



RESEARCH ARTICLE

Effects of Propolis as an Organic Growth Promoter on Growth Performance and Carcass Characteristics of Cobb 500 Broiler Chickens

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Abstract

Objective: This study aimed to evaluate the efficacy of propolis extract as a natural organic growth promoter on growth performance, carcass characteristics and meat quality of Cobb 500 broiler chickens, in comparison with a commercial broiler booster.

Materials and Methods: A total of 100 day-old broiler chicks were randomly allocated to five treatment groups: Control (CTR), commercial broiler booster (CBB) and propolis extract administered via drinking water at concentrations of 100 g/L (P1), 200 g/L (P2) and 300 g/L (P3). Birds were reared under deep-litter conditions for six weeks and fed standard starter, grower and finisher diets. Growth performance, carcass traits, organ weights and meat quality parameters were assessed at the end of the experimental period.

Results: Propolis supplementation at 100 g/L (P1) significantly improved feed conversion ratio, weight gain and muscle development, particularly breast and thigh weights, compared with the control group. Despite lower feed intake, birds in P1 exhibited higher weight gain, indicating superior feed efficiency. Meat quality analysis showed that P1 resulted in the lowest shear force and pH values, along with higher redness (a*) values, suggesting improved meat tenderness and enhanced antioxidant status. Organ weights, including liver, intestine and gizzard, were significantly higher in P1, indicating improved metabolic and digestive activity. In contrast, higher propolis concentrations (P2 and P3) were associated with reduced performance, demonstrating a dose-dependent response. Carcass weights were numerically higher in P1 and P3, although these differences were not statistically significant.

Conclusion: Propolis extract administered at 100 g/L in drinking water effectively enhanced growth performance, carcass characteristics and meat quality in broiler chickens. This dosage represents an optimal, natural and sustainable alternative to synthetic growth promoters, supporting improved poultry productivity while reducing reliance on antibiotics.

INTRODUCTION

Worldwide broiler production has become increasingly important due to the rising demand for poultry meat. It is estimated that approximately 66 billion broilers are slaughtered annually and poultry meat accounts for nearly 70% of total meat consumption worldwide¹. In Tanzania, the chicken population is estimated at 97.9 million, comprising 45.1 million indigenous chickens and 52.8 million improved commercial chickens². Rapid population growth in Tanzania is associated with increased demand for animal protein sources, including fish, eggs, meat, milk and dairy products, a trend expected to continue in the coming years³. Poultry meat is widely available, affordable and highly accepted and it constitutes an important component of the human diet due to its high nutritional value, moderate energy content, highly digestible proteins of superior quality, unsaturated lipids (primarily found in the skin and easily removed), B-group vitamins (particularly thiamine, vitamin B and pantothenic acid) and essential minerals such as iron, zinc and copper⁴. Broiler meat is regarded as one of the most cost-effective and sustainable sources of animal protein due to the birds' efficiency in converting feed into meat. Broilers are among the heaviest and fastest-growing livestock species globally and are characterized by rapid growth rates, low production costs per unit of live weight, superior feed efficiency and excellent breast muscle yield⁵.

Antibiotics have been widely used as growth promoters in poultry production because of their low cost, availability and ease of use⁶. Their application has transformed poultry production by reducing infections and improving gut health, thereby enhancing growth rate, feed conversion efficiency and overall productivity through increased intestinal thickness and improved nutrient absorption⁷. Research has demonstrated that antibiotics promote growth by suppressing toxic and nutrient-consuming microorganisms, thereby increasing nutrient availability to the host and reducing nutrient diversion toward immune responses in the gastrointestinal tract^{8,9}. However, prolonged and indiscriminate use of antibiotics in animal production has contributed to the emergence of antimicrobial resistance, leading to increased morbidity and mortality in livestock. In addition, improper antibiotic use has resulted in drug residues in animal products¹⁰, which pose potential risks to human health. Khaligh *et al.*¹¹ estimated that nearly 10 million people worldwide could die from antibiotic-resistant bacterial infections by 2050. These concerns have eroded consumer confidence in broiler products.

As an alternative to synthetic antibiotics, natural organic compounds with antimicrobial properties have gained increasing attention. Among these, propolis, a resinous substance produced by honeybees, has been widely studied due to its broad-spectrum antimicrobial, anti-inflammatory and antioxidant activities¹². Propolis is a natural brown, sticky hive product collected by bees from flowers, buds and plants and modified by enzymatic processes to seal, repair and polish the honeycomb, thereby protecting the hive from pathogens and predators. Previous studies have demonstrated the potential of propolis in poultry production by enhancing feed intake, feed conversion ratio and body weight gain in chickens^{1,13,14}. Furthermore, propolis supplementation has been associated with improved sensory attributes of breast meat, including taste, aroma, tenderness and juiciness, as well as enhanced digestibility, skin pigmentation, moisture retention, bone strength and breast muscle protein content^{9,11}. Tanzanian propolis, similar to propolis from other regions, has demonstrated strong antimicrobial activity; however, its efficacy varies depending on geographical origin within Tanzania. Although the antimicrobial and antiprotozoal properties of Tanzanian propolis are well established, its potential application as a growth promoter in poultry, particularly in broiler chickens, remains largely unexplored. Therefore, this study aimed to evaluate the efficacy of propolis extract as a natural growth-promoting agent on growth performance, carcass characteristics and meat composition of Cobb 500 broiler chickens.

MATERIALS AND METHODS

Collection of propolis and preparation of extracts: Ten kilograms of raw propolis were purchased from the Kigoma region of Tanzania. The propolis was divided into three bolus types based on weight: 100 g (P1), 200 g (P2) and 300 g (P3). A total of 51 boluses were prepared, comprising 18 P1, 17 P2 and 16 P3 boluses. Every three days, one bolus from each group was processed to produce Propolis Extract (PE). Each bolus was placed into a container containing one liter of water and heated in a water bath maintained at 100°C until complete melting occurred. The initial time of heating and the final time at which the propolis was fully dissolved were recorded. After melting, the mixture was allowed to settle and cool, after which the PE was separated from the residual solid material.

Experimental design and treatments: The experiment was conducted using a Completely Randomized Design (CRD) with five treatment groups. Treatment 1 (CTR) served as the

negative control, in which birds received untreated drinking water. Treatment 2 (CBB) served as the positive control and received drinking water supplemented with a commercial broiler booster known to enhance broiler growth. Treatment 3 (P1) received drinking water supplemented with PE prepared from 100 g of propolis per liter of water. Treatment 4 (P2) received PE prepared from 200 g of propolis per liter of water and Treatment 5 (P3) received PE prepared from 300 g of propolis per liter of water. For all propolis-treated groups, PE was administered via drinking water at a ratio of 0.1:1 (0.1 L of PE per 1 L of drinking water).

Source and management of experimental animals: A total of 100 day-old chicks (DOCs) were obtained from Irvines Company in Morogoro Municipality and transported to the poultry unit at DAARS, where they were reared for the six-week experimental period. All chicks were wing-tagged on day 1 and individually weighed to record initial body weights. The birds were brooded for the first two weeks in a well-ventilated facility. Rice hulls were used as deep litter at a depth of 4-5 cm to absorb moisture and maintain dryness and warmth. Birds were fed commercial broiler diets throughout the study: starter diet during the first two weeks, grower diet for the subsequent three weeks and finisher diet during the final week. Feed and water were provided twice daily. The quantity of feed offered and the residual feed were weighed using an automatic weighing balance and all measurements were recorded. Chicks were vaccinated against Newcastle disease on days 7 and 21 and against Gumboro disease on day 14.

Growth performance: Birds were weighed individually at the beginning of the experiment and subsequently at weekly intervals throughout the study period. Body weight and feed intake were measured using a digital balance. Average Feed Intake (AFI), Average Growth Rate (AGR) and Feed Conversion Ratio (FCR) were calculated using the following equations¹⁵:

$$\text{Average daily feed intake} = \frac{\text{Weight of feed provided} - \text{weight of leftover feed}}{\text{Total number of days during the data collection period}}$$

$$\text{Average growth rate} = \frac{\text{Final weight} - \text{initial liveweight}}{\text{Total number of experimental days}}$$

$$\text{Feed conversion ratio} = \frac{\text{Total feed intake}}{\text{Total weight gain}}$$

Carcass characteristics: At 42 days of age, 20 chickens (four birds per treatment) were randomly selected and humanely slaughtered. Feathers, head, feet and viscera were removed

and carcass weight was recorded. Each carcass was subsequently dissected into back, drumstick, breast, thigh and wing portions, which were weighed individually. The amounts of lean tissue, fat and bone from the breast and leg muscles, as well as abdominal fat weight, were also determined separately.

$$\text{Dressing (\%)} = \frac{\text{Carcass weight}}{\text{Live weight}} \times 100$$

The liver, gizzard, spleen, heart, bile, intestines and abdominal fat were obtained and weighed individually and calculated as a percentage of body weight.

Meat parameters: Meat tenderness of the thigh portion was evaluated using parallel muscle fiber strips measuring approximately $2 \times 2 \times 1$ cm. Shear force was determined using a Warner-Bratzler shear blade attached to a Zwick/Roell testing instrument (Z 2.5, Germany) and values were expressed in Newtons (N). Meat color was assessed on breast muscle samples using the CIELAB color system with a portable colorimeter (Minolta CR-200b, Osaka, Japan), which provided measurements of lightness (L^*), redness (a^*) and yellowness (b^*). Meat pH was measured in breast muscle samples using a spear-end digital portable pH meter (Knick Portamess® 910, Germany), calibrated with standard buffer solutions to ensure measurement accuracy.

Statistical analysis: All data were analyzed using R software (version 4.3.2). One-way analysis of variance (ANOVA) was performed to evaluate the effects of growth promoters (commercial booster and propolis extract) on feed intake, growth performance, carcass characteristics and meat quality parameters. Differences among treatment means were determined using Tukey's Honest Significant Difference (HSD) test at a significance level of $p < 0.05$. Results were expressed as means $\pm$ standard error of the mean (SEM).

Statistical model:

$$Y_{ij} = \mu + \tau_i + \epsilon_{ij}$$

Where:

Y_{ij} : Observed value of the dependent variable (e.g., feed intake, weight gain, organ weight) for the j^{th} replication in the i^{th} treatment group

μ : Overall mean

τ_i : Effect of the i^{th} treatment ($i = 1, 2, 3, 4, 5$ corresponding to CTR, CBB, P1, P2 and P3)

ϵ_{ij} : Random error associated with the observation, assumed to be independently and normally distributed with mean zero and constant variance [$\epsilon_{ij} \sim (0, \sigma^2)$]

RESULTS

Effects of growth promoters on meat quality of broiler chickens:

The effects of different growth promoters on meat quality parameters are presented in Table 1. Breast muscle shear force differed significantly among treatment groups ($p < 0.05$). The highest shear force values were observed in chickens from the control group (CTR), followed by those from P3, P2 and CBB ($p < 0.05$). However, differences among P3, P2 and CBB were not statistically significant ($p > 0.05$). The lowest shear force was recorded in chickens reared under P1, which differed significantly from all other treatments ($p < 0.05$).

Meat pH also differed significantly among treatments, with the highest pH observed in breast muscle from chickens in the CTR group ($p < 0.05$). The mean difference in pH between P3 and P2 was not significant ($p > 0.05$). The lowest pH values were recorded in chickens reared under CBB and P1 ($p < 0.05$), with P1 exhibiting the lowest overall pH among all treatments. Meat color parameters varied significantly across treatments ($p < 0.05$). Meat lightness (L^*) was highest in chickens reared under CTR, followed by those under P3, CBB and P1 ($p < 0.05$), while the lowest L^* value was observed in P2 ($p < 0.05$). Redness (a^*) differed significantly among treatments, with the highest value in P3, followed by P1, CTR and CBB ($p < 0.05$).

However, the difference in redness between CTR and CBB was not significant ($p > 0.05$) and the lowest a^* value was observed in P2 ($p < 0.05$). Meat yellowness (b^*) also differed significantly among treatments ($p < 0.05$), with higher b^* values observed in chickens reared under CTR and P2 ($p < 0.05$). Lower b^* values were observed in chickens reared under CBB, P1 and P3 ($p < 0.05$), although differences among these three groups were not statistically significant ($p > 0.05$).

Water-holding capacity (WHC) of breast meat differed significantly among treatments ($p < 0.05$). The highest WHC was observed in chickens reared under CTR, followed by those under P3. Lower WHC values were recorded in chickens reared under CBB, P1 and P2 ($p < 0.05$).

Effects of different growth promoters on growth performance of broiler chickens:

The effects of different growth promoters on growth performance are presented in Table 2. Total Feed Intake (TFI) differed significantly among treatments, with the highest intake observed in chickens receiving the Commercial Broiler Booster (CBB) and the lowest intake in chickens receiving 100 g of propolis per liter of water (P1) ($p < 0.05$). Mean differences in Average Daily Feed Intake (ADFI) were also significant among treatments ($p < 0.05$). ADFI was highest in chickens receiving CBB, followed by those receiving 300 g of propolis per liter of water (P3), while the lowest ADFI was observed in chickens reared without growth promoters (CTR).

Table 1: Effects of growth promoter on meat quality of broiler chickens

Parameters	Treatments					SEM	p-value
	CTR	CBB	P1	P2	P3		
Shear force (N)	36.19 ^a	34.83 ^{ab}	29.44 ^b	30.82 ^{ab}	32.43 ^{ab}	1.38	0.027
pH	6.17 ^a	5.72 ^b	5.71 ^b	5.92 ^{ab}	6.07 ^a	0.05	0.001
L	56.04 ^a	49.89 ^c	47.76 ^d	45.15 ^e	51.08 ^b	0.55	0.001
A	1.52 ^{ab}	1.52 ^{ab}	1.88 ^b	0.40 ^c	2.21 ^a	0.06	0.001
B	4.37 ^a	3.19 ^b	3.44 ^b	4.19 ^a	3.49 ^b	0.12	0.001
WHC	5.56 ^a	2.46 ^c	2.39 ^c	2.41 ^c	3.52 ^b	0.35	0.001

L: Lightness, ^aRedness, ^bYellowness and WHC: Water holding capacity

Table 2: Effects of growth promoters on the growth performance of broiler chickens

Parameters (G)	Treatments					SEM	p-value
	CTR	CBB	P1	P2	P3		
TFI	4375.60 ^b	4387.30 ^a	4092.45 ^e	4260.80 ^c	4206.950 ^d	0	0.001
ADFI	175.90 ^e	183.85 ^a	179.45 ^c	179.40 ^d	182.850 ^b	0	0.001
ILW	37.05	36.05	36.60	35.95	36.100	0.52	0.565
FLW	1851.05	1974.95	1968.20	1882.40	1935.450	46.91	0.727
TWG	1665.00 ^e	1928.32 ^b	1902.00 ^c	1796.22 ^d	1930.120 ^a	0	0.001
ADG	39.64 ^e	45.91 ^b	45.30 ^c	42.77 ^d	45.960 ^a	0	0.001
FCR	2.63 ^a	2.28 ^c	2.15 ^e	2.37 ^b	2.181 ^d	0	0.001

TFI: Total feed intake, ADFI: Average daily feed intake, ILW: Initial live weight, FLW: Final live weight, TWG: Total weight gain, ADG: Average daily gain and FCR: Feed conversion ratio

Table 3: Effects of growth promoters on slaughter characteristics of broiler chickens

Parameters (G)	Treatments					SEM	p-value
	CTR	CBB	P1	P2	P3		
LW	1851.05	1974.95	1968.20	1882.40	1935.45	46.91	0.727
CW	1486.25	1509.50	1561.50	1441.25	1566.50	65.69	0.68
DP	76.45	74.36	73.88	74.01	75.51	0.88	0.47
Breast	414.80 ^b	555.50 ^{ab}	580.50 ^a	569.70 ^a	544.00 ^{ab}	22.90	0.015
Drumstick	181.50	194.30	204.50	182.50	188.20	6.15	0.325
Thigh	173.20 ^b	212.50 ^{ab}	248.00 ^a	229.50 ^a	220.00 ^a	7.03	0.001
Back	346.50 ^b	418.80 ^{ab}	429.00 ^a	371.00 ^{ab}	396.00 ^{ab}	11.62	0.02
Wings	154.30 ^{ab}	174.30 ^a	165.50 ^{ab}	150.0 ^b	161.20 ^{ab}	3.75	0.031

Table 4: Effects of growth promoters on weights of different organs

Parameters (G)	Treatments					SEM	p-value
	CTR	CBB	P1	P2	P3		
NCW	306.75	281.0	332.5	279.25	292.5	17.36	0.255
Heart	7.50	8.0	8.0	9.50	9.5	0.550	0.067
Liver	32.80 ^b	51.0 ^a	46.5 ^a	39.00 ^b	39.5 ^b	1.300	0.001
Legs	72.30 ^{ab}	65.2 ^b	84.0 ^a	72.50 ^{ab}	68.0 ^{ab}	3.240	0.030
Head	45.60	49.4	53.0	45.50	50.5	2.180	0.188
Spleen	1.50	1.5	2.0	2.00	1.8	0.330	0.698
Fat	22.00 ^b	33.2 ^a	33.5 ^a	35.00 ^a	35.5 ^a	1.750	0.002
Intestine	62.50 ^c	80.8 ^b	88.0 ^a	82.00 ^{ab}	80.5 ^b	1.250	0.001
Bile	3.00	1.7	3.0	2.50	4.0	0.520	0.090
Gizzard	33.00 ^b	47.0 ^a	33.5 ^a	30.00 ^a	32.5 ^a	1.480	0.001

No significant differences were observed in initial live weight or Final Live Weight (FLW) among treatment groups ($p>0.05$). However, total weight gain differed significantly among treatments ($p<0.05$), with the highest weight gain observed in chickens under P3, followed by those under CBB and the lowest in chickens under CTR. Average Daily Gain (ADG) also differed significantly across treatments ($p<0.05$), with the highest ADG in chickens under P3, followed by those under CBB and P1. The lowest ADG was observed in chickens under CTR ($p<0.05$).

Feed Conversion Ratio (FCR) differed significantly among treatments ($p<0.05$). The highest FCR (least efficient feed utilization) was observed in chickens under CTR, while the lowest FCR (most efficient feed utilization) was recorded in chickens reared under P1 ($p<0.05$).

Effects of growth promoters on slaughter characteristics of broiler chickens:

The effects of growth promoters on slaughter characteristics are presented in Table 3. No significant differences were observed in Carcass Weight (CW) among broiler chickens subjected to different growth promoters ($p>0.05$). Nevertheless, numerically higher CW values were recorded in chickens reared under P1 and P3. Similarly, non-carcass weight (NCW) and dressing percentage did not differ significantly among treatments ($p>0.05$).

Breast weight differed significantly among treatments ($p<0.05$), with the highest value observed in chickens reared

under P1 and the lowest in the control group (CTR). However, breast weights among the Booster, P1, P2 and P3 groups were statistically similar ($p>0.05$) and no significant differences were observed between CTR, Booster and P3 ($p>0.05$). High weight also differed significantly among treatments ($p<0.05$). Higher thigh weights were recorded in chickens under P1, P2 and P3, while lower values were observed in CTR and Booster groups. The mean thigh weight of CTR differed significantly from those of P1, P2 and P3 ($p<0.05$), whereas thigh weights among Booster, P1, P2 and P3 were statistically similar ($p>0.05$).

Back weight differed significantly among treatments ($p<0.05$). Mean back weights were statistically similar among Booster, P1, P2 and P3 ($p>0.05$). However, a significant difference was observed between CTR and P1 ($p<0.05$), while back weights among CTR, Booster, P2 and P3 were not significantly different ($p>0.05$). Wing weight also differed significantly among treatments ($p<0.05$). The highest wing weight was observed in the Booster group, whereas the lowest was recorded in P2 ($p<0.05$). Wing weights were statistically similar among CTR, Booster, P1 and P3 ($p>0.05$), although a significant difference was observed between Booster and P2 ($p<0.05$). Additionally, wing weights among CTR, P1, P2 and P3 did not differ significantly ($p>0.05$).

Effects of growth promoters on weights of non-carcass components:

The effects of growth promoters on organ and non-carcass component weights are presented in Table 4.

Liver weight differed significantly among treatments ($p < 0.05$). The highest liver weight was observed in the Booster group, while the lowest was recorded in the CTR group ($p < .05$). Liver weights were statistically similar between Booster and P1 ($p > 0.05$); however, liver weight in the Booster group differed significantly from those in P2, P3 and CTR ($p < 0.05$).

Leg weight also differed significantly among treatments ($p < 0.05$). The highest leg weight was observed in P1, while the lowest was recorded in the Booster group ($p < 0.05$). A significant difference was observed between P1 and Booster ($p < 0.05$). However, leg weights were statistically similar among P1, P2, P3 and CTR ($p > 0.05$), although significant differences were observed among Booster, CTR, P2 and P3 ($p < 0.05$).

Fat weight differed significantly among treatments ($p < 0.05$), with the highest value recorded in P3 and the lowest in CTR ($p < 0.05$). Fat weights were statistically similar among Booster, P1, P2 and P3 ($p > 0.05$). However, fat weight in the CTR group differed significantly from all other treatments ($p < 0.05$).

Intestinal weight differed significantly among treatments ($p < 0.05$). The highest intestinal weight was observed in P1, which differed significantly from CTR ($p < 0.05$). Intestinal weights were significantly different among P1, CTR, Booster and P3 ($p < 0.05$), while P2 was statistically similar to other treatments ($p > 0.05$). Furthermore, intestinal weights were statistically similar among Booster, P2 and P3 ($p > 0.05$) but differed significantly in CTR and P1 ($p < 0.05$).

DISCUSSION

Non carcass components: The similar weights of non-carcass components observed among treatment groups indicate that the different growth promoters exerted comparable effects on tissue development. This finding is consistent with the report of Toghyani *et al.*¹⁶, who observed no significant differences in internal organ weights and carcass characteristics among treatments. Nevertheless, the non-carcass weight (NCW) in the P1 group was numerically higher than in other groups, suggesting a potential stimulatory effect of propolis extract at 100 g/L on tissue growth and development.

The similarity in heart weights among chickens reared under different growth promoters suggests comparable effects on cardiovascular development. However, the numerically higher heart weight observed in broilers receiving higher doses of propolis extract over 42 days may indicate increased cardiac activity, tissue stress and potential cellular damage, possibly associated with elevated oxidative stress, which can lead to cardiac enlargement^{3,17}. The higher liver weights observed in birds receiving CBB and P1 may be

attributed to their higher growth rates, as reflected by greater live weights (Table 3), a condition associated with increased metabolic demands. This observation is in agreement with Seddon *et al.*¹⁸, who reported higher liver weights in fast-growing chickens compared with slow-growing counterparts. The increased abdominal fat weight observed in chickens receiving growth promoters suggests a strong influence of these additives on adipose tissue deposition. This effect may be attributed to enhanced feed intake and improved nutrient utilization, potentially mediated through modulation of gut microbiota and improved intestinal morphology, which collectively enhance digestive efficiency. Similar findings were reported by Rabie *et al.*¹⁹, who observed increased fat deposition in animals supplemented with phyto-genic additives.

The higher intestinal weight observed in chickens receiving P1 further supports the role of propolis as a growth promoter that enhances feed utilization efficiency. This increase may be associated with increased villus height and intestinal length resulting from enhanced cellular proliferation, likely influenced by bioactive compounds in propolis, such as flavonoids. In contrast, the reduced intestinal weight observed at propolis doses above 100 g/L suggests a dose-dependent response, whereby higher concentrations may exert adverse effects on tissue development.

The higher gizzard weight observed in chickens receiving CBB, followed by those receiving P1, may reflect enhanced feed utilization efficiency, which is typically associated with increased mechanical digestion in the gizzard. Increased gizzard weight may therefore indicate greater grinding activity required to optimize nutrient utilization. This finding is consistent with Hassan *et al.*³, who reported significantly higher gizzard weights in broilers supplemented with propolis.

Carcass components: The carcass characteristics of broiler chickens were evaluated under different dietary treatments, including the control (CTR), Commercial Broiler Booster (CBB) and three levels of propolis supplementation (P1, P2 and P3). The observed similarity in Live Weight (LW), Carcass Weight (CW), Dressing Percentage (DP) and drumstick weight indicates that the different growth promoters exerted comparable effects on growth performance and slaughter characteristics. This further suggests that the growth promoters did not adversely affect weight gain or carcass yield. Similarly, Sadarman *et al.*²⁰ reported that natural additives such as propolis did not significantly influence overall weight gain.

Nevertheless, the numerically higher LW, CW and drumstick weights observed in chickens receiving growth promoters compared with the control group suggest

a positive influence of these additives on slaughter characteristics. Furthermore, the higher breast, thigh and back weights observed in chickens receiving growth promoters relative to the control indicate the potential of these additives to enhance carcass quality. This finding is consistent with the report of He *et al.*²¹, who observed a positive effect of propolis supplementation on breast muscle weight in broiler chickens. The highest breast weight was recorded in broilers reared under P1, followed by a progressive decline at higher propolis concentrations, suggesting that 100 g/L may represent the optimal dosage for maximizing breast muscle development. Although drumstick weights did not differ significantly among treatments, the numerically higher value observed in P1 further supports the potential of this dosage as optimal for propolis supplementation in broiler drinking water.

Growth performance: Total Feed Intake (TFI) and Average Daily Feed Intake (ADFI) were higher in chickens reared under the CTR and CBB groups and lower in propolis-supplemented groups. Among the propolis treatments, P1 exhibited the lowest feed intake, suggesting that less feed was required to meet nutritional requirements due to improved feed utilization efficiency. This improvement may be associated with enhanced digestive enzyme activity and improved gut health. Similarly, Heiss *et al.*²² reported improved feed efficiency in birds supplemented with propolis.

Although, no significant differences were observed in Final Live Weight (FLW) among treatments, numerically higher values were recorded in the CBB group, followed by the P1 group, likely reflecting improved feed utilization efficiency associated with these growth promoters. Despite the higher Total Weight Gain (TWG) and Average Daily Gain (ADG) observed in chickens receiving P3, the correspondingly higher Feed Conversion Ratio (FCR) indicates reduced feed efficiency at this dosage, suggesting that this level of propolis supplementation is not optimal. This finding is consistent with previous studies reporting that higher doses of propolis increased feed intake but resulted in poorer feed efficiency, as reflected by higher FCR values^{22,23}.

Furthermore, although TWG and ADG were lower in chickens receiving P1 compared with those receiving CBB, the significantly lower FCR observed in the P1 group indicates superior feed efficiency, supporting this dosage as the most effective for improving growth performance. This observation aligns with previous reports indicating that moderate doses of phytogenic growth promoters exert greater positive effects on feed efficiency than higher doses²⁴.

Meat physical characteristics: The lower shear force observed in meat from chickens reared under the P1 group may be attributed to improved muscle fiber structure or enhanced activity of proteolytic enzymes responsible for post-mortem proteolysis, which is essential for meat tenderization. Similar findings were reported by Cox *et al.*⁶, who observed improved meat tenderness following moderate supplementation with polyphenol blends, attributed to enhanced antioxidant status and reduced muscle protein oxidation.

The lower meat pH observed in the P1 group indicates adequate muscle glycogen reserves at slaughter, which are necessary for proper post-mortem glycolysis²⁵. This suggests that moderate doses of propolis did not impose physiological stress on the chickens, unlike higher propolis doses and the control group. Meat lightness values observed in chickens receiving growth promoters were within the normal range, except for the control group, which exhibited lighter-than-normal meat⁹. The lower lightness (L^*) values observed in meat from the P1 and P2 groups suggest increased myoglobin retention or reduced protein denaturation, likely due to enhanced antioxidant protection provided by propolis supplementation. In contrast, the increased lightness observed in P3 may be associated with reduced myoglobin concentration, possibly resulting from altered iron metabolism affecting myoglobin synthesis at higher propolis dosages. This finding contradicts the report of Idoko *et al.*²⁶, who observed no effect of propolis supplementation on meat lightness.

The higher degree of redness (a^*) observed in the P1 group reflects enhanced oxidative stability, likely attributable to the presence of flavonoids and phenolic acids in propolis, which act as antioxidants. This observation is consistent with the findings of Gaskins *et al.*⁹, who reported numerically higher redness values in broiler meat under comparable conditions. The lower yellowness (b^*) values observed at lower propolis dosages (P1) indicate reduced lipid oxidation, which may be attributed to the strong antioxidant properties of propolis. A similar trend was reported by Idoko *et al.*²⁶, who observed reduced meat yellowness at lower propolis dosages and increased yellowness at higher dosages.

The higher water-holding capacity (WHC) observed in the control group may be attributed to its relatively higher meat pH, whereas the lower WHC observed in all treated groups likely resulted from their lower pH values, which reduce the ability of myofibrils to retain water. This observation is consistent with Bowker and Zhuang²⁷, who reported that WHC in chicken breast meat corresponds directly to meat pH, with higher pH associated with higher WHC and vice versa.

CONCLUSION

This study demonstrates that propolis extract has significant potential as a natural growth promoter, enhancing growth performance, carcass characteristics and organ development in broiler chickens. Among the tested dosages, 100 g/L (P1) of propolis was most effective, improving muscle fiber structure, reducing fat and lipid oxidation, lowering meat pH and increasing redness, indicative of enhanced antioxidant activity in the meat. Overall, these findings suggest that moderate propolis supplementation may serve as a sustainable natural alternative to synthetic growth promoters in broiler production. It is recommended that this concentration be considered for broiler production to improve performance, carcass quality and reduce reliance on chemical additives.

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