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Changes in the bioactive compounds of sun-dried ginger rhizome and their effects on growth performance, blood profile, carcass and meat quality of broiler chickens

Egenuka, F. C., Okeudo, N. J., Obikaonu, H. O., Ogbuewu, I. P. and Aladi, N. O*

Department of Animal Science and Technology
Federal University of Technology, Owerri, Nigeria

***Corresponding author:** *nnnanyerealadi@gmail.com*

Abstract

Phytogenic feed additives such as ginger, garlic and turmeric are plant derived products which when added to livestock feed have the ability to enhance livestock performance through the improvement of digestibility, absorption of nutrients, and are also able to eliminate pathogenic microbes residing in the gut of the animal. The effects of sun drying on the bioactive components of ginger and subsequent performance of broiler chickens were evaluated using 180 broiler chicks of Arbor Acres strain. Fresh ginger rhizomes were cut into 2-3 mm thick slices., sundried and then milled. The proximate and bioactive compositions of fresh and sundried samples were determined. Thereafter, three experimental broiler diets were formulated such that diets 1 (control) and 3 contained no ginger. Diet 2 contained 0.5 % sundried ginger meal. However, broilers placed on diet 3 were also offered a fresh equivalent of 0.5 % sundried ginger through the drinking water. Data was collected on growth performance parameters, haematology and serum biochemical indices, carcass and meat quality characteristics. Twenty and nineteen bioactive compounds were identified in the fresh ginger and sundried ginger rhizomes respectively, with most of the components being higher in concentration in fresh than in dry ginger. Gingerol and shogaol were present in fresh but not in dry ginger while alpha-cedrol detected in dry ginger was not found in fresh ginger. Final live-weight, weight gain, feed intake and feed conversion ratio were not significantly ($p>0.05$) affected by dietary treatments in the starter phase. In the finisher phase, live-weight, weight gain and growth rate were significantly ($p < 0.05$) higher in the fresh ginger group compared to dry ginger and control groups. The cost of feed consumed was significantly ($p < 0.05$) higher in the ginger groups compared to the control group while feed cost per kilogram weight gain was significantly higher in dry ginger compared to fresh ginger and control groups. Carcass and meat quality parameters were not significantly ($p>0.05$) affected by fresh or dry ginger treatment. The haematological indices were not significantly ($p>0.05$) affected by either form of ginger supplementation. Serum glucose concentration was significantly ($p<0.05$) reduced by the inclusion of dry ginger in broiler chicken diets (T2). The study, therefore, concluded that providing broiler chickens with fresh ginger through drinking water was more efficacious in promoting growth performance than the inclusion of sundried ginger in the diets.

Keywords: Broiler chickens, performance, blood profiles, carcass, meat quality, ginger bioactive components

Running title: Bioactive compounds in fresh and sun-dried ginger rhizome and performance, of broiler chickens

Modifications des composés bioactifs du rhizome de gingembre séché au soleil et leurs effets sur les performances de croissance, le profil sanguin, la carcasse et la qualité de la viande des poulets de chair

Résumé

Les additifs alimentaires phytogéniques tels que le gingembre, l'ail et le curcuma sont des produits dérivés de plantes qui, lorsqu'ils sont ajoutés à l'alimentation du bétail, ont la capacité d'améliorer les performances du bétail en améliorant la digestibilité et l'absorption des nutriments, et sont également capables d'éliminer les microbes pathogènes résidant dans l'intestin des animaux. l'animal. Les effets du séchage au soleil sur les composants bioactifs du gingembre et les performances ultérieures des poulets de chair ont été évalués en utilisant 180 poussins de chair de la souche Arbor Acres. Les rhizomes de gingembre frais ont été coupés en tranches de 2 à 3 mm d'épaisseur, séchés au soleil puis moulus. Les compositions immédiates et bioactives d'échantillons frais et séchés ont été déterminées. Par la suite, trois régimes expérimentaux pour poulets de chair ont été formulés de telle sorte que les régimes 1 (témoin) et 3 ne contenaient pas de gingembre. Le régime 2 contenait 0,5 % de farine de gingembre séché au soleil. Cependant, les poulets de chair soumis au régime 3 se sont également vu proposer un équivalent frais de 0,5 % de gingembre séché au soleil dans l'eau de boisson. Des données ont été collectées sur les paramètres de performance de croissance, les indices hématologiques et biochimiques sériques, les caractéristiques de qualité des carcasses et de la viande. Vingt et dix-neuf composés bioactifs ont été identifiés respectivement dans les rhizomes du gingembre frais et du gingembre séché, la plupart des composants ayant une concentration plus élevée dans le gingembre frais que dans le gingembre sec. Le gingérol et le shogaol étaient présents dans le gingembre frais mais pas dans le gingembre sec, tandis que l'alpha-cédrol détecté dans le gingembre sec n'était pas trouvé dans le gingembre frais. Le poids vif final, le gain de poids, la consommation alimentaire et le taux de conversion alimentaire n'ont pas été affectés de manière significative ($p > 0,05$) par les traitements diététiques pendant la phase de démarrage. Dans la phase de finition, le poids vif, le gain de poids et le taux de croissance étaient significativement ($p < 0,05$) plus élevés dans le groupe de gingembre frais par rapport au groupe de gingembre sec et aux groupes témoins. Le coût de l'alimentation consommée était significativement ($p < 0,05$) plus élevé dans les groupes de gingembre par rapport au groupe témoin, tandis que le coût de l'alimentation par kilogramme de gain de poids était significativement plus élevé dans le groupe de gingembre sec que dans le groupe de gingembre frais et de contrôle. Les paramètres de qualité de la carcasse et de la viande n'étaient pas affectés de manière significative ($p>0,05$) par le traitement au gingembre frais ou sec. Les indices hématologiques n'étaient pas affectés de manière significative ($p>0,05$) par l'une ou l'autre forme de supplémentation en gingembre. La concentration sérique de glucose était significativement ($p <0,05$) réduite par l'inclusion de gingembre sec dans l'alimentation des poulets de chair (T2). L'étude a donc conclu que fournir aux poulets de chair du gingembre frais dans l'eau potable était plus efficace pour favoriser les performances de croissance que l'inclusion de gingembre séché au soleil dans l'alimentation.

Mots-clés: Poulets de chair, performances, profils sanguins, carcasse, qualité de la viande, composants bioactifs du gingembre

Introduction

The use of ginger as a phytogenic feed additive in broiler production has yielded positive results due to its antibacterial, anti-inflammatory, antiseptic, anti-parasitic properties (Shewita and Taha, 2018). Over 50 bioactive compounds have been identified in ginger (Ding *et al.,* 2012); with the most potent ones responsible for its pungency and pharmacological effects being gingerol, shagaol, zingerone (Yu, *et al.,* 2007). Phytogenic feed additives (PFAs) otherwise called phytobiotics or botanicals are products derived from plants and added to animal feeds to enhance performance and health of farm animals. These PFAs have been reported to improve feed digestibility, nutrient absorption and eliminate pathogens residing in the guts of animals (Balunas and Kinghorn, 2005; Athanasiadou *et al*., 2007). Phytogenics contribute positively to performance, the histomorphology of the intestinal wall, the biochemical profile, carcass characteristics, and the population of bacteria found in the gut (Da Silveira Deminicis *et al*, 2021), stimulation of feed intake, antimicrobial, coccidiostatic and anthelmintic effects (Grashorn, 2010). According to Mohammadi-Gheisar & Kim (2018), the antimicrobial, antioxidant, anti-inflammatory and growth promoting effects of phytobiotics are largely responsible for their positive effects. Higher carcass weights and dressing percentages and improved carcass quality have been reported in broiler chickens fed diets containing ginger (Zhang *et al*., 2009). The growing interest in phytogenic feed additives (PFAs) has largely been driven by concerns over antibiotic residues in poultry food products which are believed to be responsible for antibiotic resistance in recent years.

Ginger supplementation in poultry diets has largely been in dry powdery form. Processing of ginger into powder involves drying and milling and sometimes pricking (Okafor and Okafor, 2007). Drying and milling of ginger is an additional cost for farmers and may lead to reduction or loss of some of the volatile active components (Kurniasari *et al*., 2022). According to An *et al*. (2016), gingerol and the shagaol contents tended to increase while the free radical scavenging ability (a measure of antioxidation capacity) was lower in dried ginger. Ding *et al*. (2012) reported that most bioactive compounds in ginger decreased with drying irrespective of methods. The essential oil and oleoresin content of dry ginger decreased with thickness and diameter of slice, temperature and period of drying. The colour of ginger products was also affected by drying (Okafor and Okafor, 2007). It is therefore likely that fresh or dried ginger would have varied physiological effect on broiler chickens. In most developing countries of sub-Saharan Africa, drying of ginger is largely accomplished by sun drying with attendant consequences on the composition of the active components. Physiological functions are largely dependent on interplay of these bioactive compounds as antioxidants, prebiotics, immune modulators and humoral stimulators. This study was designed to determine the effect of dietary inclusion of sundried ginger versus blended fresh ginger administered through drinking water on the performance of broiler chickens.

Materials and methods

Source and processing of ginger

Freshly harvested common ginger rhizomes were washed, thinly sliced (about 3 mm thickness), sundried on concrete slabs to constant weight (within 5 – 7 days) and then milled using a hammer mill fitted with a 0.01 mm sieve. The milled sample was stored in an air-tight plastic container until needed for feed formulation. During the feeding trial, an equivalent weight of fresh ginger rhizomes was cut into thin slices and

then blended into a paste using kitchen type blender (Molino Tolva Alta, model 121; Landers, Medellin, Colombia). The paste was mixed with water and filtered through cheese cloth and the filtrate recovered. The volume of water used in the extraction was limited to the amount the birds would finish before late afternoon each day as estimated from Oluyemi and Roberts (2000).

Proximate composition of fresh and sundried ginger

Exactly forty grammes (40 g) each of blended fresh ginger and powdery mass of sun-dried ginger were used to determine the proximate composition of ginger by the procedures of Association of Official Analytical Chemists (AOAC, 1995). The moisture content was determined by weighing samples into crucibles and drying in oven at 105 °C until a constant weight was obtained. Crude protein was determined by the Kjeldahl method (AOAC, 1990). Samples were digested in acid followed by alkaline digestion to determine the crude fibre. Ash content was determined by ashing at 550 °C for 3 hours. Soxhlet extraction method was used to determine the ether extract (lipid) content while total soluble carbohydrate or nitrogen-free extract (NFE) was calculated as: NFE = 100 – (% crude protein + % crude fibre + % ether extract + % ash + % moisture).

Determination of bioactive constituents of fresh and sundried ginger

Twenty grammes (20 g) each of blended fresh ginger and powdered sliced sun-dried ginger were used to determine the biochemical components. Samples were soaked in 80 ml methanol and left for 72 hours to dissolve alkaloids, flavonoids and other constituents present. Whatman No. 1 filter paper was used to filter the methanol extract and the residue removed (Jasim *et al*., 2015). The bioactive constituents of the ginger extracts were determined by gas chromatography-mass spectrometry (GC-MS) method in a 789 Agilent Instrument under computer control at the energy of 70 electron volt (eV). About 1 µl of the ginger methanol extract was injected into the GC-MS instrument by use of a micro syringe and then scanned for 45 minutes (Mohammed and Imad, 2013; Imad *et al*., 2014; Muhanned *et al*., 2015). As the components were resolved and got eluted from the gas chromatographic column, they entered the electron ionization (mass spectrometry) detector which detected them by flame ionization (Tranchida and Mondello, 2020).

Experimental birds and diets

One hundred and eighty (180) day-old broiler chicks of Abor-acre strain were weighed on arrival and allotted to three treatment groups of 60 each. Each group was sub-divided into four replicates of fifteen 15 birds each in a completely randomized design (CRD). Each replicate was reared on deep litter in a pen measuring 1m x 1m. The starter diet was fed from 1 – 27 days while the finisher diet was fed from 28 – 56 days of age. Feed and water were provided *ad libitum t*hroughout the feeding trial. Three experimental broiler chicken diets were formulated as shown in Table 1. Diets 1 contained no ginger and served as the control diet while Diet 2 contained 0.5 % of the sundried ginger meal. Diet 3 did not contain ginger, but the birds that received the diet were offered the aqueous fresh ginger extract in drinking water every morning. The quantity of sundried ginger birds in T_2 would consume each day was estimated and used to determine the quantity of fresh aqueous ginger extract as previously described. The gross composition of experimental diets is presented in Table 1.

Table 1: Gross composition of experimental diets

	Starter diets			Finisher diets		
Diet /ginger level	T1 (0.00)	T2 (0.50)	T3 (0.00)	T1 (0.00)	T2 (0.50)	T3 (0.00)
Maize	49.50	49.00	49.50	58.00	57.50	58.00
Ginger	0.00	0.50	0.00 [a]	0.00	0.50	0.00 [a]
Soybean meal	22.50	22.50	22.50	17.00	17.00	17.00
Blood meal	2.00	2.00	2.00	2.00	2.00	2.00
Fish meal	5.00	5.00	5.00	5.00	5.00	5.00
Palm kernel cake	10.00	10.00	10.00	10.00	10.00	10.00
Spent grain	5.00	5.00	5.00	-	-	-
Wheat offal	2.00	2.00	2.00	4.00	4.00	4.00
Bone meal	3.00	3.00	3.00	3.00	3.00	3.00
Vitamin and mineral premix*	0.25	0.25	0.25	0.25	0.25	0.25
Salt	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
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrient composition (%)						
Crude protein	23.05	23.04	23.05	20.40	20.40	20.40
Ether extract	4.33	4.33	4.33	4.21	4.21	4.21
Crude fibre	5.78	5.78	5.78	5.32	5.32	5.32
Ash	38.44	38.66	38.44	34.48	34.71	34.48
Nitrogen free extract	28.40	28.18	28.40	35.59	35.36	35.59
Calcium	1.33	1.34	1.34	1.31	1.31	1.31
Phosphorus	1.07	1.07	1.07	1.00	1.00	1.00
Metabolizable energy (Kcal/kg)	2868.97	2868.91	2868.97	2927.74	2927.14	2927.74

[a] fresh aqueous ginger equivalent to ginger content of Diet 2

*Agrited® Formulated to provide per kg feed: Vitamin A: 8,000,000 IU, Vitamin D_3: 1,800,000IU, Vitamin E: 20,000 IU, Vitamin K: 2,200mg, Vitamin B1: 1,600mg, Vitamin B2: 5000mg, Vitamin B6: 2,4000mg, Vitamin B12: 13mg, Niacin: 23,500mg, Folic acid: 700mg, Pantothenic acid: 6,500mg, biotine:42mg, antioxidant:13,300mg, manganese: 85,000mg, Cobalt: 220mg, Copper: 6,000mg, Iodine: 1,100mg, Iron: 25,000mg, Manganese: 1800mg, Selenium: 120mg and zinc: 50,000mg, Choline chloride: 15,000mg

Growth performance

Day-old broiler chickens were weighed on arrival to obtain the initial weight, and thereafter at the end of each week until the 8th week of age. The difference between the final weight and the initial weight was recorded as the weight gain. Feed intake was determined daily on replicate basis as the difference between weight of the feed offered daily and the weight of left-over feed the next morning. Feed conversion ratio was calculated by dividing the average daily feed intake by the average daily weight gain. Cost of feed consumed per bird was calculated by multiplying the unit cost of feed by quantity of feed consumed per bird.

Feed cost per kilogram weight gain was calculated by dividing the cost of feed by the feed conversion ratio (Bai *et al.*, 2022; Dritz, 2012).

Haematological and serum biochemical indices

At 8 weeks of age, blood samples were collected from 2 broiler chickens per replicate (i.e. 8 birds from each treatment) in the morning hours (7.00 – 8.00 am). Two (2) ml of blood was collected into Ethylene Diamine Tetraacetate (EDTA) bottles for haematological analysis and 3 ml into plain Bijou bottles for the determination of serum biochemical indices. Blood samples obtained were analysed with an auto haematology analyser (iCell-820 model, Icubio, Shenzhen, China) for haematological parameters and semi-auto chemistry analyser (BA-88A model, Mindray, Nanshan, Shenzhen, China) was used for serum biochemical parameter determinations. Haematological indices determined were packed cell volume (PCV), haemoglobin concentration (Hb), red blood cell counts (RBC), RBC indices (mean corpuscular volume – MCV, mean corpuscular haemoglobin – MCH and mean corpuscular haemoglobin concentration – MCHC), platelets, total white blood cell counts (TWBC) and differential WBC (lymphocytes and heterophils or neutrophils). Serum biochemical parameters analysed were glucose, cholesterol, triglyceride, high density lipoprotein (HDL) cholesterol, low density lipoprotein (LDL) cholesterol.

Carcass evaluation

At the end of the feeding trial, two broiler chickens were randomly selected from each replicate, tagged and starved of feed overnight (12) hours, but allowed unlimited access to clean drinking water. The chickens were reweighed and bled to death by severing the carotid arteries. They were scalded by immersion in hot water (65 $^{\circ}$C) for 30 seconds and de-feathered. Evisceration was done manually, followed by decapitation and the removal of offal. Carcass weights were subsequently determined. Weights of internal organs, carcass parts (drumstick, thigh, breast, back cut) were determined following the procedures described by USDA (1998). All weights were expressed as percentages of live weight.

Organoleptic quality analysis

One drumstick from each broiler chicken was separated and labelled for organoleptic quality assessment. The drumsticks were kept in the refrigerator overnight. The following morning, each drumstick was halved along the femur immersed in 3% brine for 30 seconds, and then placed in labelled transparent polythene bags. Bags were tied and cooked for 30 minutes under steam and allowed to cool at room temperature. The cooked samples were presented to a trained taste panellist who assessed them for juiciness, tenderness, flavour intensity, amount of connective tissue and hedonic rating using the 9-point rating scale (AMSA, 1978).

Statistical analysis

The data was subjected to one - way analysis of variance (ANOVA) for the completely randomized design and significant means were separated using the least significant difference (LSD) method at 5 % level of probability as described by Steel and Torie (1980).

Results and discussion

Proximate composition of fresh and dry ginger samples

The proximate compositions of the fresh and dry ginger samples used are presented in Table 2. The moisture content of fresh ginger was 80.74 % while that of sundried ginger was 14.70. Based on the moisture

content of fresh ginger and that of dry ginger observed in this result, 5.5 times of fresh ginger is needed to yield an equivalent weight of the dry ginger. The moisture content of 80.74 % for fresh ginger observed in this research is similar to 83.45 % but the 14.70 % for dry ginger is lower than 20.21 % reported by Agu *et al*. (2017). Agu *et al.* (2017) air-dried their samples in an open ventilated room, away from the heat of the sun, hence the differences in moisture contents reported is most likely due to the drying process used in the separate studies. The ash content of the dry ginger meal (5.92 %) was similar to 6.63, 6.57 and 7.08 % reported for ginger meal by Ugwoke and Nzekwe (2010), Ogbuewu *et al*. (2014) and Agu *et al*. (2017), respectively. The crude protein content of sundried ginger in this study (9.32 %) was similar to 8.83 % reported by Ugwuoke and Nzekwe (2010) for ginger rhizome powder (ginger meal) but varied from 5.45 % and 13.19 % recorded by Ogbuewu *et al*. (2014) and Agu *et al*. (2017), respectively. The crude fibre observed for fresh and dry ginger meal (8.74 % and 2.61 %) varied from the values (1.90 % and 5.95 %) recorded by Agu *et al*. (2017). The observed variations could be a result of differences in crop variety and maturity and processing methods (including the particle size of material). Ideally, and as has been observed in most other feed components, crude fibre is expected to be higher in dry than in fresh ginger. The deviation in expected result in crude fibre observed in this study could be due to exposure of the dry ginger to greater acid and alkaline dissolution by the drying and milling processes. This increases the nitrogen free extract with proportionate reduction in the value of the crude fibre (Fahey *et al*., 2019).

Table 2: Proximate composition of fresh and sundried ginger

			Dry matter basis	
Parameter (%)	Fresh ginger	Dry ginger	Fresh ginger	Dry ginger
Moisture content	80.74	14.7	-	-
Ash	0.68	5.92	3.53	6.94
Crude protein	2.66	9.32	13.81	10.93
Crude fibre	8.74	2.61	45.38	3.06
Ether extract	0.79	8.21	4.10	9.62
NFE (Soluble carbohydrate)	6.4	59.24	33.23	69.45

Bioactive constituents in fresh and sundried ginger

Result of the bioactive compounds in fresh and sundried ginger is shown in Table 3. A total of 20 and 19 compounds were found in fresh and sundried ginger, respectively. Most of the constituents had higher concentration in fresh than in sundried ginger. These are thujopsene, camphor, beta-pinene, zingiberene, alpha-cedrenes, etc. Bisabolene, acetonitrile, citral and cineole were, however, found to be in slightly higher amounts in the sundried than in fresh ginger. Our findings are supported by earlier report by Weiss (1997) that oils from fresh ginger rhizomes are volatile compounds with low boiling points and hence, tend to be evaporated by the drying processes. Sasidharan and Nenon (2010) also noted decreased concentration in most ginger compounds in dry compared to fresh ginger. Findings by Jayashree *et al*. (2014)

also showed that ginger compounds are reduced by drying. Contrary to the findings in this study however, Lawrence (2000) noted a lower abundance of citral in dried ginger oil compared to fresh ginger. The observed difference may likely be due to differences in plant maturity, production location of rhizome or different processing methods applied to the rhizome.

The most abundant component in both fresh and sundried ginger was zingiberene. This result confirms earlier reports (Lawrence, 2000; Sasidharan and Nenon, 2010; Koch *et al*., 2017; Oforma *et al.*, 2019) that the dominant volatile oil found in ginger rhizome was zingiberene. The least component in the two samples was thujopsene. Gingerol and shogaol were detected only in fresh ginger and completely absent in sundried ginger with gingerol being higher in abundance than shogaol. Koch *et al.* (2017) also noted gingerol and shogaol as main phenolic compounds in fresh ginger. The higher concentration of gingerol in fresh ginger relative to shogaol agrees with Butt and Sultan (2011) that gingerols are the major bioactive non-volatile pungent phytochemicals of fresh ginger rhizomes. Complete absence of gingerol and shogaol in the sundried ginger could be attributed to the highly thermolabile nature of gingerol reported by Baliga *et al*. (2013), and its possible loss with the shogaol during the drying process or conversion of the phenolic compounds to other components. Semwal *et al*. (2015), however, reported that gingerols and shogaols were present in the rhizomes of fresh and sundried ginger.

Absence of gingerol and shogaol in sundried ginger suggests they are highly volatile negating the report of Butt and Sultan (2011) that gingerols and shogaols are non-volatile. Harold (2004) classified gingerol and shogaol as volatile oils reporting them as responsible for the ginger characteristic odour and flavour in addition to other volatile compounds. The volatility or otherwise of gingerol and shogaol is, therefore, inconsistent considering earlier reports (Harold., 2004; Schadich *et al*., 2016; Ji *et al*. 2017; You *et al*., 2019). Alpha-cedrol was detected only in the sundried ginger and not in fresh ginger suggesting that the compound is a dehydration product of fresh ginger. The presence of cedrol in sun-dried ginger and its absence in fresh ginger supports Kamal *et al*. (2023) who identified cedrol in the essential oil obtained from sun-dried Thailand ginger but not in oven-dried or fresh ginger samples. This suggests that cedrol is produced from fresh ginger if sun-dried. Zhang *et al.* (2021) reported that cedrol is a sesquiterpene and the main anti-inflammatory factor responsible for ginger being an anti-arthritic agent, and that it is used extensively in ameliorating rheumatoid arthritis. Earlier reports (Chen *et al.,* 2020) noted cedrol to have effectively ameliorated the paw oedema volume and arthritis score in mice without affecting the body weight. The presence of alpha-cedrol in sundried ginger and its absence in fresh ginger suggest dry ginger as a better option in the herbal treatment of arthritis than fresh ginger.

Table 3: Bioactive compounds in fresh and sundried ginger and their relative abundance

Constituents (ppm)	Fresh ginger	Sundried ginger
Acetonitrile	0.9161	0.9959
Alpha- pinene	3.4841	3.0617
Alpha-cedrenes	4.3752	3.465
Alpha-cedrol	-	0.7149
Atlantone	6.34	2.6447
Beta-cedrenes	14.6434	14.6129
Beta-pinene	25.6207	6.4957
Bisabolene	2.8568	3.9331
Camphor	6.7004	3.7736
Cardinol	11.4917	4.4646
Cineole	0.9473	1.741
Citral	2.0326	2.765
Gamma-terpinene	3.3008	1.921
Genaniol	6.508	2.2057
Gingerol	5.9067	-
Sesquiphelion	7.0551	3.5196
Shogaol	3.2164	-
Terpineol	5.5831	3.1916
Terpinolene	2.3064	1.4612
Thujopsene	0.7712	0.7139
Zingiberene	43.5385	41.2715

3.3 Growth performance

The growth performance of the broiler chickens at the starter phase is presented in Table 4 while that of the finisher phase is presented in Table 5. The cumulative performance (starter – finisher) data of the feeding trial is presented in Table 6. None of the performance parameters measured in the starter phase showed diet related significant differences ($p > 0.05$), though cost of total feed intake was significantly ($p < 0.05$) higher in the ginger groups compared to the control group. In the finisher phase, final live-weight, weight gain and average daily weight gain were significantly ($p < 0.05$) higher in the fresh ginger group compared to the groups fed sundried ginger and control diet. Cost of total feed intake was significantly ($p< 0.05$) higher in the ginger groups compared to the control group, while feed cost/kg gain was significantly ($p< 0.05$) higher in the sundried ginger group compared to fresh ginger and control groups. When the starter and finisher phases were considered together (Table 6), final live-weight and total weight gain were significantly ($p < 0.05$) higher in the fresh ginger group compared to sundried ginger and control groups. The sundried ginger group had similar final live-weight and weight gain with the control group. Cost of feed consumed was significantly ($p < 0.05$) higher in the ginger groups compared to control group while feed cost/kg gain was significantly higher in the sundried ginger compared to fresh ginger and control groups. Average daily feed intake and feed conversion ratio were not affected by ginger treatment ($p> 0.05$) throughout the period of study.

Table 4: Performance and economics of feed utilization of the starter broiler chickens fed fresh and sundried ginger

Parameter	0.0 % ginger	0.5%sundried ginger	0.5 % fresh ginger	SEM
Initial live weight (g)	36.24	35.24	37.83	1.38
Final live weight (g)	784.00	829.82	849.52	23.77
Weight gain (g)	747.76	794.59	811.69	23.33
Av. Daily weight gain (g/day)	26.71	28.38	28.99	0.83
Av. Daily feed intake (g)	52.18	53.36	53.88	1.46
Feed conversion ratio	1.96	1.88	1.87	0.06
Cost of feed (□/kg)	144.93	170.63	160.33	-
Total feed intake/bird (kg)	1.461	1.494	1.509	-
Cost feed consumed bird (□)	211.73[b]	254.94[a]	241.87[a]	6.51
Feed cost (□)/kg gain	284.06	320.78	299.82	9.78

[a, b] Means within a row with different superscripts are significantly different ($p < 0.05$)

Table 5: Performance and economics of feed utilization of finisher broiler chickens fed fresh and sundried ginger

Parameter	0.0 % ginger	0.5%sundried ginger	0.5 % fresh ginger	SEM
Initial live weight (g)	784.00	829.82	849.52	23.77
Final live weight (g)	2255.19[b]	2401.45[b]	2631.77[a]	58.84
Weight gain (g)	1471.19[b]	1571.62[b]	1782.25[a]	64.10
Av. Daily weight gain (g/day)	52.54[b]	56.13[b]	63.65[a]	2.29
Av. Daily feed intake (g)	132.57	142.90	144.08	3.41
Feed conversion ratio	2.54	2.55	2.27	0.09
Cost (□)/kg feed	148.58	174.28	163.98	-
Total feed intake/bird (kg)	3.712	4.001	4.034	-
Cost of feed consumed (□/bird)	551.47[b]	697.32[a]	661.52[a]	14.09
Feed cost (□)/kg gain	377.39[b]	444.41[a]	372.23[b]	16.10

[a, b] Means within a row with different superscripts are significantly different ($p < 0.05$)

Table 6: Performance and economics of feed utilization of the broiler chickens fed fresh and sundried ginger (0–8 weeks) of age

Parameter	0.0 % Ginger	0.5%Sundried Ginger	0.5 % Fresh Ginger	SEM
Initial live weight (g)	36.24	35.24	37.83	1.38
Final live weight (g)	2255.19[b]	2401.45[b]	2631.77[a]	58.84
Weight gain (g)	2218.95[b]	2366.21[b]	2593.94[a]	58.84
Av. Daily weight gain (g/day)	39.63	42.25	46.32	3.35
Av. Daily feed intake (g)	92.37	98.13	98.98	2.07
Feed conversion ratio	2.34	2.32	2.14	0.05
Total feed intake/bird (kg)	5.17	5.50	5.54	0.11
Cost of feed consumed (□)	763.20[b]	952.26[a]	903.39[a]	19.77
Feed cost (□)/ kg weight gain	345.23[b]	403.34[a]	348.81[b]	8.91

[a, b] Means within a row with different superscripts are significantly different ($p < 0.05$)
Av.= Average

That these increases occurred during the finisher phase and not during the starter phase suggest that the effect of the bioactive ingredients might be age dependent or additive in nature. This however, needs to be further investigated. The significantly higher daily weight gain observed in the finisher phase was not observed in the whole trial result. Obviously, the non-significant daily weight gain in the starter phase diluted the significant effect achieved in the finisher phase. Close examination of the results showed that live weight was highest in the groups fed fresh ginger in the starter phase, and this trend continued into the finisher phase. The higher weight gains observed in broilers fed fresh ginger could be attributed to the presence of gingerol and shogaol in the fresh ginger sample which got accumulated and exhibited significant effect at the finisher phase. The antioxidant efficacy of ginger has been attributed to its gingerol and shogaol contents. Srinivasan (2017) noted that gingerol and shogaol are absorbed rapidly in the body of animals and humans and accumulate in many tissues and are highly metabolized. Tchoffo *et al*. (2017) noted the ability of phenolic compounds to limit alteration of cells or organs of egg production because of their antioxidant activity with resultant enhancement of egg production. Higher weight gains of the fresh ginger group could also be attributed to the higher concentration of most bioactive compounds in fresh ginger. Phytogenic feed additives have the ability of promoting intestinal health and gut performance in livestock and poultry with resultant effect of optimal productivity (Murugesan *et al*., 2015).

The bioactive components (gingerol, shogaol, etc.) could be responsible for the significantly ($p < 0.05$) higher final weight and weight gain of broiler chickens fed diets containing ginger. Gingerols and shagaols have been reported to be the most potent phenolic compounds of ginger responsible for its beneficial effects in animals and humans (Yu *et al*., 2007; Ding *et al*., 2012). Ginger and other spices such as pepper lose their pungency when milled and stored (Bartley and Jacobs, 2000). The sundried and blended ginger samples used in this study were stored in air-tight containers, hence loses in volatile components must have occurred during sun drying, milling and possibly during storage of compounded feed. Nonetheless, strong evidence exists in literature supporting the positive influence of sundried ginger on the growth performance of broiler chickens (Mohamed *et al*., 2012; Agu *et al*., 2017) and egg production (Malekizadeh *et al*., 2012; Tchoffo *et al*., 2017).

The feed conversion ratio (FCR) was reduced when broilers were fed a diet with 0.25 % level of ginger, but feed intake was not affected (Onu, 2010). Zhao *et al.* (2011) reported that 5, 10, 15 and 20 g/kg inclusion levels of dried ginger in the diet of laying hens had no significant effect on feed intake and feed conversion ratio. Supplementation of ginger in broiler diets up to 2 % level (Onimisi *et al*., 2005; Ademola *et al*., 2009) and 2 % - 6 % level (Al-Hormidan, 2005) increased body weight. The body weight, weight gain and feed conversion ratio were significantly improved whereas feed intake depressed in broilers fed ginger diets at levels of 0.1 and 0.2 % from three to six weeks of age (Mohamed *et al*., 2012). Malekizadeh *et al*. (2012) reported that the addition of ginger root powder at level of 1 % in the diet of laying hens improved egg production, feed intake and feed conversion ratio. Dooley *et al*. (2009) did not observe any difference in feed intake in broilers fed ginger extract for a period of six weeks, while Herawati (2010) reported that ginger extracts had a depressing ($p < 0.05$) effect on feed intake. Turkey poults fed ginger powder at levels 0.2, 0.4 and 0.6 % from 14 - 56 days of age had improved final weight, weight gain and feed conversion ratio compared to the control group (Daramola *et al*., 2020).

Haematological parameters

Result on haematological parameters of the broiler chickens fed supplemental ginger from 0 – 8 weeks of age is presented in Table 7. No significant differences ($p > 0.05$) were found in all the haematological parameters measured. In addition, all the haematological values were within normal ranges for healthy chickens (Bounous and Stedman, 2000), except for MCH and MCHC which were higher. The higher MCH and MCHC values recorded in this study is suggestive of macrocytic anaemia but does not seem to be related to the ginger supplementation as the birds on control diet were also affected. This condition has been attributed to deficiencies of cobalamin and folate in diets (Northrop-Clewes and Thurnham, 2013), a condition that is rarely reported in chickens (Lumeij, 2008). MCHC may also be falsely high in the presence of lipemia, cold agglutinins, and with high heparin concentrations (Fischbach and Dunning, 2009).

Haematological responses of chickens to dietary inclusion of ginger have not shown consistent results. Agu *et al*. (2017) reported that broiler chickens fed a diet containing 0.2 % ginger meal had superior Hb and PCV compared to the control group fed a diet without ginger; while birds fed 0.4 % and 0.6 % ginger meal diets had significantly higher TWBC. TWBC and heterophils were significantly increased ($p < 0.05$), whereas all other haematological parameters measured were not significantly affected ($p > 0.05$) in broilers with increased ginger level in the diets (Al-Khalifa *et al*., 2018). No significant effect ($p > 0.05$) on PCV, Hb, RBC, TWBC and lymphocytes was observed when ginger was fed to white cockerels from two weeks of age (Kehinde *et al*., 2011). Quails fed diets supplemented with ginger, garlic and their mixture up to the 6th week of age had significantly increased Hb, RBC and PCV while MCV and MCH were not affected (Swain *et al*., 2017). In the report by Ajao *et al*. (2018), the haematological indices (PCV, Hb, RBC, WBC, heterophils and lymphocytes) were all significantly affected ($p < 0.05$) in starter turkeys (29 – 56 days of age) fed ginger at levels of 2 and 4 g/kg. These variations have been attributed to the variety of ginger, geographical location, the processing, contaminants or other unidentified factors.

Table 7: Haematological parameters of 8 weeks old broiler chickens fed fresh and sundried ginger

Parameter	Normal ranges	0.0 % ginger	0.5 %Sundried ginger	0.5% fresh ginger	SEM
PCV (%)	22 -35	29.13	29.98	28.70	0.83
Haemoglobin (g/dl)	7 -13	14.05	14.45	13.75	0.44
RBC ($\times 10^{12}$/L)	2.5 -3.5	2.60	2.73	2.53	0.09
MCV (*f*l)	90 -140	112.25	109.75	113.53	1.25
MCH (*p*g)	33 -47	53.83	53.00	54.45	0.61
MCHC (g/dl)	26 -35	50.00	48.30	47.98	1.00
Platelets ($\times 10^{12}$/L)		19.00	20.25	23.25	3.53
TWBC ($\times 10^{9}$/L)		99.65	95.58	89.13	3.52
Lymphocytes (%)	40 – 100	91.50	90.50	90.50	1.32
Heterophils (%)		8.50	9.50	9.00	1.24

Differences in rows without superscripts are not statistically significant ($p > 0.05$).

Reference range for lymphocytes are according to Jain (1993). Reference ranges for the other haematological indices are according to Bounous and Stedman (2000).

PCV = Packed Cell Volume, RBC = Red Blood Cells, MCV = Mean Corpuscular Volume, MCH = Mean Corpuscular Haemoglobin, MCHC = Mean Corpuscular Haemoglobin Concentration, TWBC =Total white blood cell counts; SEM = Standard Error of Means.

The result of serum biochemical indices of broiler chickens fed fresh and sundried ginger is presented in Table 8. Serum cholesterol, triglyceride, HDL and LDL levels were not significantly affected ($p > 0.05$), but serum glucose level was significantly ($p < 0.05$) reduced in broiler chickens fed sundried ginger diet when compared to those fed control diet or fresh ginger. In addition, the sundried ginger group had lower numerical values of all the parameters studied. This suggests that sundried ginger may possess some glucose-reducing bioactive components. Ginger is reported to be hypoglycaemic, 6-paradol (a constituent of ginger) reduced blood glucose in mice fed high-fat diets (Wei *et al*., 2017), and the compound exhibited anti-hyperglycaemic activity compared to other non-volatile constituents of ginger. Composition and hence clinical efficacy of ginger varies with the type, variety, geographical location of the plant, agronomic conditions, curing method, and drying and storage conditions (Govindarajan, 1982; Gungnani and Ezenwanze, 1985; Chrubasik *et al*., 2005;). These differences may cause variations in ginger bioactivity and response of animals to ginger. Reduced glucose level in the sundried ginger group could also be due to constant and slow release of the bioactive compounds in the dry ginger as it moves through the gut. Cholesterol, triglycerides and LDL levels were not significantly affected. HDL level was significantly higher ($p < 0.05$) in broiler chickens reared on 0.4 % compared to those reared on 0.2 % ginger meal (Agu *et al*., 2017). Total cholesterol, LDL and very low-density lipoprotein (VLDL) significantly decreased, and HDL concentration was increased ($p < 0.05$) in broiler chickens fed 0.4 and 0.6 % aqueous ginger extract (Saeid *et al*., 2010). Though, the triglyceride levels were not significant, the lowest value was also observed in the sundried ginger group. It is likely that the reduced triglycerides and glucose concentration in dry ginger group had the same biochemical underpinnings. It has been noted that physiologically, triglyceride level is positively correlated to glucose level (Daboul, 2011). However, these results suggest that sundried ginger is a stronger glycolytic (Mozaffari-Khosravi *et al*., 2014, Daily *et al*., 2015) and lipolytic agent (Pulbutr *et al*., 2011; Salaramoli *et al*., 2022) than fresh ginger

Table 8: Serum biochemical parameters of broiler chickens fed ginger based diets

Parameter	Reference ranges	0.0 % Ginger	0.5% Sundried Ginger	0.5% Fresh Ginger	SEM
Cholesterol (mg/dl)	75.3 – 196[1]	104.83	74.58	107.00	12.70
Triglyceride (mg/dl)	45.7 – 172[2]	103.75	47.48	74.08	19.45
HDL (mg/dl)		27.08	17.73	25.00	3.88
LDL (mg/dl)		56.95	47.33	67.30	12.76
Glucose (mg/dl)	125– 200[3]	142.13[a]	111.43[b]	139.98[a]	8.04

[a, b] Means within a row with different superscripts are significantly ($p < 0.05$) different.

[1]Reference range for cholesterol is according to Gessica *et al*. (2019).
[2]Reference range for triglyceride is according to Meluzzi *et al*. (1992).
[3]Reference range for glucose are according to Jain (1993). T1 = 0.0% ginger, T2 = 0.5% sundried ginger, T3 = 0.5% fresh ginger, HDAL = High density lipoprotein, LDL = Low density lipoprotein, SEM = Standard Error of Means.

Carcass and sensory quality of broiler chickens fed ginger based- diets

Result on carcass evaluation is shown in Table 9. No significant ($p>0.05$) differences were recorded in all the carcass parameters and internal organs evaluated. However, abdominal fat content of broiler chickens fed sundried ginger was reduced. This shows that 0.5 % dietary inclusion of dry ginger meal has a tendency in lowering abdominal fat in broiler chickens. Dressing percentages, and percentages of wings, breast, drumsticks, thighs, empty gizzards, etc. were not affected. This result agrees with Onu (2010) who reported no significant effect of dietary ginger on carcass traits of broiler chickens. However, Zhang *et al*. (2009) and Agu *et al*. (2017) reported improved carcass weights and dressing percentages in broiler chickens fed ginger in their diet. Increased neck percentage was also noted in broiler chickens fed 0.4 % inclusion level of ginger meal compared to control group without ginger in their diet (Agu *et al*., 2017). Egenuka *et al*. (2021) also reported significant influences ($p< 0.05$) on the neck and abdominal fat percentages in eight weeks old broiler chickens fed 1.5 % dietary inclusion of dry ginger. Similar results obtained in this study in the percentages of heart and liver + gall bladder shows that 0.5 % fresh or dry ginger fed to broiler chickens was well tolerated and did not inflict physiological effects on the birds. Differences in carcass indices of broiler chickens fed ginger could be related to differences in crop variety, maturity and processing methods.

Table 10 shows the result of ginger treatment on organoleptic quality of broiler chicken meat. Neither sundried nor fresh ginger had significant effect ($p > 0.05$) on all parameters assessed. All the meat samples tasted were moderately tender and juicy, slightly flavoured and moderately liked by panellists. Results of the sensory/ organoleptic assessment of the broilers revealed no diet related alteration in the eating quality. Agu *et al*. (2017) reported a significant increase in tenderness in broiler chickens fed ginger in their diets compared to the control (without ginger), but juiciness, flavour and hedonic score were not affected. It is to be expected that variable results are possible when feeding ingredients like ginger that change considerably during processing and storage. Broiler chickens fed ginger meal had higher lean growth resulting in overall improvement in carcass weight with increases in meat tenderness compared to broiler chickens with 0.0 % ginger content in their diet (Agu *et al*., 2017).

Table 10: Carcass and internal organ weights of broiler chickens fed ginger based-diets

Parameter (% LW)	0.0 % ginger	0.5 % Sundried ginger	0.5 % fresh ginger	SEM
Live weight (g)	2187.50	2155.00	2187.50	51.92
Dressed weight (g)	1555.00	1437.50	1543.75	70.94
Dressing percentage	70.75	66.75	70.50	3.16
Head	2.39	2.28	2.06	0.12
Neck	4.98	5.00	5.16	0.29
Wings	9.30	9.40	9.49	0.43
Breast	21.13	21.16	21.08	0.82
Thighs	10.99	11.13	12.05	0.39
Drumsticks	10.51	10.51	9.68	0.26
Shanks	4.29	4.15	3.91	0.38
Abdominal fat	1.16	0.83	1.47	0.43
Heart	0.41	0.45	0.42	0.03
Liver + gall bladder	2.38	1.82	2.18	0.16
Empty gizzard	1.96	2.01	1.87	0.17

Differences were not statistically significant ($p > 0.05$).

Table 10: Organoleptic quality of meat samples from broiler chickens fed ginger based - diets

Parameter	0.0 % ginger	0.5%Sundried ginger	0.5 % fresh ginger	SEM
Juiciness	6.50	7.50	6.38	0.47
Tenderness	7.38	7.38	6.88	0.34
Hedonic rating	6.25	6.38	6.50	0.27
Connective tissue	6.25	6.38	5.88	0.49
Flavour intensity	6.25	6.38	5.88	0.48
Off-flavour intensity	4.13	3.88	3.88	0.68

Differences in the same row without superscripts are statistically similar ($p > 0.05$).

9-Points Category Rating Scale used: Extremely tender/juicy/flavoured = 9; very tender/juicy/flavoured = 8; moderately tender/juicy/flavoured =7; slightly tender/juicy/flavoured = 6; neither tender/juicy/flavoured nor tough/dry/unflavoured = 5; slightly tough/dry/unflavoured = 4; moderately tough/dry/unflavoured = 3; very tough/dry/unflavoured = 2; extremely tough/dry/unflavoured =1. Hedonic Scoring: Extremely liked = 9; very liked = 8; moderately liked = 7; slightly liked = 6; neither liked nor disliked = 5; slightly disliked = 4; moderately disliked = 3; very disliked = 2; extremely disliked = 1.

Conclusion and recommendations

Results from this study demonstrated that fresh ginger promotes broiler productivity better than sundried ginger at 0.5 % level of inclusion. Doubtlessly, handling costs including labour costs are increased when fresh ginger extract had to be prepared every morning. To overcome this problem, it may be necessary to extract the fresh ginger juice, and after adding an appropriate preservative like sodium benzoate (C_6H_5-COONa), potassium metabisulphite (K_2S_2O5) and citric acid, bottled and stored for daily usage. The efficacy of this product should be the subject of future research investigation.

Declarations

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Data availability: The dataset generated during and/or analysed during the current study are not publicly available due to data restrictions policy of the host institution, Federal University of Technology, Owerri. They can be made available from the corresponding author on reasonable request.

Ethical approval: The ethics governing the use and conduct of experiments on animals were strictly observed, and the experimental protocol was approved by the Research and Ethics Committee of the Department of Animal Science and Technology, Federal University of Technology, Owerri, Nigeria.

Consent to participate: Permission and informed consent of all persons involved in the sensory evaluation of samples was sought and freely given.

Conflict of interest: There was no conflict of interest. All authors certified that as of the time of this research, they had no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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