

Research Article

Effect of Aqueous Propolis Supplementation on Performance in Hematological and Serum Biochemical Parameters of Cobb 500 Broiler Chicken

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Abstract

The increased usage of synthetic antibiotics for treatment and growth promotion in livestock has significantly resulted into antimicrobial resistance among livestock and human. To combat this challenge, the current study evaluated the effects of propolis, as a natural growth promoter, compared to a commercial synthetic booster on hematological and serum biochemical parameters of Cobb 500 broiler chickens. A total of 100 day-old chicks were randomly assigned to five treatment groups in a completely randomized design (CRD). The control group (CTR) received plain water, while the positive control group (CBB) received water supplemented with a commercial broiler booster. Three experimental groups (P1, P2, and P3) received propolis extract prepared from 100g, 200g, and 300g of raw propolis per liter of water, respectively. Birds were reared for 42 days, and blood samples were collected at days 3 and 42 for analysis of hematological and biochemical indices. The results showed that white blood cell indices responded variably to the type and dose of growth promoter. At day 42, the P1 group exhibited significantly elevated lymphocyte counts, suggesting enhanced humoral immunity. In contrast, the BST group showed increased neutrophil and monocyte levels, indicating possible innate immune activation or stress. Red blood cell parameters remained largely unchanged at day 3 but showed significant variations at day 42, particularly in MCV, MCHC, and RDW metrics, suggesting dose-related impacts on erythrocyte morphology. No significant differences were observed in total protein and cholesterol levels across all treatments, indicating minimal effects on liver function and lipid metabolism. Overall, the study suggests that moderate doses of propolis can enhance immune responses in broilers without adversely affecting blood biochemistry, supporting its use as a natural alternative to synthetic growth promoters.

Keywords

Propolis, Broiler Chickens, Hematology, Serum biochemistry, Immune Response, Growth Promoter

1. Introduction

As demand for poultry meat continues to rise, a scenario resulted from increased global human population; the search for healthier and more sustainable growth promoters to im-

prove broiler chicken production has become increasingly important [3, 5]. For many years, livestock farmers have relied mainly on the use of synthetic additives like antibiotics

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to enhance growth and feed efficiency in poultry. Despite being effective, these synthetic additives have raised serious public health concerns due to their contribution to antimicrobial resistance and the potential for drug residues in meat products [4, 5].

This has led the researchers and poultry producers to explore safer, natural alternatives that can support growth and health without compromising food safety. Among the suggested promising option is propolis, a resin-like substance collected by bees from plant buds and bark. Propolis is known for its rich content of bioactive compounds such as flavonoids and phenolic acids, which make it to have the powerful antioxidant, antimicrobial, and anti-inflammatory properties [8, 10, 12, 14]. These qualities make propolis a strong candidate as an organic growth promoter in poultry diets [1, 2].

Although Propolis is primarily used as a natural growth promoter, it is equally important to assess its effects on the overall health of broiler chickens. Hematological and biochemical blood parameters are reliable indicators of physiological and metabolic responses to dietary interventions. These markers reflect vital functions such as organ performance, immune status, and stress levels, which are essential for maintaining healthy and productive poultry flocks [7, 9, 11]. Some researchers have reported that the use of Propolis in diets significantly affected not only growth performance but some blood parameters as well such as heterophils [6, 13, 15].

Despite growing interest in propolis, relatively little is known about its specific effects on blood profiles especially when it is supplemented through water. This study, therefore, aims to investigate how supplementing broiler chickens with propolis influences key hematological and biochemical markers. The goal is to better understand the potential of propolis not only as a natural growth promoter but also as a way to support bird health in antibiotic-free production systems.

2. Methodology

2.1. Collection of Propolis and Preparation of Extracts

Raw Propolis of 10 kg was bought from Kigoma region in Tanzania. It was then weighed into three different types of portions which vary in weights of 100g (P1), 200g (P2) and 300g (P3). A weighed propolis corresponding to the treatment groups was added to the conical flask followed with the addition of one Liter of water to the flask subjected to heat at 100 °C in a water bath container. The initial and the final time of melting of propolis were successfully recorded. Then, the mixture was cooled and filtered to obtain the Propolis Extract (PE). The dose used was 100ml/L of water was used to administer to the chicken.

2.2. Experimental Design and Treatments

In this study, Completely Randomized Design (CRD) was used with five treatment groups. Treatment one was control group (CTR) which was given water only without Propolis Extract. Treatment two was a positive control group (CBB) which was given water supplemented with Commercial Broiler Booster. Treatment three (P1) group was given water supplemented with PE made from 100g/L of water. Treatment four (P2) group was given PE made from supplemented with 200g/L of water. Treatment five (P3) group was supplemented with PE of 300g/L of water.

2.3. Source of Experimental Animals and Their Management

A total of 100 day old chicks (DOCs) were bought from the Irvine Company and taken to the poultry farm unit at Department of Animal, Aquaculture and Range Sciences (DAARS) at Sokoine University of Agriculture (SUA), Morogoro, Tanzania. They were reared for six weeks throughout the study. Chicks were brooded for two successive weeks in a well-ventilated area and infra-red bulb was used for heat purposes in the brooding weeks and reduced gradually following the next week. For absorption purposes, rice hulls were used in each pen at 4-5cm deep. Commercial broiler feed was used throughout the experiment and chicks were vaccinated against Newcastle disease on the 7th and 21th day and Gumboro disease on 14th day of age. Feed and water were supplied twice a day. The amount of feed before and refusals were weighed before the next feed using a digital weighing balance and the measurements were recorded.

2.4. Blood Sample Collection and Analysis

At the end of the experimental period (day 42), blood samples were collected from randomly selected birds from each treatment group. A total of 20 broiler chickens (Cobb 500) per treatment were sampled, ensuring representative coverage. Blood was drawn in the early morning hours to minimize stress and diurnal variation. Birds were manually restrained, and 2 ml of blood was collected from the brachial vein using sterile 23-gauge needles and disposable syringes. The collected blood was divided into two portions one for hematological analysis and the other for biochemical analysis.

For hematological analysis approximately 1 ml was transferred into sterile tubes containing ethylenediaminetetraacetic acid (EDTA) as an anticoagulant. Samples were gently inverted and stored at 4 °C until analysis within 6 hours. The remaining 1 ml was placed into plain, non-heparinized tubes and allowed to clot at room temperature. Samples were then centrifuged at 3000 rpm for 10 minutes, and the serum was separated and stored at -20 °C ready for biochemical analysis. Hematological parameters such as white blood cell count (WBC), red blood cell count (RBC), hemoglobin (Hb),

mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) were determined using an automated hematology analyzer (Model: UN73 Vet) manufactured in China. Biochemical analyses included measurement of total protein and cholesterol. These were assessed using commercial diagnostic kits and an automated clinical chemistry analyzer (XL-200) made in Germany, following the manufacturer's (Erba Mannheim) instructions. All analyses were conducted in Physiology laboratory located at College of Veterinary medicines and biomedical sciences (CVMBS) at SUA.

3. Results

3.1. Effects of Growth Promoters on White Blood Cell Indices of Broiler Chickens at 3 Days of Age

Table 1 presents the results of effects in propolis and booster as growth promoter in white blood cells indices of broiler chickens. The mean difference in eosinophils percentage was statistically significant between treatments groups ($P < 0.05$). Moreover, the statistical mean of eosinophils percentage at P3 was higher ($P < 0.05$) than at CTR, BST, P1 and P2. However, the mean difference in eosinophils number across different growth promoters was not significant ($P > 0.05$).

Table 1. Effects of growth promoter on white blood cell indices at day 3.

		Treatment					SEM	P-Value
Cell type		CTR	BST	P1	P2	P3		
Lymphocytes	N	81.38	84.23	85.05	86.01	62.19	5.42	0.226
	%	88.13	91.29	90.74	92.12	71.01	3.91	0.092
Monocytes	N	1.13	1.27	0.79	0.88	1.18	0.33	0.827
	%	1.2	1.33	1.01	0.9	1.94	0.38	0.390
Eosinophils	N	0.005 ^b	0.013 ^b	0.01 ^b	0.111 ^a	0.187 ^a	0.05	0.053
	%	0 ^b	0 ^b	0 ^b	0 ^b	0.345 ^a	0.03	0.002
Basophils	N	0.405	0.393	0.425	0.438	0.424	0.04	0.990
	%	0.425	0.475	0.477	0.482	0.358	0.03	0.057
Neutrophils	N	9.468 ^{ab}	6.39 ^{ab}	7.247 ^{ab}	4.134 ^b	14.515 ^a	1.78	0.019
	%	10.25	6.90	7.57	5.00	8.01	1.28	0.095
Total WBC		92.39	92.29	94.58	93.99	76.76	3.91	0.315

The mean neutrophils number was significantly different between treatments groups ($p < 0.05$). The higher mean neutrophils number was at P3 and lower at P2 ($P < 0.05$). Moreover, the number of neutrophils at P3 was statistically similar to that of CTR, BST and P1 ($P > 0.05$) ($P < 0.05$). The mean difference of the neutrophils number between CTR, BST and P1 was not significant ($P > 0.05$). Furthermore, the mean neutrophils percentage across the treatments was similar ($P > 0.05$). The mean percentage of lymphocytes, monocytes, basophils and total white blood cells (WBC) were not statistically different between treatment groups ($P > 0.05$). Moreover, the mean difference of the lymphocytes, monocyte, basophils and total WBC at day 3 were not significantly dif-

ferent across the treatments groups ($P > 0.05$).

3.2. Effects of Growth Promoters on Red Blood Cell Indices of Broiler Chickens at 3 Days of Age

The results for the effects of growth promoters on red blood cells indices at day 3 are presented in Table 3. The mean difference of HGB, HCT, MCV, MCHC, RDVC, RDWSD and Total RBC were not statistically significant across the treatments groups ($P > 0.05$).

Table 2. Effects of growth promoter on red blood cell indices at day 3.

Cell type	Treatment					SEM	P-Value
	CTR	BST	P1	P2	P3		
HGB	8	6.4	9.33	9.62	5.88	1.24	0.315
HCT	25.78	20.9	29.82	31.57	16.70	4.12	0.251
MCV	162.55	164.75	166.51	166.01	168.54	1.75	0.276
MCH	50.78	51.15	52.12	52.39	52.26	0.53	0.266
MCHC	31.25	31.08	31.28	31.17	30.87	0.26	0.851
RDWCV	15.88	14.03	14.28	14.88	14.56	0.72	0.540
RDWSD	76.45	69.15	76.3	75.93	73.06	4.08	0.785
Total RBC	1.58	1.27	1.79	1.92	1.46	0.25	0.556

3.3. Effects of Growth Promoters on White Blood Cell Indices of Broiler Chickens at 42 Days of Age

The effects of growth promoters on white blood cells indices at day 42 are presented on Table 3. The percentage and number of lymphocytes were statistically different between the treatments ($P < 0.05$). The higher values of percentage and number of lymphocytes were at P1 ($P < 0.05$) and least at BST

($P > 0.05$). However, the mean number of lymphocytes at P1 was significantly similar to that of CTR, P2 and P3 ($P < 0.05$) but statistically different to BST ($P < 0.05$). The mean difference in lymphocytes percentage between CTR, P2 and P3 was not significant ($p > 0.05$). Nevertheless, mean values of lymphocytes number was significantly similar between CTR and BST ($p > 0.05$) which differed significantly from that of P1, P2 and P3 ($P < 0.05$).

Table 3. Effects of growth promoter on white blood cell indices at day 42.

Cell type		Treatment					SEM	P-Value
		CTR	BST	P1	P2	P3		
Lymphocytes	N	88.17 ^{ab}	79.90 ^b	90.53 ^a	82.73 ^{ab}	82.48 ^{ab}	1.41	0.030
	%	88.25 ^{bc}	77.18 ^b	90.53 ^a	84.14 ^c	84.03 ^c	0.88	0.001
Monocytes	N	3.34 ^b	7.06 ^a	2.87 ^b	3.38 ^b	4.73 ^{ab}	0.41	0.001
	%	3.67 ^{ab}	6.11 ^a	2.88 ^b	3.47 ^{ab}	4.32 ^{ab}	0.41	0.032
Eosinophils	N	0.11 ^b	0.44 ^b	0.45 ^b	1.13 ^a	0.19 ^b	0.09	0.002
	%	0.14	0.52	0.44	0.56	0.24	0.10	0.113
Basophils	N	0.44 ^a	0.39 ^b	0.45 ^a	0.42 ^{ab}	0.41 ^{ab}	0.01	0.002
	%	0.47	0.42	0.45	0.43	0.39	0.02	0.112
Neutrophils	N	6.19 ^b	11.03 ^a	5.86 ^b	11.14 ^a	10.40 ^a	0.60	0.001
	%	6.48 ^c	13.66 ^a	5.85 ^c	11.77 ^b	10.35 ^{ab}	0.50	0.001
Total WBC		98.86 ^{ab}	97.73 ^b	99.58 ^a	99.47 ^a	98.35 ^{ab}	0.30	0.009

The mean number and percentage of the monocytes of the broiler chicken was significantly different across the treatment groups ($p < 0.05$). The percentage and number of monocytes was higher at BST ($p < 0.05$) and lower at P1. The mean number of the monocytes on chickens across different growth promoters was statistically different with higher value being at BST and lower at P1, P2 and CTR ($p < 0.05$). The mean value of monocytes number at BST was significantly similar to that of P3 ($p < 0.05$). The mean value of the monocytes percentage at BST was significantly similar to that of CTR, P2 and P3 ($p < 0.05$). The mean value of eosinophil number was significantly different between the treatments ($p < 0.05$). The mean number of the eosinophil was higher at P2 ($p < 0.05$) while lower at CTR ($p < 0.05$) whereas, the mean difference of eosinophil number between CTR, BST, P1 and P3 was not significant ($p > 0.05$). The mean eosinophil percentage was significantly similar across the treatments ($p > 0.05$). The mean number of the basophils was statistically different across the treatment groups ($p > 0.05$) with the higher mean basophil number being at P1 ($p < 0.05$) and lower at BST ($p < 0.05$). However, the mean value of basophils number at P1 was significantly similar to that of CTR, P2 and P3 ($p < 0.05$). The mean difference of Basophils percentage between the treat-

ments was not significant ($p > 0.05$).

3.4. Effects of Growth Promoters on Red Blood Cell Indices of Broiler Chickens at 42 Days of Age

The effects of growth promoters on red blood cells indices at day 42 are presented on Table 4. The mean values of haemoglobin (HGB), haematocrit (HCT), mean corpuscular haemoglobin (MCH) and the total red blood cells (RBC) were significantly similar between treatments ($P > 0.05$). The mean value of the mean corpuscular volume (MCV) of broiler chickens across different growth promoters was statistically different ($P < 0.05$). Mean value of MCV was significantly higher at CTR and lower at P2 ($P < 0.05$). However, the mean MCV at CTR was significantly similar to that of BST, P1 and P3 ($P > 0.05$). The mean value of the mean corpuscular haemoglobin concentration (MCHC) was significantly different between treatments ($P < 0.05$). The higher MCHC was observed at BST while the least value being at CTR and P1 ($P < 0.05$). However, the mean MCHC at BST was significantly similar to that of P2 and P3 ($P > 0.05$).

Table 4. Effects of growth promoter on red blood cell indices at day 42.

Cell type	Treatment					SEM	P-Value
	CTR	BST	P1	P2	P3		
HGB	1328	12.91	14.52	13.81	13.63	0.38	0.142
HCT	39.70	37.64	51.44	39.90	38.33	0.98	0.211
MCV	144.59 ^a	137.37 ^{ab}	140.18 ^{ab}	133.38 ^b	136.27 ^{ab}	1.82	0.028
MCH	47.14	47.05	46.39	45.78	46.77	0.33	0.082
MCHC	32.58 ^b	34.66 ^a	32.96 ^b	34.10 ^{ab}	34.20 ^{ab}	0.30	0.004
RDW-CV	10.63 ^{ab}	10.24 ^b	10.84 ^{ab}	11.20 ^a	10.51 ^b	0.14	0.005
RDW-SD	44.87 ^{ab}	41.56 ^b	45.97 ^a	43.50 ^{ab}	41.67 ^b	0.80	0.013
Total RBC	2.72	2.74	3.15	2.93	2.90	0.11	0.123

The mean value of red cell distribution width - coefficient of variation (RDW-CV) for chickens reared under different growth promoters was significantly different ($P < 0.05$). The RDW-CV value was statistically higher at P2 ($P < 0.05$) and lower at BST and P3 ($P < 0.05$). The mean values of RDW-CV for chickens given BST and P3 were significantly similar ($P > 0.05$) to those reared under CTR and P1. The mean value of red cell distribution width - standard deviation (RDW-SD) of broiler chickens was significantly different across the treatments groups ($p < 0.05$). Moreover the higher mean value

of RDW-SD was on chickens reared under P1 whereas the lower mean value of RDW-SD was from those reared under BST and P3 ($P < 0.05$). Furthermore, the mean value of RDW-SD at P1 was significantly similar ($p < 0.05$) to that at CTR and P2.

3.5. Effects of Growth Promoters on Serum Metabolites/Biochemical Markers

The effects of growth promoters on serum metabolites or se-

rum biochemical markers are presented in the Table 5. There was no significant difference in total protein (TP) and total chole-

sterol (TCHOL) across the treatment groups ($P > 0.05$).

Table 5. Effects of Growth Promoters on Serum Metabolites.

Serum metabolites	Treatment						P-Value
	CTR	BST	P1	P2	P3	SEM	
TP	3.14	2.99	3.6	4.1	3.14	0.26	0.217
TCHOL	151.74	152.6	164.18	163.67	146.55	5.76	0.341

4. Discussion

The current study demonstrates the immunomodulatory potential of natural (propolis) and synthetic (booster) growth promoters in broiler chickens, with effects varying by age and dosage. At both 3 and 42 days of age, the white blood cell (WBC) profile showed selective responsiveness to the type and dose of growth promoter administered, while red blood cell (RBC) indices and serum metabolites exhibited limited but noteworthy changes. These findings underline the importance of dose optimization in using growth-promoting agents to avoid adverse physiological responses [1, 13].

The immunostimulatory effect of propolis, particularly at moderate doses, appears to be dose-dependent and aligns with prior studies that attribute its immune-enhancing properties to its rich content of phenolic compounds and flavonoids [2, 8, 12]. The elevated lymphocyte numbers and percentages at day 42 in the P1 group point to an enhanced humoral immune response, potentially leading to improved resistance to infections and better responses to vaccination. This observation supports previous assertions that propolis can bolster immune function without triggering over activation, especially when administered at appropriate levels [1, 14]. This supports the idea that moderate inclusion of propolis can optimize immune status without inducing excessive inflammatory responses.

Conversely, the synthetic booster (BST) group exhibited marked increases in neutrophils and monocytes at both day 3 and 42, suggestive of heightened innate immune activity. While this may be beneficial for early immune defense, it may also indicate low-grade inflammation or physiological stress, particularly if sustained over time. According to [6], commercial boosters often contain antibiotic-like compounds or immune-enhancing agents that can cause leukocyte shifts; however, such shifts may not always be beneficial if they reflect stress or immune overstimulation. Notably, increased neutrophil counts can be indicative of immune stimulation or systemic stress, especially in the presence of unchanged lymphocyte counts [5].

The minimal alterations in RBC indices at day 3 suggest

that short-term exposure to either propolis or synthetic boosters does not immediately influence erythropoiesis or oxygen-carrying capacity. However, at day 42, changes in MCV, MCHC, RDW-CV, and RDW-SD were observed, especially in the P2 and BST groups. These alterations may reflect underlying stress responses or altered erythrocyte turnover, potentially linked to prolonged exposure to bioactive compounds in propolis or synthetic additives [16, 17]. Increased RDW, in particular, has been associated with oxidative stress and nutrient imbalances, which may compromise red blood cell integrity over time [7, 11].

Interestingly, neither propolis nor booster treatments significantly altered total serum protein or cholesterol levels, suggesting minimal effects on liver function and lipid metabolism. This may be due to the birds' capacity to maintain homeostasis under standard nutritional and management conditions (Deng et al., 2012; Burdock, 1998). It also implies that the administered dosages were within physiological tolerance limits for metabolic regulation [10].

5. Conclusion and Recommendation

In conclusion, Propolis particularly at moderate concentrations (especially 100 mg/kg) demonstrated potential as a natural alternative to synthetic growth promoters by enhancing immune responses without significantly disrupting hematological balance or metabolic markers. However, higher doses (P2, P3) and synthetic boosters may provoke stress-associated changes in blood parameters. Future studies should explore the long-term physiological impacts of propolis and define optimal dosing strategies to support both productivity and welfare in broiler production systems.

Abbreviations

CBB	Commercial Broiler Booster
CRD	Completely Randomized Design
CTR	Control
DAARS	Department Of Animal, Aquaculture and Range

	Sciences
DOC	Day Old Chicks
EDTA	Ethylenediaminetetraacetic acid
HB	Hemoglobin
HCT	Hematocrit
MCH	Mean Corpuscular Hemoglobin
MCHC	Mean Corpuscular Hemoglobin Concentration
MCV	Mean Corpuscular Volume
P1	100 G Of Propolis Per Litre of Water
P2	200 G Of Propolis Per Litre of Water
P3	300 G Of Propolis Per Litre of Water
PE	Propolis Extract
RBC	Red Blood Cells
RDW	Red Blood Cell Distribution Width
RDWCV	Red Blood Cell Distribution Width-Coefficient of Variation
RDWSD	Red Blood Cell Distribution Width-Standard Deviation
TCHOL	Total Cholesterol
TP	Total Protein
WBC	White Blood Cells

Author Contributions

Glory Zerah Azza: Conceptualization, Formal Analysis, Methodology, Writing - original draft

Sebastian Wilson Chenyambuga: Conceptualization, Methodology, Supervision, Writing - review & editing

Charles Moses Lyimo: Conceptualization, Supervision, Writing - review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Abdelsalam, M. E., El-Shafei, R. A., & Mohamed, M. A. (2019). Blood hematological and biochemical parameters and humoral immunity as affected by added dietary propolis supplementation of Cobb broiler chicks. *Egyptian Journal of Nutrition and Feeds*, 22(3), 491-500.
- [2] Babaei, M., Moghaddam, A. Z., & Rezaei, A. (2016). Effects of dietary propolis supplementation on performance, immune response and blood characteristics of broiler chickens. *Brazilian Journal of Poultry Science*, 18(1), 49-56. <https://doi.org/10.1590/1806-9061-2015-0152>
- [3] Burdock, G. A. (1998). Review of the biological properties and toxicity of bee propolis (propolis). *Food and Chemical Toxicology*, 36(4), 347-363. [https://doi.org/10.1016/S0278-6915\(97\)00145-2](https://doi.org/10.1016/S0278-6915(97)00145-2)
- [4] Deng, W., Dong, X.-F., Tong, J. M., & Zhang, Q. (2012). The probiotic *Bacillus licheniformis* ameliorates heat stress-induced impairment of egg production, gut morphology, and intestinal mucosal immunity in laying hens. *Poultry Science*, 91(3), 575-582. <https://doi.org/10.3382/ps.2010-01293>
- [5] Gadde, U., Kim, W. H., Oh, S. T., & Lillehoj, H. S. (2017). Alternatives to antibiotics for maximizing growth performance and feed efficiency in poultry: A review. *Animal Health Research Reviews*, 18(1), 26-45. <https://doi.org/10.1017/S1466252316000207>
- [6] Ghasemi, H. A., Ghasemi, R., Torki, M., & Khosravi, H. (2014). Supplementation of broiler diets with phyto-genic products: Performance, immune responses and cecal microflora. *South African Journal of Animal Science*, 44(3), 211-221. <https://doi.org/10.4314/sajas.v44i3.5>
- [7] Hashemipour, H., Kermanshahi, H., Golian, A., & Veldkamp, T. (2013). Effect of thymol and carvacrol feed supplementation on performance, antioxidant enzyme activities, fatty acid composition, digestive enzymes and immune response in broilers. *Poultry Science*, 92(8), 2059-2069. <https://doi.org/10.3382/ps.2012-02685>
- [8] Huang, S., Zhang, C. P., Wang, K., Li, G. Q., & Hu, F. L. (2014). Recent advances in the chemical composition of propolis. *Molecules*, 19(12), 19610-19632. <https://doi.org/10.3390/molecules191219610>
- [9] Jain, N. C. (1993). *Essentials of veterinary hematology* (5th ed.). Lea & Febiger.
- [10] Krol, W., Scheller, S., Czuba, Z., & Sytykiewicz, H. (1993). Anti-oxidant property of ethanolic extract of propolis and its components. *Zeitschrift für Naturforschung C*, 48(11-12), 982-985. <https://doi.org/10.1515/znc-1993-11-1221>
- [11] Miller, J. K., Brzezinska-Slebodzinska, E., & Madsen, F. C. (1993). Oxidative stress, antioxidants, and animal function. *Journal of Dairy Science*, 76(9), 2812-2823. [https://doi.org/10.3168/jds.S0022-0302\(93\)77620-1](https://doi.org/10.3168/jds.S0022-0302(93)77620-1)
- [12] Orsi, R. O., Funari, S. R. C., Soares, A. M. V. C., Calvi, S. A., Oliveira, S. L., Sforcin, J. M., & Bankova, V. (2005). Immunomodulatory action of propolis on macrophage activation. *Journal of Venomous Animals and Toxins including Tropical Diseases*, 11(2), 135-139. <https://doi.org/10.1590/S1678-91992005000200007>
- [13] Seven, P. T., Seven, I., Yilmaz, M., & Simsek, Ü. G. (2010). Effects of Turkish propolis on performance and digestive tract traits in broiler chicks. *British Poultry Science*, 51(6), 830-835. <https://doi.org/10.1080/00071668.2010.528792>
- [14] Seven, P. T., Yilmaz, S., Seven, I., Çiftçi, M., Azman, M. A., & Yilmaz, M. (2011). Effects of Turkish propolis on the growth performance, carcass characteristics and serum parameters of Japanese quails. *Animal Feed Science and Technology*, 164(3-4), 246-253. <https://doi.org/10.1016/j.anifeedsci.2011.01.008>
- [15] Shaddel-Tili, S., Rahimi, S., Karimi, A., & Bagheri, A. (2017). Effect of propolis on growth performance and hematological parameters of broiler chickens. *Poultry Science Journal*, 5(2), 123-132. <https://doi.org/10.22069/psj.2017.12170.1241>

- [16] Donsbough, A. L., Powell, S., Waguespack, A., Bidner, T. D., & Southern, L. L. (2010). Effects of supplemental selenium on the performance and selenium status of broilers. *Poultry Science*, 89(11), 2526-2532.
<https://doi.org/10.3382/ps.2010-00832>
- [17] Thrall, M. A., Weiser, G., Allison, R. W., & Campbell, T. W. (Eds.). (2012). *Veterinary hematology and clinical chemistry* (2nd ed.). Wiley-Blackwell.