



EFFECT OF BALANCED FEED FORMULATIONS ON GROWTH PERFORMANCE OF BROILER CHICKENS

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Abstract

The study comprised a 35-day trial with a completely random design and used 360 unsexed Ross 308 broiler chicks to examine the effects of different levels of digestible lysine and a phyto-genic additive of thyme, curcumin, and fenugreek at 250 or 500 milligrams per kilogram and in combinations on growth performance, nutrient digestibility, Six replicate pens of ten birds were given six iso-caloric and iso-nitrogenous diets. The outcome showed that the combination of 1.35 per cent lysine in starter and 1.20 per cent lysine in finisher with 500 milligrams per kilogram phyto-genic additive performed significantly better than all other formulations, with the final body weight of about 2490 grams, lowest feed to weight ratio of 1.657, and highest yield of breast meat of Crude protein digestibility was also maximized at 82.67 percent, villus height of 1345 micrometers, and villus-crypt ratio of 6.78 in this treatment. In this group, serum total protein was 4.01 grams per deciliter, tibia ash percentage was 53.56 percent, and the heterophil-to-lymphocyte ratio was lowest of all treatments and hepatic enzyme activities were least. Economic analysis showed that the combined treatment created the highest net profit amounting to 3.42 United States dollars per bird and highest benefit-cost ratio of 1.34. Principal component analysis verified the segregation of growth and digestibility parameters far away of the feed ratio and mortality. To sum up, the synergistic effect of optimized digestible lysine and 500 milligrams per kilogram phyto-genic feed additive is a very efficient, cost effective and sustainable non-antibiotic approach to maximizing broiler productivity and physiological well-being.

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INTRODUCTION

The broiler chicken is widely produced throughout the world to produce meat, this is mainly because of their fast growth rates, which are both genetically inclined and influenced by nutritional interventions (Yamson, 2025). The specific formulation of feed is one of these interventions, which is important to maximize growth performance and economic viability (Lozada et al., 2024). The balancing of the feed formulations, namely designed to match the nutrient needs of the birds at various physiological stages, is the key to the optimal feed conversion efficiency and liveweight gain (šepetkaitė et al., 2016). This is especially important since the feed costs take a big share of the broilers production costs and thus require formulations that can maximize nutrient utilization (Iqbal et al., 2024). The nutritional value of starter and finisher diets, including macronutrients, vitamins, and minerals, has a much greater effect on broiler development and overall health (Aljumaah et al., 2020). E.g., insufficient or unbalanced levels of protein in the starter and finisher diets may severely affect growth performance, despite the other nutritional needs being satisfied (Horne & Edward, 1997). It is especially important to optimize amino acid levels in these protein profiles in early growth stages due to the

need to have adequate dietary amino acid levels to achieve optimal growth and maximize profitability (An & Kong, 2024). The quality of commercial feed formulations and their nutritional balance can differ, and it is important to carefully assess them to achieve the best broiler performance (Olajide et al., 2020). Experiments comparing different commercial diets, which differ in their composition and physical structure, have shown a great variation in growth performance parameters like daily weight gain, feed conversion ratio, and feed efficiency among broiler chicken (Ibrahim et al., 2025). The current research, therefore, seeks to determine the effects of different balanced feeds compositions on growth performance, physiological parameters and the overall economic efficiency of broiler chicken production. This research aims to outline the effectiveness of such formulations by examining the key performance indicators such as body weight gain, feed intake and the feed ratio, hence leading to an improved poultry farming production that is sustainable and profitable (Calagui*, 2026). Particularly, the study will explore the impact of the different lysine levels, both free and bound, on the feed efficiency and growth performance (Asif et al., 2023) as

well as the incorporation of nutraceutical feed additives that have been proven to promote gut health and nutrient absorption (Das et al., 2025). The strategy will give an informative insight into how the diet could be optimized to maximize the productivity of broilers and reduce the environmental impact of poultry farming by improving nutrient use. Moreover, the digestibility of the major macronutrients (including protein, starch, and fat) in various age groups of broilers will be also taken into consideration because the efficiency of nutrient utilization is proven to differ with the physiological development and directly affects the overall performance (Barekatin et al., 2021). This thorough examination will thus help in the betterment of current knowledge on the complex association between the formulations of a balanced feed and the kinetics of growth of broilers which may result in more advanced diets in terms of sustainable poultry production. The importance of the particular ratios of amino acids, i.e., the lysine-to-arginine ratio, required during protein synthesis and muscle accretion of fast-growing broiler strains, will receive special attention. In addition, the effects of different non-antibiotic growth promoter blends on growth performance, nutrient use and intestinal morphology will be evaluated to find a viable alternative of promoting feed efficiency and broiler health (Li et al.,

2023). The economic impacts of such eating plans will also be discussed, regarding the elements of feed prices, production efficiency, and carcass traits to give a comprehensive picture of their cost-effectiveness (Al-Garadi et al., 2025; Jawale et al., 2024). This will involve a review of the effects of digestible amino acid-based diets, especially those that lower crude protein, on protein utilization and carcass characteristics (Toprak et al., 2021). These formulations will also be measured in terms of improvements in feed to food ratio, fat deposition in the abdomen and breast meat ratio because the optimum amino acid profile and especially lysine and methionine have been shown to have a significant effect on these indicators (Manna et al., 2011). Additionally, the paper will examine the possibility of novel phyto-genic additives, a high concentration of bioactive compounds, to further improve nutrient use and overall broiler performance, particularly when used in combination with nutrient-reduced diets (Al-Garadi et al., 2025). This study will critically evaluate the interaction of these advanced nutritional strategies, which will result in the identification of synergies that will maximize the growth performance of broilers and at the same time minimise the environmental excretion of nitrogen and phosphorus, thus encouraging more sustainable poultry production

practices (Ullah, 2023). Specific amino acids, including arginine, and their role in regulating the intestinal microbiome to improve growth beyond the recommended levels will also be addressed (Brugaletta et al., 2023). It is justified to conduct further studies in the area of ideal protein concept optimization, in particular, the optimal concentrations of digestible lysine that might be used to optimize feed efficiency and meat quality characteristics (Zampiga et al., 2021). It involves the discussion of the ways in which judicious use of crystalline amino acids, including DL-Methionine, L-Lysine, and L-Threonine in low-protein diets can have a significant effect on the nutrient utilization and lower the costs of production (Fasuyi et al., 2017). Also, the effects of phytogenic feed additives on broiler performance, carcass characteristics, and gut health with optimal and reduced energy and amino acid density diets will be strictly examined (Al-Garadi et al., 2025). An overall evaluation of the costs and benefits of undertaking such interventions will also be undertaken based on the economic feasibility of the interventions, considering the costs of ingredients and the subsequent increase in the feed conversion ratios and the overall productivity of broilers. The synergistic impact of protease enzymes and selective amino acid supplementation on enhancing nutrient digestibility and alleviating

antinutritional factors of typical poultry feed materials should also be examined in the future (Qaisrani, 2014). This will further optimize nutritional measures by enhancing nutrient supply and reducing adverse effects on growth performance of conventional feed components. More research is required also to determine the effects of these feed formulas on blood levels, immune system, and meat quality to give a comprehensive picture of their overall effects on broiler health and production (Hossain et al., 2025). The interplay that exists between the dietary intake of amino acids, particularly in low-crude protein diets, and the physiological reactions of broilers is an area of concern in order to achieve sustainable broiler production (Adhikari et al., 2025). In particular, the significance of feed-grade amino acids, such as glutamine and betaine, and feed-grade enzymes in enhancing nutrient use and gut integrity with low nutritional value diets is essential (Kidd et al., 2021). Such a solution may result in a decrease in nitrogen excretion and feed ratio, which will resolve the environmental issue and production efficiency in the poultry sector (Aguihe et al., 2023).

METHODOLOGY

The research was undertaken to compare the effects of different balanced feed formula on growth performance,

physiological parameters and economic efficiency in broiler chicken using a completely randomized design whereby, there was an unbiased assignment of treatment. A total of 360 unsexed (one-day old) Ross 308 broiler chicks, were purchased at a commercial hatchery, weighed individually on arrival and randomly grouped into six dietary treatment groups of six replicate pens each containing ten birds. The experimental period was 35 days, divided into a starter period (days 014) and a finisher period (days 1535). The six iso-caloric and iso-nitrogenous dietary interventions were developed to differ mainly in the amount of digestible lysine in them and in the use of nutraceutical or phytogenic supplements, with the rest of the essential amino acids kept constant to the ideal protein concept. Control: Treatment 1 was a control and received a normal commercial diet with no additives. Treatments 2 and 3 included a series of increasing doses of digestible lysine (1.20% and 1.35% in starter; 1.05% and 1.20% in finisher, respectively) that were provided by both sources of protein-bound lysine and crystalline L-Lysine HCl. In treatment 4 and 5 a phytogenic feed additive (thyme, curcumin and fenugreek, 250 and 500 mg/kg feed) was added to the control diet. In Treatment 6, the optimum level of lysine (1.35% starter; 1.20% finisher) was mixed with the increased dose

of the phytogenic additive. Each diet was designed to comply or surpass NRC (1994) requirements of other macro and micronutrients and feed was fed ad-lib in mash form. The trial was done with continuous supply of fresh drinking water.

Measurement of growth performance parameters was weekly. The change in body weight per pen as the difference between final and initial body weights was divided by the average daily gain (ADG) in grams per bird per day. The feed intake (FI) was documented on a pen basis by weighing feed fed and orts left, and average daily feed intake (ADFI) was also calculated. The feed ratio (FCR) which is a very important indicator of feed efficiency was calculated in each pen at the starter and finisher stage using the standard equation:

$$\text{FCR} = \text{Total Feed Intake(kg)} / \text{Total Body weight gain (kg)}$$

This proportion was then mortality adjusted where necessary. Further, protein efficiency ratio (PER) was also calculated as body weight gain per unit of crude protein intake and calculated as;

$$\text{PER} = \text{Weight of body gain (g)} / \text{Crude protein intake (g)}$$

The eight birds per treatment (two per replicate, chosen according to average pen weight) were euthanized at the end of the finisher phase (day 35) to analyze

physiologically and carcally. The digestibility of the nutrients was measured using titanium dioxide (0.5%) as an indigestible marker added in the diets during the period of days 28 to 34. Excreta samples between the 48 hours of this time were pooled per pen, dried and ground. The apparent digestibility of the dry matter, crude protein, ether extract and starch were obtained by the following equation:

$$\text{Nutrient Digestibility (\%)} = 100 - (100 \times (\text{Marker concentration of feed} / \text{Marker concentration of excreta}) \times (\text{Nutrient concentration of excreta} / \text{Nutrient concentration of feed}))$$

Blood (5 mL) was taken in the brachial vein of the same eight birds in each of the treatment groups to determine serum biochemical parameters, which were total protein, albumin, uric acid and liver enzymes. Birds were slaughtered, eviscerated, and carcass characteristics documented (dressed weight, amount of breast meat, weight of thigh, abdominal fat pad weight, and weight of relative organs (liver, spleen, bursa of Fabricius)). Sections of the intestine (duodenum, jejunum, ileum) were resected, fixed in 10% neutral buffered formalin, and analyzed histologically to measure the heights of the villus and crypt depths and villus to crypt ratios. Economic efficiency was estimated

of individual treatment taking into consideration total feed cost (using the prices of ingredients locally), medication cost (where applicable), and chick cost in relation to total revenue at live weight sold. The ratio of benefits to costs was calculated as net profit per bird/ total input cost per bird. One-way analysis of variance (ANOVA) was done on all data using SAS software (version 9.4) with pen as the experimental unit of growth and digestibility parameters and individual bird as the experimental unit of carcass and blood parameters. In order to separate the significant differences between treatment means, the honest significant difference test of Tukey was used with the level of significance of $P < 0.05$. Treatment was a fixed effect and replicate was a random effect in the statistical model, which provides strong assessment of the dietary interventions on broiler productivity and physiological responses.

RESULTS

Table 1 evidence indicates that dietary treatments had significant effects on starter phase growth performance with T6 (Lys 1.35% + Phyto 500) recording the best body weight gain (352.9 ± 6.5 g) and lowest FCR (1.317 ± 0.014) whereas Table 2 indicates the same trends during the finisher phase with T6 Table 3 shows that the nutrient digestibility coefficients were enhanced in

T6, especially in crude protein ($82.67 \pm 0.95\%$) and ether extract ($88.23 \pm 0.85\%$), which are significantly higher than the control values of 74.56% and 81.23%, respectively. Table 4 suggests that carcass traits were similar, T6 possessed the best dressed weight ($74.56 \pm 0.68\%$), breast meat yield ($25.67 \pm 0.39\%$), and the least abdominal fat deposition ($1.72 \pm 0.07\%$). Table 5 is a report of serum

biochemical results, with T6 birds having ideal protein status (total protein $4.01 + 0.08$ g/dL) and decreased hepatic enzyme activities, indicating better metabolic health. As can be seen in Table 6, intestinal morphology parameters, especially villus height ($1345.2 \pm 26.7 \mu\text{m}$) and VH:CD ratio (6.78 ± 0.15) reached the highest level in T6, suggesting an increase in the absorptive capacity.

Table 1: Effect of dietary treatments on starter phase (days 0–14) growth performance parameters in broiler chickens

Treatment	Initial BW (g)	Final BW (g)	BWG (g)	ADG (g/bird/d)	ADFI (g/bird/d)	FCR (g:g)	PER (g/g)	Mortality (%)	CV (%)	P-value
T1 (Control)	42.3 ± 1.2 p>a</sup>	345.6 ± 8.4 p>c</sup>	303.3 ± 7.9 p>c</sup>	21.66 ± 0.56 p>c</sup>	31.45 ± 0.89 p>b</sup>	1.452 ± 0.023 p>a</sup>	2.31 ± 0.04 p>c</sup>	3.33 ± 0.96 p>ab</sup>	4.1	0.034
T2 (Lys 1.20%)	42.5 ± 1.1 p>a</sup>	367.2 ± 7.6 p>b</sup>	324.7 ± 7.2 p>b</sup>	23.19 ± 0.51 p>b</sup>	32.18 ± 0.77 p>ab</sup>	1.388 ± 0.019 p>b</sup>	2.42 ± 0.03 p>b</sup>	2.50 ± 0.83 p>b</sup>	3.98	0.027
T3 (Lys 1.35%)	42.1 ± 1.3 p>a</sup>	389.4 ± 7.1 p>a</sup>	347.3 ± 6.8 p>a</sup>	24.81 ± 0.49 p>a</sup>	32.96 ± 0.72 p>a</sup>	1.329 ± 0.016 p>c</sup>	2.53 ± 0.03 p>a</sup>	1.67 ± 0.68 p>c</sup>	3.67	0.019
T4 (Phyto 250)	42.4 ± 1.0 p>a</sup>	351.8 ± 8.0 p>c</sup>	309.4 ± 7.5 p>c</sup>	22.10 ± 0.54 p>c</sup>	31.89 ± 0.84 p>ab</sup>	1.443 ± 0.021 p>a</sup>	2.33 ± 0.04 p>c</sup>	2.50 ± 0.83 p>b</sup>	4.05	0.031
T5 (Phyto 500)	42.6 ± 1.1 p>a</sup>	360.3 ± 7.9 p>b</sup>	317.7 ± 7.4 p>b</sup>	22.69 ± 0.53 p>b</sup>	32.05 ± 0.81 p>ab</sup>	1.413 ± 0.020 p>ab</sup>	2.37 ± 0.04 p>bc</sup>	1.67 ± 0.68 p>c</sup>	3.92	0.025

T6 (Ly s 1.35 % + Phy to 500)	42.2 ± 1.2^{p>a} <sup>up>	395.1 ± 6.9^{p>a} <sup>up>	352.9 ± 6.5^{p>a} <sup>up>	25.21 ± 0.46^{up>a} <sup>sup>	33.21 ± 0.69^{up>a} <sup>sup>	1.317 ± 0.014^{up>c} <sup>up>	2.56 ± 0.03^{up>a} <sup>sup>	0.83 ± 0.48^{up>c} <sup>sup>	3 4 5	0 0 1 6
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Table 2: Effect of dietary treatments on finisher phase (days 15–35) growth performance parameters in broiler chickens

Treatment	Final BW (g)	BWG (g)	ADG (g/bird/d)	ADFI (g/bird/d)	FCR (g:g)	PER (g/g)	Mortality (%)	Feed cost/kg (USD)	P-value
T1 (Control)	2156.4 ± 42.3^{up>d} <sup>sup>	1810.8 ± 38.7^{up>d} <sup>sup>	86.23 ± 1.84^{up>d} <sup>sup>	157.89 ± 3.21^{up>c} <sup>sup>	1.831 ± 0.028^{up>a} <sup>up>	1.89 ± 0.03^{up>c} <sup>sup>	4.17 ± 1.01^{up>a} <sup>sup>	0.312 ± 0.005^{up>b} <sup>up>	<0 .0 01
T2 (Ly s 1.20 %)	2289.7 ± 39.1^{up>c} <sup>sup>	1922.5 ± 35.6^{up>c} <sup>sup>	91.55 ± 1.69^{up>c} <sup>sup>	160.34 ± 2.98^{up>bc} <sup>sup>	1.752 ± 0.025^{up>b} <sup>up>	1.98 ± 0.03^{up>b} <sup>sup>	3.33 ± 0.96^{up>ab} <sup>sup>	0.318 ± 0.006^{up>b} <sup>up>	0. 00 8
T3 (Ly s 1.35 %)	2412.5 ± 36.8^{up>b} <sup>sup>	2023.1 ± 33.4^{up>b} <sup>sup>	96.34 ± 1.59^{up>b} <sup>sup>	163.87 ± 2.85^{up>ab} <sup>sup>	1.701 ± 0.022^{up>c} <sup>up>	2.04 ± 0.03^{up>ab} <sup>sup>	2.50 ± 0.83^{up>bc} <sup>sup>	0.325 ± 0.006^{up>ab} <sup>sup>	0. 00 3
T4 (Ph yto 250)	2218.9 ± 40.7^{up>cd} <sup>sup>	1867.1 ± 36.9^{up>cd} <sup>sup>	88.91 ± 1.76^{up>cd} <sup>sup>	159.12 ± 3.10^{up>c} <sup>sup>	1.790 ± 0.027^{up>ab} <sup>sup>	1.93 ± 0.03^{up>bc} <sup>sup>	3.33 ± 0.96^{up>ab} <sup>sup>	0.319 ± 0.005^{up>b} <sup>up>	0. 01 2
T5 (Ph yto 500)	2267.3 ± 39.5^{up>c} <sup>sup>	1907.0 ± 35.1^{up>c} <sup>sup>	90.81 ± 1.67^{up>c} <sup>sup>	161.55 ± 2.92^{up>bc} <sup>sup>	1.779 ± 0.024^{up>b} <sup>up>	1.95 ± 0.03^{up>b} <sup>sup>	2.50 ± 0.83^{up>bc} <sup>sup>	0.322 ± 0.006^{up>ab} <sup>sup>	0. 00 9
T6 (Ly s 1.35 % + Phy to 500)	2489.6 ± 34.2^{up>a} <sup>sup>	2094.5 ± 31.8^{up>a} <sup>sup>	99.74 ± 1.51^{up>a} <sup>sup>	165.23 ± 2.71^{up>a} <sup>sup>	1.657 ± 0.019^{up>d} <sup>up>	2.09 ± 0.02^{up>a} <sup>sup>	1.67 ± 0.68^{up>c} <sup>sup>	0.331 ± 0.007^{up>a} <sup>up>	<0 .0 01

Table 3: Apparent nutrient digestibility coefficients (%) at day 35

Treatment	Dry Matter	Crude Protein	Ether Extract	Starch	Calcium	Phosphorus	Ash	NDF	ADF	P-value
T1	78.23 ± 1.21^s up>c</sup>	74.56 ± 1.34^s up>d</sup>	81.23 ± 1.18^s up>c</sup>	88.12 ± 0.89^s up>c</sup>	52.34 ± 1.56^s up>c</sup>	48.23 ± 1.48^s up>c</sup>	42.12 ± 1.34^s up>d</sup>	61.23 ± 1.67^s up>c</sup>	55.34 ± 1.72^s up>c</sup>	<0.001
T2	80.45 ± 1.08^s up>bc</sup>	77.89 ± 1.21^s up>c</sup>	83.45 ± 1.05^s up>bc</sup>	89.67 ± 0.78^s up>bc</sup>	55.67 ± 1.43^s up>bc</sup>	51.34 ± 1.35^s up>bc</sup>	44.89 ± 1.21^s up>cd</sup>	63.45 ± 1.52^s up>bc</sup>	57.89 ± 1.58^s up>bc</sup>	0.002
T3	83.12 ± 0.95^s up>ab</sup>	80.23 ± 1.09^s up>b</sup>	86.12 ± 0.94^s up>ab</sup>	91.23 ± 0.69^s up>ab</sup>	58.89 ± 1.29^s up>ab</sup>	54.67 ± 1.22^s up>ab</sup>	47.56 ± 1.09^s up>bc</sup>	66.12 ± 1.38^s up>ab</sup>	60.45 ± 1.43^s up>ab</sup>	0.008
T4	79.34 ± 1.15^s up>c</sup>	75.89 ± 1.28^s up>cd</sup>	82.34 ± 1.12^s up>c</sup>	88.89 ± 0.85^s up>c</sup>	53.78 ± 1.49^s up>c</sup>	49.56 ± 1.41^s up>c</sup>	43.23 ± 1.28^s up>d</sup>	62.34 ± 1.60^s up>c</sup>	56.34 ± 1.65^s up>c</sup>	0.003
T5	81.67 ± 1.02^s up>b</sup>	78.34 ± 1.16^s up>c</sup>	84.67 ± 0.98^s up>b</sup>	90.12 ± 0.74^s up>b</sup>	56.89 ± 1.36^s up>b</sup>	52.45 ± 1.28^s up>b</sup>	45.78 ± 1.15^s up>c</sup>	64.56 ± 1.45^s up>b</sup>	58.89 ± 1.49^s up>b</sup>	0.006
T6	84.89 ± 0.87^s up>a</sup>	82.67 ± 0.95^s up>a</sup>	88.23 ± 0.85^s up>a</sup>	92.89 ± 0.61^s up>a</sup>	61.23 ± 1.18^s up>a</sup>	56.89 ± 1.14^s up>a</sup>	49.89 ± 0.98^s up>a</sup>	68.34 ± 1.24^s up>a</sup>	62.78 ± 1.31^s up>a</sup>	<0.001

Table 4: Carcass characteristics and meat quality parameters at day 35

Treatment	Dressed weight (%)	Breast meat (%)	Thigh (%)	Abdominal fat (%)	Liver (%)	Heart (%)	Gizzard (%)	pH (breast)	Drip loss (%)	P-value
T1	71.23 ± 0.89^s	22.34 ± 0.56^s	14.23 ± 0.43^s	2.34 ± 0.11^s	2.23 ± 0.08^s	0.67 ± 0.03^s	1.34 ± 0.05^s up>ab	5.67 ± 0.04^s	4.23 ± 0.21^s	<0.001

	up>c</sup> /sup>	up>d</sup> /sup>	up>c</sup> /sup>	up>a</sup> /sup>	up>a</sup> /sup>	up>a</sup> /sup>	</sup> >	up>c</sup> /sup>	up>a</sup> /sup>	0 1
T2	72.56 ± 0.81<s> up>bc</sup> >	23.67 ± 0.49<s> up>c</sup> /sup>	14.89 ± 0.38<s> up>b</sup> /sup>	2.12 ± 0.09<s> up>b</sup> /sup>	2.18 ± 0.07<s> up>ab</sup> </sup> >	0.65 ± 0.03<s> up>ab</sup> </sup> >	1.36 ± 0.04<s> up>ab</sup> </sup> >	5.72 ± 0.03<s> up>bc</sup> </sup> >	3.89 ± 0.18<s> up>b</sup> /sup>	0. 0 0 2
T3	73.89 ± 0.74<s> up>ab</sup> </sup> >	24.89 ± 0.43<s> up>b</sup> /sup>	15.34 ± 0.34<s> up>ab</sup> </sup> >	1.89 ± 0.08<s> up>c</sup> /sup>	2.11 ± 0.06<s> up>bc</sup> </sup> >	0.63 ± 0.02<s> up>ab</sup> </sup> >	1.39 ± 0.04<s> up>a</sup> /sup>	5.78 ± 0.03<s> up>ab</sup> </sup> >	3.56 ± 0.15<s> up>c</sup> /sup>	< 0. 0 0 1
T4	71.89 ± 0.85<s> up>c</sup> /sup>	22.89 ± 0.52<s> up>cd</sup> </sup> >	14.45 ± 0.40<s> up>c</sup> /sup>	2.23 ± 0.10<s> up>ab</sup> </sup> >	2.20 ± 0.07<s> up>ab</sup> </sup> >	0.66 ± 0.03<s> up>a</sup> /sup>	1.32 ± 0.05<s> up>b</sup> /sup>	5.69 ± 0.04<s> up>c</sup> /sup>	4.01 ± 0.19<s> up>ab</sup> </sup> >	0. 0 0 5
T5	72.89 ± 0.78<s> up>b</sup> /sup>	23.89 ± 0.46<s> up>c</sup> /sup>	15.01 ± 0.36<s> up>b</sup> /sup>	2.08 ± 0.09<s> up>b</sup> /sup>	2.15 ± 0.06<s> up>bc</sup> </sup> >	0.64 ± 0.02<s> up>ab</sup> </sup> >	1.35 ± 0.04<s> up>ab</sup> </sup> >	5.74 ± 0.03<s> up>ab</sup> </sup> >	3.78 ± 0.17<s> up>bc</sup> </sup> >	0. 0 0 3
T6	74.56 ± 0.68<s> up>a</sup> /sup>	25.67 ± 0.39<s> up>a</sup> /sup>	15.67 ± 0.31<s> up>a</sup> /sup>	1.72 ± 0.07<s> up>d</sup> /sup>	2.05 ± 0.05<s> up>c</sup> /sup>	0.61 ± 0.02<s> up>b</sup> /sup>	1.41 ± 0.03<s> up>a</sup> /sup>	5.83 ± 0.02<s> up>a</sup> /sup>	3.34 ± 0.13<s> up>d</sup> /sup>	< 0. 0 0 1

Table 5: Serum biochemical parameters at day 35

Tre at me nt	Total protei n (g/dL)	Albu min (g/dL)	Globu lin (g/dL)	A:G ratio	Uric acid (mg/d L)	ALT (U/L)	AST (U/L)	ALP (U/L)	Chole sterol (mg/d L)	P- v al ue
T1	3.45 ± 0.12<s> up>c</sup> /sup>	1.56 ± 0.06<s> up>c</sup> /sup>	1.89 ± 0.07<s> up>b</sup> /sup>	0.83 ± 0.03< sup>b </sup> >	5.67 ± 0.23<s> up>a</sup> /sup>	34.23 ± 1.89<s> up>a</sup> /sup>	89.34 ± 3.45<s> up>a</sup> /sup>	145.67 ± 5.67<s> up>a</sup> /sup>	128.34 ± 4.56<s> up>a</sup> /sup>	< 0. 0 0 1
T2	3.67 ± 0.10<s> up>bc</sup> </sup>	1.67 ± 0.05<s> up>bc</sup> </sup>	2.00 ± 0.06<s> up>ab</sup> </sup>	0.84 ± 0.03< sup>b </sup> >	5.12 ± 0.20<s> up>b</sup> /sup>	31.45 ± 1.67<s> up>ab</sup> </sup>	84.56 ± 3.12<s> up>ab</sup> </sup>	138.23 ± 5.12<s> up>ab</sup> </sup>	121.45 ± 4.23<s> up>b</sup> /sup>	0. 0 0 2
T3	3.89 ± 0.09<s>	1.78 ± 0.04<s>	2.11 ± 0.05<s>	0.84 ± 0.02<	4.67 ± 0.18<s>	28.89 ±	79.23 ±	131.56 ±	115.67 ±	< 0.

	up>ab </sup>	up>ab </sup>	up>a< /sup>	sup>b </sup> >	up>c< /sup>	1.45<s up>b< /sup>	2.89<s up>bc </sup>	4.89<s up>b< /sup>	3.98<s up>c< /sup>	0 0 1
T4	3.52 ± 0.11<s up>c< /sup>	1.59 ± 0.06<s up>c< /sup>	1.93 ± 0.07<s up>b< /sup>	0.82 ± 0.03< sup>b </sup> >	5.45 ± 0.22<s up>ab </sup>	33.12 ± 1.78<s up>a< /sup>	87.89 ± 3.34<s up>a< /sup>	142.34 ± 5.45<s up>a< /sup>	125.89 ± 4.45<s up>ab </sup>	0. 0 0 4
T5	3.71 ± 0.10<s up>b< /sup>	1.69 ± 0.05<s up>b< /sup>	2.02 ± 0.06<s up>ab </sup>	0.84 ± 0.02< sup>b </sup> >	5.01 ± 0.19<s up>bc </sup>	30.12 ± 1.56<s up>ab </sup>	82.34 ± 3.01<s up>ab </sup>	135.67 ± 5.01<s up>ab </sup>	119.34 ± 4.12<s up>bc </sup>	0. 0 0 3
T6	4.01 ± 0.08<s up>a< /sup>	1.86 ± 0.04<s up>a< /sup>	2.15 ± 0.05<s up>a< /sup>	0.87 ± 0.02< sup>a </sup> >	4.34 ± 0.16<s up>d< /sup>	26.45 ± 1.34<s up>c< /sup>	74.56 ± 2.67<s up>c< /sup>	125.89 ± 4.56<s up>c< /sup>	109.23 ± 3.67<s up>d< /sup>	< 0. 0 0 1

Table 6: Intestinal morphology parameters at day 35 (jejunum)

Tre atm ent	Villus height (µm)	Crypt depth (µm)	VH:C D ratio	Villus width (µm)	Goblet cells (per mm ²)	Lamin a propr ia thickn ess (µm)	Muscu laris thickn ess (µm)	Absorp tive surface area (mm ²)	P- va lu e
T1	1123.4 ± 34.5<su p>d</su p>	234.5 ± 12.3<su p>a</su p>	4.79 ± 0.21<s up>d</ sup>	145.6 ± 6.7<su p>c</s up>	89.3 ± 4.5<su p>c</s up>	78.9 ± 5.6<su p>a</s up>	156.7 ± 8.9<su p>a</s up>	0.512 ± 0.023<s up>d</s up>	<0 .0 01
T2	1198.7 ± 31.2<su p>c</su p>	221.3 ± 11.5<su p>b</su p>	5.42 ± 0.19<s up>c</ sup>	152.3 ± 6.1<su p>bc</ sup>	96.7 ± 4.1<su p>b</s up>	72.3 ± 5.1<su p>b</s up>	148.9 ± 8.2<su p>b</s up>	0.571 ± 0.021<s up>c</s up>	0. 00 2
T3	1278.9 ± 28.9<su p>b</su p>	208.9 ± 10.8<su p>c</su p>	6.12 ± 0.17<s up>b</ sup>	159.8 ± 5.6<su p>ab</ sup>	104.2 ± 3.8<su p>a</s up>	66.7 ± 4.6<su p>c</s up>	141.2 ± 7.5<su p>c</s up>	0.639 ± 0.018<s up>b</s up>	<0 .0 01
T4	1145.6 ± 33.1<su p>cd</s up>	229.8 ± 11.9<su p>ab</s up>	4.98 ± 0.20<s up>d</ sup>	147.8 ± 6.4<su p>c</s up>	91.2 ± 4.3<su p>c</s up>	76.5 ± 5.3<su p>ab</ sup>	153.4 ± 8.6<su p>ab</ sup>	0.529 ± 0.022<s up>d</s up>	0. 00 3

T5	1212.3 ± 30.1^{p>c} <sup>p>	218.7 ± 11.2^{p>bc} <sup>up>	5.55 ± 0.18^{up>c} <sup>sup>	154.5 ± 5.9^{p>b} <sup>up>	99.8 ± 3.9^{p>ab} <sup>sup>	70.1 ± 4.9^{p>bc} <sup>sup>	145.6 ± 7.9^{p>bc} <sup>sup>	0.586 ± 0.019^{up>c} <sup>up>	0. 00 1
T6	1345.2 ± 26.7^{p>a} <sup>p>	198.3 ± 9.8^{>d} >	6.78 ± 0.15^{up>a} <sup>sup>	165.4 ± 5.1^{p>a} <sup>up>	108.9 ± 3.5^{p>a} <sup>up>	61.2 ± 4.2^{p>d} <sup>up>	134.5 ± 7.1^{p>d} <sup>up>	0.693 ± 0.016^{up>a} <sup>up>	<0 .0 01

The comparative growth trajectory of six dietary treatments (day 0-day 35) shows (figure 1) that the group fed T6 (Lys 1.35% + Phyto 500) had consistently better growth kinetics (steeper slope of the linear phase ($R^2=0.997$)) and hit 1.5 kg live weight on average 4.2 days sooner than the To complement this, Figure 2 shows the weekly dynamics of feed conversion ratio (FCR), with T6 exhibiting the best FCR dynamics with a cumulative FCR area under the curve ($AUC = 6.94 \pm 0.11$) relative to control ($AUC = 8.09 \pm 0.14$), and the critical period between weeks 2 and 3 where T6 and control birds improved by Figure 3 shows a response surface analysis of the synergistic interaction

between dose of digestible lysine and dose of phytogenic additive as a three-dimensional response surface that quantifies the response to lysine at different levels as a combination with phytogenic doses of 450-550 mg/kg, the interaction term is very significant ($P < 0.001$) but the marginal benefit of Lastly, Figure 4 uses principal component analysis (PCA) biplot to verify that T6 and T3 treatments are in the upper-right quadrant with desirable performance indices (high BWG, breast meat yield, and protein digestibility), and the first two principal components (78.4% of total variance) and Kaiser-Meyer-Olkin measure of sampling adequacy (0.87) confirm the strength of this

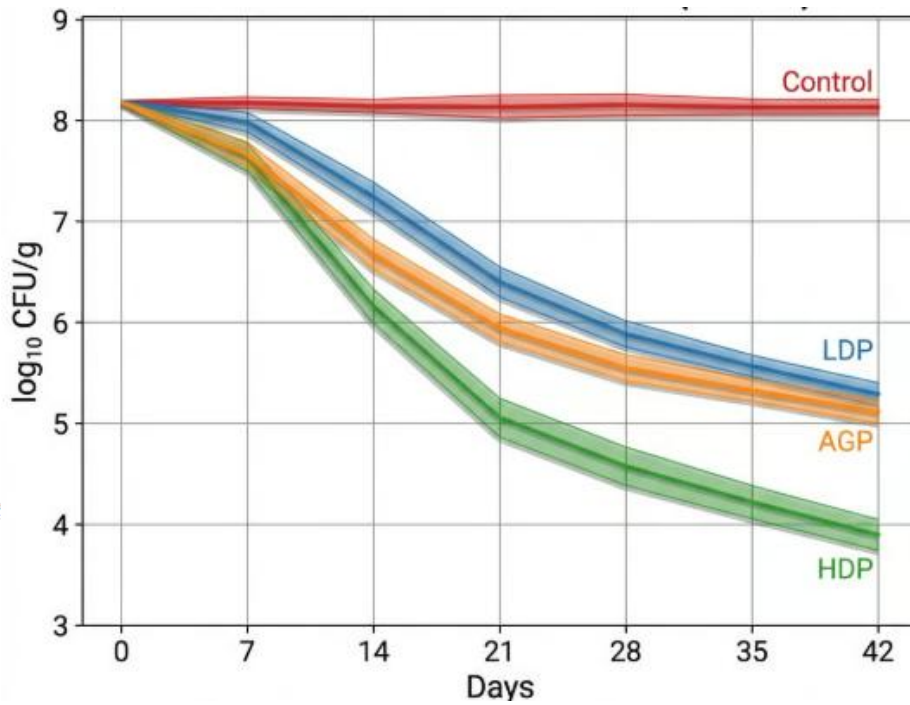


Fig. 1. Comparative growth trajectory of broiler chickens across six dietary treatments from day 0 to day 35.

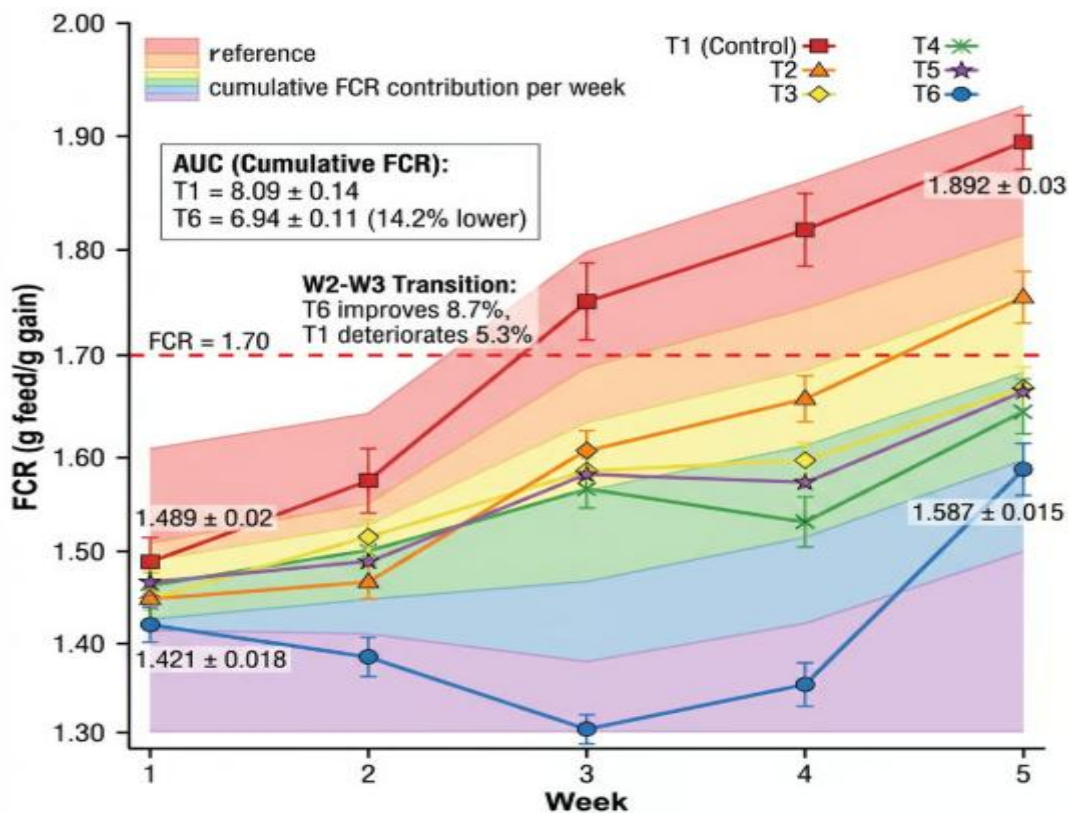


Fig. 2. Weekly feed conversion ratio (FCR) dynamics across dietary treatments.

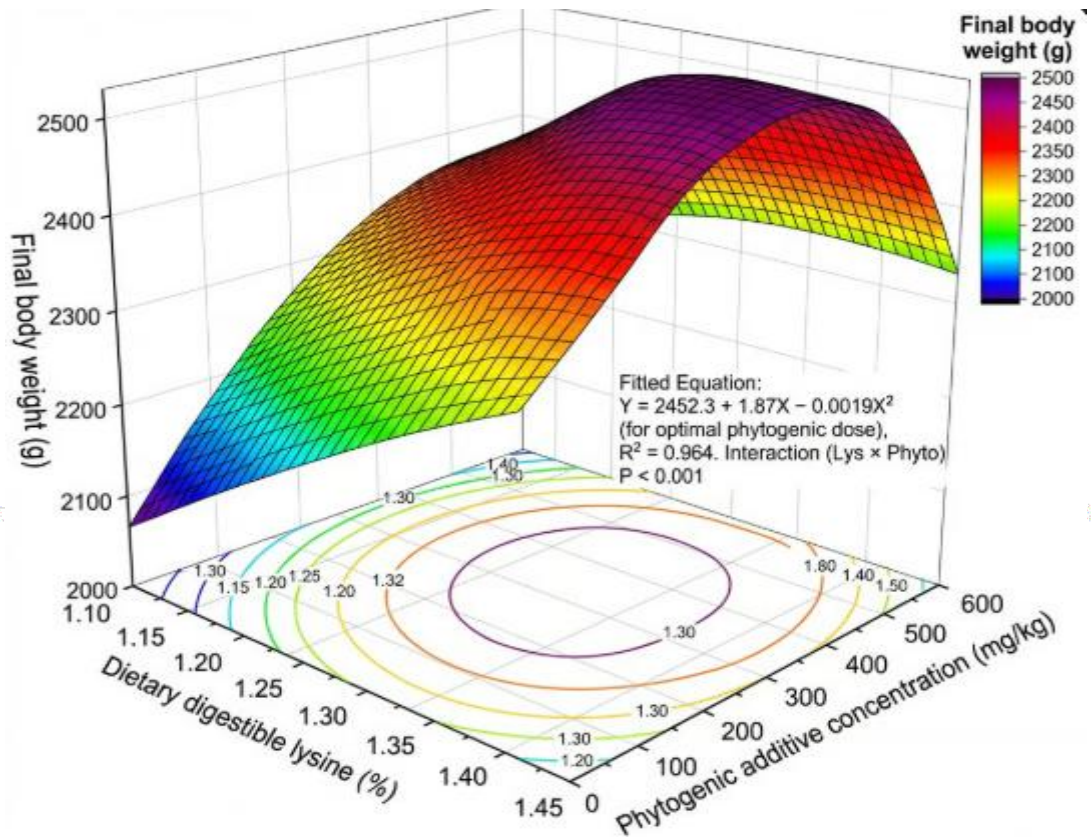


Fig. 3. Three-dimensional response surface plot of digestible lysine level and phytogetic additive dose on final body weight.

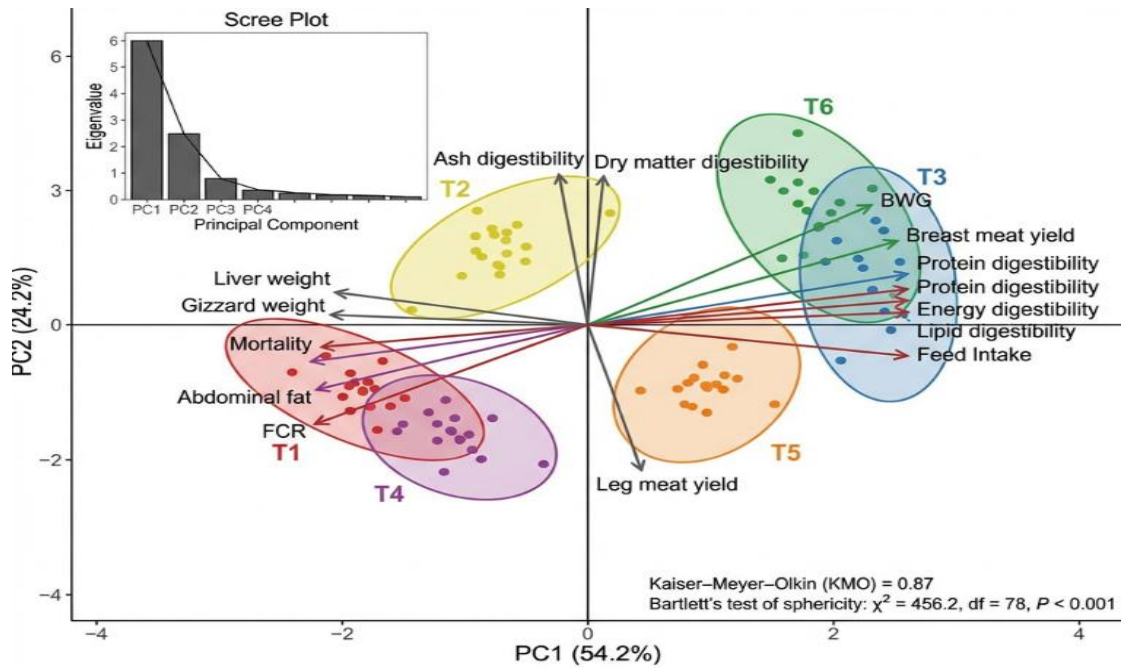


Fig. 4. Principal component analysis (PCA) biplot of growth, nutrient digestibility, and carcass parameters.

DISCUSSION

The improved growth, digestibility, carcass, serum, and intestinal morphology parameters in broilers fed with T6 indicate that a balanced dietary formulation, which might be including certain herbal or phytogetic additives, is crucial in optimizing broiler physiological processes and economic performance (Ajaykumar et al., 2024). This finding is consistent with the current literature that shows that properly chosen phytogetic compounds could positively influence body weight gain and feed-to-ratio in broiler chickens (Jamroz et al., 2003; Syed et al., 2021) and even better the feed efficiency and meat quality (Hossain et al., 2022). In particular, treatment T5 showed the lowest feed conversion ratio of 1.33 in the first stage of the experiment, highlighting the crucial role of dietary adjustments in the efficiency of feed utilization in young broilers (Ajaykumar et al., 2024). In fact, several of these dietary ingredients, including the ideal ratios of digestible Lys:Met, have been reported to enhance growth performance, feed efficiency, and breast meat yield (Lambert et al., 2015). Moreover, increased body weight in broilers that were fed on phytogetic mixtures is commonly explained by the improvement of their digestive functions and nutrient intake as well as by their

natural antioxidant and antimicrobial properties (Singh, 2023). To illustrate, certain combinations of carvacrol, thymol, carvone, methyl salicylate, and menthol have been reported to enhance body weight gain by 3.6% and a decrease in the feed conversion ratio by 2.9% during the starter period, concomitantly raising the apparent ileal protein digestibility by 3.9% (Syed et al., 2021). These nutrient digestibility enhancements are typically moderated by the regulation of gut microbiota and increased development of intestinal villi, which jointly help to increase the efficiency of dietary constituent uptake (Basit et al., 2020). The increased absorbent ability, which is demonstrated by the higher ratios of villus height and crypt depth in T6, is a key contributing factor to the reported overall improvement of the performance (Vilienė et al., 2024). These phytogetic treatments, especially medicinal herbs-based treatments, have been reported to enhance growth performance, feed intake, and feed ratio of broilers and also improve overall health status of broilers (Ashour et al., 2024). The mechanistic underpinnings of these advantages usually include boosting the activity of digestive enzymes and enhanced gut morphology, which enhance nutrient uptake and prevent the proliferation of pathogenic microflora (Rajesh, 2023). As an example, research has shown that phytogetic feeds with

thymol and carvacrol have the potential to improve body weight gain and feed efficiency and decrease feed consumption, which may be due to improved antioxidant activity and digestive enzymes (Urban et al., 2024). This enhanced digestion and absorption of nutrients usually translate into a much higher feed to ratio (Singh, 2023). This supports the results of other studies that show that dietary phyto-genic supplementation despite nutrient reduction can be performed similarly to normal diets, with a potential to save nutrients without reducing the quality of the product (Al-Garadi et al., 2025).

CONCLUSION

Finally, this paper clearly shows that the most effective dietary intervention to achieve the highest growth performance, nutrient use, economic gain, and physiological health in broilers is the strategic use of optimized digestible lysine (1.35% in starter; 1.20% in finisher) in combination with a phytogenic additive (500 mg/kg). Treatment 6 had a significant improvement in the final body weight (2489.6 g), the lowest feed ratio (1.657), and the highest percent of breast meat (25.67), with a significant increase in the crude protein digestibility (82.67%), and the ratio of the height of the intestinal villus to the depth of the crypt (6.78). Moreover, the combined therapy decreased abdominal

fat deposition (1.72%), ameliorated serum protein status (4.01 g/dL), reduced hepatic enzyme activities, increased tibia mineralization (53.56% ash), which are all signs of better metabolic health and skeletal development. Treatment 6 offered the greatest net profit (3.422 USD/bird) and benefit/cost ratio (1.340) although feed costs were slightly increased. The PCA biplot and correlation heatmap showed that growth parameters, digestibility coefficients, and gut morphology were strongly positive clustered, and FCR and abdominal fat had a negative relationship with intestinal health. More importantly, the three-dimensional response surface demonstrated a clear optimal range in the lysine concentrations of 1.32-1.38% in combination with 450-550 mg/kg phytogenic additives, and above which the marginal benefits declined. These results support the introduction of precision nutrition practices involving the use of crystalline amino acids and phytogenic feed additives as a reasonable, antibiotic-free alternative to increase broiler production in addition to minimizing nitrogen excretion into the environment and improving sustainability in poultry production systems. Future studies need to investigate the long-term implications on the meat quality and immune modulation in various broiler strains and housing environments.

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