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Growth Performance, Quantitative Analysis and Economics of Broiler Chickens as Influenced by Herbal Dietary Additives as Alternative Growth Booster

R. Ajaykumar[1], K. Harishankar[2], S.R. Shri Rangasami[3], V. Saravanakumar[4], G. Yazhini[5], V. Rajanbabu[6], K. Premalatha[3]

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ABSTRACT

Background: The range of synthetic medications and growth promoters fed to broilers is expensive, negatively impacts the health of the birds and has long-term side effects. Refocusing their efforts, poultry farmers are looking for herbal extracts that have therapeutic properties and may be used safely to boost productivity. This study was conducted to assess the effect of Garlic (*Allium sativum*), Ginger (*Zingiber officinale*) and Cinnamon (*Cinnamomum zeylanicum*) on the growth performance of broiler chickens.

Methods: One hundred and forty day old broiler chicks were distributed randomly into seven treatment groups *viz*., T_0 (Control: basal diet), T_1 (basal diet + 0.5% Garlic), T_2 (basal diet + 0.5% Ginger), T_3 (basal diet + 0.5% Cinnamon), T_4 (basal diet + 0.25 % Garlic + 0.25 % Ginger), T_5 (basal diet + 0.25 % Garlic + 0.25% Cinnamon), T_6 (basal diet + 0.25% Ginger + 0.25% Cinnamon) having 70 chicks in each group with 10 replicates.

Result: The results (0-6 weeks) of present study indicated that supplementation of a combination of 0.25% garlic and 0.25% ginger to the basal diet of broilers (T_4) significantly improved overall average daily gain (ADG), better feed conversion ratio (FCR) and broiler performance efficiency index (BPEI) and body weight (BW) of broilers followed by diet supplemented with combination of 0.25% ginger and 0.25% cinnamon (T_6) compared to control and other groups. Highest profit per bird (Rs. 25.17) and benefit cost ratio (1.59) was observed in T_4 followed by T_6. It can be concluded that dietary supplementation of garlic (0.25%) along with ginger (0.25%) has the potential to improve growth performance of broiler chickens.

Key words: Broiler chickens, Daily gain, Feed conversion ratio, Feed intake, Growth promoters, Quantitative analysis.

INTRODUCTION

The poultry sector in India has transformed into a dynamic agribusiness, propelled by domestic economic growth and changes in consumption patterns. Ranking as the world's fourth-largest chicken producer, India follows China, Brazil and the USA. Over the past five years, chicken meat consumption in India has escalated from 400 grams to 2.5 kilograms per person annually (Gaikwad *et al.,* 2019). Broiler meat known for its rich content of high-quality proteins, minerals and vitamins is often treated with various synthetic medications and growth enhancers. These substances, while costly, can negatively impact bird health and possess long-term residual effects (Thi Huong-Anh *et al.,* 2020). Growth promoters are commonly added to chicken feed to enhance appetite, improve feed conversion, stimulate the immune system and regulate intestinal microflora among other benefits. However, the last five decades have seen both advantages and disadvantages in the use of antibiotics, leading to a renewed focus on natural antimicrobial agents as vital resources.

Natural growth promoters like garlic, ginger and cinnamon have emerged as viable substitutes for conventional artificial enhancers such as antibiotics (Rathaur *et al*., 2023). Garlic (*Allium sativum*), long used as a spice

[1]Department of Agronomy, Vanavarayar Institute of Agriculture, Pollachi-642 103, Tamil Nadu, India.
[2]Department of Social Science, Vanavarayar Institute of Agriculture, Pollachi-642 103, Tamil Nadu, India.
[3]Department of Forage crops, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.
[4]Department of Agricultural Economics, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.
[5]Department of Soil Science and Agricultural Chemistry, Vanavarayar Institute of Agriculture, Pollachi-642 103, Tamil Nadu, India.
[6]Department of Genetics and Plant Breeding, Anbil Dharmalingam Agriculture College and Research Institute, Trichy-620 027, Tamil Nadu, India.

Corresponding Author: R. Ajaykumar, Department of Agronomy, Vanavarayar Institute of Agriculture, Pollachi-642 103, Tamil Nadu, India. Email: ajaykumar.tnau@gmail.com

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and traditional medicine is known for its antibacterial, antifungal, antiparasitic, antiviral, antioxidant, anti-cholesteremic, anticancer and vasodilatory properties. Allicin, garlic's primary active compound, decomposes into several bioactive organosulphur compounds (Gopikrishnan *et al*., 2022).

Ginger, the rhizome of *Zingiber officinale*, serves as a delicacy, medicine and spice. Early studies suggest that compounds in ginger may interact with serotonin receptors, potentially affecting gastrointestinal functions. In-vitro studies have shown that ginger extract can manage free radical levels and lipid peroxidation, as well as exhibit anti-diabetic properties (Al-Amin *et al*., 2006 and Morakinyo *et al*., 2011).

Cinnamon (*Cinnamomum cassia*) commonly known as "dalchini" is important medicinal plants and widely used in India. A member of the Lauraceae family, cinnamon is reported by Nath *et al.* (2023) to have appetite and digestion-stimulating properties. It contains essential oils like cinnamic acid, cinnamaldehyde, cinnamate and others, which possess antibacterial and antioxidant properties, as well as other medicinal benefits, including antiulcer, anti-diabetic and anti-inflammatory effects (Singh *et al*., 2007). Based on the aforementioned information, the current study was conducted to assess the growth performance of broiler chickens supplemented with garlic, ginger, cinnamon powder and their combination at different levels.

MATERIALS AND METHODS

The research was conducted during the year of 2022, 2023 and month of February - March, summer season at the AnSan Poultry Farm, located in the Palakkad District of Kerala. During this period, the average temperature varied between 27 to 35°C with relative humidity levels ranging from 63 to 75 per cent. The ingredients for the study, readymade powder of garlic, ginger and cinnamon were purchased from the local market. The experiment involved one hundred and forty day-old broiler chicks, each weighing approximately 36.88±0.24 grams, obtained from Sakthi Farms Pvt. Ltd., based in Tiruppur, Tamil Nadu.

Upon arrival, the chicks were identified using wing bands and placed in a brooding environment, where the temperature was meticulously maintained between 33.9 to 35°C for the first three days. Vaccinations against Marek's Disease, Ranikhet Disease and Infectious Bursal Disease were administered according to the standard schedule. Throughout the experiment, strict biosecurity protocols were observed.

The chicks were individually weighed and evenly distributed into seven distinct treatment groups, labeled T_0 through T_6, with each group containing 10 chicks. This distribution was carried out in accordance with a randomized block design (RBD). The experimental diets, detailed in Table 1, were specially formulated for both the starter and finisher phases to meet the nutrient requirements as per ICAR guidelines. The control group, T_0, was given a basal diet while groups T_1 through T_6 received variations of the basal diet with different combinations of garlic, ginger and cinnamon.

The performance of the broiler chickens was meticulously monitored during the starter and finisher phases, as well as throughout the entire experiment. Key metrics such as body weight, average daily gain, average daily feed intake and feed conversion ratio were recorded. Additionally, the broiler performance efficiency Index was calculated following the method described by Martins *et al.* (2016). The data collected during the experiment were analyzed using RStudio, employing one-way ANOVA for statistical analysis. The results were further examined using a post-hoc test (Tukey HSD test) at a 5% significance level. The economics of broiler production was worked out by considering the total cost of production which included the feed cost, chicks, labour, medicines, vaccines and the overhead costs.

RESULTS AND DISCUSSION

The study conducted to evaluate the effects of garlic, ginger and cinnamon on broiler chickens gives notable results across various performance metrics: average daily feed intake (ADFI), average daily gain (ADG), feed conversion ratio (FCR), body weight (BW) and broiler performance efficiency index (BPEI). The comparative treatment effects through boxplots of ADFI, ADG and FCR and its standardized residuals and normality Q-Q plots for ANOVA are visualized in Fig 1 and 2.

Average daily gain

The study's assessment of the effect of dietary supplements on the Average Daily Gain (ADG) of broiler chickens across various treatments (T_0 through T_6) provides insightful results (Table 2 and Fig 3). Body weight gain (g)

Table 1: Ingredient and chemical composition of the basal diet (% DM basis) during starter and finisher phase.

Ingredients	Starter (d 7-21)	Finisher (d 22-42)
Maize	57.612	59.282
Soybean meal	35.095	31.518
Oil	3.921	5.624
Calcite/LSP	0.658	0.687
Dicalcium phosphate	1.639	1.634
Methionine	0.227	0.223
Lysine	0.277	0.225
SodaBicarb	0.100	0.100
Salt	0.218	0.200
Trace mineral premix1	0.050	0.050
Vitamin premix2	0.050	0.050
Threonine	0.050	0.025
Maduramicin	0.000	0.050
Robimidine	0.033	0.000
Choline chloride (60%)	0.120	0.150
Liver tonic	0.050	0.050
Emulsifier	0.050	0.050
Toxin binder	0.100	0.100
Total	100	100

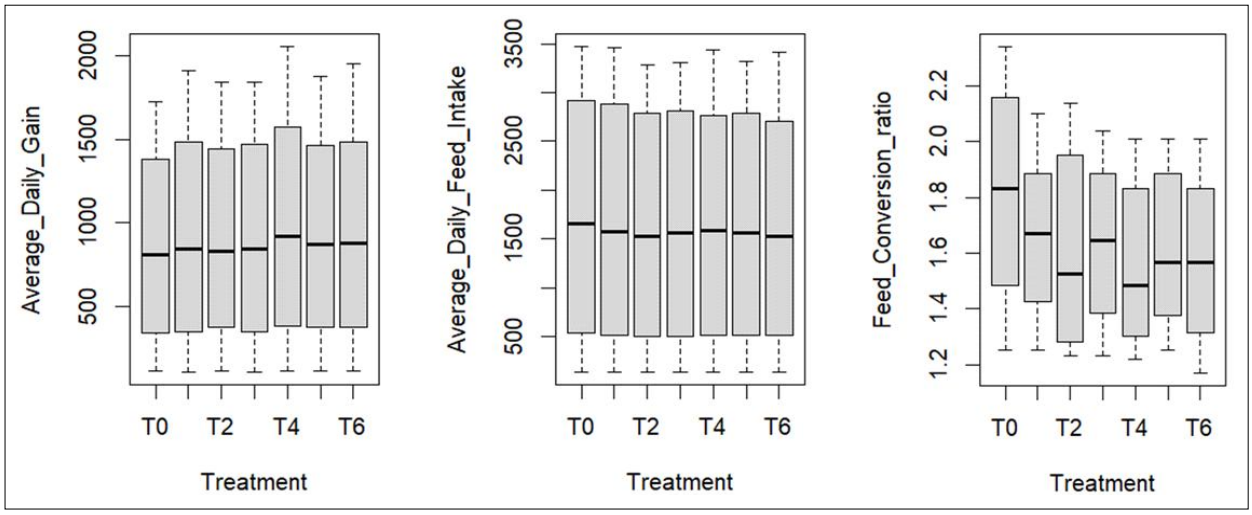

Fig 1: Comparative boxplots of ADG, ADFI and FCR over treatments.

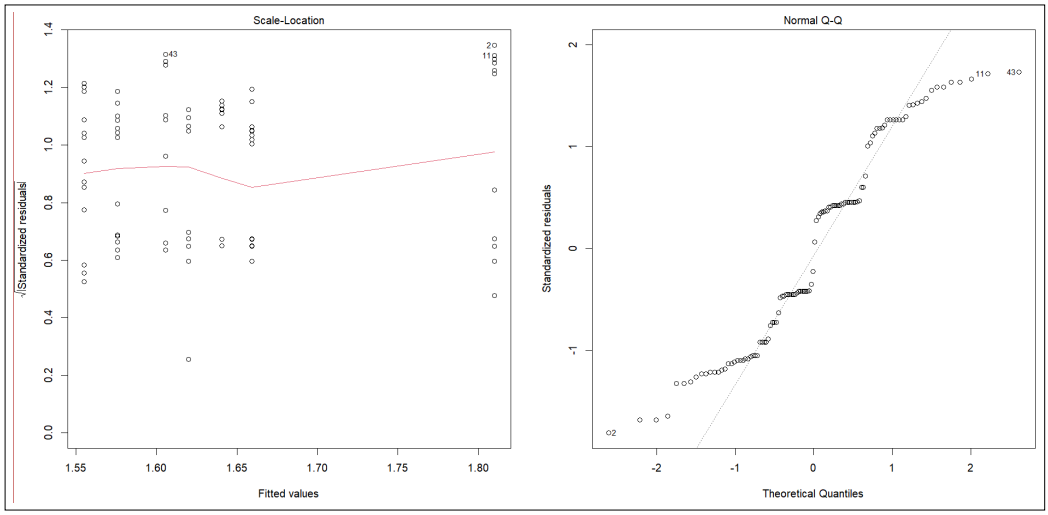

Fig 2: Standardized residuals and normal Q-Q plots for ANOVA.

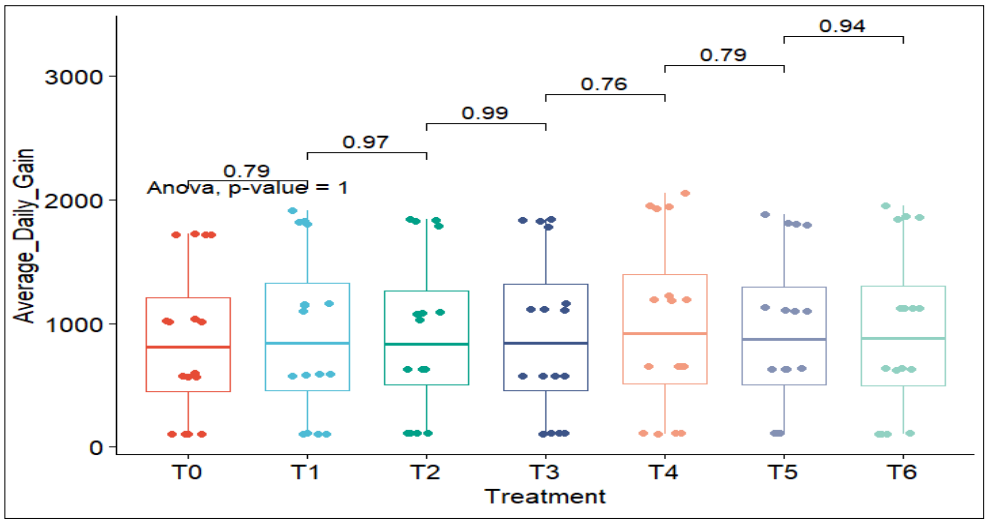

Fig 3: Visualization of ANOVA and post-hoc tests for ADG.

of birds in combination of garlic and ginger T_4 (1971.29 g) showed significantly (P<0.001) higher values as compared to control and it was followed by T_6 (1880.62 g). Garlic contains compounds like allicin and oregano sulfur compounds responsible for inhibition of pathogenic bacteria and fungi resulting in improved gut environment and higher weight gain of experimental birds. It has been an established fact that ginger in the diets stimulate lactic acid bacteria and decreases pathogenic bacteria such as mesophilic aerobic, coliform and E. coli and thus improves absorption of nutrients for better weight gain of the birds. The results are consistent with Arshad *et al*. (2012) who stated that use of ginger in broilers had a significant (P<0.001) positive effect on the body weight gain as compared to the control. Sang-oh *et al*. (2013) also concluded that cinnamon treated birds had higher body weight gain.

Quantitative analysis

The ADG was measured during different growth phases: 0-6 days, 7-21 days, 22-42 days and the overall period of 0-42 days. In the initial growth phase (Days 0-6), our analysis revealed modest but noticeable differences in ADG among the treatments (F-statistic = 3.6, p-value = 0.02). The initial days post-hatching, as these studies suggest, are crucial for setting the trajectory of growth, albeit the response to dietary changes is comparatively subdued (Giraldo-Deck *et al*., 2022).

A pronounced increase in ADG was observed during these phases (Days 7-21) and (Days 22-42), particularly for treatment T_4 (basal diet + 0.25% Garlic + 0.25% Ginger), which recorded the highest ADG (651.27 g/day for days 7-21; 1198.91 g/day for days 22-42). This might be due to synergistic effects of garlic and ginger in enhancing growth rates, potentially by improving nutrient assimilation and metabolism. The interplay of these spices, as per recent studies, seems to optimize physiological functions crucial for growth (Singh *et al*., 2019).

Throughout the 42-day period, T_4 consistently demonstrated superior growth performance, indicating its efficacy across the broiler's lifespan. The cumulative ADG for T_4 stood at 1971.29 g/day, significantly outperforming other treatments. This comprehensive growth enhancement aligns with findings from the works of Eltazi (2014) emphasizing the holistic benefits of combining natural dietary additives like Garlic and Ginger. These ingredients are becoming increasingly recognized for their role in sustainable and efficient poultry growth promotion.

Average daily feed intake

The assessment of the Average Daily Feed Intake (ADFI) in broiler chickens subjected to various dietary supplements reveals notable findings, particularly when comparing the control group (T_0) with treatments T_1 through T_6 (Table 3 and Fig 4). The analysis spanned different growth phases: 0-6 days, 7-21 days, 22-42 days and an overall period of 0-42 days.

It was observed that ADFI differed significantly (P<0.001) during days 7-21 and days 22-42. During d 7-21, ADFI was highest in T_0, followed by T_6 and lowest in T_1 group. Overall feed intake (d 0-42) significantly (P<0.05) decreased in response to supplementation than control. This might be due to effect of increasing levels of dietary herb ginger powder caused a significant reduction in feed consumption. Present findings were in agreement with, Arshad *et al*., (2012) who concluded that addition of garlic and ginger extract in poultry diet reduced the feed intake.

Quantitative analysis

In the earliest phase of the broilers' growth (Days 0-6), our study noted negligible variations in ADFI across all treatments (F-statistic = 0.7, p-value = 0.60). This aligns with findings by Murugesan *et al*. (2015), who also observed minimal impact of dietary changes in the first week of broiler chickens' life. This phase, as per current understanding, seems less responsive to dietary manipulations, perhaps due to the inherent metabolic and physiological characteristics of newly hatched broilers. A significant shift was observed during days 7-21, where treatment T_2 (basal diet + 0.5% Ginger) exhibited the lowest ADFI (861.25 g/day) (F-statistic = 18.27, p-value = 0.00). This reduction in feed intake may be attributable to ginger's bioactive compounds,

Table 2: Average daily gain (gram/day) of broiler chickens (Pooled data).

Treatment	d 0-6	d 7-21	d 22-42	d 0-42
T_0	108.01^{dgjln}	$578.4d^{f}$	1021.1	1721.71
T_1	107.12^{kmn}	$585.3d^{e}$	1141.75^{ab}	1842.78^{aefg}
T_2	113.24	630.12^{bc}	1071.68	1824.28^{behijk}
T_3	109.53^{behijk}	576.61^{ef}	1124.47^{acd}	1821.67^{dgikl}
T_4	110.84^{abcd}	651.27	1198.91	1971.29
T_5	110.01^{aefg}	634.13^{ab}	1110.36^{df}	1822.91^{cfhjl}
T_6	109.27^{cfhilm}	632.01^{ac}	1121.03^{bcf}	1880.62^{abcd}
S. Ed	1.34	4.62	13.83	27.96
CD	2.91	10.03	30.02	60.68
CV	1.81	4.72	4.63	6.76
F-statistic	54.08	91.21	32.80	14.81
p-value	0.02	0.00	0.00	0.00

which, as per Al- Zaffer *et al*. (2022), can influence gut health and metabolism. Ginger's role in modulating feed intake has been increasingly recognized in poultry nutrition, possibly due to its impact on enhancing digestive efficiency.

The most significant outcome was observed in treatment T_6 (basal diet + 0.25% Ginger + 0.25% Cinnamon), which showed the lowest ADFI both in the later phase and overall (F-statistic = 4.91, p-value = 0.00 for days 22-42; F-statistic = 6.40, p-value = 0.00 for days 0-42). This synergistic effect of ginger and cinnamon is corroborated by recent studies, such as those by Al-Ghamdi (2022), which suggest that certain spice combinations can optimize feed efficiency by influencing digestive enzymes and gut microbiota. The use of these spices, particularly in combination, has emerged as a promising strategy in poultry nutrition, reflecting a shift towards more natural and sustainable feeding practices.

Feed conversion ratio

The investigation into the effects of dietary supplements on Feed Conversion Ratio (FCR) in broiler chickens, encompassing treatments T_0 to T_6, unveils significant insights (Table 4 and Fig 5). During d 7-21 and 22-42, all the supplemented groups (T_1 to T_6) showed better FCR (P<0.001) than control group. Overall FCR (d 0-42) ranged from 1.67 to 1.96 in supplemented groups, which was significantly (P<0.001) better than control (1.96). Within supplemented groups, T_4, T_5 and T_6 groups performed better than other groups. This effect was more pronounced for birds fed with Garlic, Ginger and Cinnamon supplemented groups. The findings of present study were in accordance with results reported by Najafi and Taherpour (2014). Windisch *et al*. (2009) work on the proven effects of phytobiotic feed additives in different poultry species, indicated a reduced feed intake and improved feed conversion ratio.

Quantitative analysis

The FCR, a crucial indicator of feed efficiency, was meticulously monitored across various growth stages: 0-6 days, 7-21 days, 22-42 days and the entire 42-day period. Integrating these findings with contemporary research and developments in poultry science provides a deeper understanding.

Table 3: Average daily feed intake (gram /day) of broiler chickens (Pooled data).

Treatment	d 0-6	d 7-21	d 22-42	d 0-42
T_0	139.64^{bglmnop}	972.62	2350.54^{ac}	3469.01^{a}
T_1	139.58^{chlqrs}	880.51^{dgijk}	2365.27^{ab}	3385.26^{abcd}
T_2	139.82^{aghijk}	861.25^{k}	2270.81^{dghi}	3301.29^{bef}
T_3	138.09^{fkpsuv}	887.36^{cfhj}	2269.02^{egjk}	3298.25^{ceghi}
T_4	138.12^{ejortv}	890.23^{behi}	2297.34^{bcdef}	3297.18^{dfgjk}
T_5	138.25^{dimnqtu}	895.29^{aefg}	2258.49^{fhjl}	3279.8^{1hjl}
T_6	140.01^{abcdef}	901.52^{abcd}	2201.86^{ikl}	3249.69^{ikl}
S. Ed	1.40	11.62	35.82	41.89
CD	3.03	25.21	77.73	90.91
CV	0.63	3.62	2.45	2.27
F-statistic	0.77	18.27	4.91	6.40
p-value	0.60	0.00	0.00	0.00

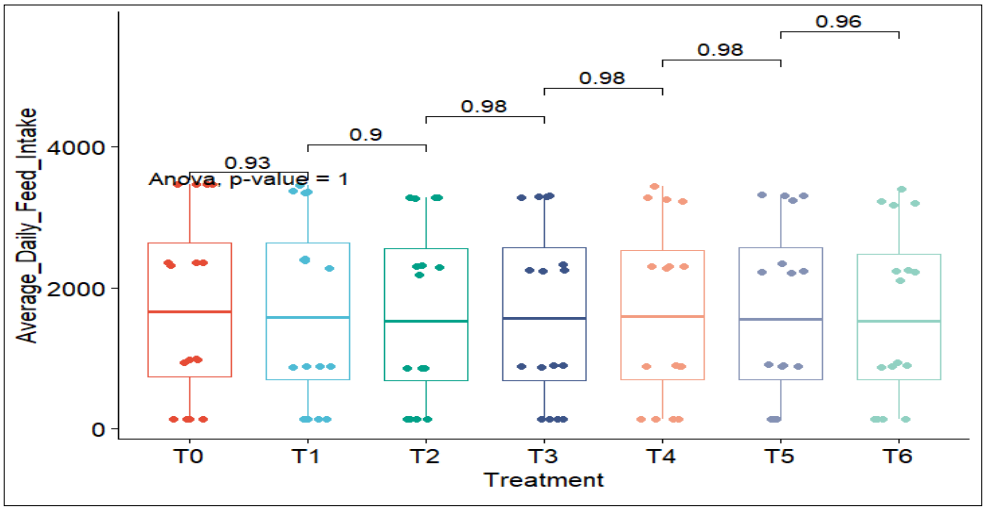

Fig 4: Visualization of ANOVA and post-hoc tests for ADFI.

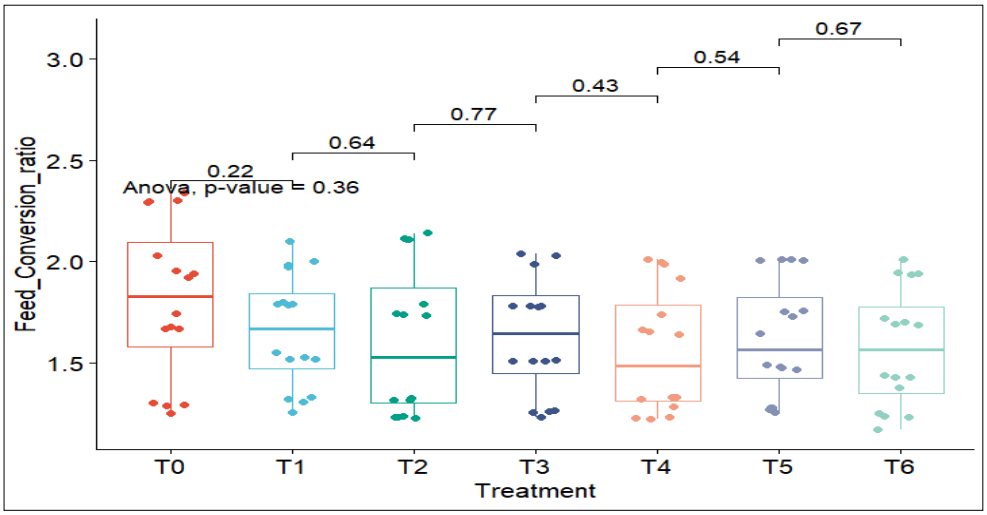

Fig 5: Visualization of ANOVA and post-hoc tests for FCR.

Table 4: Feed conversion ratio (FCR) of broiler chickens (Pooled data).

Treatment	d 0-6	d 7-21	d 22-42	d 0-42
T_0	1.28^{ab}	1.69	2.31	1.96
T_1	1.3^{a}	1.53^{a}	2.12	1.79^{ab}
T_2	1.23^{fgi}	1.51^{a}	2.02^{abc}	1.78^{ac}
T_3	1.25^{cdf}	1.48	2.01^{ade}	1.75^{bcd}
T_4	1.24^{dgh}	1.42	2.01^{bdf}	1.72^{de}
T_5	1.27^{bc}	1.33^{b}	1.98^{cefg}	1.7^{ef}
T_6	1.22^{hi}	1.32^{b}	1.96^{g}	1.67^{f}
S. Ed	0.02	0.01	0.02	0.02
CD	0.04	0.03	0.05	0.05
CV	2.12	8.07	5.48	4.99
F-statistic	5.53	214.01	54.08	30.04
p-value	0.00	0.00	0.00	0.00

Table 5: Body weight (BW) and broiler performance efficiency index (BPEI) of broiler chickens (Pooled data).

Treatment	Body weight	BPEI
T_0	1748.8	142.65
T_1	1885.02^{bcefg}	168.59^{c}
T_2	1862.59^{defh}	160.26
T_3	1857.43^{gh}	169.86^{c}
T_4	2011.92	209.68^{b}
T_5	1898.57^{acd}	213.47^{ab}
T_6	1914.38^{ab}	215.94^{a}
S. Ed	17.45	2.70
CD	37.87	5.85
CV	4.17	14.97
F-statistic	30.28	240.62
p-value	0.00	0.00

During this early phase (Days 0-6), the study noted moderate yet statistically significant variations in FCR among the treatments (F-statistic = 5.53, p-value = 0.00). This is in line with Zou (2018) observations, which highlighted the early influence of dietary additives on young broilers' feed efficiency. The initial days post-hatching are crucial and even subtle dietary modifications can set the trajectory for future feed utilization efficiency. (Days 7-21), a noteworthy reduction in FCR was observed with treatment T_5 (basal diet + 0.25% Garlic + 0.25% Cinnamon), registering the lowest FCR of 1.33. This aligns with the findings of Krauze *et al*. (2021), who reported the potent effects of Garlic and Cinnamon in enhancing nutrient absorption and metabolic efficiency. The bioactive compounds in these spices appear to play a significant role in optimizing feed conversion during this critical growth phase.

In the later growth phase and overall, treatment T_6 (basal diet + 0.25% Ginger + 0.25% Cinnamon) demonstrated the most efficient FCR. These results resonate with recent studies, such as those by Shehata (2022), which underscore the synergistic effects of Ginger and Cinnamon in improving feed utilization. The combination of these spices seems to enhance digestive

Table 6: Economics analysis of broiler chickens as influenced by herbal dietary additives (Pooled data).

Treatment	Total cost of production (Rs./Bird)	Average price realized @ Rs. 105 per kg live weight (Rs.)	Net profit per bird (Rs.)	Benefit cost ratio
T_0	139.9	150.9	9.47	1.32
T_1	143.7	161.2	18.51	1.48
T_2	141.2	159.5	12.09	1.45
T_3	140.3	158.8	10.96	1.42
T_4	150.4	166.5	25.17	1.59
T_5	145.4	162.5	19.27	1.52
T_6	149.5	164.4	22.15	1.56

processes and nutrient uptake, leading to a more efficient conversion of feed into body mass.

Body weight and broiler performance efficiency index

The research examining the effects of dietary supplements on body weight (BW) and broiler performance efficiency index (BPEI) across various treatments, from T_0 to T_6, offers pivotal insights into broiler chicken growth and efficiency (Table 5). Which indicate the highest live weight (g) was obtained in T_4 (2011.92 g) followed by T_6 (1914.38 g) treatments. The zero days average live weights of each treatment were comparable. The final body weight of birds was significantly ($P<0.001$) higher in all supplemented treatment groups in comparison to control. The significant increase in final body weight of birds fed garlic and ginger confirms the findings of Tikate *et al*., 2008) who fed herbal plants (garlic and ginger) as growth promoters in broiler diets and observed a pronounced improvement in their body weight. Better performance was observed when basal diet with combination of 0.25% garlic and 0.25% ginger were fed to broiler chickens. This may be due to synergistic effect of Garlic and Ginger. Synergistic feed additives operate by combining their individual effects to produce outcomes that are superior to those of their single use (Ren *et al*., 2019). These results might be due to the good health status of the birds, which may be caused by the addition of garlic and might also be due to the chemical composition of garlic Fadlalla *et al.* (2010). Farinu *et al*. (2004) also reported that the body weight of the cinnamon powder groups were increased significantly ($P<0.05$) when compared to the control group.

Quantitative analysis

The significant F-statistic and p-values for BW (30.28 and 0.00, respectively) and BPEI (240.62 and 0.00, respectively) strongly support these findings. These statistical figures indicate a pronounced difference between the treatment groups and the control, underscoring the effectiveness of the dietary interventions.

The study's finding that treatment T_4 (basal diet with 0.25% Garlic and 0.25% Ginger) led to the highest BW increase is in harmony with findings by Karangiya *et al.* (2016). These researchers highlighted the significant role of natural additives like Garlic and Ginger in boosting growth, potentially due to enhanced nutrient absorption and improved gut health. The recorded BW of 2011.92 grams in T_4, surpassing the control group's BW, underscores the efficacy of this dietary combination. For BPEI, treatment T_6 (basal diet with 0.25% Ginger and 0.25% Cinnamon) showed the most remarkable efficiency, with a score of 215.94. This aligns with the findings of Irawan (2021), who emphasized the synergistic impact of Ginger and Cinnamon on overall broiler performance. Such combinations are thought to enhance metabolic efficiency, thereby improving the broilers' overall growth and health.

Economics

Higher broiler production with lesser cost of cultivation could result in better economic parameters like net returns and B: C ratio (Table 6). Moreover, broilers in treatment groups T_4 gained highest body weight with feed cost of Rs. 150.4 and lowest in T_0 (control) group gained lowest body weight with feed cost Rs. 139.9. Highest profit per bird was observed in T_4 (basal diet with 0.25% garlic and 0.25% ginger) (Rs. 25.17) followed by T_6 (basal diet with 0.25% ginger and 0.25% Cinnamon (Rs. 22.15) and other treatments while lowest in T_0 (9.47). Similarly highest benefit cost ratio (1.59) was found in T_4 supplemented with garlic and ginger powder followed by T_6 (1.56). Present findings are in agreement with (Arshad *et al*., 2012; Eltazi, 2014).

CONCLUSION

The research establishes that incorporating 0.25% garlic and 0.25% ginger into the basal diet of broilers significantly enhances their growth performance. This dietary approach notably improves average daily gain, feed conversion ratio, broiler performance efficiency index, body weight, highest profit per bird and benefit cost ratio. Furthermore, the combination of 0.25% ginger and 0.25% cinnamon also demonstrates a positive impact on growth metrics. These findings highlight the efficacy of garlic and ginger at specific concentrations as potent dietary supplements for broiler chickens. From the result of present study it was concluded that dietary inclusion of 0.25% garlic and 0.25% ginger can be used as growth promoters for more profit per bird.

They underscore the potential of these natural additives in promoting healthier and more efficient poultry growth. This research paves the way for more sustainable and natural approaches in poultry nutrition.

Conflict of interest

All authors declare that they have no conflicts of interest.

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