63.55 ± 1.88	64.62 ± 1.61	63.47 ± 1.20	61.69 ± 1.50	64.82 ± 1.24	0.7757
Albumen height (mm)	6.83 ± 0.73^{b}	6.78 ± 0.57^{b}	6.98 ± 0.55^{b}	8.89 ± 0.25^{a}	8.34 ± 0.23^{a}	0.0213
Albumen weight (g)	43.23 ± 1.87	43.18 ± 0.31	41.07 ± 1.24	41.30 ± 1.62	42.93 ± 1.28	0.8275
% Albumen weight	67.80 ± 0.99	66.73 ± 0.53	64.57 ± 0.87	66.76 ± 1.35	66.08 ± 0.71	0.1632
Yolk weight (g)	13.85 ± 0.29^{b}	14.49 ± 0.30^{ab}	15.34 ± 0.26^{a}	14.62 ± 0.43^{ab}	15.01 ± 0.23^{ab}	0.0040
% Yolk weight	21.95 ± 0.66	22.48 ± 0.39	24.27 ± 0.63	23.81 ± 0.78	23.28 ± 0.65	0.0512
Yolk colour	5.92 ± 0.66^{b}	6.29 ± 0.39^{ab}	6.00 ± 0.24^{ab}	5.96 ± 0.11^{ab}	7.00 ± 0.11^{a}	0.0284
Haugh unit	78.04 ± 5.33^{b}	78.71 ± 4.01^{b}	80.19 ± 4.35^{b}	93.51 ± 1.32^{a}	89.86 ± 1.29^{a}	0.0187
Shell weight (g)	6.47 ± 0.19^{ab}	6.96 ± 0.14^{ab}	7.06 ± 0.13^{a}	6.37 ± 0.17^{b}	6.88 ± 0.13^{ab}	0.0067
% Shell weight	10.25 ± 0.35	10.79 ± 0.16	11.16 ± 0.37	9.43 ± 0.91	10.64 ± 0.19	0.1355
Shell thickness (mm)	0.35 ± 0.00	0.35 ± 0.01	0.36 ± 0.01	0.33 ± 0.01	0.35 ± 0.01	0.0756

Table 3 – Effects of phytobiotic type and inclusion levels on egg quality traits of hens.
$^{a, b, c}$ Means within the same row with different superscripts differ significantly ($p<0.05$).

4.2. Effects of phytobiotic type and inclusion levels on hematological indices of laying hens

The interactive effects of phytobiotic type and inclusion levels on hematological indices of laying pullets are presented in Table IV. All the parameters measured were not significantly ($p>0.05$) influenced by the interaction between phytobiotic type and levels of inclusion. The mean values of packed cell volume, hemoglobin, and red blood cells increased as ginger and turmeric powder inclusion levels increased, respectively.

Parameters	Ginger powder			Turmeric powder		p-value
	0%	1.5%	3%	1.5%	3%	
Packed cell volume (%)	29.50 ± 0.29	32.50 ± 3.38	33.25 ± 1.89	33.50 ± 1.44	36.25 ± 1.80	0.1323
Haemoglobin (g/dl)	10.10 ± 0.17	10.60 ± 1.04	11.10 ± 0.58	11.10 ± 0.44	11.85 ± 0.74	0.3334
Red blood cells (x10^{12}/L)	2.50 ± 0.06	2.83 ± 0.33	2.88 ± 0.23	2.83 ± 0.17	3.10 ± 0.15	0.2309
White blood cells (x10^{9}/L)	11.65 ± 1.07	10.88 ± 0.56	11.33 ± 0.96	10.68 ± 0.66	10.60 ± 0.24	0.8826
Heterophils (%)	37.50 ± 0.87	31.75 ± 2.87	35.50 ± 2.96	33.25 ± 2.66	31.25 ± 2.98	0.2897
Lymphocytes (%)	61.00 ± 0.58	66.00 ± 3.67	63.75 ± 2.59	65.50 ± 2.72	66.50 ± 3.18	0.4706
Heterophils:lymphocytes	0.62 ± 0.02	0.49 ± 0.07	0.56 ± 0.07	0.52 ± 0.06	0.48 ± 0.07	0.4050
Eosinophils (%)	0.50 ± 0.29	0.50 ± 0.29	0.25 ± 0.25	0.25 ± 0.25	0.50 ± 0.29	0.9501
Basophils (%)	0.00 ± 0.00	0.50 ± 0.29	0.00 ± 0.00	0.25 ± 0.25	0.25 ± 0.25	0.3485
Monocytes (%)	1.00 ± 0.00	1.25 ± 0.75	0.50 ± 0.29	1.00 ± 0.58	1.50 ± 0.50	0.7443
MCV (fL)	118.10 ± 1.56	115.68 ± 2.39	116.78 ± 5.96	119.05 ± 4.09	117.13 ± 3.65	0.9882
MCH (pg)	40.40 ± 0.23	37.83 ± 0.89	39.05 ± 2.19	39.43 ± 0.94	38.35 ± 1.85	0.6552
MCHC (g/dl)	33.48 ± 0.52	32.70 ± 0.49	33.43 ± 0.58	33.15 ± 0.39	32.63 ± 0.60	0.7396

Table 4 – Effects of phytobiotic type and inclusion levels on hematological indices oflayers.
MCV – Mean corpuscular volume, MCH – Mean corpuscular hemoglobin, MCHC – Mean corpuscular hemoglobin concentration.

5. Discussion

The lowest value of FCR (2.64) obtained in the present study among birds offered 1.5% ginger powder suggests that this inclusion percentage was optimal for efficient feed utilization and stimulated endogenous digestive enzymes for absorption of ingested nutrients, resulting in optimum egg production (Incharoen & Yamauchi, 2009). This can be attributed to the biological activities of gingerol, gingerdiol gingerone, and other bioactive compounds in ginger powder, which elicit the enhanced reproductive performance of birds (Dosu et al., 2023). 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 2.5 kg of feed to produce 1 kg of eggs. Thus, feed intake and efficient feed utilization are the main concerns for commercial egg enterprises because feed contributes 60-70% of the total cost of production in egg-type chickens (Mian, 1994).

The higher values of egg mass (46.14 g/bird/day) among birds fed a diet containing 1.5% ginger powder in this study indicated that ginger enhanced egg production of laying hens at this level of inclusion The earlier findings of Abdollah et al. (2011) and Moeini et al. (2011) also revealed an improvement in egg weights with dietary ginger. The egg mass is a reflection of the hen-day egg production. The upsurge in egg mass among birds fed ginger powder rations may be attributed to the antioxidant properties of ginger powder (Zhao et al., 2011), which enhanced the reproductive performance of the laying hens.

The lower mortality observed in the chickens of the phytobiotic groups compared to the control groups (9.82%) in the present study could be attributed to the beneficial roles of the bioactive compounds of the phytobiotics (Chattopadhyay et al., 2004), culminating in improved liveability. Previous studies using phytobiotics as feed additives have shown encouraging results regarding lowered mortality and increased liveability in poultry (Oleforuh-Okoleh et al., 2014). Turmeric used as an additive, has been noted to ameliorate the effects of aflatoxin common in maize-based feed, which causes hepatotoxic and hepatocarcinogenic effects and poses severe challenges to poultry production (Oke, 2018). According to Kumari et al. (2007), turmeric powder inclusion (at 1 g/kg diet) could raise the immune response and antibody titer values of the poultry after Newcastle vaccination by its supplementation in feed. Such an effect would be beneficial when vaccinating against a highly contagious viral disease like Newcastle disease, which causes high mortality and substantial economic losses.

Conversely, the higher mortality rate experienced among the control groups (9.82%) in the present study could partly be due to the hot environment. The average ambient temperature and relative humidity recorded during the period were 32.68°C and 55.60%, respectively. Whereas, the thermoneutral zone for laying hens is 19-22°C (Lin et al., 2006). High ambient temperature in the environment or heat stress has been a major environmental stressor (Oke et al., 2021). It has been a growing concern for the poultry industry, mostly in the hot regions of the world. Feed intake, growth, and egg production are usually negatively influenced (Kim et al., 2024) during heat stress. Good management, which includes good control of feeding regime, lighting program as well as nutritional strategies aimed at reducing 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 has been of immense advantage (Lin et al., 2006). Specifically, supplementation of Vitamin A (8000 IU/kg diet) alleviated the detrimental effects of heat stress on the laying performance of hens (Lin et al., 2002) According to Liu et al. (2020), supplementing laying hens with 150 mg/kg of curcumin enhanced their immune system, antioxidant enzyme activity, and productivity during heat stress.

The late attainment of lay among all the treatment groups may be connected to the body weight at first lay among all treatment groups. Age at sexual maturity is a very vital trait from an economic standpoint. The age at first oviposition is crucial, not only because it determines its first-year production but because the earlier pullets begin laying eggs, the sooner revenue is generated (Oke et al., 2015). In most domestic animals, reproductive functions are known to be considerably affected by nutrition (Armstrong & Benoit, 1996; Williams, 1998). Feed intake, lighting schedule, length of daylight, and environmental factors are major factors that determine age and weight at sexual maturity (Robbinson et al., 2007). The commercial layer would normally come to lay between 18 and 19 weeks (126-133 days) of age; it may be up to 22 weeks in some cases. Egg production then rises sharply (www.HendrixGenetics.com) at 26-27 weeks of age and finally declines gradually (Rahman, 2003). Therefore, the probable explanation for this delay could be that a threshold of ovary and oviduct weights was not achieved early enough before sexual maturity was attained; and this could result from the effect of bioactive compounds of turmeric powder on the adipocyte number leading to decreased fat accretion influencing body weight and in turn prolonging the age at first lay (Attia, 2018).

Egg production is the most important index of performance of the commercial layer and accounts for 90% of the income from the enterprise (Oluyemi & Robert, 1979). The results obtained in this study depicted that hens offered 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 boosts 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 egg production and egg mass in white leghorn-laying birds. 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 the control groups. In this study, the impact that ginger and turmeric powder and their levels of inclusion had on laying performance is in contrast with the findings of Samarasinghe et al. (2003), who reported that 0.1, 0.2 and 0.3% turmeric treatments did not affect egg production and egg mass. This may indicate that their potency in livestock feeding is dependent on inclusion level.

The incorporation of phytobiotics at varied inclusion levels did not impact egg weight among the dietary treatment groups in the present study. This could be due to the reduced concentrations of the primary (protein content and fats) compounds and the volatility of the secondary compounds (volatile oils) in ginger and turmeric powder which could enhance egg weight. 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. Samarasinghe et al. (2003) also reported similar findings

The mean values obtained for egg shape index (ESI) in the current study did not differ 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 in ESI among the groups. Nasiroleslami & Torki (2010) also reported that the addition of the essential oil of ginger had no significant impact on ESI. The significantly higher values of albumen height noted in hens placed on 1.5 and 3% turmeric powder suggest that eggs produced by this group are of superior quality compared to the other treatment groups. Elevated albumen height 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 a substantial amount of albumen (Saraswati et al., 2013).

Regarding yolk parameters, the highest yolk color value recorded for hens fed 3% turmeric powder diets could denote that turmeric powder had a major role to play in improving the yolk color of eggs. Park et al. (2012) reported similar observations where the value of yolk color in Lohmann Brown laying hens fed 0.50% turmeric powder was higher than those in control. Yolk color is a vital feature that 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) and Karaskova et al. (2015) reported that the body system of laying hens cannot synthesize egg yolk pigments by their biochemical processes. Hence, this suggests that the yellow-orange pigment present in turmeric was deposited in the yolk. This also may have possibly contributed to the higher yolk weight detected for this group of birds. According to Riasi et al. (2012), the enhancement of yolk color could result from curcumin, curcuminoids, and its related compounds, which are the yellowish pigment of turmeric.

Consumers prefer deep yolk color (Englmaierova et al., 2014) as it is perceived that they are associated with 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 color and are a source of red and yellow (xanthophylls) pigments (Englmaierova et al., 2014).

The higher Haugh unit of birds placed on 1.5% and 3% turmeric powder in the current 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 revealed higher values of the Haugh unit (93.51 and 89.86) than those obtained by Nasiroleslami & Torki (2010), who reported an average 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 primarily determined by their physical structure and chemical composition (Seidler, 2003).

The results of shell weight (7.06 g) obtained in 3% dietary ginger groups revealed that the 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 the addition of the essential oil of ginger increased eggshell weight and thickness in laying hens. In contrast, Incharoen and Yamauchi (2009) reported no difference in shell thickness and shell ratio with 1 and 5% dietary dried fermented ginger. The trend observed between eggshell thickness and ESI in the current study conforms with the findings of Altuntaş and Şekeroğlu (2008), who reported that the mean shell thickness increased as ESI increased.

The significant rise in PCV and RBC concentration with an increase in the level of inclusion may indicate an enhanced oxygen-carrying capacity of the blood (Larsson et al., 1985). Increased RBC depicts better transportation of red blood components in response to erythropoietic system stimulation, which may be associated with the effects of bioactive compounds in ginger and turmeric powder to improve the antioxidant status of the birds (Rababah et al., 2004). Afolabi (2010) stated that the hematological parameters of farm animals are affected by some factors: breed, climate, geographical location, season, day length, time of day, nutritional status, life habits of species, and present status of individuals, among other factors. MCV, MCH, and MCHC levels obtained in this study were within 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 anemia (Aster, 2004) in farm animals and humans. It is noteworthy that the normal levels of these parameters among birds could mean that phytobiotic inclusion levels in the diet did not negatively impair the transport of oxygen in the body tissues via the blood throughout their laying period.

6. Conclusion

Based on the results of this study, it could be concluded that the effect of ginger and turmeric powder depends on the inclusion levels. Ginger powder enhanced the attainment of sexual maturity and the onset of egg lay in egg-type chickens. Ginger and turmeric powder diets could be fed up to 3% inclusion levels to egg-type chickens over their commercial production lifespan without impairing their overall growth under hot, humid tropics. Laying birds that consumed diets with 1.5% ginger powder had the best performance in terms of hen-day, egg mass, and FCR. The external egg qualities (shell weight) were enhanced by ginger powder inclusion, while superior internal qualities (albumen height, yolk color, and Haugh unit) were obtained from eggs produced by birds raised on turmeric powder diets.

Conflict: Authors declare no conflict of interest.

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