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Effects of Origanum Syriacum Essential Oil on Blood Parameters of Broilers Reared at High Ambient Heat

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ABSTRACT

The biochemical and hematological blood values of broilers fed under heat stress and that were administered *Origanum syriacum* (OS) essential oil were investigated in this study. In total, 400 male broilers (Ross-308; age, 1 day) were used for the period of 42-days of the study. The experiment included ten groups (n = 50/group; each group divided into five sub-groups): normal heat, 22°C: basal feed (BF)-positive control group (PC), BF + 100 ppm OS; BF + 300 ppm OS; BF + 600 ppm OS). Heat stress, 36°C: BF-positive control group (PC), BF + 100 ppm SOS; BF + 300 ppm OS; and BF + 600 ppm OS). Biochemical and hematological parameters were measured in blood collected into EDTA tubes. Total bilirubin, cholesterol, low-density cholesterol, Na^+, Ca^{2+}, and Mg^{2+} increased, whereas alanine aminotransferase, aspartate aminotransferase, creatine kinase (CK), CK-MB, urea, uric acid, Cl^-, and K^+ decreased ($p<0.05$); however, no changes were detected in the other hematological values.

INTRODUCTION

Stress emerges from endogenous (nutrition and feeding problems, fast growth, sexual maturation period, and infection) and exogenous factors (climate, high density insufficient ventilation), and causes dire economic losses in poultry (Chenga & Muırb, 2004; Olanrewaju *et al.*, 2006; Hadımlı *et al.*,2007). One stressor is high temperature which causes hyperventilation, blood pH > 7, and a decrease in plasma pyruvate kinase along with an increase in CO_2 density in the lungs; thus, causing livestock to perish within a short period (Hartlova *et al.*, 2002; Lin *et al.*, 2006; Al-fataftah & Abu-dieyeh, 2007) . Antibiotics have been used in the poultry industry to reduce the impact of stress, increase stock performance, and regulate gastrointestinal microflora. Nevertheless, the European Union (EU) banned antibiotics when the World Health Organization reported that microorganisms can become immune to specific antibiotics over time thus causing the emergence of resistant bacteria that pose a risk to human health (Gue *et al.*, 2004; Yörük *et al.*, 2008). In addition, growing sensitivity towards issues, such as human health, food safety, and environmental pollution, have emerged among consumers despite the progresses achieved in food production techniques and slaughterhouse hygiene in EU countries (Mazmanoğlu, 2008). Therefore, growing organic products by adding natural feed additives as an alternative to synthetic additives has begun in recent years. One of these alternative feed additives is thyme. Thyme is a herb in the Lamiaceae family with 40 species worldwide. Thyme contains carvacrol and thymol along with various phenolic monoterpenes. *Origanum syriacum* (OS) is an aromatic herb within the thyme family that grows primarily in Syria, Jordan, Lebanon, and the Sinai Peninsula, where it has different names, such as Syrian oregano, biblical hyssop,

Za'atar, and marjoram (Alma *et al.*, 2003; IUCN, 2005; Lukas, 2010) . While the fatty acids in the OS essential oil generally contains polymorphic compounds, such as thymol and carvacrol, compounds, such as γ-terpinene, P-cymene, and thymoquinene, can also be found depending on the growing area (Lukas *et al.*, 2009) . Some studies have reported that essential fatty acids in OS have antioxidant (Luna *et al.*, 2010; Tavarez *et al.*, 2011), anti-microbial (Mitsch *et al.*, 2004;Gürakan *et al.*, 2008), anti-inflammatory (Yoshino *et al.*, 2006), anti-viral (Pilau *et al.*, 2011), anti-tumoral (El-desoukya *et al.*, 2009; Al-kalaldeh *et al.*, 2010), anti-ulcer (Afify *et al.*, 2012), anti-fungal (Manohar *et al.*, 2001), and anti-parasitic (Değerli *et al.*, 2012; Remmal *et al.*, 2013) properties, all of which have positive effects on stock performance (Jang *et al.*, 2007; Tekçe & Gül, 2016).

In this study, the effects of various doses of OS essential oil added to feed as an alternative to antibiotics in broilers fed under nominal heat (22°C) and heat stressed (36°C) conditions on biochemical and hematological parameters were studied.

MATERIALS AND METHODS

Animals, Experimental Design, Feeds

In this study, 400 1-day-old Ross-308 male broilers were used in the experiment. During the 7-day adaptation and a 35-day fattening period, the animals were kept indoors in 121 × 110 × 108 cm cages at Atatürk University Veterinary Faculty Husbandry Research and Practice Unit; each group consisted of 10 animals. For each of the experimental periods, 5 treatments were prepared by supplementing the standard commercial ration with 100 mg/kg of Avilamycin antibiotic (Kartal chem, İstanbul, Turkey) or 0 mg/kg (PC), 100 mg/kg, 300 mg/kg or 600 mg/kg of OS. The animals were equal in live weight, and were separated into ten groups (PC, A-100, OS-100, OS-300, OS-600, NC,SA-100, SOS-100, SOS-300, and SOS-600) each of which contained 50 animals. Then, all groups were separated into five sub-groups each of which consisted of 10 animals. During the experimental period, the groups: positive control (PC, A-100, OS-100 ppm, OS-300 and OS-600 were exposed to a temperature of 22°C, while the NC, SA-100, SOS-100, SOS-300 and SOS-600 groups were exposed to 36°C. Basal broiler feed was given to the animals every day at the same hour (around 17:00). The PC and NC groups were provided with only the basal broiler feed, whereas the diets of the OS-100, OS-300, OS-600, SOS-100, SOS-300, and SOS-600 groups were supplemented with 100, 300, 600, 100, 300, and 600 ppm OS essential oil (Mahan cosmetic, Antakya, Turkey), respectively. Four different basal broiler feeds were given to the animals at certain intervals (Table 1). This study was approved by the ethics committee of Atatürk University Veterinary Faculty (25.10.2013/5/126).

Table 1 – Composition and analyses of the basal diet (g/kg).

Raw Materials	Pre-Starter (0-14 d)	Starter (14-21 d)	Grower (21-28 d)	Finisher (28-42 d)
Maize 7.6	52.11	53.77	47.73	50.12
Wheat	-	-	10	10
Soybean meal 44%	23.4	17.87	12.47	11
Full Fat Soybean	17	20	20	20
Meat Bone's	-	1	1	-
Chicken Reputation 56	2.53	2.53	3.53	3.53
Soy Oil	1	1.53	1.27	0.6
Animal Fat	-	-	0.8	1.53
Salt	0.23	0.23	0.2	0.2
L-Lysine	0.17	0.15	0.15	0.15
L-Threonine	0.09	0.09	0.07	0.07
Mono-calcium Phosphate	0.87	0.6	0.47	0.53
Vitamin-mineral premix[1]				
		Chemical Analysis		
ME (Mj/kg)	12.64	13.08	13.40	13.44
Crude Protein %	23.2	23.4	23.3	22.5
Crude Oil %	8.2	8.8	8.9	9
Dry Matter %	89.3	90.5	90.7	89.6
Crude Cellulose %	3.4	3.7	4	4

The vitamin-mineral premix provided the following (per kg of diet): vitamin A, 12 000 IU; vitamin D3, 1500 IU; vitamin E, 50 mg; vitamin K3, 5 mg; vitamin B1, 3 mg; vitamin B2, 4 mg; vitamin B6, 4 mg; vitamin B12, 0.03 mg; calcium –D-pantothenate, 15 mg; folic acid, 1 mg; niacin, 25 mg; D-biotin, 0.115 mg; Co, 0.2 mg; Cu, 6 mg; Fe, 60 mg; K, 0.75 mg; Mn, 80 mg; Se, 0.15 mg; Zn, 60 mg.

Origanum Syriacum Essential Oil Composition

The OS essential oil contained 28.9% carvacrol, 19.9% ɤ-terpinene, 12.4% p-cymene, 7.1% thymol, and 6.5% α-terpinene.

Poultry House Heat Moisture and Illumination

The general temperature of the poultry house was 32–33°C during the first 2 days and 27–28°C during the next 5 days. On the other hand, a 36°C temperature and 75–85% relative humidity were applied to the groups subjected to heat stress, while 22°C temperature and 55–60% relative humidity were applied to the others. All groups were provided with illumination (60 W) for 24 hours.

Feed Analyses

A proximate analyses of the feeds used for this research was performed in accordance with the methods stated in A.O.A.C 2005.

Blood Analyses

On day 42 of the study, the chickens were fasted overnight for biochemical analyses. Then, 100 animals (10 from each group) were slaughtered randomly by cervical dislocation. Blood samples were collected into 10 ml biochemistry tubes and 5 ml EDTA hemogram tubes (Becton Dickinson Co. Brea, CA, USA), centrifuged at 4,100 rpm for 12 min at 4°C (NF 1200R, Nüve, Ankara Turkey), and the serum was transferred to Eppendorf tubes. Serum levels of glucose, albumin (ALB), creatinine, globulin, total protein, urea, alanine aminotransaminase (ALT), aspartate aminotransaminase (AST), glutamic pyruvate transaminase, total cholesterol, triglycerides (TG), high density lipoprotein cholesterol (HDL), low density lipoprotein cholesterol (LDL), very low density lipoprotein cholesterol (VLDL), Ca^{2+}, P, Mg^{2+}, Cl^{-}, Fe^{2+}, amylase, gamma-glutamyl transferase, alkaline phosphatase, and uric acid were assayed at the Erzurum Technical Chemistry and Medical Laboratories using a Cobas-8000 auto-analyzer, which is a closed spectrophotometric system, with Roche kits (Mannheim, Germany).

Statistical Analyses

The data were analyzed using SSPS 17.0. software (SPSS Inc., Chicago, IL, USA). Data are presented as mean ± standard error. Repeated-measures analysis of variance was used to identify if differences existed in the blood values between the groups. Duncan's multiple range test was applied to identify the group differences. A p-value < 0.05 was considered significant.

RESULTS

The effects of the OS essential oil added at different dosages (100, 300, and 600 ppm) on the metabolic, blood, and biochemical values are shown in Tables 2–5. Some of the serum values in broilers fed under heat stress and control conditions are as follows: glucose (22°C control: 270 vs. 36°C OS 300 ppm: 263.9 vs. 36°C O.S 600 ppm: 258.7 mM; $p<0.01$; ALT (22°C control: 2.2 vs. 36°C OS 300 ppm: 1.3; $p<0.00$); AST (22°C control: 295.8 vs. 36°C OS 300 ppm: 308.6; $p<0.01$, ALB (22°C control: 1.3 vs. 36°C OS 300 and 600 ppm: 1.2; $p<0.04$); CK-MB (22°C control: 0 vs. 36°C OS 600 ppm: 0; $p<0.01$); Ca2+ (22°C control: 10.2 vs. 36°C OS 600 ppm: 11; $p<0.01$); K+ (22°C control: 9.4 vs. 36°C OS 300 ppm: 6.6; $p<0.01$). Adding the OS essential oil at various dosages had no effect on most hematological values compared to the values after administering the antibiotic or heat stress. However, the OS oil did have an effect on glucose ($p<0.01$), liver enzymes (ALT and AST) and CK-MB ($p<0.01$), which indicates heart and skeletal muscle degeneration. The 600 ppm OS essential oil dosage completely protected the muscles against various pathological defects ($p<0.01$.

DISCUSSION

The levels of various biochemical parameters vary depending upon numerous biochemical reactions such as digestion and absorption of food. These parameters also vary with factors like strain, health, and environmental conditions (Gümüş, 2013). Blood glucose level is a biochemical indicator that increases in broilers under stress (Khaksar *et al.*, 2012). Due to increased gluconeogenesis and activation of muscle glycogen stores after corticosterone is released from the adrenal gland. While glucose and corticosterone concentrations increase in response to stress, the number of lymphocytes decreases, which diminishes the effectiveness of the humoral and cellular defense systems (Hayırlı *et al.*, 2005). Serum glucose level has been reported to increase in broilers as temperature rises over 30°C (Khan *et al.*, 2002; İsmail *et al.*, 2013; Toplu *et al.*, 2014). In our study, the OS essential oil had no effect on blood glucose level (Table 2), and the glucose levels after exposure to heat stress were

Table 2 – Serum biochemical parameters in the experimental groups.

Blood Biochemical	Glucose(mg/ dL)		Triglycerides (mg/ dL)		LDH U/L		Uric acid mg/ dL		Na mmol/ L		Cl mmol/ L	
	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C
Control	270,8±5,4	265,9±6,0	28,6±1,6	32,8±1,6	1399,7±160,8	2366,1±179,8	6,7±1,3	10,7±1,1	159,8±1,8	155,3±1,5	126,8±1,6	121,2±1,3
Antibiotic 100 ppm	245,9±5,4	252,6±6,0	29,6±1,6	38±1,6	1894,7±160,8	2206,7±179,8	6,4±3,3	10,3±1,2	158,0±4,5	154,7±1,6	122,0±4,0	119,1±1,4
O.S 100 ppm	237,7±5,4	280,2±6,0	32,8±1,6	37,3±1,6	1653,6±160,8	1999,1±169,5	6,0±1,9	7,3±1,1	157,3±2,6	161,8±1,5	123,0±2,3	122,7±1,3
O.S 300 ppm	242,0±5,4	263,9±6,0	33,7±1,6	34±1,6	2164,4±160,8	1596,0±169,5	4,0±1,9	5,3±1,1	155,0±2,6	156,8±1,5	120,3±2,3	121,7±1,3
O.S 600 ppm	258,3±5,4	258,7±6,0	30,6±1,6	38,3±1,6	1545,4±160,8	1868,4±160,8	5,6±1,2	6,5±1,4	160,9±1,6	162,5±1,8	125,0±1,4	124,0±1,6
Source of variation (P values)												
Diet	0,00		0,00		0,01		0,04		0,98		0,20	
Temperature	0,01		0,08		0,36		0,06		0,03		0,19	
Temperature x Diet	0,00		0,10		0,00		0,71		0,15		0,29	
Main effect means diet												
Control	268,6^{a}		30,4^{b}		1829,2^{a}		9,1^{a}		157,1^{bc}		123,4^{a}	
Antibiotic 100 ppm	248,9^{b}		33,3^{ab}		2033,4^{a}		9,8^{a}		155,1^{c}		119,4^{b}	
OS 100 ppm	257,8^{ab}		33,8^{a}		1817,3^{a}		6,9^{ab}		160,6^{ab}		122,8^{ab}	
OS 300 ppm	252,4^{b}		34,6^{ab}		1895,2^{a}		5,0^{b}		156,3^{c}		121,3^{ab}	
OS 600 ppm	258,5^{ab}		34,9^{a}		1706,9^{a}		5,0^{b}		161,5^{a}		124,5^{a}	
Temperature												
22 °C	250,9		31,1		1731,6		5,74		158,2		123,4	
36 °C	264,3		36,1		2007,3		8,02		158,2		121,7	

Table 3 – Serum biochemical values in the experimental groups.

Blood Biochemical	Urea mg/dL		ALT U/L		AST U/L		Cholesterol mg/ dL		HDL-C mg/ dL		ALB g/ dL	
	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C
Control	4±0,8	5,8±0,6	2,2±0,4	4,0±0,4	295,8±25,86	478,3±25,86	150,6±5,7	135,7±5,7	98,7±3,7	85,6±3,7	1,3±0,06	1,2±0,06
Antibiotic 100 ppm	5±2,0	5,9±0,7	2,3±0,4	4±0,4	302,9±25,86	404,1±25,86	159,1±5,7	162,6±5,7	103,4±3,7	92,2±3,7	1,2±0,06	1,4±0,06
O.S 100 ppm	3,3±1,1	4,6±0,6	2±0,4	3±0,4	317,5±25,86	424,3±25,86	157,6±5,7	164,6±5,7	100,2±3,7	94±3,7	1,1±0,06	1,3±0,06
O.S 300 ppm	4,3±1,1	3,4±0,6	1,7±0,4	1,3±0,4	290,6±25,86	308,6±25,86	150,9±5,7	156±5,7	99,8±3,7	101,2±3,7	1±0,06	1,2±0,06
O.S 600 ppm	4,1±0,7	4,8±0,8	2,2±0,4	2,2±0,4	290,6±25,86	332±25,86	162,3±5,7	146,9±5,7	104,8±3,7	95,1±3,7	1,2±0,06	1,2±0,06
Source of variation (P values)												
Diet	0,27		0,0		0,00		0,43		0,00		0,02	
Temperature	0,62		0,0		0,00		0,02		0,21		0,05	
Temperature x Diet	0,66		0,0		0,03		0,13		0,33		0,04	
Main effect means diet												
Control	5,1^{ab}		3^{a}		381,7^{a}		143,6^{b}		92,5^{a}		1,2^{ab}	
Antibiotic 100 ppm	5,7^{a}		3,1^{a}		347,8^{ab}		160,6^{a}		98,4^{a}		1,3^{a}	
OS 100 ppm	4,2^{ab}		2,5^{ab}		368,1^{a}		160,8^{a}		97,2^{a}		1,2^{ab}	
OS 300 ppm	3,6^{b}		1,5^{c}		299,1^{b}		153,3^{ab}		100,4^{a}		1,1^{b}	
OS 600 ppm	4,4^{ab}		2,2^{bc}		311,3^{b}		154,6^{ab}		99,9^{a}		1,2^{ab}	
Temperature												
22 °C	4,1±0,5		2,1		299,4		156,1		101,3		1,16	
36 °C	4,8±0,3		2,9		389,4		153,1		93,6		1,25	

Table 4 – Serum biochemical values in the experimental groups.

Blood Biochemical	ALP U/L		CK-MB U/L		Ca mg/dL		Mg mg/ dL		K mmol/ L	
	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C
Control	1800,5±364,5	1663,8±364,5	0,0±2259,1	11895,6±2259,1	10,2±0,2	9,1±0,2	2,7±0,1	2,6±0,1	9,4±0,4	8,2±0,4
Antibiotic 100 ppm	1564,1±364,5	1511,8±364,5	0,0±2259,1	26065,7±2259,1	9,9±0,2	10,9±0,2	2,8±0,1	3±0,1	6,9±0,4	9,1±0,4
O.S 100 ppm	2712,8±364,5	2093,9±364,5	512,1±2259,1	17708,2±2259,1	10±0,2	10,9±0,2	2,7±0,1	2,9±0,1	8,4±0,4	6,6±0,4
O.S 300 ppm	2077,3±364,5	1966,2±364,5	1246,7±2259,1	12692,4±2259,1	10,4±0,2	10,3±0,2	2,5±0,1	2,9±0,1	7,8±0,4	8,1±0,4
O.S 600 ppm	1616,1±364,5	1870,3±364,5	0,0±2259,1	0,0±2259,1	10,8±0,2	11±0,2	2,9±0,1	3,1±0,1	8,4±0,4	6,7±0,4
Source of variation (P values)										
Diet	0,58		0,00		0,24		0,03		0,12	
Temperature	0,18		0,00		0,00		0,04		0,03	
Temperature x Diet	0,83		0,00		0,00		0,36		0,00	
Main effect means diet										
Control	1736,1^{ab}		5947,8^{b}		9,6^{c}		2,6^{b}		8,7^{a}	
Antibiotic 100 ppm	1540,8^{b}		11584,7^{a}		10,3^{b}		2,9^{ab}		7,8^{ab}	
OS 100 ppm	2419,6^{a}		8557,6^{bc}		10,4^{b}		2,8^{ab}		7,5^{b}	
OS 300 ppm	2024,6^{ab}		6969,6^{bc}		10,3^{b}		2,7^{b}		7,9^{ab}	
OS 600 ppm	1743,2^{ab}		0,0^{c}		10,9^{a}		3^{a}		7,5^{b}	
Temperature										
22 °C	1954,1±164,9		351,7		10,2		2,7		8,1	
36 °C	1821,1±174,5		13672,4		10,4		2,9		7,7	

Table 5 – Serum hematological in the experimental groups.

Blood Hematology	WBC 10^3/µL		RBC 10^6/µL		HGB g/dL		HCT %		MCV fL		MCH pg		MCHC g/dL	
	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C	22 °C	36 °C
Control	279,2±7,4	298,3±7,4	2,4±0,8	2,7±0,8	10,8±0,3	12,1±0,3	37,9±1,2	42,6±1,2	155,8±1,4	156,9±1,4	44,6±0,4	44,8±0,4	28,6±0,2	28,5±0,2
Antibiotic 100 ppm	285,7±7,4	307,8±7,4	2,4±0,8	2,7±0,8	10,5±0,3	12,1±0,3	37,1±1,2	41,9±1,2	152,8±1,4	154,8±1,4	43,3±0,4	44,9±0,4	28,3±0,2	29,1±0,2
O.S 100 ppm	289,5±7,9	306,2±7,4	2,5±0,9	2,8±0,8	11,1±0,4	12,7±0,3	38,1±1,3	43,8±1,2	150,2±1,4	153,7±1,4	43,6±0,5	44,5±0,4	29,0±0,2	28,9±0,2
O.S 300 ppm	279,8±7,4	298,7±7,4	2,4±0,8	2,7±0,8	10,6±0,3	12,2±0,3	37,6±1,2	42,1±1,2	156,9±1,4	153,9±1,4	44,3±0,4	44,6±0,4	28,2±0,2	29,1±0,2
O.S 600 ppm	305,1±8,4	303,4±7,4	2,5±0,9	2,7±0,8	11,5±0,4	12,4±0,3	39,8±1,4	42,9±1,2	153,2±1,5	156,5±1,4	44,4±0,4	45,2±0,4	28,9±0,2	28,9±0,2
Source of variation (P values)														
Diet	0,239		0,392		0,247		0,579		0,021		0,323		0,065	
Temperature	0,003		0,000		0,000		0,000		0,111		0,009		0,014	
Temperature x Diet	0,573		0,823		0,733		0,898		0,127		0,500		0,004	
Main Effect Means Diet														
Control	288,7		2,6		11,5		40,3		156,4^{a}		44,7		28,6^{b}	
Antibiotic 100 ppm	296,8		2,6		11,3		39,5		153,8^{ab}		44,1		28,7^{ab}	
OS 100 ppm	298,4		2,7		11,9		41,1		152,0^{b}		44,1		28,9^{a}	
OS 300 ppm	289,3		2,6		11,4		39,8		155,4^{a}		44,5		28,6^{ab}	
OS 600 ppm	304,1		2,7		12,0		41,6		155,1^{a}		44,9		28,9^{a}	
Temperature														
22 °C	287,9±3,47		2,48±0,03		10,9±0,15		38,1±0,56		153,7±0,62		44,0±0,20		28,6±0,07	
36 °C	302,9±3,34		2,75±0,03		12,3±0,14		42,0±0,54		155,1±0,60		44,8±0,20		28,9±0,07	

within the normal range for broilers (Reece, 2009). In our study, the effects of adding OS essential oil at different dosages to the diets of the heat stressed and unstressed groups were incompatible with some previous data (Khan *et al.*, 2002; Khaksar *et al.*, 2012; İsmail *et al.*, 2013).

Thymol and carvacrol, which are the main components of OS, have been reported to have a cholesterol lowering property by inhibiting hepatic 3-hydrox-3-methylglutaryl coenzyme A reductase, which is a cholesterol synthesis enzyme (Mazmanoğlu, 2008). Al-Kassie, (2009) reported that adding 200 ppm thyme oil to broiler feed significantly reduces cholesterol level. Khaksar *et al.* (2012) determined that 1 g/kg thyme oil in the feed of Japanese quail significantly reduces total cholesterol and TGs. Hong *et al.* (2012) reported that a mixture of 125 ppm thyme, anise seed, and citrus peel oils added to broiler feed significantly reduces cholesterol level. Sarıca *et al.* (2005) stated that 1 g/kg thyme powder added to broiler feed significantly reduces total plasma cholesterol. In contrast, Demir *et al.* (2005) reported that 1 g/kg origanum powder added to broiler feed significantly increases total cholesterol and TG levels, and Bölükbaşı *et al.* (2006) obtained similar results with 200 ppm thyme oil. In the present study, 100, 300, and 600 ppm OS added to the feed of the heat stressed broiler group (Tables 2 and 3) significantly increased HDL, LDH, TG, and total cholesterol levels. This may be attributed to decreased hepatic 3-hydrox-3-methylglutaryl coenzyme A reductase enzyme activity. The high-fat diet also increased the capacity of the liver to store lipids and reduce liver function (Chawda *et al.*, 2014). OS also reduced CK-MB (Zhang *et al.*, 2014) and liver enzymes (ALT and AST) levels compared to the control and antibiotic groups.

Urea and uric acid are protein metabolites. Serum protein levels are important for preserving the immune system, and these values can increase under diseased or stressed conditions, such as toxicity (Arslan, 2012). Uric acid is an antioxidant that eliminates free radicals as a result of xanthine oxidase activity (Koizumi *et al.*, 1991). Al-kassie (2009) reported that 200 ppm origanum oil in boiler feed increases total serum protein, whereas Demir *et al.* (2005) found the same result with 1 g/kg origanum powder. In contrast, Köksal *et al.* (2012) reported a decrease in serum total protein in response to 0.75 g/kg essential oil mix (*Origanum vulgare*, *Thymus vulgare*, garlic, anise seed and raziyane). OS (300 ppm) significantly reduced urea and all dosages decreased uric acid levels in the heat stressed groups compared with those in the control and antibiotic groups in the present study. The literature has few data on urea and uric acid in broilers.

In summary, the OS essential oil showed some protective effects against heat stress in broilers. We believe that it is necessary to better understand teh effcets of origanum syriacum essential oil by testing it under various stress conditions in further future research.

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