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Effects of Ginger (*Zingiber officinale*) Supplementation via Drinking Water on Growth Performance and Intake Responses of Heat-Stressed Broilers

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Abstract

Heat stress is a major constraint in poultry production, particularly in tropical environments, adversely affecting growth performance, feed efficiency, and overall physiological function. This study evaluated the effects of powdered ginger (Zingiber officinale) supplementation via drinking water on growth performance, feed intake, feed conversion ratio (FCR), and water intake of broiler chickens under heat stress, following phytochemical characterization of the ginger powder. A total of 150 Cobb 500 broilers were randomly assigned to five treatments: control (plain water), 1.5 g/L, 2.5 g/L, 3.5 g/L, and 4.5 g/L ginger supplementation in drinking water. Birds were exposed to cyclic heat stress (32– 35 °C for 6 h daily) from day 15 to 35. Phytochemical analysis of the ginger powder revealed the presence of phenolics (8.86–10.19 mg GAE/g), flavonoids (4.16–4.55 mg CE/g), tannins (0.41–0.45 mg CE/g), and measurable antioxidant activity (29.61–31.45% DPPH scavenging), indicating its potential as a functional phytogenic additive. Ginger supplementation did not significantly affect ($P > 0.05$) body weight, weight gain, feed intake, FCR, or water intake across most weeks. Ginger supplementation did not significantly affect ($P > 0.05$) overall growth performance, feed intake, FCR, or water intake. However, treatment-specific responses were observed. Broilers in the 4.5 g/L group (T5) consistently showed the highest final body weight (2122.22 g) and cumulative weight gain (2082.22 g), along with the highest cumulative feed intake. The 3.5 g/L group (T4) recorded the lowest numerical FCR (1.58) and the highest weight gain during Week 4 ($P < 0.05$), indicating improved feed utilization during peak heat stress. Meanwhile, the 2.5 g/L group (T3) demonstrated stable growth performance across the experimental period. Water intake increased with heat exposure but was not affected by ginger supplementation, indicating good palatability. Overall, ginger supplementation supported performance stability under heat stress, with 4.5 g/L enhancing growth, 3.5 g/L improving feed efficiency, and 2.5 g/L providing consistent performance.

Keywords: Heat Stress, Ginger (*Zingiber Officinale*), Broiler Chickens, Growth Performance, Feed Intake, Phytogenic Additive

1. Introduction

Heat stress remains a critical challenge in broiler production, particularly in tropical and subtropical environments where high ambient temperatures directly affect productivity, physiological performance, animal welfare, and farm profitability. In poultry, thermal stress reduces feed intake, alters metabolic processes, weakens growth performance, and compromises feed efficiency, immune response, reproductive performance, and meat quality (Sohail et al., 2012; Renaudeau et al., 2012, Nawab et al., 2018; Vandana et al., 2021; Bilal et al., 2021; Livingston et al., 2022). As climate change intensifies heat-related production risks, there is a need for practical, affordable, and natural interventions that can help broilers maintain performance under thermal stress. This study focuses on powdered ginger (Zingiber officinale) supplementation through drinking water as a phytogenic strategy to support the growth performance, intake response, feed conversion, and physiological resilience of heat-stressed broilers.

Heat stress is a major constraint in commercial chicken production because it affects productivity, health, and welfare. Broilers exposed to heat stress commonly show reduced average daily gain and final body weight, while layers may experience lower egg production and reduced shell quality (Mashaly et al., 2004). These effects are linked to reduced feed intake and altered metabolism, which negatively influence growth performance, egg production, feed conversion efficiency, immune response, egg quality, semen quality, fertility, and meat quality (Sohail et al., 2012; Renaudeau et al., 2012, Nawab et al., 2018; Vandana et al., 2021; Bilal et al., 2021; Livingston et al., 2022). The economic burden of heat stress is substantial, with poultry production losses reaching billions of dollars worldwide due to reduced performance and increased mortality (Hatfield et al., 2014; Abdel-Moneim et al., 2021). Climate change and increasing environmental temperatures further worsen this concern, making heat-stress mitigation an urgent priority for sustainable poultry production (Livingston et al., 2022; IPCC, 2022).

The literature emphasizes that heat stress weakens poultry productivity by disturbing normal feeding behavior, metabolism, thermoregulation, and physiological function. Nutritional, genetic, and environmental interventions have therefore been proposed to improve resilience against thermal stress. However, many advanced technologies used in large-scale poultry production, such as automation, precision farming, and genetic improvement, remain difficult to apply in backyard and small-scale production systems because of cost and management limitations. Traditional heat-abatement approaches such as ventilation and cooling systems may also be costly or impractical for small and medium-scale operations. At the same time, concerns over antimicrobial resistance and the increasing demand for antibiotic-free meat have contributed to restrictions on antibiotic growth promoters (Castanon, 2007; Windisch et al., 2008). Consumer concerns regarding synthetic additives have also increased, especially in relation to animal welfare, environmental sustainability, and food safety (Henry & Oliver, 2022; OECD-FAO, 2024). In this context, phytogenic feed additives have gained attention as natural alternatives for supporting poultry performance under stress. Ginger (Zingiber officinale) contains gingerols and shogaols, which are associated with antioxidant, anti-inflammatory, and thermoregulatory properties. Previous studies have reported improvements in performance and oxidative status with ginger supplementation, suggesting its potential as a natural additive for heat-stressed broilers.

Globally, heat stress threatens poultry productivity and food production systems, especially as climate change increases the frequency and intensity of high-temperature conditions (Livingston et al., 2022; IPCC, 2022). In tropical countries, this challenge is more pronounced because poultry are frequently exposed to environmental temperatures that exceed their thermoneutral comfort zone. In the Philippine context, backyard broiler production continues to face efficiency and productivity constraints due to limited resources, management challenges, and restricted access to advanced technologies (Manuel, 2015). These problems are further complicated by declining farmgate prices, persistently high retail prices, and increasing importation (Gomez, 2024). These conditions highlight the need for low-cost, practical, and locally feasible interventions that may support poultry productivity without relying heavily on expensive infrastructure or synthetic growth-promoting additives.

The conceptual basis of the study is anchored on the relationship between heat stress, physiological response, feed intake, and growth performance in broilers. Under thermal stress, chickens reduce feed intake and alter metabolic activity to regulate body temperature, resulting in lower weight gain and poorer feed conversion. The study therefore assumes that a natural phytogenic additive with antioxidant, anti-inflammatory, and thermoregulatory properties may help support physiological resilience and maintain production performance. Ginger supplementation is conceptually linked to the presence of bioactive compounds such as gingerols and shogaols, which may help reduce oxidative stress and support thermoregulation. By administering powdered ginger through drinking water, the study examines whether this natural additive can influence growth performance, feed intake, feed conversion ratio, and water intake among broilers exposed to heat stress.

Although previous studies have examined ginger supplementation in poultry, limited information is available on its effects when administered specifically through drinking water under heat-stress conditions. There is also a need to examine how ginger supplementation affects intake responses, growth performance, and feed conversion in broilers exposed to controlled thermal stress. The study addresses this gap by evaluating varying concentrations of powdered ginger supplementation through drinking water among heat-stressed Cobb 500 broilers. The rationale of the study is grounded in the need for an affordable, natural, and practical strategy that can be applied in poultry production systems where costly cooling technologies or synthetic additives may not be feasible. By testing different ginger supplementation levels, the study contributes evidence on whether ginger can support performance stability and intake behavior under heat stress.

This study aligns with SDG 2 – Zero Hunger because it addresses poultry productivity, food production stability, and the need to sustain broiler performance under heat-stress conditions. It also supports SDG 3 – Good Health and Well-Being by exploring a natural alternative to synthetic additives and antibiotic growth promoters, which is relevant to consumer health, food safety, and concerns about antimicrobial resistance (Castanon, 2007; Windisch et al., 2008). The study is also connected to SDG 8 – Decent Work and Economic Growth because heat stress causes economic losses in poultry production, while practical mitigation strategies may help improve productivity and profitability among poultry producers (Hatfield et al., 2014; Abdel-Moneim et al., 2021). It further supports SDG 12 – Responsible Consumption and Production by examining ginger as a phytogenic additive that responds to consumer demand for more natural, animal-welfare-conscious, and environmentally sustainable production systems (Henry & Oliver, 2022; OECD-FAO, 2024). Finally, the study relates to SDG 13 – Climate Action because it responds to the production challenges brought by rising environmental temperatures and climate-related heat stress (Livingston et al., 2022; IPCC, 2022).

The study contributes to multidisciplinary sustainability by connecting animal science, agricultural productivity, environmental adaptation, food safety, and small-scale enterprise resilience. From an agricultural sustainability perspective, it explores a natural supplementation strategy that may help broilers cope with heat stress and maintain production performance. From a socio-economic perspective, the study is relevant to poultry growers, especially small and medium-scale producers who may not have access to expensive cooling technologies. The study also contributes to public health and responsible production by responding to concerns about antimicrobial resistance, synthetic additives, and consumer preference for safer and more natural poultry products. Its climate-related relevance lies in its attempt to identify a practical adaptation measure for poultry production under rising temperatures. Overall, the research supports sustainable poultry management by examining ginger supplementation as a possible low-cost, natural, and production-oriented intervention for heat-stressed broilers.

2. Material and methods

2.1 Research Design

The study employed a completely randomized design. A total of 150 day-old Cobb 500 broiler chicks were randomly distributed into five treatments with three replicates per treatment and 10 birds per replicate. The treatment groups consisted of a control group given plain water and four experimental groups given powdered ginger supplementation at 1.5 g/L, 2.5 g/L, 3.5 g/L, and 4.5 g/L through drinking water.

2.2 Locale of the Study

The experimental study was conducted at Nueva Vizcaya State University, Bayombong, Nueva Vizcaya, Philippines, where the broiler chickens were housed and maintained under controlled rearing conditions throughout the duration of the experiment. Furthermore, the phytochemical analysis of the powdered ginger was conducted at the Analytical Services Laboratory, Institute of Plant Breeding, University of the Philippines Los Baños, Laguna, to ensure reliable and standardized analysis of the ginger sample.

2.3 Respondents of the Study

The experimental subjects of the study were 150 day-old Cobb 500 broiler chicks. These broilers were used to evaluate the effects of varying concentrations of powdered ginger supplementation through drinking water under heat-stress conditions..

2.4 Sample and Sampling Procedure

The sample consisted of 150 broiler chicks randomly assigned to five treatment groups. Each treatment had three replicates composed of 10 birds each. Random assignment was used to ensure that the broilers were fairly distributed across the control and experimental groups.

2.5 Research Instrument

The main experimental treatment was powdered ginger mixed with potable water at different concentrations. Prior to its use, the powdered ginger was subjected to phytochemical analysis to determine the presence of phenolic compounds, flavonoids, tannins, anthocyanins, and antioxidant activity. Growth performance indicators were measured through body weight, body weight gain, feed intake, feed conversion ratio, mortality rate, and water intake. Weighing scales, measured feed quantities, known water volumes, digital hygrometers, and an infrared thermometer were used to monitor the broilers' performance, intake behavior, and heat-stress conditions.

2.6 Data Gathering Procedure

The first 14 days served as the acclimation and brooding period, during which the broilers were allowed to adapt to the experimental housing, feeding, watering, and general management conditions before the start of ginger supplementation and heat-stress exposure. Beginning on day 15, powdered ginger was mixed thoroughly with potable water and administered to Treatments 2 to 5 from 6:00 AM to 6:00 PM daily. After this period, ginger-infused water was replaced with plain potable water from 6:00 PM to 6:00 AM the following day. Water intake was measured at every changeover to determine consumption and assess the acceptability of ginger-infused water. From day 15 to day 35, the broilers were exposed to controlled heat stress using a 100-watt incandescent lamp. The ambient temperature was raised to 32–35°C for six hours daily, usually from 10:00 AM to 4:00 PM, while normal ambient temperature of 24–26°C was maintained outside the heat-stress period. Plastic tarpaulin sheets were installed between pens and overhead to help regulate temperature. Digital hygrometers were placed at chick level in different locations to monitor temperature distribution, while an infrared thermometer was used to check litter surface temperature and identify possible hot or cold spots. A commercially formulated diet appropriate for the birds' age and growth stage was provided throughout the experiment. Feed and water were offered ad libitum. Body weight was recorded weekly before afternoon feeding, while body weight gain was computed by subtracting the initial body weight from the final body weight on a weekly basis. Feed intake was measured daily by subtracting feed refusal from the total feed offered, while feed conversion ratio was calculated by dividing total feed consumed by total weight gain. Mortality was recorded daily. Water intake was determined by subtracting the remaining water volume from the total volume offered and summarizing the values weekly.

2.7 Data Analysis Techniques

The collected data were analyzed using analysis of variance (ANOVA) through the STAR or Statistical Tool for Agricultural Research software, version 2013, developed by the International Rice Research Institute. When significant differences were found at $p < 0.05$, treatment means were compared using Tukey's Honestly Significant Difference (HSD) test. The level of significance was set at $p < 0.05$.

2.8 Ethical Considerations

All animal handling and experimental procedures were conducted in accordance with institutional animal care and welfare guidelines. The study protocol was reviewed and approved by the Institutional Animal Care and Use Committee (IACUC).

3. Results and Discussion

3.1 Performance and Intake Responses of Heat-Stressed Broilers

3.1.1 Phytochemical Composition of Ginger Powder

The phytochemical analysis showed that the ginger powder had DPPH radical scavenging activity ranging from 29.61% to 31.45%. Its total phenolic content ranged from 8.86 to 10.19 mg GAE/g, while total flavonoid content ranged from 4.16 to 4.55 mg CE/g. Total tannin content was relatively low at 0.41 to 0.45 mg CE/g, while total anthocyanins were not detected. These results indicate that the ginger powder contained measurable antioxidant activity and relevant bioactive compounds. The antioxidant activity of the ginger powder may be mainly attributed to its phenolic and flavonoid contents, since these compounds are known to neutralize free radicals and reduce oxidative stress (Shahidi & Ambigaipalan, 2015). The findings are generally consistent with previous reports showing the presence of phenols, flavonoids, and tannins in ginger (Orinya et al., 2023; Iheanacho et al., 2017). Although ginger essential oil may contain higher phytochemical concentrations because of its more concentrated form (Alagbe et al., 2021), the present results still suggest that ginger powder contains sufficient bioactive compounds for practical poultry application. The low tannin content may also be favorable because high tannin levels can impair broiler growth performance (Brugaletta et al., 2020; Hidayat et al, 2021; Zhao et al. 2025), while the absence of anthocyanins is expected because ginger rhizomes are not major sources of these pigments (Khoo et al., 2017).

3.1.2 Body Weight of Broilers

The average weekly body weight of broilers did not differ significantly among treatments across all weeks. During the first week, body weights ranged from 158.67 g to 163.00 g, while Week 2 values ranged from 366.67 g to 400.00 g. At the onset of heat stress and ginger supplementation in Week 3, body weights ranged from 820.00 g to 892.59 g, with the 4.5 g/L group recording the highest numerical value. By Week 4, the 4.5 g/L and 3.5 g/L groups recorded the highest body weights at 1269.63 g and 1265.56 g, respectively, while the control group recorded the lowest value at 1140.74 g. By Week 5, the 4.5 g/L group maintained the highest final body weight at 2122.22 g, followed by the 2.5 g/L group at 2026.67 g and the 1.5 g/L group at 1996.67 g. Although the differences were not statistically significant, the numerical pattern suggests that higher ginger supplementation levels may have supported growth stability during the mid- to late-growth stages. Early body weights recorded were below the Cobb 500 recommended standard (Cobb-Vantress, 2022). This reduced growth performance coincided with lower feed intake and early brooding challenges, including suboptimal temperature and limited lighting caused by power interruption. These conditions may have adversely affected thermoregulation, reduced feed consumption, and consequently delayed early growth in the broilers. Heat stress is known to impair nutrient digestion, reduce protein synthesis, and increase oxidative stress, thereby suppressing growth (Lin et al., 2006; Lara & Rostagno, 2013). Ginger contains gingerols and shogaols that may improve digestion, gut function, metabolic efficiency, enzyme activity, gut motility, and bile secretion (Zhang et al., 2009; Mao et al., 2019; El-Gharib et al., 2021; Mahasneh et al. 2024). Its antioxidant and anti-inflammatory properties may also help reduce cellular damage under elevated temperatures (Habibi et al., 2014), while phytogenic additives may improve gut integrity and microbial balance, supporting nutrient absorption under heat stress (Windisch et al., 2008).

3.1.3 Weight Gain of Broilers

Weekly weight gain did not differ significantly during Weeks 1, 2, 3, and 5. Week 1 gains ranged from 118.67 g to 123.00 g, while Week 2 gains ranged from 203.67 g to 241.33 g. In Week 3, the 4.5 g/L group recorded the highest numerical gain at 525.93 g. A significant difference was observed in Week 4, where the 3.5 g/L group recorded the highest weight gain at 432.22 g, while the control group had the lowest gain at 303.70 g. By Week 5, the 4.5 g/L group again recorded the highest gain at 852.59 g. Cumulative weight gain did not differ significantly, but the 4.5 g/L group recorded the highest cumulative gain at 2082.22 g, followed by the 2.5 g/L group at 1986.67 g and the 1.5 g/L group at 1956.67 g. The lower early weight gains suggest that early growth was constrained, likely because suboptimal brooding conditions affected thermoregulation, gut development, enzyme activity, and nutrient absorption efficiency (Lilburn & Loeffler, 2015; Pakiding et al., 2020; Ravindran & Abdollahi, 2021). The significant Week 4 response in the 3.5 g/L group indicates that ginger supplementation may have supported growth during the peak stress period. Heat stress reduces growth by suppressing feed intake and diverting energy toward thermoregulation (Lin et al., 2006; Purswell et al., 2012; Lara & Rostagno, 2013), while gingerols and shogaols may improve digestive activity and nutrient use (Zhang et al., 2009). The antioxidant properties of ginger may also help reduce oxidative stress and support protein deposition during high-temperature exposure (Habibi et al., 2014), while phytogenic additives may improve nutrient absorption through better gut health and microbial balance (Windisch et al., 2008). The observed growth suppression is also consistent with findings on heat-stressed broilers (Kim et al., 2025), and may have been compounded by early suboptimal thermal conditions that can affect later performance and thermoregulatory responses (Moreira et al., 2024; Kamkrathok et al., 2025).

3.1.4 Feed Intake of Broilers

Feed intake was uniform in Week 1, while Week 2 showed no significant treatment difference despite higher numerical intake in the control group. A significant difference was observed in Week 3, which coincided with the onset of heat stress and ginger supplementation. The 4.5 g/L group recorded the highest feed intake at 654.91 g, followed by the 2.5 g/L group at 643.97 g and the 3.5 g/L group at 627.57 g, while the control group recorded the lowest intake at 521.70 g. In Weeks 4 and 5, no significant differences were observed, although ginger-supplemented groups generally maintained higher numerical intake. Cumulative feed intake was also not significantly different, but the 4.5 g/L group recorded the highest total intake at 3328.11 g, followed by the 2.5 g/L group at 3319.07 g, while the control group recorded the lowest value at 3093.24 g. The higher feed intake among ginger-supplemented groups, particularly during Week 3, suggests that ginger may have helped reduce heat stress–related appetite suppression. Feed intake during the early and heat-stress periods remained below Cobb 500 guidelines, likely due to early brooding stress and thermal challenge. Broilers under heat stress often reduce feed consumption to minimize metabolic heat production, while activation of the hypothalamic-pituitary-adrenal axis may increase corticosterone secretion and contribute to lower appetite (Bhawa et al., 2023). The findings are consistent with reports of higher feed consumption or improved performance in ginger-supplemented birds (Ademola et al., 2009; Sultan et al., (2024); Habibi et al., 2014; Agu et al., 2017; Shah et al., 2022; Arshad et al., 2022; Ajayi et al., 2024; Kairalla et al., 2022; Talukder et al., 2017; Ismail et al., 2020). Ginger may stimulate digestive secretions, enzyme activity, and gastrointestinal function (Liu et al., 2012; Saber et al., 2025; Kumar et al., 2020), and similar benefits have been reported when ginger is administered through drinking water (Sa'aci et al., 2017, 2018). However, the findings also acknowledge contrasting results from studies reporting reduced or unchanged feed consumption in ginger-supplemented birds (Al-Khalaifah et al. (2022); Đurić Jarić et al., (2025); Dosu et al., 2023; Fakhim et al. 2013).

3.1.5 Feed Conversion Ratio of Broilers

The cumulative feed conversion ratio did not differ significantly among treatments. Numerically, the 3.5 g/L group recorded the lowest FCR at 1.58, followed by the 2.5 g/L group at 1.63, the 1.5 g/L group at 1.65, the 4.5 g/L group at 1.68, and the control group at 1.72. Although the differences were not significant, the lower FCR values in ginger-supplemented groups indicate a numerical tendency toward better feed efficiency under heat stress. The FCR values were higher than the Cobb 500 standard of approximately 1.44 at 35 days under optimal conditions (Cobb-Vantress, 2022), suggesting reduced feed efficiency due to early brooding stress and sustained exposure to high ambient temperature. The relatively lower FCR in the 3.5 g/L group suggests that moderate ginger supplementation may have supported feed utilization during heat stress. This may be linked to the ability of ginger to stimulate digestive secretions and enhance enzymatic activity (Liu et al., 2012; Jamshidi & Raie, 2014). However, the lack of significant difference indicates that ginger supplementation may help maintain feed efficiency but may not be sufficient to fully overcome the negative effects of heat stress. This is consistent with studies reporting that ginger supplementation does not always significantly improve feed conversion efficiency in broilers (Zomrawi et al., 2012; Habibi et al., 2014; Dosu et al., 2023).

3.1.6 Water Intake of Broilers

Water intake increased progressively from Week 1 to Week 5 across treatments. Week 1 showed identical water intake among groups, while Week 2 showed a significant difference, with the control group recording higher water intake than the ginger-supplemented groups. From Week 3 onward, water intake increased substantially across all treatments as heat stress and rapid growth progressed. Differences from Weeks 3 to 5 were not significant, although the 3.5 g/L group recorded the highest intake during Weeks 4 and 5 and the highest cumulative water intake. Overall, ginger supplementation did not significantly affect cumulative water intake, indicating that ginger-infused water was accepted by the broilers. The increase in water intake reflects the normal physiological response of broilers to heat stress, as birds consume more water to compensate for losses from panting and to support thermoregulation, blood volume, digestion, nutrient transport, and metabolic processes (Lin et al., 2006; Lara & Rostagno, 2013; Wasti et al., 2020; Bhawa et al., 2023). The higher water intake in the 3.5 g/L group during Week 4 coincided with improved weight gain and feed efficiency, suggesting that hydration supported physiological balance during peak heat stress (May et al., 2000; Lara & Rostagno; 2013; Nawab et al., 2018; Wasti et al., 2020). Water intake generally followed patterns observed in feed intake, growth rate, and feed efficiency, supporting the role of hydration in maintaining performance under high temperatures (Belay & Teeter, 1993; Sohail et al., 2012; Quinteiro-Filho et al., 2010; Wasti et al., 2020). The absence of significant differences also suggests that ginger's phenolic and flavonoid contents did not negatively affect palatability or water acceptance. In contrast, Rasve et al. (2022) reported increased water intake in broilers supplemented with ginger extract, indicating that responses may vary depending on dosage, preparation, and environmental conditions.

3.2 Overall Interpretation of Treatment Responses

Overall, powdered ginger supplementation through drinking water did not significantly affect most growth performance, feed intake, feed conversion, or water intake indicators of heat-stressed broilers. However, the 4.5 g/L group consistently showed the highest final body weight, cumulative weight gain, and cumulative feed intake. The 3.5 g/L group produced the lowest numerical FCR and the highest Week 4 weight gain, while the 2.5 g/L group showed stable performance across the experimental period. These results suggest that ginger supplementation may contribute more to performance stability than to statistically significant growth enhancement under heat stress. Higher levels may favor body weight and cumulative gain, moderate levels may support feed utilization, and intermediate levels may promote consistency. Therefore, ginger supplementation appears to have practical potential as a phytogenic additive for supporting broiler resilience under heat-stress conditions, particularly within the 2.5–4.5 g/L supplementation range depending on the intended production objective.

4. Conclusion & Recommendations

Powdered ginger (Zingiber officinale) supplementation through drinking water did not significantly affect the overall growth performance, feed intake, feed conversion ratio, or water intake of heat-stressed broilers; however, the observed treatment-specific trends indicate its potential role in maintaining performance stability under thermal stress. The 4.5 g/L supplementation level produced the highest final body weight, cumulative weight gain, and feed intake, while the 3.5 g/L level recorded the lowest feed conversion ratio and highest weight gain during the peak stress period. The 2.5 g/L level provided the most consistent growth response, suggesting that ginger supplementation may exert dose-dependent effects in supporting broiler performance under heat-stress conditions.

Based on the findings, powdered ginger supplementation may be considered as a practical phytogenic additive for broilers exposed to heat stress, particularly within the 2.5–4.5 g/L range depending on the production objective. A 4.5 g/L level may be used when the goal is to enhance body weight and cumulative gain, 3.5 g/L may be considered for improving feed utilization efficiency, and 2.5 g/L may be used to support consistent growth performance under heat-stress conditions.

The findings are limited to 150 Cobb 500 broilers assigned to five treatment levels, exposed to cyclic heat stress from day 15 to 35, and evaluated mainly in terms of growth performance, feed intake, feed conversion ratio, and water intake. As such, the results should be interpreted within the specific experimental conditions, supplementation levels, and production indicators covered in the study.

Compliance with ethical standards

The study was conducted in accordance with institutional ethical standards for animal care and welfare, and the research protocol was reviewed and approved by the Institutional Animal Care and Use Committee (IACUC). No human participants were involved; thus, informed consent and confidentiality concerns were not applicable. The authors acknowledge their respective contributions, declare no conflict of interest, and affirm responsibility for the originality, integrity, and copyright compliance of the manuscript.

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