Black Sea Journal of Agriculture
doi: 10.47115/bsagriculture.1647464

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 8 - Issue 3 : 412-420 / May 2025

PROPOLIS SUPPLEMENTATION IN BROILER BREEDER CHICKENS: ENHANCING MEAT QUALITY

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Abstract: This study aimed to evaluate the effects of dietary propolis supplementation on the meat quality of 35-week-old broiler breeder chickens. A total of 100 Ross 308 chickens were divided into five groups and supplemented with 0, 100, 200, 400, and 800 ppm of propolis in their diet. The study measured various meat quality parameters, including pH, color (L*, a*, b*), cooking loss, and drip loss over three storage periods (1, 4, and 7 days). Results showed that propolis supplementation influenced pH, with the P800 group exhibiting the highest pH value by day 7. Color parameters, particularly yellowness (b*), were significantly reduced in thigh meat in the 200 ppm group. Propolis supplementation, especially at 800 ppm, significantly reduced drip loss and cooking loss, improving water retention and texture in both breast and thigh meat. These findings suggest that propolis supplementation, particularly at 800 ppm, can improve meat quality by enhancing water-holding capacity and influencing color stability. The improved meat quality in terms of water retention and texture, makes propolis supplementation a promising option for enhancing the quality of processed poultry products, such as salami and sausages. Further research is needed to optimize the appropriate dosage for maximizing the benefits of propolis in poultry meat.

Keywords: Propolis, Meat quality, Drip loss, Cooking loss, Poultry

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Received: February 26, 2025
Accepted: April 18, 2025
Published: May 15, 2025

Cite as: Konanç K, Öztürk E. 2025. Propolis supplementation in broiler breeder chickens: enhancing meat quality. BSJ Agri, 8(3): 412-420.

1. Introduction

In recent years, the use of natural feed additives, particularly propolis, has gained significant attention due to its promising effects on animal health and meat quality. Propolis, a biologically active substance produced by bees from plant resins, is widely utilized in animal nutrition for its strong antimicrobial, antioxidant, and immunomodulatory properties. Numerous studies have investigated its effects on growth performance, immune function, and meat quality in broiler chickens (Zulhendri et al., 2021; Abdel-Maksoud et al., 2023, Sahin and Ozturk, 2018). However, while most research has focused on younger broilers (Mahmoud et al., 2016; Prakatur et al., 2020), the impact of propolis on the meat quality of broiler breeders, particularly at 35 weeks of age, remains largely unexplored.

Propolis is composed of flavonoids, aromatic acids, and phenolic compounds such as galangin and pinocembrin (Koohsar et al., 2018). These bioactive compounds play a crucial role in reducing oxidative stress in muscle tissue and preventing lipid oxidation (Kaewsatuan et al., 2023; Mujica et al., 2017), which can contribute to extending meat shelf life while preserving freshness. Oxidative stability is a key factor influencing meat quality parameters such as color (particularly the red hue associated with a* values) and flavor (Sabuncular et al., 2021). As muscle pigmentation changes with age, evaluating the effects of propolis on this process is critical for meat processing and marketing.

Meat quality traits such as pH, color (L*, a*, b*), water-holding capacity, drip loss, and cooking loss directly impact consumer preferences and market value. Age-related changes, including increased connective tissue and variations in intramuscular fat distribution, significantly affect meat texture and chewiness (Yalcın et al., 2014). Compared to beef or pork, poultry meat is more susceptible to spoilage, making the monitoring of quality losses during storage essential for maintaining freshness and ensuring quality assurance. Effective control of meat quality is critical for enhancing sensory attributes, minimizing economic losses, and improving the efficiency of the poultry meat industry.

Understanding meat quality changes in older broilers is important for both scientific research and commercial applications. The breast and thigh meat from older broilers may exhibit differences in flavor, aroma, texture, and nutrient composition compared to younger broilers (Komiyama et al., 2010). These age-related changes provide a valuable opportunity to examine the effects of bioactive feed additives such as propolis on meat characteristics. Evaluating propolis's impact on muscle pH, water-holding capacity, and color in 35-week-old broiler breeders could provide crucial insights into its role

in improving meat quality.

In certain markets, meat from older broilers is preferred for processed products such as sausages and salami. Since muscle glycogen levels and connective tissue content change with age, variations in pH, water-holding capacity, and tenderness can significantly influence meat processing characteristics (Khan et al., 2019). Investigating 35-week-old broilers can yield valuable data on the quality of breeder meat and support the development of high-quality processed poultry products.

This study investigates the effects of dietary supplementation with different levels of propolis extract (100, 200, 400, and 800 ppm) on meat quality parameters, including pH, color, drip loss, and cooking loss, in 35-week-old broiler breeders. The use of propolis as a natural feed additive has the potential to enhance meat production quality. However, further research is needed on the optimal dosage and economic sustainability of propolis to improve the applicability of broiler meat in processed products. The findings of this study will provide insights into the impact of propolis on meat quality and contribute to understanding the market potential of more mature broilers, ultimately supporting the production of healthier and higher-quality meat.

2. Materials and Methods

2.1. Animals, Diet, and Experimental Design

This study was conducted on 35 week-old 100 Ross 308 female broiler breeder chickens, which were randomly allocated into five groups (each group consisted of four replicates, with five chickens per replicate, resulting in a total of 20 chickens per group). The experimental groups included a control group (C) and four treatment groups supplemented with propolis at varying concentrations (P100, P200, P400, and P800). The broilers were housed on wood shaving under standardized conditions throughout the experimental period (for four weeks), following the management guidelines for Ross 308 hybrids (AVIAGEN, 2014).

Broilers had ad libitum access to water and were fed a standard basal diet at an average of 155 g per day. The composition and nutritional profiles of the diets used during the chick, pullet, and breeder stages are presented in Table 1.

2.2. Propolis Extraction and Characterization

Raw propolis used in this study was obtained from a local beekeeper in Giresun, Türkiye, who collected the material from a consistent floral source. Upon collection, the propolis was stored at –20 °C until extraction, following the protocol described by Choi et al. (2006). For extraction, the hardened propolis was ground into a fine powder using a mortar and pestle. Ethanol extraction was performed as outlined by Shalmany and Shivazad (2006), and the resulting extracts were stored in dark-colored glass jars at room temperature until use (Cetin et al., 2010).

The chemical composition of the extract was determined using gas chromatography-mass spectrometry (GC-MS). The analysis confirmed the presence of key bioactive compounds, including phenolic acids and flavonoids, which are known for their antioxidant and antimicrobial properties. These findings were consistent with the results reported by Konanç and Ozturk (2025).

The doses of propolis extract have been determined based on the recommended dose ranges in the literature (Irawan et al., 2021). Propolis extract supplementation was performed by spraying onto the feed, and the treatment groups received ethanol-extracted propolis for four weeks. The control group was fed a basal diet without any additives (Table 2).

2.3. Sample Collection and Measurements

At 35 weeks of age, four broiler (one broiler each replicate) from each group were randomly selected and slaughtered following a 10-hour feed withdrawal period. The broilers were euthanized by cervical dislocation and exsanguinated for two minutes. Carcasses were manually defeathered, eviscerated, and immediately processed without prior chilling.

Carcass body weight was recorded using an electronic scale with a precision of 0.01 g. Carcass yield was calculated as the percentage of live weight converted into carcass weight. The technological meat quality parameters were assessed on breast and thigh muscles, including pH, drip loss, cooking loss, and color measurements.

2.4. pH Measurement

The pH of breast and thigh muscles was measured at three post-mortem time points: 1 day (45 minutes after slaughter), 4 days, and 7 days. The initial pH was recorded 45 minutes after slaughter using a calibrated pH meter (Thermo 205) with a solid probe at ambient temperature. The electrode, immersed in the muscle samples, was kept in place until the pH meter reading stabilized. The measurement was then recorded once the value on the screen became constant. The measurements were repeated for samples stored at +4°C for 4 and 7 days. Each measurement was performed three times, and the average value was recorded.

2.5. Drip Loss Measurement

Breast and thigh muscle samples (~10 g; 3 cm in length, 2 cm in diameter) were placed in polyethylene bags and suspended in a refrigerator at +4°C for 24 hours. The samples were weighed before and after refrigeration. Drip loss was determined using the following formula (equation 1):

$$\text{Drip Loss (\%)} = [(\text{Initial Weight} - \text{Final Weight}) / \text{Initial Weight}] \times 100 \quad (1)$$

where initial sample weight refers to the weight of the fresh sample before storage, and final sample weight represents the weight after a specific storage period at refrigeration temperature. The process was repeated for samples stored for 4 and 7 days.

Table 1. The composition of the feed mixture, for chicks (1-28 days old)[1], for pullets (28-154 days old)[2], for broiler breeders (155+ days old)[3]

Ingredients	%			Nutrient composition	%		
	1	2	3		1	2	3
Corn	547.00	619.00	687.28	Crude protein	19.000	15.000	15.000
SBM*	229.24	109.24	154.16	Eher extract	3.050	3.000	3.370
Wheat bran	72.97	109.15	13.03	Crude Fiber	4.080	4.860	3.550
Wheat meal	60.00	60.00	60.00	Total Ash	5.930	5.200	10.700
SFM**	50.00	100.00	50.00	Total P	0.763	0749	0.583
Limestone powder	11.33	10.14	70.18	Av. Phospho.	0.450	0.420	0.350
MCP***	9.41	7.75	6.79	Calcium	1.000	0.900	3.000
Vegetable oil	5.00	1.81	6.57	DL-Methionine	0.423	0.320	0.300
Salmonella inhibit	3.00	3.00	2.00	Lysine	1.010	0.740	0.740
Broiler mix****	3.00	3.00	3.00	Tryptophan	0.236	0.175	0.175
Salt	2.09	2.20	2.20	Threonine	0.724	0.565	0.567
DL-methio. (99%)	1.18	0.47	0.39	İsoleucine	0.798	0.585	0.624
Toxin binder	1.00	1.00	1.00	Histidine	0.520	0.403	0.416
Vitamin D3	1.00	1.00	0.50	Valine	0.901	0.700	0.715
$NaHCO_3$	1.00	0.71	1.06	Leucine	1.573	1.244	1.335
Organic minerals	1.00	1.00	1.00	Arginine	1.293	0.969	0.995
Probiotics	1.00	0.50	-	Phenylalanine	0.922	0.692	0.732
Lysine (99%)	0.68	1.67	0.33	Clor	0.167	0.202	0.160
Threonine	0.11	0.27		Sodium	0.160	0.160	0.160
Vitamin E	-	-	0.50	Potassium	0.814	0.634	0.600
				Linoleic acid	1.387	1.325	1.552
				Cholin mg/kg	0.311	0.285	0.286
Total	1000.00	1000.00	1000.00	ME*****	2800	2800	2800

SBM*; Soybean meal (46 %CP), SFM**; Sunflower meal (36 %CP), MCP (%22.7 Ca)***; Monocalcium fosfat, Broiler mix****; V+M+E=Vitamin +Mineral+Enzyme, ME*****; Metabolisable Energy (Kcal/kg).

Table 2. Feeding protocol for groups

Groups	Number of chickens	Feeding Protocol
Control (C)	20	Feed mixture
P100	20	Feed mixture+100 ppm propolis extract
P200	20	Feed mixture+200 ppm propolis extract
P400	20	Feed mixture+400 ppm propolis extract
P800	20	Feed mixture+800 ppm propolis extract

2.6. Cooking Loss Measurement

Approximately 10 g of minced breast and thigh meat from each sample was sealed in a polyethylene bags and heated in a water bath at 80°C for 20 minutes. The samples were then cooled to room temperature, dried with a paper towel, and reweighed. Cooking loss was calculated using the following formula(equation 2):

$$\text{Cooking Loss (\%)} = [(\text{Initial Weight} - \text{Final Weight}) / \text{Initial Weight}] \times 100 \quad (2)$$

where pre-cooking weight represents the initial sample weight before cooking, and post-cooking weight refers to the final weight after cooking. The process was repeated for samples stored for 4 and 7 days.

2.7. Color Measurement

Breast and thigh muscle color was evaluated after 24 hours of refrigeration at +4°C. Color measurements were performed using a Minolta CR 300 Chroma Meter (Minolta Camera Co., Osaka, Japan) after making a fresh vertical incision in the middle of the muscle. The color parameters were recorded in the CIE-Lab* system, measuring lightness (L*), redness (a*), and yellowness (b*) at three points on the skinless left thigh and breast muscles (Hunt et al., 1991). Each measurement was performed three times, and the average value was recorded.

2.8. Statistical Analysis

The effect of propolis supplementation on measured parameters was analyzed using one-way analysis of variance (ANOVA), considering treatment groups as the main factor. Means were compared using Duncan's multiple range test within the GLM procedure SPSS v26 (IBM Inc.). Data were expressed as mean ± standard deviation (SD). Statistical significance was set at P< 0.05.

3. Results

3.1. Body weight

The average carcass body weight and yield values are presented in Table 3. The lowest live weight was observed in the 100 ppm group (3552.86 g), while the highest was in the 400 ppm group (3812.17 g), with no statistically significant differences among groups (P=0.217). Similarly, carcass body weight ranged from 2714.17 g (200 ppm) to 3118.00 g (400 ppm), and carcass yield varied between 75.94% (200 ppm) and 81.59% (400 ppm), but these differences were not significant (P>0.05). These findings indicate that propolis supplementation did not affect live weight, carcass weight, or yield.

Table 3. Estimated average ± SD of live weight (g), carcass body weight (g) and carcass yield (%) according to the groups

Groups/ Parameters	Live weight (g)	Carcass body weight (g)	Carcass yield (%)
Control	3719.500±197.234	2948.250±199.587	79.216±1.488
P100	3552.857±379.768	2835.142±409.023	79.595±1.378
P200	3556.000±342.015	2714.166±412.787	75.941±1.488
P400	3812.166±295.655	3118.000±367.262	81.589±1.488
P800	3680.000±340.073	2934.000±371927	79.575±1.630

Means within rows without common superscripts differ significantly according to ANOVA (P<0.05).

3.2. pH values

The pH values of thigh and breast meat over postmortem days 1, 4, and 7 are shown in Table 4. Overall, pH values increased over time. On day 1, thigh pH ranged from 5.87 to 5.99, reaching 6.89–7.25 by day 7. Breast pH followed a similar pattern, increasing from 5.68–5.76 on day 1 to 6.12–6.53 by day 7. On day 4, the 800 ppm group had the lowest thigh pH (6.03), significantly lower than the control group (6.46) (P<0.05). On day 7, the highest thigh pH was in the 800 ppm group (7.25), but all groups were statistically similar (P=0.359). For breast meat, significant differences were observed on day 7, with the 100 ppm group having the highest pH (6.53) and the 400 ppm group the lowest (6.12) (P<0.05).

3.3. L*, a*, b* values

Table 5 summarizes the color parameters. Lightness (L*) values did not differ significantly among groups for thigh (P=0.873) or breast meat (P=0.243). Redness (a*) values were also not significantly affected by propolis supplementation in either meat type (P>0.05). However, yellowness (b*) showed significant variation, with the 800 ppm group having the highest thigh meat b* value (9.206) and the 200 ppm group the lowest (6.558) (P<0.05). A similar trend was noted in breast meat, where the 200 ppm group exhibited significantly lower yellowness compared to the control (P<0.05).

3.4. Drip loss

Drip loss values over days 1, 4, and 7 are presented in Table 6. Propolis supplementation, particularly at 800 ppm, reduced drip loss in both thigh and breast meat. The control group had the highest drip loss values across all time points, while the 800 ppm group consistently showed the lowest values. Significant reductions were observed on days 4 and 7 for both meat types, with the P800 group exhibiting the lowest values (P<0.05).

Table 4. Estimated average ± SD of pH values according to the groups on thigh and breast meat

	pH values	1.day	4.day	7.day	P-value
Thigh meat	Control	5.866±0.088^{Ac}	6.460±0.333 ^{Ab}	6.966±0.321 ^{Aa}	0.001
	P100	5.994±0.185 ^{Ac}	6.334±0.173 ^{ABb}	7.067±0.391 ^{Aa}	0.001
	P200	5.981±0.128 ^{Ab}	6.358±0.327 ^{ABb}	6.888±0.409 ^{Aa}	0.001
	P400	5.938±0.148 ^{Ac}	6.246±0.238 ^{ABb}	6.931±0.106 ^{Aa}	0.001
	P800	5.930±0.119 ^{Ab}	6.028±0.195 ^{Bb}	7.246±0.123 ^{Aa}	0.001
	P-value	0.538	0.114	0.359	-
Breast meat	Control	5.681±0.024 ^{Ab}	6.005±0.096 ^{Aa}	6.260±0.357 ^{ABa}	0.001
	P100	5.731±0.063 ^{Ac}	6.064±0.208 ^{Ab}	6.534±0.255 ^{Aa}	0.001
	P200	5.748±0.113 ^{Ab}	6.156±0.246 ^{Aa}	6.403±0.295 ^{ABa}	0.001
	P400	5.710±0.072 ^{Ab}	6.093±0.193 ^{Aa}	6.123±0.115 ^{Ba}	0.001
	P800	5.756±0.087 ^{Ab}	6.096±0.206 ^{Aab}	6.446±0.382 ^{ABa}	0.005
	P-value	0.491	0.769	0.136	-

Means within rows without common superscripts (a-c) are significantly different according to ANOVA (P<0.05), indicating differences between groups at the same time point. Similarly, means within columns without common superscripts (A-B) are significantly different (P<0.05), representing differences between time points within the same group. Groups sharing the same superscripts do not show statistically significant differences.

Table 5. Estimated average ± SD of color values of chicken thigh and breast meat expressed as L*a*b* according to the groups

	L*a*b* values	L	a	b
Thigh meat	Control	53.885±1.893^{Aa}	23.053±2.430 ^{Aa}	8.273±2.158 ^{ABa}
	P100	53.583±3.866 ^{Aa}	20.269±4.155 ^{Aa}	7.294±2.116 ^{ABa}
	P200	52.565±0.826 ^{Aa}	21.867±1.428 ^{Aa}	6.558±1.065 ^{Ba}
	P400	53.697±2.993 ^{Aa}	21.415±2.739 ^{Aa}	7.887±2.012 ^{ABa}
	P800	52.580±3.069 ^{Aa}	23.997±2.828 ^{Aa}	9.206±1.839 ^{Aa}
	P-value	0.873	0.244	0.217
Breast meat	Control	59.390±2.802 ^{Aa}	4.255±1.908 ^{Aa}	4.310±1.527 ^{Aa}
	P100	59.530±4.537 ^{Aa}	4.715±0.907 ^{Aa}	3.697±1.378 ^{ABa}
	P200	59.285±3.038 ^{Aa}	3.964±0.843 ^{Aa}	2.279±1.482 ^{Ba}
	P400	56.818±2.132 ^{Aa}	5.439±1.703 ^{Aa}	3.123±1.483 ^{ABa}
	P800	56.249±1.808 ^{Aa}	4.570±0.774 ^{Aa}	4.020±1.073 ^{ABa}
	P-value	0.243	0.393	0.137

Means within rows without common superscripts (a-c) are significantly different according to ANOVA (P<0.05), indicating differences between groups at the same time point. Similarly, means within columns without common superscripts (A-B) are significantly different (P<0.05), representing differences between time points within the same group. Groups sharing the same superscripts do not show statistically significant differences. lightness [L*], redness [a*], and yellowness [b*]

Table 6. Estimated average ± SD of drip loss (%) values according to the groups on thigh and breast meat

	Drip loss (%)	1.day	4.day	7.day	P-value
Thigh meat	Control	3.692±1.453^{Ac}	7.161±1.779^{Ab}	11.272±3.010^{Aa}	0.001
	P100	2.216±1.409^{Ac}	5.831±3.011^{Ab}	9.306±2.998^{ABa}	0.001
	P200	2.128±1.496^{Ab}	5.254±3.349^{Aab}	8.083±3.486^{ABa}	0.011
	P400	2.379±0.760^{Ac}	5.339±1.353^{Ab}	9.023±3.248^{ABa}	0.001
	P800	2.471±1.568^{Ab}	4.222±1.656^{Aab}	5.992±1.543^{Ba}	0.015
	P-value	0.286	0.381	0.088	-
Breast meat	Control	3.102±1.308^{Ab}	9.474±5.849^{Aa}	10.931±4.505^{Aa}	0.016
	P100	2.145±1.086^{Ac}	5.305±1.415^{Bb}	8.464±1.996^{ABa}	0.001
	P200	2.890±1.936^{Ab}	6.828±3.551^{ABa}	7.875±0.866^{ABa}	0.006
	P400	2.077±0.595^{Ac}	4.955±0.943^{Bb}	7.418±1.520^{Ba}	0.001
	P800	2.142±0.928^{Ac}	4.285±1.083^{Bb}	6.548±1.918^{Ba}	0.001
	P-value	0.483	0.073	0.066	-

Means within rows without common superscripts (a-c) are significantly different according to ANOVA (P<0.05), indicating differences between groups at the same time point. Similarly, means within columns without common superscripts (A-B) are significantly different (P<0.05), representing differences between time points within the same group. Groups sharing the same superscripts do not show statistically significant differences.

3.5. Cooking loss

Table 7 shows the cooking loss results. While propolis supplementation reduced cooking loss, the effect was statistically significant only on day 7 for breast meat, where the 800 ppm group had the lowest loss (19.30%) compared to the control (P=0.049). No significant differences were found on days 1 and 4 (P>0.05), though numerical reductions were noted, suggesting a potential long-term benefit of propolis in improving water retention.

Table 7. Estimated average ± SD of cooking loss (%) values according to the groups on thigh and breast meat

	Cooking loss (%)	1.day	4.day	7.day	P-value
Thigh meat	Control	26.330±6.110^{Aa}	22.921±5.242^{Aa}	24.988±3.271^{Aa}	0.511
	P100	25.951±4.262^{Aa}	25.091±3.713^{Aa}	23.997±6.744^{Aa}	0.880
	P200	27.336±1.531^{Aa}	22.551±5.150^{Aab}	21.295±4.471^{Ab}	0.048
	P400	26.991±3.884^{Aa}	24.465±3.881^{Aa}	23.055±2.679^{Aa}	0.181
	P800	27.526±4.518^{Aa}	26.453±4.014^{Aa}	23.371±1.093^{Aa}	0.194
	P-value	0.878	0.671	0.573	-
Breast meat	Control	22.925±1.946^{Aa}	22.778±1.685^{Aa}	22.845±1.108^{Aa}	0.988
	P100	23.477±1.820^{Aa}	22.373±1.909^{Aa}	21.864±2.130^{ABa}	0.312
	P200	21.253±2.045^{Aa}	22.298±1.079^{Aa}	20.058±2.578^{Ba}	0.186
	P400	21.353±1.166^{Aa}	22.340±2.591^{Aa}	20.930±2.010^{ABa}	0.477
	P800	21.888±1.708^{Aa}	20.286±5.382^{Aa}	19.306±1.929^{Ba}	0.509
	P-value	0.129	0.623	0.049	-

Means within rows without common superscripts (a-c) are significantly different according to ANOVA (P<0.05), indicating differences between groups at the same time point. Similarly, means within columns without common superscripts (A-B) are significantly different (P<0.05), representing differences between time points within the same group. Groups sharing the same superscripts do not show statistically significant differences.

4. Discussion

The use of propolis in broiler chickens, particularly at higher doses (P400 and P800), has been shown to improve meat quality and enhance water-holding capacity. These effects could contribute to the enhancement of the quality of processed meat products at an industrial level. However, considering the potential higher cost of propolis compared to traditional feed additives, its economic sustainability requires careful evaluation. The efficacy of higher doses may increase production costs, yet the long-term health benefits and potential reduction in antibiotic use could enhance the economic value. The widespread availability of propolis is also closely tied to the supply chain and beekeeping production, making it essential to assess the conditions under which propolis can be reliably sourced.

The results of this study highlight the significant effects of propolis supplementation on broiler meat quality. Propolis, rich in phenolic compounds and flavonoids, reduces oxidative stress and inhibits lipid oxidation, contributing to meat freshness and shelf life. Oxidative stability influences key quality parameters such as color, water-holding capacity, and flavor (Huang and Ahn, 2019). Propolis supplementation, particularly at higher doses, improved meat color and water-holding capacity, with notable effects in the P800 group.

No statistically significant differences were observed in live weight, carcass weight, or yield among the treatment groups. The P400 group had the highest live and carcass weight, but differences were not significant. Previous studies suggest dietary supplements, including propolis, can influence poultry growth (Prakatur et al., 2020). However, Haščík et al. (2015) reported that lower doses improve growth performance, while higher doses may have variable effects. The non-significant reduction in live and carcass weights in the P200 group may be dose-dependent. The P400 group yielded the best results in carcass weight, suggesting that this dose positively influences the overall growth and development of broiler chickens, leading to improved carcass yield. The ability of this dose of propolis to support muscle development and enhance body composition may explain the observed increase in carcass weight. On the other hand, the P800 group demonstrated a more significant improvement in water-holding capacity, indicating that the biochemical effects of higher doses of propolis on water retention in meat are more pronounced. It can be hypothesized that higher doses of propolis may enhance the meat's water-holding capacity, leading to reduced dehydration and extended shelf life. However, the impact of P800 on carcass weight may be more limited, as the increased water retention could potentially influence other structural parameters of the meat, which may lead to differing outcomes in carcass weight. While propolis did not significantly affect body weight or carcass yield, its benefits for meat quality remain evident. Mahmoud et al. (2013) found that high propolis doses reduced body weight gain ($P<0.05$). This suggests higher doses might limit growth. Our results indicate that 400 ppm propolis may enhance carcass yield, but further research is needed to determine the optimal dosage.

The pH values of broiler meat were within expected ranges and increased during storage, consistent with postmortem glycolysis. Values were slightly lower than those reported by Barbut et al. (2005) and Swatland (2008), possibly due to differences in breed and diet. The postmortem pH increase was more prominent in thigh meat, especially in the P800 group on day 7, suggesting a potential metabolic influence of propolis. Similar findings were reported by Šulcerová et al. (2011).

Meat color, assessed via L* (lightness), a* (redness), and b* (yellowness) values, was not significantly affected by propolis supplementation. However, the P800 group had the highest a* and b* values, indicating a possible trend toward increased redness and yellowness, potentially due to the antioxidant properties of propolis. This aligns with findings by Lee et al. (2022), suggesting natural antioxidants help retain meat color by reducing oxidative changes.

Propolis supplementation significantly improved water-holding capacity, particularly in the P800 group, which exhibited a 47% and 40% reduction in drip loss for thigh and breast meat, respectively, on day 7. Increased pH levels in this group further support its role in enhancing water retention (Türkyılmaz et al., 2021). The P200 group also showed a significant reduction in drip loss ($P=0.011$). These findings align with research highlighting the benefits of natural supplements on meat quality (Lee et al., 2022; Prakatur et al., 2020).

Cooking loss showed no significant differences among groups ($P=0.573$ for breast and $P=0.511$ for thigh), but a trend toward lower values in the P200 group was observed. The P200 group exhibited a decrease in cooking loss from 27.34% on day 1 to 21.30% on day 7 ($P=0.048$), indicating a possible improvement in meat texture. This is consistent with Tan et al. (2022), who reported similar cooking loss values for poultry meat.

Propolis supplementation, particularly at 800 ppm, significantly enhanced broiler meat quality by improving water retention and reducing drip loss, resulting in juicier and more tender meat. While the impact on color parameters was minimal, higher doses exhibited a trend toward increased pH levels and enhanced antioxidant effects, which may contribute to an extended shelf life. These findings highlight propolis as a promising natural supplement for improving poultry meat quality, with potential applications in processed products.

Consistent with the current results, the use of propolis at different doses in broiler diets has shown potential to improve meat quality, enhance water-holding capacity, and optimize carcass yield. Notably, the higher doses (P400 and P800) were particularly effective in increasing water-holding capacity, and positive effects were observed on carcass weight. However, the absence of sensory testing is a significant limitation of this study. Organoleptic attributes such as flavor, texture, and

tenderness are crucial in determining consumer acceptability, especially for industrial applications. Therefore, future studies should incorporate sensory analysis to provide a more comprehensive evaluation of propolis's impact on meat quality.

Economically, while propolis may help reduce health-related costs as a natural alternative to antibiotics, its commercial use faces certain limitations. The seasonal and geographical constraints of propolis production, along with the high costs of standardization and quality control, can impact its economic feasibility. Particularly in regions where beekeeping is not widespread, propolis might need to be imported, increasing production costs.

Moreover, the chemical composition of propolis varies according to its botanical and geographical origin, as well as the season of harvest and extraction methods (Kasote et al., 2022). This variability may influence its consistency and efficacy as a feed additive. Thus, the development of standardized guidelines for propolis characterization and its use in poultry nutrition is essential.

From a food safety perspective, while propolis is generally considered safe, the potential accumulation of bioactive compounds in edible tissues over long-term use warrants attention (Tumbarski et al., 2022). Currently, there are no established maximum residue limits (MRLs) for propolis-derived substances in meat or egg products. This highlights the need for further toxicological and regulatory studies to ensure its safe use in food animal production systems.

In this context, it is important to consider the balance between the beneficial effects of propolis and its economic and regulatory feasibility. Although its antioxidant and immune-supportive effects make it a strong candidate as a natural additive, its variable composition, cost of standardization, and lack of residue regulations present challenges to routine use (Wojtacka, 2022). Therefore, broader studies investigating not only the physiological responses in poultry but also the economic, compositional, and safety-related aspects of propolis are essential for its integration into industrial-scale poultry nutrition.

5. Conclusion

In summary, propolis shows great promise as a natural feed additive to improve broiler meat quality, particularly in terms of water-holding capacity and carcass yield. However, to fully establish its industrial applicability, future studies should focus on determining the optimal dosage by evaluating intermediate concentrations, conducting sensory analyses to assess organoleptic qualities, performing toxicological assessments and residue analyses to address food safety concerns, and developing cost-effective extraction and standardization methods for broader commercial use. Such research will be essential to clarify the role of propolis in poultry nutrition and its potential as a safe, sustainable, and effective alternative in modern poultry production.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	K.K.	E.Ö
C	70	30
D	100	
S		100
DCP	70	30
DAI	70	30
L	70	30
W	70	30
CR	70	30
SR	70	30
PM	70	30

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgements

We would like to thank Ondokuz Mayıs University Faculty of Agriculture Research and Application Farm and Dr. Hasan Alp Sahin for their support in carrying out this study.

Ethical Consideration

The experimental procedures were approved by the Animal Experiments Local Ethics Committee of Ondokuz Mayıs University (Approve date: October 10, 2013 and protocol code: 2013-10).

References

Abdel-Maksoud EM, Daha AAEF, Taha NM, Lebda MA, Sadek KM, Alshahrani MY, Ahmed AE, Shukry M, Fadl SE, Elf-Eky M. 2023. Effects of ginger extract and/or propolis extract on immune system parameters of vaccinated broilers. Poult Sci, 102: 1-12.

AVIAGEN W. 2014. Ross 308 Broiler nutrition specifications. Aviagen Group, Huntsville, USA, pp: 25.

Barbut S, Zhang L, Marcone M, 2005. Effects of pale, normal, and dark chicken breast meat on microstructure, extractable proteins, and cooking of marinated fillets. Poult Sci, 84(5): 797-802.

Cetin E, Silici S, Cetin N, Kocaoglu Guclu B. 2010. Effects of diets containing different concentrations of propolis on hematological and immunological variables in laying hens. Poult Sci, 89: 1703-1708.

Choi YM, Noh DO, Choc SY, Suh HJ, Kim KM, Kim JM. 2006. Antioxidant and antimicrobial activities of propolis from several regions of Korea. LWT, 39: 756-761.

Haščík P, Trembecká L, Bobko M, Kačániová M, Bučko O, Tkáčová J, Kunová S. 2015. Effect of different dietary supplements on selected quality indicators of chicken meat. Potr S J F Sci, 9(1): 427.

Huang X, Ahn DU. 2019. Lipid oxidation and its implications to

meat quality and human health. Food Sci Biotechnol, 28(5): 1275-1285.

Hunt MC, Acton JC, Benedict RC, Calkins CR, Cornforth DP, Jeremiah LE, Olson DG, Salm CP, Savell JW, Shivas SD. 1991. Guidelines for meat color evaluation. National Livestock and Meat Board. Chicago, USA, pp:36.

Irawan A, Hidayat C, Sholikin MM, Harahap RP, Rusli RK, Solfaine R, Jayanegara A. 2021. Propolis supplementation on broiler chicken performances, nutrient digestibility, and carcass characteristics: a meta-analysis. Trop Anim Sci J, 44(4): 425-433.

Kaewsatuan P, Poompramun C, Kubota S, Yongsawatdigul J, Molee W, Uimari P, Molee A. 2023. Thigh muscle metabolic response is linked to feed efficiency and meat characteristics in slow-growing chicken. Poult Sci, 102(7): 1-11.

Kasote D, Bankova V, Viljoen AM. 2022. Propolis: Chemical diversity and challenges in quality control. Phytochem Rev, 21(6): 1887-1911.

Khan U, Hussain J, Mahmud A, Khalique A, Mehmood S, Badar IH, Usman M, Jaspal MH, Ahmad S. 2019. Comparative study on carcass traits, meat quality and taste in broiler, broiler breeder and Aseel chickens. Braz J Poult Sci, 21(1/001): 1-10.

Komiyama CM, Mendes AA, Sanfelice C, Canizares MC, De Oliveira Roca R, Takahashi SE, De Godoi Cardoso KF. 2010. Physical, chemical and sensorial breast meat quality of spent breeder hens/Qualidade Fisico-Quimica E Sensorial Da Carne De Peito De Matrizes Pesadas De Descarte. Cienc Rural, 40(7): 1623-1630.

Konanc K, Ozturk E. 2025. Effects of propolis extract supplementation in breeder and broiler diets and it's in ovo injection on immune status, blood parameters, vaccine-antibody response and intestinal microflora of broiler chick. Trop Anim Health Prod, 57(2): 89.

Koohsar SAA, Sayyed-Alangi SZ, Shamloofar M, Sharifian S. 2018. Effect of different extracts of Iranian propolis on shelf-life of silver carp (Hypophthalmichthys molitrix) fillet in the refrigerator. Iran J Food Sci Technol, 15(3): 51-65.

Lee SK, Chon JW, Yun YK, Lee JC, Jo C, Song KY, Seo KH. 2022. Properties of broiler breast meat with pale color and a new approach for evaluating meat freshness in poultry processing plants. Poult Sci, 101(3): 1-7.

Mahmoud UT, Abdel-Rahman MA, Darwish MHA. 2013. The effect of Chinese propolis supplementation on Ross broiler performance and carcass characteristics. J Adv Vet Res, 3(4): 154-160.

Mahmoud UT, Cheng HW, Applegate TJ. 2016. Functions of propolis as a natural feed additive in poultry. J World's Poult Sci, 72(1): 37-48.

Mujica V, Orrego R, Pérez J, Romero P, Ovalle P, Zúñiga-Hernández J, Leiva E. 2017. The role of propolis in oxidative stress and lipid metabolism: a randomized controlled trial. eCAM, 2017(1): 1-11.

Prakatur I, Miškulin I, Senčić Đ, Pavić M, Miškulin M, Samac D, Domaćinović M. 2020. The influence of propolis and bee pollen on chicken meat quality. Vet Arh, 90(6): 617-625.

Sabuncular G, Akbulut G, Yaman M. 2021. Ette lipit oksidasyonu ve etkileyen faktörler. EJOSAT, 27: 362-369.

Sahin HA, Ozturk E. 2018. Effects of raw propolis or water and ethanol extract of propolis on performance, immune system and some blood parameters of broiler breeders. Rev Bras Zootec, 47: e20170161.

Shalmany SK, Shivazard M. 2006. The effect of diets propolis supplementation on Ross broiler chicks performance. Int J Poult Sci, 5(1): 84-88.

Šulcerová H, Mihok M, Jůzl M, Haščík P. 2011. Effect of addition of pollen and propolis to feeding mixtures during the production of broiler chickens ROSS 308 to the colour of thigh and breast muscle and pH determination. Acta Univ Agric Silvic Mendel Brun, 59: 359-366.

Swatland HJ. 2008. How pH causes paleness or darkness in chicken breast meat. Meat Sci, 80(2): 396-400.

Tan FJ, Li DC, Kaewkot C, Wu HD, Świąder K, Yu HC, Chen CF, Chumngoen W. 2022. Application of principal component analysis with instrumental analysis and sensory evaluation for assessment of chicken breast meat juiciness. Br Poult Sci, 63(2): 164-170.

Tumbarski Y, Topuzova M, Todorova M. 2022. Food industry applications of propolis: a review. JHED, 2022: 40.

Türkyılmaz D, Sisik Ogras S, Dagdelen U, Yaprak M, Esenbuga N. 2021. The effect of aging time and breed on some meat quality traits in Morkaraman and Awassi ram lambs. JIST, 11(4): 3292-3299.

Wojtacka J, 2022. Propolis contra pharmacological interventions in bees. Mol, 27(15): 4914.

Yalcın S, Guler HC, Yasa İ, İzzetoglu GT, Ozkan S. 2014. Effect of breeder age and slaughter weight on meat quality traits of broiler breast and leg meats. EPS, 78: 1-10.

Zulhendri F, Chandrasekaran K, Kowacz M, Ravalia M, Kripal K, Fearnley J, Perera CO. 2021. Antiviral, antibacterial, antifungal, and antiparasitic properties of propolis: a review. Foods, 10(6): 1360.