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ASSESSMENT OF GREEN TEA AND/OR GINGER POWDER ON GROWTH PERFORMANCE, CARCASS TRAITS, AND BLOOD PROFILES OF BROILERS EXPOSED TO HEAT STRESS CONDITIONS FOR SUSTAINABLE BROILER FARMING

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Abstract

The present study is designed to assess the influence of supplementation with green tea powder (GTP) and/or ginger powder (GP) supplements on various aspects of the welfare and productivity of chicks aged 1 to 5 weeks, exposed to high ambient temperatures ranging from 30.3 to 40.7°C for sustainable broiler production. Specifically, the study analyzes development indices, carcass characteristics, hematological parameters, and economic efficiency to determine whether these supplements can mitigate the negative effects of extreme heat, thereby improving the overall health and productive performance of the animals. A 3 × 3 factorial arrangement was carried out, including 9 experimental groups with 3 levels of adding GTP (0, 0.15 and 0.30%) and 3 levels of GP (0, 0.50 and 0.10%). A total of 450, mixed sex strain Cobb 500 broilers were homogenously distributed to 9 groups, each consisting of 5 replications of 10 chicks with similar initial body weights. The findings demonstrated a marked (P<0.05) increase in growth when chicks were fed diets supplemented with GTP at 0.3%. The feed conversion ratio (FCR) improved considerably due to 0.15 and 0.30 GPT supplementation in comparison to the control group. The economic efficiency increased gradually as the GPT level rose and when GP was added at 0.5% in comparison to the control group. Use of GTP resulted in a significant increase in total serum proteins and globulins, as well as a decrease in AST. There was a considerable rise in total plasma proteins and globulin and a decrease in AST due to use of GTP; in contrast, HDL was significantly decreased. At the same time, globulin increased only due to GP supplementation; however, glutamate-oxaloacetate transaminase (GOT) and glutamate pyruvate transaminase (GPT) decreased. In conclusion, 0.15% GTP showed beneficial results on development indices, the animal's carcass traits, and blood metabolites of chicks from 7–35 days of age under heat stress conditions, although 0.30% GTP resulted in the highest economic efficiency and sustainable broiler farming.

Key words: herbal, green tea, ginger, animal's carcass, hematological parameters

Aviculture aims to supply safer food and raise productive performance and welfare aspects of animals (Khan et al., 2012). A wide range of nutritional factors can significantly influence health and output of farmed animals. Among that, phytogenic additives are used in poultry production to enhance growth performance and increase sustainability of broiler farming (Khan et al., 2012; Khan, 2014). Including herbs in poultry nutrition can improve feed intake, nutrient digestibility, immune response, and antioxidant status of animals, acting as anti-heat stress modulators (Shewita and Taha, 2018). Heat stress is a significant environmental factor that influences carbohydrate and lipid metabolism, energy regulation, the endocrine system, and adipokine expression in poultry. (Bayraktar et al., 2023). Poultry are homeothermic animals, they maintain their body temperature within a certain range, regardless of the ambient temperature. Whenever the temperature exceeds this level, the animals are stressed (Bayraktar et al., 2020). Due to the absence of sweat glands and their rapid metabolism in farmyard animals, stress is a common problem leading to growth retardation, increased mortality rates, and physiological problems due to immunosuppressive effects (Naslund et al., 2002; Moraes et al., 2003; Bayraktar and Tekce, 2018).

Some studies indicated that plant offshoots in welfare feeds have supported impacts on production, fitness, and output goodness (Ashour et al., 2020). Heat stress is one of the major limiting factors that significantly hinder the growth and development of tea plants, adversely affecting both the quality and yield of tea products. Tea plants have evolved a series of complex physiological and bio-

chemical adaptations to cope with and withstand various environmental stresses (Wang et al., 2018). Generally, tea can be divided into three kinds based on fermentation level: unfermented tea, partially oxidized tea, and fully fermented tea (Chan et al., 2011). The oxidation of phenols in tea is a process promoted by the presence of a thermosensitive enzyme called phenolates; the reaction is attenuated during the fermented process due to vapor, leading to a higher retention of polyvalent phenolic compounds in unfermented tea (Anandh Babu and Liu, 2008) compared to fully fermented tea.

Tea polyvalent phenols are potent antioxidants that neutralize unstable molecules and modulate the activity of various oxidases within the organism and can mitigate different pathologies. The electron delocalization due to the composition of phenol contributes to the above. The attenuated binding affinity of hydrogen ions facilitates their dissociation, enabling them to act as potent scavengers of unstable molecules and other reactive oxygen species, effectively neutralizing these harmful entities (Zuo et al., 2014). Polyvalent phenols are the primary constituents of tea leaves (Balentine et al., 1997). Fresh tea leaves harbor a diverse array of additional compounds, encompassing 1,3,7-trimethylxanthine, 3,7-dimethylxanthine, methylxanthines, lignin, organic acids, chlorophyll, pigments, theanine, amino acids, and an assortment of aromatic compounds (Graham, 1992). In addition, various other components were detected in tea leaves, encompassing flavones, phenolcarboxylic acids, carbs, alkaloids, micro-nutrients, and enzymes (Chaturvedula and Prakash, 2011). The antioxidant efficacy of unfermented tea polyvalent phenol is predominantly ascribed of aromatic rings and hydroxyl groups that assemble their chemical structure, enabling them to effectively bind and neutralize lipid's unstable molecules through the action of these hydroxyl groups (Chaturvedula and Prakash, 2011; Michalak, 2006). A multitude of research stated that polyvalent phenols and tea catechins are amazing electron-donating capabilities and potent scavenging efficacy against oxygen species *in vitro*, particularly superoxide anions (Michalak, 2006). Tea is particularly rich in polyphenols, including catechins, theaflavins, thearubigins, flavonols, and phenolic acids, which are believed to contribute to the health benefits of tea. The beneficial health effects of tea polyphenols are thought to be linked to their cellular defense properties. Tea polyphenols function as direct antioxidants by scavenging reactive oxygen/nitrogen species, chelating transition metals, and inhibiting the oxidation of lipids, proteins, and DNA (Truong and Jeong, 2021). They also act by directly suppressing pro-oxidant enzymes, inducing endogenous antioxidants, and cooperating with vitamins. Moreover, tea polyphenols regulate cellular signaling pathways, significantly contributing to the prevention of chronic diseases and the promotion of physiological functions (Truong and Jeong, 2021). Rahman et al. (2018) found that unfermented tea powder significantly impacts feed consumption and increases weight of broilers, reducing the total cholesterol when included at 0.5% compared to antibiotic group.

Active ingredients within ginger have been extensively documented to exhibit a multitude of beneficial properties, including antimicrobial, antioxidant, anti-tumorigenic, immune-regulating, anti-apoptotic, anti-flogistic, anti-lipidemic, anti-hyperglycemic, and antiemetic (Morakinyo et al., 2011). Sadeghi and Moghaddam (2018) demonstrated a positive correlation between ginger supplementation and broiler growth performance. Conversely, Saleh et al. (2014) documented a reduction in feed consumption among birds fed ginger-enriched diets. Huang et al. (2013) demonstrated that GTP addition in chicken feed induced a favorable modulation of adipose layer and blood lipid profile.

Hassan et al. (2019) found that chicks fed diets integrated with GP at 0, 0.2, 0.4, and 0.6% enhanced FCR, and the best result was obtained in 0.4% group.

Conversely, insignificant differences were observed in feed intake, blood parameters, or serological profile among the distinct GP treatment groups. Abd El-Hack et al. (2020) stressed that extensive research and additional information are needed in the future to clarify the optimal dose levels of phytogenic feed additives. Therefore, the purpose of this research was to assess the effects of green tea and/or ginger powder as diet supplement on growth performance, carcass traits, and hematological parameters of broiler chicks exposed to high temperature.

Material and methods

The trial was carried out on a non-public poultry farm in San Al-Hagar city, Sharkia governorate, Egypt. All procedures were performed as outlined in the rules established by the local animal welfare committee and were further vetted by the ethics of the Institutional Council of the Poultry Department, Faculty of Agriculture, Zagazig University, Zagazig, Egypt, according to protocol no. ZU-IACUC/2/F/56/2021. The stages of the research experiment were carried out with continuous follow-up by the supervisory committee. The experimental period lasted 4 weeks, during middle July and middle August of the year 2020.

Experimental design, chicks and diets

A total of 450, one-day-old, mixed-sex Cobb 500 chicks, were bought from a commercial retailer and fed the starter diet indicated in Table 1. At 1st week of age, chickens were homogenously divided into 9 treatment groups and each group was distributed into 5 replicates with 10 chicks per replicate. The average body weight of the chicks was 212.84 g ±7.53. The experimental design involved a 3 × 3 factorial arrangement, including three levels of dietary green tea powder (GTP, 0, 0.15 and 0.30%) and three dietary levels of ginger powder (GP, 0, 0.5 and 1.0%). Thus, there were 9 dietary treatments: T1 group feeding the standard diet (control); T2, T3, T4

and T5 groups feeding the standard diet supplemented with 0.15% GTP, 0.3% GTP, 0.5% GP, and 1.0% GP, respectively; T6 group fed the standard diet supplemented with 0.15% GTP + 0.5% GP; T7 group fed the standard diet supplemented with 0.30% GTP + 1.0% GP; T8 group supplemented with 0.30% GTP + 0.5% GP; and T9 group was supplemented with 0.3% GTP + 1.0% GP. The levels of GTP and GP were selected based on previous research (Abd El-Hack et al., 2020; Hassan et al., 2019; Rahman et al., 2018). The GTP and GP were added to the standard diets at 7–21 and 28–35 days of age by replacing the same amount of the standard diets in starter and grower-finishing phase. The GTP and GP were purchased from a certified commercial supply. Starter and finisher diets were formulated to meet broiler requirements according to Cobb 500 Broiler Management Guide (www.cobb-vantress.com) and CVB (www.cvbdiervoeding.nl). Samples of diets were collected and analyzed according to AOAC (2012) standard procedures. Ingredients and chemical-nutritional components of the diets are reported in Table 1.

Table 1. Chemical composition of the diets used in the trial

Ingredients (%)	Starter, 1–3 weeks of age	Grower-finisher, 4–5 weeks of age
Yellow corn	55.89	57.00
Soybean meal	31.50	29.50
Gluten meal	6.50	4.83
Di-calcium phosphate	1.70	1.70
Limestone	1.24	1.15
Vit-min Premix*	0.30	0.30
NaCl	0.30	0.30
DL-methionine	0.13	–
L-lysine HCl	0.24	0.18
Choline 50%	0.20	0.20
Soybean oil	2.00	4.84
Total	100	100
Calculated and determined*** analysis**		
Metabolizable energy kcal/kg**	2996	3150
Dry matter %***	91.72	90.43
Crude protein %***	23.00	20.94
Calcium %**	1.00	0.96
Phosphorous, available %**	0.44	0.44
Lysine %**	1.30	1.17
Methionine + cysteine %**	0.90	0.70
Crude fibre %***	3.52	3.38

*Vitamins and minerals mixture provide per kilogram of diet: vit. A (as all-trans retinyl acetate), 1200 IU; vit. E (as all-rac-alpha-tocopheryl acetate), 10 IU; vit. K_3, 3 mg; vit. D_3, 2200 ICU; riboflavin, 10 mg; Ca pantothenate, 10 mg; niacin, 20 mg; vit. B_{12}, 10 mg; vit. B_6, 1.5 mg; thiamine (as thiamine mononitrate), 2.2 mg; folic acid, 1 mg; biotin, 50 mg. Trace minerals (milligrams per kilogram of diet): Mn, 66; Zn, 50; Fe, 30; Cu, 4; Se, 0.1 and ethoxyquin, 3 mg. **Calculated according to CVB (2018). *** Determined according to AOAC (2012).

Management

Throughout the experimental trial, the birds were housed in experimental pens, on the ground in an environmental controlled room. Gas-powered heating systems have been utilized to meet the thermal needs of chicks during brooding. The ambient temperature during the initial 4 days was maintained at an optimal level of 34°C. Thereafter, the temperature was steadily lowered by 2°C each week, finally attaining a temperature of 24°C, which was sustained throughout the remainder of the experimental period. The lighting program was as follows: until 3rd day, 24 h light followed by 23 h of light through the 4th day of the first week of age; then, the photoperiod of 20 L: 4 D was used during 7–35 days of age. Avian subjects were provided with an unlimited supply of feed and fresh water. Chicks were housed in wooden floor pens (one replicate per pen, 40 cm high × 100 cm wide × 100 cm long). The experimental diets were given in 2 stages: starter (7–21 days of age) and grower-finisher (28–35 days of age).

Investigated measurements

The weight of the chicks was determined individually at 7, 14, 21, 28, and 35 days of age with body weights recorded to the nearest gram in the early morning prior to feed administration. These individual body weight measurements were subsequently aggregated and divided for each treatment group to determine the mean live body weight (LBW). Average body weight gain was determined by subtracting from the average final live weight the average initial live weight of the corresponding period. Prior to start of each experimental phase, predetermined quantities of each experimental diet were carefully weighed and allocated to each replicate within each treatment group of chicks. Upon termination of the experimental periods, the residual quantities of feed were meticulously weighed and removed from the initially provided feed amounts to determine the cumulative feed intake (FI) for each experimental period. Subsequently, the total FI for each period was calculated and used to estimate the average FI per chick as follows:

Average FI/chick/period = Feed intake (g) during a given period/Number of chicks during the same period.

The feed conversion ratio (FCR) was determined by calculating the quantity of feed (in grams) necessary to achieve a unit of body weight gain (also in grams) during a specified period:

$$\textit{Feed conversion ratio} = \frac{\textit{Average feed intake (g) during a given period}}{\textit{Average weight gain (g) during the same period}}$$

The mortality rate was determined during each experimental period as a percent to the initial number of

birds. This calculation was performed using the following equation:

$$MR = (initial\ number - final\ number \times 100/initial\ number).$$

The economic analyses were done using output-input/input values. The input included the cost of chick, feeding, medication and management (litter, electricity, water, and labor). The output included the rerun of selling the chickens and litter.

Carcass traits

At the end of the experimental periods (7 weeks), 5 birds from each treatment group (1 per replicate) were randomly selected, subjected to an overnight fasting period and weighed. Subsequently, the selected birds were butchered using a sharp knife to ensure total exsanguination. The feathers were removed, and the carcass weight was recorded. After butchering, the animal's carcass, edible organs, and intestinal fat have been meticulously weighed using electric digital balance with 0.01 g sensitivity and expressed as % of slaughter weight (SW). Additionally, the live weight of the animals with and without offal was studied.

Biochemical hematology parameters

Blood samples (5 ml) were collected using cervical dislocation from 5 birds per group (1 per replicate) and centrifuged (Janetzki, T32c, 5000 rpm, Germany) at 2,146.6 × g for 15 min to separate the plasma. The plasma was stored at –25°C for subsequent examination.

The overall value of protein, albumin, dextrose, glutamate-oxaloacetate transaminase (GOT), glutamate pyruvate transaminase, and ureic nitrogen were determined. Serum total proteins profiles (g/dl) were quantified employing specific commercial diagnostic kits (Spectrum Diagnostics, Egypt Co. for Biotechnology, S.A.E) according to Zheng et al. (2017). The quantification of serum albumin (g/dl) was performed using the colorimetric technique outlined by Doumas et al. (1971). The globulin level was determined by subtracting the serum albumin concentration from the total serum protein concentration. Total lipids, cholesterol (mmol/L), and low-density lipoprotein (LDL) were determined utilizing commercially available kits as per the manufacturer's guidelines (Spinreact Co., Spain) according to the method of Cooper et al. (1992). The catalytic activities of GOT and glutamate pyruvate transaminase (U/L) were determined through calorimetric methods utilizing commercial kits obtained from Spectrum Diagnostics, following the protocol outlined by Cooper et al. (1992).

Statistical analysis

Data analysis was performed utilizing statistical package of social sciences SPSS (2014), employing statistical procedures and methodologies as described by Snedecor and Cochran (1982) using a 3 × 3 factorial design bases as shown in the following model:

$$Y_{ijk} = M + A_i + S_j + AS_{ij} + e_{ijk}$$

Where: Y_{ijk} = a single observation, M = the overall mean, A_i = the influence of dietary GTP levels (i = 1 to 3), S = the impact of dietary GP levels (j=1 to 3), AS_{ij} = the interaction effect between nutritional levels of GTP and GP, and e_{ijk} = random error. Duncan's multiple range tests, as described by Duncan (1955), were applied to ascertain the statistical significance of any observed differences between mean values. The results were expressed as average value, and the significance level was set at $P<0.05$.

Results

Results in Table 2 displayed a significant and similar increase in live body weight due to the GTP supplementation at 0.15 and 0.30% in comparison to the other groups during all tested times ($P<0.01$ and $P<0.05$, respectively). Supplementation with GP exhibited no meaningful effect on broiler growth performance during all examined periods, nor a significant interaction of GRP and GP levels on growth of broilers during most of the experimental periods was recorded, except for the body weight at 28 days of age, when the value of growth increased gradually over time in GTP groups with increasing concentration, but GP induced a superior increase in growth compared to GPT groups. The combination of GTP and GP did not boost the effect of the single supplements but generated drawbacks in growth when the high level was combined compared to GTP or GP alone. GTP and/or GP levels did not affect the mortality rate during the experimental period.

Table 3 shows no significant interaction between GTP and GP on feed consumption during the research. In addition, there was no significant effect of GTP during 1–2 weeks of age and due to GP supplementation during 1–2 and 4–5 weeks. Feed intake was decreased considerably due to GTP during all tested periods. The overall effect was similar between 0.15 and 0.30% GTP even though the two groups exhibited evident disparities during 3–4 and 4–5 weeks with contrary trends between both periods.

The GP at 1% significantly decreased feed intake compared to 0.5% during most of the experimental period. Still, differences between the untested group and 1.0% GP were insignificant, except for 2–3 weeks of age, which indicates a negative effect due to the highest level of GP.

Table 2. Growth and mortality rate as affected by green tea powder and/or ginger powder supplemented from 1 to 5 weeks of age of broilers

Items	Body weight					MR
	Initial BW	2 wk	3 wk	4 wk	5 wk, final BW	1–5 wk
GTP level						
Without	212.1	580.2 b	1014 b	1378 b	1939 b	2.00
0.15% GTP	218.4	607.0 a	1044 a	1501 a	1980 a	0.00
0.30% GTP	208.1	600.9 a	1051 a	1447 a	2002 a	0.00
SEM	3.14	2.93	8.32	8.90	20.79	0.03
P-value	0.170	<0.001	0.013	<0.001	0.010	0.237
GP level						
Without	212.8	595.2	1038	1424	1953	2.00
0.50% GP	211.9	598.8	1052	1456	1990	0.00
1.00% GP	212.8	594.1	1020	1447	1979	2.00
SEM	4.05	3.96	7.16	9.35	17.30	0.05
P-value	0.98	0.59	0.051	0.061	0.447	0.308
Interaction between GTP and GP						
Without	212.0	601.5	1056	1393 d	2030	2.00
0.15% GTP	208.0	598.0	1061	1457 c	2022	0.00
0.30% GTP	216.3	603.3	1037	1493 b	1956	0.00
0.50% GP	217.3	611.0	1038	1521 a	1906	2.00
1.00% GP	219.5	607.5	1059	1536 a	1965	0.00
0.15% GTP + 0.50% GP	218.4	602.6	1035	1446 c	1942	0.00
0.15% GTP + 1.00% GP	209.2	573.0	1020	1359 e	1920	0.00
0.30% GTP + 0.50% GP	211.1	591.0	1035	1374 e	1979	2.00
0.30% GTP + 1.00% GP	203.9	576.6	989	1402 d	2039	0.00
SEM	7.58	11.74	19.92	39.18	81.57	0.00
P-value	0.812	0.155	0.849	0.001	0.152	0.573

a, b, c, d – means within the same column within the same parameter not sharing common letters are different (P≤0.05). SEM = standard error of the mean; GTP = green tea powder; GP = ginger powder; MR = mortality rate.

Table 3. Feed consumed by chicks as affected by green tea powder and/or ginger powder and their interaction

Items	Feed intake (g/bird)				
	1–2 wk	2–3 wk	3–4 wk	4–5 wk	1–5 wk
1	2	3	4	5	6
GTP level					
Without	515.1	783.4 a	607.9 b	957.2 a	2839 a
0.15% GTP	483.1	673.2 b	703.8 a	752.0 c	2596 b
0.30% GTP	459.7	634.6 b	637.6 b	865.6 b	2583 b
SEM	9.89	12.05	10.71	7.98	13.09
P-value	0.051	0.010	0.008	0.003	0.001
GP level					
Without	470.3	695.2 a	629.0 b	908.8	2679 b
0.50% GP	471.4	675.2 a	769.1 a	896.8	2768 a
1.00% GP	457.5	626.1 b	674.7 b	893.8	2614 b
SEM	10.37	11.15	14.07	8.98	15.06
P-value	0.110	0.032	0.013	0.196	0.014
Interaction GTP and GP					
Without	511.3	577.4	783.1	945.3	2817
0.15% GTP	487.3	662.5	678.4	789.2	2617
0.30% GTP	462.6	678.6	643.1	822.8	2607

Table 3 – contd.

1	2	3	4	5	6
0.50% GP	513.0	704.4	672.3	799.7	2689
1.00% GP	486.9	764.1	688.9	805.3	2745
0.15% GTP + 0.50% GP	474.9	612.6	696.0	897.8	2681
0.15% GTP + 1.00% GP	478.3	742.6	683.2	799.9	2684
0.30% GTP + 0.50% GP	469.5	644.6	635.7	857.1	2607
0.30% GTP + 1.00% GP	494.0	730.2	667.2	812.3	2704
SEM	11.73	13.20	15.37	9.96	12.47
P-value	0.217	0.210	0.183	0.391	0.190

a, b, c – means within the same column within the same parameter not sharing common letters are different (P≤0.05). SEM = standard error of the mean; GTP = green tea powder; GP = ginger powder.

Table 4. FCR and economic efficiency as affected by green tea powder and/or ginger powder supplemented from 1 to 5 weeks of age of broilers

Items	Feed conversion ratio, kg feed/kg body weight gain					Economic efficiency
	1–2 wk	2–3 wk	3–4 wk	4–5 wk	1–5 wk	1–5 wk
GTP level						
Without	1.40 a	1.70 a	1.67 a	1.71	1.62 a	49.7 c
0.15% GTP	1.24 b	1.53 b	1.54 b	1.57	1.47 b	55.2 b
0.30% GTP	1.17 c	1.41 c	1.61 b	1.56	1.44 b	59.0 a
SEM	0.02	0.02	0.01	0.02	0.02	1.11
P-value	0.003	0.001	0.005	0.031	0.001	0.010
GP level						
Without	1.23	1.57 a	1.63	1.72	1.54	47.1 b
0.50% GP	1.21	1.49 b	1.59	1.68	1.49	61.5 a
1.00% GP	1.20	1.47 b	1.58	1.68	1.48	50.5 b
SEM	0.01	0.02	0.02	0.03	0.04	1.22
P-value	0.140	0.021	0.315	0.226	0.109	0.009
Interaction between GTP and GP						
Without	1.17	1.59	1.63	1.65	1.51	49.6
0.15% GTP	1.14	1.57	1.57	1.67	1.49	50.4
0.30% GTP	1.18	1.54	1.54	1.62	1.49	50.8
0.50% GP	1.19	1.56	1.56	1.59	1.48	51.1
1.00% GP	1.16	1.55	1.58	1.57	1.46	51.2
0.15% GTP + 0.50% GP	1.15	1.56	1.53	1.57	1.48	50.9
0.15% GTP + 1.00% GP	1.16	1.52	1.55	1.61	1.45	51.3
0.30% GTP + 0.50% GP	1.18	1.49	1.48	1.64	1.47	51.5
0.30% GTP + 1.00% GP	1.14	1.52	1.49	1.60	1.45	51.0
SEM	0.01	0.01	0.03	0.02	0.03	1.72
P-value	0.104	0.220	0.179	0.411	0.173	0.096

a, b, c – means within the same column within the same parameter not sharing common letters are different (P≤0.05). SEM = standard error of the mean; GTP = green tea powder, GP = ginger powder.

Results in Table 4 indicate no significant interaction between GPT and GP levels on FCR during all tested times. On the other hand, results showed a significant dose-dependent effect of GTP on FCR during 1–2 and 2–3 weeks of age. For 3–4 and 1–5 weeks of age, 0.15 and 0.30% GTP showed a similar positive impact on FCR in comparison to the control group. During 4–5 weeks of age, the effect of GTP on FCR was diminished.

The GP did not affect FCR during 7–14, 21–28, 28–35, and 7–35 days of age; however, FCR was considerably enhanced due to 0.5 and 1.0% GP during 14–21 days of age. The rise was gradual in economic efficiency with increasing GTP concentrations. The GP at 0.5% had the most positive impact on economic efficiency.

Table 5. Carcass traits of 35-day-old broiler chicks as affected by green tea powder and/or ginger powder supplemented from 1 to 5 weeks of age

Items	Carcass traits					
	Carcass %	Giblets %	Dressing %	Abdominal fat %	Spleen %	Bursa %
GTP level						
Without	73.9	4.01 b	77.9 c	1.39 a	0.12	0.11
0.15% GTP	74.0	4.17 a	78.2 b	1.11 b	0.11	0.11
0.30% GTP	74.7	4.29 a	78.9 a	0.89 c	0.13	0.12
SEM	1.94	0.06	2.13	0.04	0.01	0.01
P-value	0.220	0.002	0.010	0.019	0.159	0.635
GP level						
Without	73.4 b	3.63	77.0 b	1.29 a	0.12	0.10 b
0.50% GP	74.4 a	3.71	78.1 a	1.05 b	0.11	0.09 b
1.00% GP	74.4 a	3.89	78.2 a	1.03 b	0.12	0.14 a
SEM	2.38	0.07	3.24	0.06	0.01	0.01
P-value	0.004	0.076	0.002	0.259	0.566	0.001
Interaction between GTP and GP						
Without	73.0	3.86	76.9	1.34 a	0.11	0.10 b
0.15% GTP	74.3	3.62	78.0	1.23 b	0.12	0.12 b
0.30% GTP	74.2	4.01	78.2	1.11 c	0.12	0.11 b
0.50% GP	74.0	3.25	77.2	1.22 b	0.13	0.09 bc
1.00% GP	74.6	3.58	78.2	1.09 c	0.10	0.13 b
0.15% GTP + 0.50% GP	74.6	4.13	78.7	1.14 c	0.11	0.11 b
0.15% GTP + 1.00% GP	73.1	4.14	77.2	0.99 d	0.12	0.12 b
0.30% GTP + 0.50% GP	75.2	3.85	79.0	1.02 d	0.13	0.07 c
0.30% GTP + 1.00% GP	74.1	4.12	78.3	0.94 e	0.13	0.18 a
SEM	1.46	0.35	1.13	0.21	0.02	0.04
P-value	0.110	0.095	0.089	0.003	0.219	<0.001

a, b, c, d – means within the same column within the same parameter not sharing common letters are different (P≤0.05). SEM = standard error of the mean; GTP = green tea powder; GP = ginger powder.

Table 6. Blood serum protein profile and liver enzymes as affected by green tea powder and/or ginger powder supplemented during 1–5 weeks of age of broilers at 35 days

Items	Blood parameters				
	Total protein (g/dl)	Albumin (g/dl)	Globulin g/dl))	GOT (U/l)	GPT (U/l)
1	2	3	4	5	6
GTP level					
Without	5.09 b	3.27	1.82 b	31.45 a	24.17
0.15% GTP	5.56 a	3.45	2.11 a	26.13 b	21.03
0.30% GTP	5.83 a	3.62	2.21 a	25.13 b	22.34
SEM	0.12	0.09	0.15	00.53	0.49
P-value	0.007	0.105	0.001	0.010	0.093
GP level					
Without	5.52	3.59	1.93 b	32.85 a	24.33 a
0.50% GP	5.69	3.37	2.32 a	27.26 b	21.33 b
1.00% GP	5.75	3.51	2.24 a	24.08 b	19.71 b
SEM	0.017	0.12	0.16	0.61	0.69
P-value	0.092	0.120	0.001	0.003	0.001

Table 6 – contd.

1	2	3	4	5	6
Interaction between GTP and GP					
Without	5.09	3.35	1.74	30.07	23.19
0.15% GTP	5.43	3.81	1.62	25.73	20.00
0.30% GTP	5.29	3.62	1.67	27.39	21.33
0.50% GP	5.63	3.76	1.87	25.88	20.55
1.00% GP	4.98	3.02	1.96	27.00	20.17
0.15% GTP + 0.50% GP	5.37	3.45	1.92	29.01	21.58
0.15% GTP + 1.00% GP	5.56	3.66	1.90	26.38	21.30
0.30% GTP + 0.50% GP	5.43	3.50	1.93	27.20	22.67
0.30% GTP + 1.00% GP	5.74	3.69	2.05	28.02	21.99
SEM	0.49	0.38	0.39	3.72	3.25
P-value	0.172	0.259	0.405	0.105	0.214

a, b, c – means within the same column within the same parameter not sharing common letters are different (P≤0.05). SEM = standard error of the mean; GTP = green tea powder; GP = ginger powder.

Table 7. Influence of green tea powder and/or ginger powder supplemented from 1 to 5 weeks of age and blood serum lipid profile

Items	Blood parameters			
	total lipids	total cholesterol	HDL (mg/dl)	LDL (mg/dl)
GTP level				
Without	307.5 a	185.1 a	62.8 c	98.7 a
0.15% GTP	285.3 b	157.6 b	70.8 b	83.3 b
0.30% GTP	277.3 b	152.8 b	74.5 a	79.2 b
SEM	2.73	2.35	1.60	1.96
P-value	0.009	0.001	<0.001	0.001
GP level				
Without	305.5 a	189.4 a	61.3 b	96.9 a
0.50% GP	291.7 b	172.6 b	68.8 a	89.7 b
1.00% GP	288.5 b	169.8 b	65.5 a	88.9 b
SEM	3.89	4.01	2.39	3.11
P-value	0.010	0.001	0.021	0.013
Interaction between GTP and GP				
Without	299.3	186.3 a	62.4	95.6
0.15% GTP	293.3	177.6 b	65.6	89.3
0.30% GTP	289.3	175.1 c	64.6	91.2
0.50% GP	287.5	179.8 b	63.8	92.7
1.00% GP	285.3	178.7 b	66.8	88.3
0.15% GTP + 0.50% GP	284.3	169.9 cd	67.7	87.9
0.15% GTP + 1.00% GP	301.5	173.1 c	62.8	93.7
0.30% GTP + 0.50% GP	288.3	159.6 e	63.8	88.3
0.30% GTP + 1.00% GP	281.3	163.8 d	66.3	87.2
SEM	5.17	4.13	2.69	3.87
P-value	0.106	0.001	0.067	0.093

a, b, c, d, e – means within the same column within the same parameter not sharing common letters are different (P≤0.05). SEM = standard error of the mean; GTP = green tea powder, GP = ginger powder.

Results in Table 5 showed a significant interaction between GTP and GP on percentage of carcass, giblets, dressing, and spleen. However, there was a significant interaction between GTP and GP on the percent of abdominal fat and the bursa of Fabricius.

The abdominal fat was decreased due to increased GTP and GP supplementation within each agent, and the decrease was maximized when the highest levels of GTP and GP were combined. The bursa of Fabricius was significantly decreased when 0.30% GPT and 0.50% GP were combined compared to the other treatments except for 0.5% GP. In contrast, combining the highest GTP and GP levels notably increased the bursa of Fabricius compared to the others.

The results declared a significant improvement in dressing and giblets percentages due to the treatment of GTP with a similar effect between the two added levels. Still, the dressing percentage showed a stepwise effect.

The results revealed that carcass and dressing percentages were significantly and similarly increased by GP supplementation.

The blood serum protein profile and liver leakage enzymes are shown in Table 6. There was a notable and similar rise in comprehensive serum protein and globulin and a similar decrease in GOT with increasing GTP supplementation. At the same time, globulin was substantially similarly increased only due to GP supplementation but GOT and glutamate pyruvate transaminase were similarly decreased. These findings highlight an important interaction between GTP and/or GP on blood protein profile and liver enzymes, thus emphasizing the extent of their impact on metabolism and liver function.

The effect of GTP and/or GP on blood serum lipid profiles is displayed in Table 7. Blood total lipids and LDL were similarly decreased in comparison to the control group due to GTP supplementations. However, HDL was significantly increased gradually with elevating GTP level in comparison to the control group. Conversely, comprehensive lipids and LDL were similarly and notably reduced due to GP supplementation at 0.50 and 1.0% in comparison to the control group, but HDL was increased. There was a notable interaction between GTP and GP on blood cholesterol, showing a decrease in blood cholesterol with GTP and GP supplementation, and the decrease was maximized when 0.3% GTP and 0.50% GP were combined.

Discussion

The current results indicate that for the entire experimental period, the addition of 0.15% and 0.30% GTP showed similar positive impacts on the FCR of chickens compared to the control group. This suggests stability in the effectiveness of GTP on this parameter over time. Gut performance is also an essential part of successful feeding programs (Bayraktar et al., 2021). Although the study is limited, the dose-dependent reaction of GTP shown during 7–21 days of age may be due to the rise in the intake of GTP bio-active compounds that can modulate the gut development and maturation as well as the gut microbiota at an early age (Mei et al., 2023). According to our results, 0.15% GTP was adequate for improving the growth index of Cobb 500 broiler chickens throughout 7–35 days of age. In agreement with the current results, Rahman et al. (2018) found that green tea at 0.5% and 1.0% decreased the feed intake of broilers but did not affect the growth rate. The reduction in feed intake due to GTP could be attributed to bitter taste of green tea (Rahman et al., 2018).

The addition of 0.15% GTP to broiler diets is adequate for improving FCR, too. In the literature, the supplementation with green tea extract (GTE) at 0.1 or 0.2 g/kg feed improved broilers' feed efficiency at 6 weeks of age (Erener et al., 2011). A wide range of experimental studies concerning different unfermented tea compounds have shown that GTP bioactive compounds enhance FCR in poultry (Erener et al., 2011; Khan, 2014). The positive impact of GTP could be attributed to its bioactive compounds with antioxidant properties (Anandh and Liu, 2008; Erener et al., 2011; Khan, 2014). Although the GTE supplementation (0.1 or 0.2 g/kg feed) raised the growth index of broilers at 6 weeks of age (Erener et al., 2011), subsequent investigations have yielded different findings: in fact, the unfermented tea did not show any significant improvements of poultry productivity (Farahat et al., 2016; Hrnčár and Bujko, 2017; Khalaji et al., 2011). In addition, Rahman et al. (2018) revealed that FCR did not differ among the dietary GT groups during the 2nd week of age. The contrary result in this research could be ascribed to variations of the feeding strategy, types of green tea products, and their doses.

Regarding the negative effect of GTP on feed intake of broilers, Hrnčár and Bujko (2017) noticed an adverse impact on feed intake due to the integration of GTP (0.5, 1, and 1.5%) in broiler at 6 weeks of age in comparison with an untested group.

The lack of significant impact of GP on the growth performance of broilers is in partial agreement with the recently produced outcomes by Al-Mahdawi and Al-Hassani (2023) who indicated that the use of GP at 0.5, 1.0, and 2.0 g/kg showed a detrimental impact on the growth of broilers. However, the temporary effect of GP on FCR during 2–3 weeks of age may be related to the impact of GP on the gut ecosystem and it is an age dependent effect.

There was no additive effect of the GTP and GP on the growth and FCR of broiler chickens, even though a negative effect was observed in growth at 4th week of age. The results indicated that the highest doses of supplementation showed a strong negative impact on growth compared to the individual supplementation of GTP and GP. Similarly, the use of GP at 0.5, 1.0, and 2.0 g/kg was shown to have a detrimental effect on the growth of broiler chickens (Al-Mahdawi and Al-Hassani, 2023). The result of GTP + GP on the growth of broilers ob-

served during 4th week of age may be due to its impact on energy expenditure and thus fat oxidation, decreasing energy availability for muscle growth. Also, Venables et al. (2008) indicated that GTP influenced the energy metabolism through the stimulation of lipolytic pathways and down-regulation of lipogenic pathways. In addition, GP also showed an effect on energy expenditure, oxygen consumption, and lipid oxidation (Al-Khalaifah et al., 2022; İçer and Tek, 2021). Thus, the combination of GTP and GP may have cumulative effect on lipid metabolism which is confirmed by reduced growth rate associated with a reduction in abdominal fat deposition.

The importance of the survival rate as economic feature reveals the safety of GTP and GP for broilers' health. The present investigation agreed with Hrnčár and Bujko (2017), who reported that results were found on the percentages of deaths for the integration of GTP at levels of 0.50, 1.00 and 1.50% in broilers at 7 weeks of age in comparison to the untested group.

The results indicate that GTP improved dressing percentage and reduced abdominal fat dose-dependently, and similarly increased giblets percentage. These positive effects could be to the bioactive components of GTP, such as polyphenols with antioxidant properties (Anandh Babu and Liu, 2008; Zuo et al., 2014). The current research aligns with the findings of Rahman et al. (2018), who noticed statistical differences ($P<0.05$) in dressing percentage, thigh, liver, and heart weight among the experimental broiler groups. The cited authors attributed these elevated parameters to the tea-integrated and antibiotic-treated groups compared to the untested group. In addition, the decrease in abdominal fat was accompanied with a decrease in total lipids, total cholesterol, LDL and increasing HDL. The results indicate that 0.15% GTP was adequate for controlling most of lipid profiles, but 0.30% was required to increase HDL. Parallel study by Huang et al. (2013) established that everyday administration per os of either 50 or 100 mg of GTP/kg BW for 20 days resulted in reduced adipose layer in broilers. This reduction is likely attributed to a diminished rate of *de novo* fatty acid synthesis and an enhanced rate of beta-oxidation. Additionally, Huang et al. (2013) reported that GTP integration in broiler diets effectively lowered adipose layer, serum triglycerides, LDL, and increased HDL. In addition, the current findings are analogous to those previously documented by Venables et al. (2008). Erener et al. (2011) integrated 0.2 g/kg to fresh GT liquid hydroalcoholic extract in broiler diets and revealed a significant increase in the carcass weight, dressing percentage, redness, and yellowness color pigment of the breast meat. Therefore, GTE supplementation exerts a discernible influence on the color parameters of breast meat in broiler chickens. The effect of GT on growth of broilers may be mitigated through its effect on gut health. In this regard, Hrnčár and Bujko (2017) reported a significant reduction in cecal and small intestine weights of chickens fed diets supplemented with 1 or 1.5% GTP in comparison to the untested group. Nonetheless, the control and experimental groups exhibited no significant differences among different GTP levels for crop, gizzard, liver, heart, kidney, proventriculus, pancreas, or large intestine weights.

Regarding the effect of GP on carcass traits, there are apparent enhancing effects of GP on the carcass, dressing, and abdominal fat and an increase in the bursa of Fabricius, showing an improvement in the carcass outcomes, and this may be due to the bioactive components of GP (Morakinyo et al., 2011; Sadeghi and Moghaddam, 2018). The effect of GP on the abdominal fat and carcass yield may be due to its impact on lipid metabolism (Al-Khalaifah et al., 2022).

There was a significant interaction between GTP and GP in only the abdominal fat, showing a cumulative negative effect that maximized at the highest doses of both agents. The results indicate that GTP and GP increased energy expenditure and decreased fat deposition in the abdominal cavity. Concordant findings were presented by other authors (Abo EL-Maaty et al., 2023; Al-Mahdawi and Al-Hassani, 2023; Al-Khalaifah et al., 2022; İçer and Tek, 2021; Venables et al., 2008). Moreover, a notable interaction was quoted in the bursa of Fabricius, showing that 0.30% GTP + 1.00% GP increased the bursa of Fabricius cells and/or tissue development, with enhancing effect on immune organs (An et al., 2019; Hayajneh, 2019). In the literature, GTP (Erener et al., 2011; Farahat et al., 2016; Mei et al., 2023; Nidaullah et al., 2010; Venables et al., 2008) and GP (Al-Khalaifah et al., 2022; An et al., 2019; İçer and Tek, 2021; Morakinyo et al., 2011; Saleh et al., 2014; Shewita and Taha, 2018) were found to lower epithelium thickness, coliform density, and *Clostridium perfringens* number in a dose dependent mode, while *Lactobacilli* were increased.

Our findings indicate that GTP significantly increased total serum protein and globulin and decreased AST, showing a beneficial effect on protein metabolism and liver function indices. The effect of GTP and GP showed that both agents have no harmful effects on liver function and protein metabolites. The present findings concur with the observations reported by Saraei et al. (2016) and could be attributed to the bioactive components of GTP (Anandh Babu and Liu, 2008; Balentine et al., 1997; Chaturvedula and Prakash, 2011; Graham, 1992; Zuo et al., 2014) and GP (Morakinyo et al., 2011; Sadeghi and Moghaddam, 2018; Saleh et al., 2014), and benefits of GP on protein digestibility and metabolism (Al-Khalaifah et al., 2022) .

The present findings indicate that GTP and GP improved lipid metabolism, unveiling no notable dissimilarity between the two supplemented values of GTP and GP on most of tested traits. The results showed that 0.15% GTP and 0.5% GP were adequate to improve lipid metabolites. The only HDL was significantly further improved when 0.30% GTP was supplemented, showing a dose-dependent effect. In addition, 0.3% GTP and 0.5% GP induced the highest reduction in serum cholesterol, and this concurred with a decrease in abdominal fat.

The present findings corroborate the observations of Saraei et al. (2016), who demonstrated that dietary GTP supplementation exerts benefits on the levels of serum LDL, LDL/HDL ratios, and uric acid levels, thereby contributing to the wellness of chickens.

This could cause a potentiation antioxidant level and enhanced liver function correlated with a better cardiovascular system, and GTP at 0.5 g/kg diet improved growth, and FCR and triglycerides and 0.75 g/kg decreased plasma uric acid (Abo El-Maaty et al., 2023; Al-Khalaifah et al., 2022). Given the rapid development of and stress exposure in broilers and the sudden death syndrome associated with cardiovascular diseases due to lubrication in internal organs, broiler breeding facilities are associated with high mortality (Bayraktar and Tekce, 2019). In the literature, several studies have investigated the effects of GTP on cholesterol levels in poultry. Muramatsu et al. (1986) demonstrated an association between tea leaf consumption and cholesterol, with the lowest levels observed in the liver and muscles. Khalaji et al. (2011) reported a significant reduction of cholesterol in chickens fed a diet supplemented with 500 mg/kg of GTP. Huang et al. (2013) further elucidated the beneficial effects of GTP supplementation, showing a decrease in body fat, serum triglycerides, and LDL cholesterol, along with an increase in HDL cholesterol in broiler chickens. From another view, Rahman et al. (2018) demonstrated that green tea affects the blood hematological profile across the broiler groups, and cholesterol levels remained relatively consistent. Nevertheless, the group supplemented with 0.50% GT exhibited lower total cholesterol compared to the green tea and antibiotic groups. Green tea in broilers' diet did not affect LDL of blood profile. Also, blood glucose, LDL and vLDL cholesterol were decreased due to GT supplementation (Jelveh et al., 2022). GTP and GP had a promising effect on lipid metabolism in broilers, suggesting a beneficial effect and cardiovascular protection on human and recommending further studies.

Conclusion

The findings of this study demonstrated that dietary supplementation with 0.15% GTP significantly improved the growth performance, carcass traits, and blood parameters of broilers aged 1–5 weeks when exposed to heat stress. These improvements highlight the potential of GTP as a beneficial dietary additive under heat stress conditions, suggesting its efficacy in enhancing overall poultry health and productivity. Additionally, the positive impact of GTP on broilers' physiological responses under thermal stress emphasizes its potential role in mitigating the adverse effects of climate change on poultry farming, thereby contributing to more sustainable and resilient agricultural practices.

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Institutional review board statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of Animal Production Research Institute, Giza, Egypt.

Data availability statement

The data supporting this study's findings are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Conflicts of interest

None.

Authors' contribution

YAA and RAA conceived and designed the study. RAA, AEA, and WSS executed the experimental data and analyzed the samples. KAA, FB and NFA analyzed the data. RAA and YAA acquired funding. MCO wrote and edited the manuscript. All authors interpreted the data, critically revised the manuscript for important intellectual contents, and approved the final version.

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