Effect of dietary supplementation of some antioxidants on growth performance, carcass composition and breast meat characteristics in quails reared under heat stress

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ABSTRACT: This research investigates the effects of adding vitamin E, vitamin C, vitamin E+C, and alpha lipoic acid to feed rations for Japanese quails (Coturnix coturnix japonica) exposed to heat stress. The aspects studied were growth performance, carcass composition and breast meat characteristics. Five groups of quails, containing 50 birds each (250 Japanese quails: 150 female and 100 male) were used. The 21-days-old birds were fed for a period of 21 days, and they were kept in a controlled environment with a temperature of 34°C between 08:00 and 17:00 and a temperature of 24°C for the remaining part of the day. The five groups under study included: a control group without any additive (BS), a group fed diets with vitamin E (BSE), with vitamin C (BSC), with vitamin E+C (BSEC) and with lipoic acid (BSLA). The supplement additions to the diets did not affect the growth performance and carcass composition of the birds. The TBA (malonaldehyde) value of the BS group was significantly higher ($P < 0.001$) than in the other groups. L^*, a^*, and b^* values in muscle samples, superficialis pectoralis muscle (SPM) and deep pectoralis muscle (DPM), were determined. In the samples from the SPM, the L^* value of the BS group was higher than in the BSC group; the a^* value of the BSE group was higher than in the BS group; and the b^* value of the BSC group was higher than in the BS group ($P < 0.05$). In the samples from the DPM, the L^* value of the BS group was higher than in the BSEC group ($P < 0.05$); the a^* values of the BSE and BSEC groups were higher than in the BS group ($P < 0.05$); and the b^* values of the BSC, BSEC and BSLA groups were higher than in the BS group ($P < 0.01$). In the microbiological analysis of meat, total aerobic mesophilic bacterial counts of the BS and BSE groups were higher than the counts in the BSC, BSEC, and BSLA groups ($P < 0.01$); coliform bacterial counts were higher in the BSE group than in the BSC group ($P < 0.05$); and lactic acid was higher in the BSE and BSEC groups than in the BSC and BSLA groups ($P < 0.01$). In conclusion, the supplemented antioxidants did not exhibit any significant effect on growth performance, but they significantly decreased lipid oxidation in the meat.

Keywords: quail; vitamin E; vitamin C; lipoic acid; growth performance; meat quality

It is known that a balance in the physiological activities of living beings is required to generate a suitable environment for the removal of free radicals by antioxidants. This balance is disturbed under certain conditions, such as increasing or decreasing ambient temperature, environmental pollution, old age, and illness. Some substances, having strong antioxidant characteristics, such as vitamin E, vitamin C

and alpha lipoic acid, have been well-known to play important roles in protecting this balance (Azzi and Stocker, 2000; Padayatty et al., 2003). Vitamin C and lipoic acid are synthesized while Vitamin E is not synthesized in organisms of animals (NRC, 1994; Patel and Vettakkorumakankav, 1995). Vitamin C exhibits an antioxidant effect by removing free radicals from the environment (Packer et al., 1979; Tanaka et al., 1997) while the effective mechanism of vitamin E in its reactions with active radicals is to break chains, to exert pressure, to renovate, and to increase endogen defence (Packer et al., 1979; Azzi and Stocker, 2000). Alpha-lipoic acid, also known as thioctic acid, is a strong antioxidant substance having the scavenger capacity of reactive oxygen species and preventive effect on lipid oxidation (Dinçer et al., 2002; Gonzalez-Perez and Gonzalez-Castaneda, 2006).

Sahin et al. (2003) proposed that only additions of vitamin C and folic acid as antioxidants to diets of Japanese quails under heat stress do not affect body weights after feeding and that their combinations positively affect the fattening performances of animals. It has been observed in some studies (David Peebles and Brake, 1985; Puthpongsiriporn et al., 2001; Sahin et al., 2002) that vitamin E and vitamin C added to diets of laying poultry under heat stress improved performance related with egg production. Imik et al. (2000) stated that vitamin E and vitamin C did not affect the performances of early-weaned, 21-days-old Ankara goat kids.

Studies show that antioxidants added to the diets of poultry (Lauridsen et al., 1997; Sahin et al., 2002; Young et al., 2003; Kennedy et al., 2005), ruminants (Liu et al., 1995; Schaefer et al., 1995) and pigs (Asghar et al., 1991; Buckley et al., 1995; Lahučký et al., 2005) prevent lipid oxidation.

The reasons for recruitment of quails as experimental model in this research are their easy management and higher resistance to stress than in other poultry. Thus, the effects of antioxidants, added to quail rations, on growth performance, carcass composition and breast meat characteristics of Japanese quail (*Coturnix coturnix japonica*) subjected to heat stress are investigated.

MATERIAL AND METHODS

Birds and feeding

This study was performed on the Research and Practice Farm at the Faculty of Veterinary Medicine, Ataturk University. A total of 250 (150 female and 100 male) 21-days-old Japanese quails (*Coturnix coturnix japonica*) were divided into five groups. Each group had 50 quails in 5 cages. Each cage contained a random selection of 6 female and 4 male birds. Lots were drawn to determine the placement of groups in the cages. The quail cages were placed in temperature-controlled rooms during the study, receiving 17 h of daylight. A room temperature of 34°C was maintained between 8:00 and 16:00. For the rest of the time the birds were kept at a temperature of 24°C. The study spanned a total of 21 days.

The feed rations for the studied groups of quails were prepared as follows: a basal ration containing no additional antioxidant (BS); a basal diet + vitamin E (250 mg DL-α-tocopheryl-acetate/kg of diet) (BSE); a basal ration + vitamin C (250 mg of L-ascorbic acid/kg of diet) (BSC); a basal ration + vitamin E + C (250 mg DL-α-tocopheryl-acetate/kg of diet + 250 mg L-ascorbic acid/kg of diet) (BSEC); and a basal diet + lipoic acid (250 mg α-lipoic acid/kg of diet) (BSLA).

The formulation and chemical composition of floury formed experimental diet, which was mixed according to NRC, are presented in Table 1. The crude protein proportion was determined by analysis (AOAC, 1990) and metabolizable energy, Ca, P were calculated (Jurgens, 1996). Small amounts of the basal diet were first mixed with the respective amounts of vitamin E and C as small batch, then with a larger amount of the basal diet until the total amounts of the respective diets were homogeneously mixed. All formulations of the diet were prepared freshly and stored at 15–21°C before feeding to quails.

Growth performance

The birds were weighed at the beginning of experiment and on the 7th, 14th and 21st day of the experiment. They were fed at the same hour each day during research. The daily feed prepared for the consumption by birds as well as any remaining feed were weighed. Water was supplied in automatic bowls. Feed and water were administered *ad libitum* during research.

Carcass composition

A total of 100 birds (5 groups × 20 = 100) from each group (including 2 males and 2 females chosen

from each subgroup at random) were slaughtered to determine the carcass characteristics. After the quails were fasted for ten hours, the blood of the birds was allowed to flow for 120 seconds. The birds were plucked manually. The internal organs of the birds were extracted and weighed. The carcasses were kept at +4°C for 24 h, and then the weights of the cold carcasses were determined.

Meat characteristics

A total of 50 (25 male and 25 female) birds were randomly chosen for the analysis of fresh breast meat quality, including one male and one female from each of 5 subgroups. Then moisture, pH, total ash, total protein, TBA, colour analysis (L^* (relative lightness), a^* (relative redness), b^* (relative yellowness)) and numbers of aerobic mesophilic microorganisms, coliforms and lactic acid bacteria were determined.

Analyses for moisture, total ash and total protein contents of samples were performed according to the methods declared by Gokalp et al. (2001). The pH value was determined by directly inserting a pH metre probe into the chest muscle. The protein content of the samples was determined with a Kjeldahl device.

TBA (thiobarbituric acid) was performed according to the methods suggested by Turk Standards Institute 2409 (2007). In this regard, 10 g of homogenized sample was broken into pieces and mixed with 50 ml of distilled water. This mixture was washed with 47.5 ml of distilled water and poured

Table 1. The formulation and chemical composition of the basal ration

Ingredients (%)	Starter phase (0–3 weeks)	Finisher phase (4–6 weeks)
Wheat	27.90	30.40
Maize	28.20	31.70
Maize gluten, 43% CP	15.00	15.00
Soybean meal, 44% CP	21.20	15.00
Vegetable oil	0.50	0.50
Wheat bran*	3.80	3.80
Dicalcium phosphate	1.80	2.00
DL-Methionine	0.10	0.10
Limestone	0.70	0.70
L-Lysine hydrochloride	0.10	0.10
Salt	0.20	0.20
Vitamin-mineral premix**	0.50	0.50
Nutritional levels		
Metabolizable energy (MJ/kg)	11.91	12.15
Crude protein (%)	22.20	20.00
Ca (%)	0.81	0.84
P (%)	0.43	0.45

*the additives (vitamin E, vitamin C, vitamin E+C and lipoic acid) were added in place of wheat bran

**the vitamin-mineral premix provides the following (per kg): all-trans-retinyl acetate 1.8 mg; all-rac-α-tocopherol acetate 1.25 mg; menadione sodium bisulphate 1.1 mg; riboflavin 4.4 mg; thiamine (thiamine mononitrate) 1.1 mg; vitamin B6 2.2 mg; niacin 35 mg; Ca-pantothenate 10 mg; vitamin B12 0.02 mg; folic acid 0.55 mg; d-biotin 0.1 mg; choline chloride 175 mg; manganese (from manganese oxide) 40 mg; iron (from iron sulphate) 12.5 mg; zinc (from zinc oxide) 25 mg; copper (from copper sulphate) 3.5 mg; iodine (from potassium iodide) 0.3 mg; selenium (from sodium selenite) 0.15 mg

into a ball. 2.5 ml of hydrochloric acid was added to make a pH of 1.5. This ball was then placed on a distillation unit and 50 ml of distillate was produced. 3 distillates of 5 ml were prepared. 5 ml of 0.02M-thiobarbituric acid standard solution, prepared with 90% glacial acetic acid, was added into each tube and then the tubes were placed in a double boiler for 35 seconds. 5 ml of distilled water and 5 ml of TBA standard solution were prepared as a blank and underwent the same procedures. The tubes were then cooled. The optic density of the solution in each of the three tubes was measured with a spectrometer adjusted to a wavelength of 538 nanometres against the blank. Averages were calculated as follows:

TBA amount in the sample is determined as µg MA/g.

$$TBA = a \times 7.8$$

where:

a = absorbance of the sample in a spectrometer

Colour measurements (L^*, a^*, b^*) on samples from the superficialis pectoralis muscle (SPM) and deep pectoralis muscle (DPM) (Fitzgerald, 1969) were done using a tristimulus colorimeter (Minolta Chroma Meter Measuring Head CR-200, Minolta, Osaka, Japan).

Microbiological analysis of the samples was performed with respect to the methods suggested by Baumgart et al. (1993). 25 g of the meat sample was homogenized in 225 ml of sterilized Ringer's solution. Then sterilized solutions were prepared. The pour plate method was used for the microbiological analysis. Plate Count Agar (PCA, Merck) was used for the enumeration of total aerobic mesophilic microorganisms. Plates were evaluated after being incubated at 30 ± 1°C for 72 + 1 hours. Rogosa Acetate Agar (RAA, Merck) was used for the enumeration of lactic acid bacteria. These plates were incubated anaerobically for 5 days at 30 ± 1°C. All colonies produced following the incubation were evaluated. Violet Red Bile Agar (VRBA, Merck) was used for the enumeration of coliform bacteria. The plates were incubated anaerobically at 30 ± 1°C for 24 hours. Red colonies larger than 1 mm were counted after incubation. Bacteria counts were expressed as logarithmic colony-forming units per gram of sample (log CFU/g).

Statistical analyses

The effect of antioxidants on the fattening performance and meat quality was statistically analyzed by one-way ANOVA (total). The effect of sex on meat quality and carcass characteristics was analyzed by Student's t-test for independent-samples. Finally, male and female birds were divided into two different groups and the effect of the antioxidants on meat quality was determined by one-way ANOVA. Differences between vitamin groups were determined by Duncan's multiple range test. All statistical analyses were done with SPSS. 10.00 package software programme (SPSS, 1996).

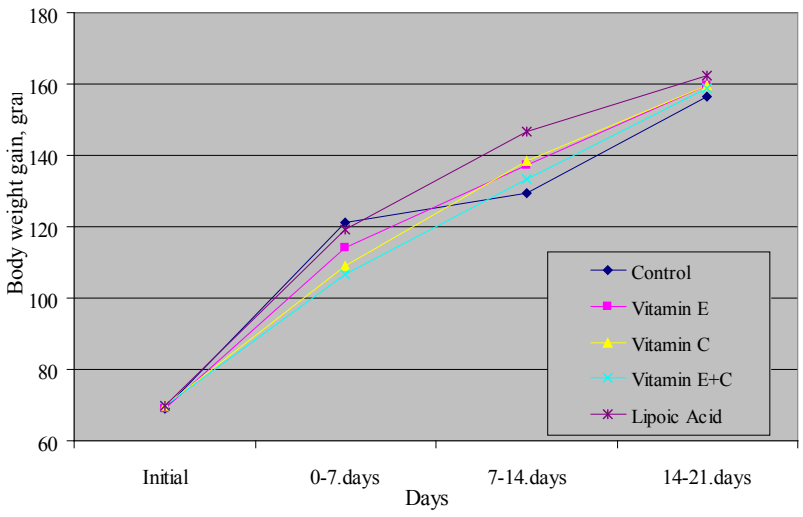

Figure 1. Body weight gains of groups during research

Table 2. Effect of dietary antioxidant addition on growth performance of quails exposed to heat stress for 21 days

Treatment*	BW initial (g)	BW final (g)	BW change (g)	BW daily (g)	Daily feed intake (g)	FCR
BS	69.20	156.30	87.10	4.15	12.43	3.02
BSE	69.00	159.80	90.80	4.32	12.49	2.90
BSC	69.90	159.44	89.54	4.27	12.21	2.86
BSEC	69.80	158.80	89.00	4.24	12.36	2.92
BSLA	69.90	162.40	92.50	4.40	13.00	2.96
SEM	0.50	2.37	1.22	0.06	0.16	0.30

BS = basal diet; BSE = diet BS plus 250 mg DL-α-tocopheryl-acetate/kg; BSC = diet BS plus 250 mg of L-ascorbic acid/kg BSEC = diet BS plus 250 mg DL-α-tocopheryl-acetate/kg + 250 mg of L-ascorbic acid/kg; BSLA = diet BS plus 250 mg α-lipoic acid/kg; BW = body weight; FCR = BW gain/feed intake; SEM = standard error of the mean
*nonsignificant; SEM = standard error of the mean

RESULTS AND DISCUSSION

Growth performance

Weekly body weight gains of the birds are presented in Figure 1. While body weight gains of quails in the control group were highest in the first week, during the second and third week their gains declined. Body weights in the groups containing antioxidants regularly increased in the course of research ($P < 0.05$), (Figure 1). High temperatures are required for better growth performance in early periods for poultry. Therefore, the temperature of 34°C did not affect the body weights of the BS group negatively in the first week of the study; but it had a negative effect in the second and third week of research. Antioxidants added to the feed rations of the other groups removed the negative effect of heat stress in the second and third week and positively affected the growth performance ($P < 0.05$),

Table 3. Effect of dietary antioxidant addition on carcass characteristics of quails exposed to stress for 21 days

	Cold carcass weight (g)	Carcass yield (%)	Total weight of internal organs (g)
Treatment*			
BS	98.70	64.68	20.80
BSE	104.10	63.76	20.40
BSC	99.70	63.87	19.30
BSEC	102.00	63.50	21.00
BSLA	102.90	62.24	21.10
SEM	3.05	0.96	1.24
Sex			
Male	99.40	64.02	20.00
Female	103.56	63.20	21.04
SEM	1.98	0.63	0.78

total weight of internal organs = liver, heart, gizzard, offal
SEM = standard error of the mean
*nonsignificant

Table 4. Effect of dietary antioxidant addition on breast meat characteristics of quails exposed to heat stress for 21 days

	Moisture (%)	pH	Total ash (%)	Total protein (%)	TBA	SPM			DPM		
						*L**	*a**	*b**	*L**	*a**	*b**
Treatment											
BS	71.36	6.14	1.79	20.82	2.07^{a}	40.76^{a}	12.11^{b}	4.54^{b}	39.79^{a}	14.35^{b}	3.43^{c}
BSE	72.89	6.12	1.89	21.56	0.71^{b}	39.18^{ab}	14.89^{a}	5.50^{ab}	37.91^{ab}	18.60^{a}	4.87^{bc}
BSC	70.66	6.14	1.78	21.06	0.74^{b}	37.1^{b}	14.34^{ab}	7.34^{a}	37.08^{ab}	15.75^{ab}	9.00^{a}
BSEC	71.82	6.08	1.77	21.11	0,47^{b}	37.00^{b}	14.26^{ab}	6.70^{ab}	36.20^{b}	17.91^{a}	6.96^{ab}
BSLA	71.42	6.12	1.98	21.06	0.51^{b}	38.49^{ab}	13.79^{ab}	6.12^{ab}	37.22^{ab}	17.36^{a}	6.64^{ab}
SEM	1.49	0.03	0.17	0.60	0.26**	0.86*	0.79*	0.71*	0.90*	0.84*	0.97**
Sex											
Male	71.55	6.13	1.73	21.20	1.08	38.09	13.64	5.33	37.37	16.53	6.45
Female	71.71	6.10	1.95	21.05	0.71	38.89	14.12	6.75	37.91	17.05	5.91
SEM	0.95	0.20	0.54	0.40	0.02	0.61	0.53	0.46*	0.61	0.65	0.72

TBA = μg malonaldehyde/g; SPM = superficialis pectoralis muscle; SEM = standard error of the mean; $^{a-c}$values within the same column having the same letters in the same sections are significantly different at *$P < 0.05$; **$P < 0.01$

Table 5. Effect of dietary antioxidant addition on breast meat characteristics of male and female quails exposed to heat stress for 21 days

	Moisture (%)	pH	Total ash (%)	Total protein (%)	TBA	SPM			DPM		
						L^*	a^*	b^*	L^*	a^*	b^*
Male											
BS	74.08 ^{a}	6.09	1.53	20.93	2.90^{a}	40.07^{a}	12.20	3.44^{b}	40.43^{a}	13.40^{b}	3.39
BSE	71.19^{ab}	6.13	2.01	22.03	0.91^{b}	38.94^{ab}	14.55	4.47^{ab}	37.83^{ab}	19.38^{a}	5.38
BSC	69.24^{b}	6.18	1.76	21.46	0.26^{b}	35.26^{b}	14.39	6.64^{a}	34.91^{b}	15.86^{ab}	7.55
BSEC	72.26^{ab}	6.10	1.77	21.19	0.66^{b}	37.91^{ab}	13.37	6.68^{a}	36.67^{ab}	17.63^{ab}	7. 97
BSLA	71.00^{ab}	6.16	1.60	20.38	0.70^{b}	38.28^{ab}	13.68	5.41^{ab}	37.00^{ab}	16.38^{ab}	7.98
SEM	1.20*	0.05	0.16	0.65	0.30***	1.23*	1.10	0.87*	1.29*	1.32*	1.33
Female											
BS	68.65	6.19^{a}	2.06	20.72	1.23	41.45^{a}	12.02	5.63	39.15	15.30	3.46^{b}
BSE	74.58	6.10^{ab}	1.77	21.09	0.52	39.42^{ab}	15.23	6.54	37.00	17.81	4.36^{b}
BSC	72.09	6.09^{ab}	1.80	20.66	1.22	38.94^{ab}	14.28	8.05	39.25	15.64	10.54^{a}
BSEC	71.38	6.06^{b}	1.77	21.04	0.28	36.07^{b}	15.15	6.72	35.72	18.18	5.94^{b}
BSLA	71.84	6.08^{ab}	2.36	21.73	0.32	38.56^{ab}	13.90	6.83	37.43	18.33	5.31^{b}
SEM	2.54	0.03*	0.27	1.03	0.28	1.12*	1.19	1.06	1.14	1.08	1.33*

TBA = μg malonaldehyde/g; SPM = superficialis pectoralis muscle; DPM = deep pectoralis muscle; SEM = standard error of the mean; $^{a–c}$ values within the same column having the same letters in the same sections are significantly different at *$P < 0.05$; **$P < 0.01$

(Figure 1). These results are coherent with Sahin et al. (2003) findings on the same issue. Finding no differences between fattening performances of the groups may be a result of the short interval of the research period.

Carcass composition

At the end of the experiment, the performance (Table 2) and carcass characteristics (Table 3) of the groups were found to be similar ($P > 0.05$). In this research, the body weight of the cut male quails was 155.20 g and the body weight of the cut female quails was 164.00 g (SEM:2.77) ($P < 0.05$). Carcass weights of male quails in groups BS, BSE, BSC, BSEC and BSLA were 95.8, 96.4, 100.6, 103.4 and 100.8 g, respectively (SEM:3.89); carcass weights of female quails were 101.6, 111.8, 98.8, 100.6 and 105.0 g, respectively (SEM:4.18). It was observed that there was no statistically significant difference in carcass yield between the males (62.59%–65.51% /SEM:1.31/) and the females (61.48%–64.92% SEM:1.24/) in the groups. There was no effect on carcass composition produced by the addition of vitamin E, C, and lipoic acid to the feed rations of quails under heat stress ($P > 0.05$).

Breast meat characteristics

The effect of the antioxidants added to quail diets on meat quality is presented in Table 4. Average moisture, pH, total ash, and total protein values of the groups were determined in this study and no differences between groups and sexes were found.

TBA values of the BS group were found to be higher ($P < 0.01$) than in other groups (Table 4). Therefore it is noted that antioxidants did not affect the TBA values in the meat of females, while antioxidants decreased the TBA values in the meat of males ($P < 0.001$), (Table 5). The TBA values of the quail groups that consumed diets containing vitamin E, vitamin C, vitamin E+C, and lipoic acid were found to be lower than in the control group in the present study ($P < 0.01$), (Table 4). Most studies show that various antioxidants added to feed rations of poultry prevented lipid oxidation (Lauridsen et al., 1997; Nam and Ahn, 2003; Young et al., 2003; Kennedy et al., 2005; Ryu et al., 2005). Some studies reported that lipoic acid decreased lipid oxidation (Dinçer et al., 2002; Shen et al., 2005).

The L^* value of the BS group was higher than in the BSC and BSEC groups; the relative redness a^* value of the BSE group was higher than in the BS group; the relative yellowness b^* value of the BSC group was higher than in the BS group ($P < 0.05$) in colour analyses from the SPM. The relative lightness L^* value of the BS group was higher than in the BSEC group; the relative redness a^* values of the BSE, BSEC and BSLA groups were higher than in the BS group ($P < 0.05$). The relative yellowness b^* values of the BSE, BSEC and BSLA groups were determined to be significantly higher than in the BS group ($P < 0.01$) in colour analyses from the DPM (Table 4).

Previous studies explained the effect of antioxidants on L, a^* and b^* values of meat in poultry (Liu et al., 1995; Nam and Ahn, 2003; Young et al., 2003) and pigs (Asghar et al., 1991; Buckley et al., 1995). Literary sources also indicate that the meat of poultry fed antioxidants lasted longer (Liu et al., 1995; Nam and Ahn, 2003). Findings in both the SPM and DPM make it clear that antioxidants affect colour parameters of the meat to a different extent (Table 4). These findings are coherent with the literature. Antioxidants added to diets of the experimental groups produced limited effects on the meat colour of female quails (SPM = L*; DPM = b*) while antioxidants added to diets of the experimental groups affected the meat colour of male quails (SPM = L^*, b^*; DPM = L^*, a^*) ($P < 0.05$) (Table 5). L^*, a^*, and b^* values of these studies by Du et al. (2000) are 53.6–58.5, 12.9–20.1 and 17.6–23.0, respectively; in Du et al. (2001) they are 80.46–85.42, 7.40–11.56 and 19.21–22.20; in Young et al. (2003) they are 50.3–52.4, 2.5–2.9 and 2.9–4.1; in the pectoralis major muscle of female broilers they are 50.5–51.0, 3.9–4.2 and 2.7–4.7 in iliotibialis muscle; in Aksu et al. (2007) they are 51.61, 7.16 and 3.63 for male quails, and 49.20, 7.01 and 4.33 for female quails; 50.34, 5.35 and 3.87 in fresh breast; and 50.47, 8.82 and 4.10 in fresh drumstick.

The L^* value of the BSC group was found to be lower than in the BS group in colour analyses from the SPM of male quails ($P < 0.05$). The b^* values of the BSC and BSEC groups were determined to be higher than in the BS group ($P < 0.05$). The L^* value of the BSC group was lower than in the BS group; the a^* value of the BS group was found to be lower than in the BSE group ($P < 0.05$) in the DPM. The L^* value of the BS group was found to be higher than

Table 6. Effect of dietary antioxidant addition on carcass total aerobic mesophilic, coliform and lactic acid bacteria in meat samples of quails exposed to heat stress for 21 days

	Total aerobic mesophilic bacteria (log CFU/g)	Coliform bacteria (log CFU/g)	Lactic acid bacteria (log CFU/g)
Treatment			
BS	5.17^{a}	2.59^{ab}	2.81^{ab}
BSE	4.89^{a}	3.70^{a}	3.85^{a}
BSC	3.63^{b}	1.80^{b}	1.83^{b}
BSEC	3.90^{b}	1.97^{ab}	3.34^{a}
BSLA	3.85^{b}	1.88^{ab}	1.47^{b}
SEM	0.29**	0.59*	0.46**
Sex			
Male	4.50	2.44	3.03
Female	4.08	2.34	2.29
SEM	0.23	0.39	0.34

SEM = standard error of the mean; ^{a,b}values within the same column having the same letters in the same sections are significantly different at *$P < 0.05$; **$P < 0.01$

Table 7. Effect of dietary antioxidant addition on carcass total aerobic mesophilic, coliform and lactic acid bacteria in meat samples of male and female quails exposed to heat stress for 21 days

	Total aerobic mesophilic bacteria (log CFU/g)	Coliform bacteria (log CFU/g)	Lactic acid bacteria (log CFU/g)
Male			
BS	5.3^{a}	2.85	2.88^{ab}
BSE	5.45^{a}	2.66	4.31^{a}
BSC	3.41^{b}	1.95	1.51^{b}
BSEC	3.58^{b}	2.87	4.64^{a}
BSLA	4.71^{a}	1.88	1.84^{b}
SEM	0.23***	0.92	0.46**
Female			
BS	5.00^{a}	2.33^{b}	2.75
BSE	4.33^{ab}	4.77^{a}	3.39
BSC	3.85^{ab}	1.66^{b}	2.16
BSEC	4.21^{ab}	1.08^{b}	2.03
BSLA	2.99^{b}	1.88^{b}	1.11
SEM	0.43*	0.69*	0.64

SEM = standard error of the mean; ^{a,b}values within the same column having the same letters in the same sections are sig-

in the BSEC group in colour analyses from the SPM of female quails ($P < 0.05$). The b* value of the BSC group was determined to be higher than in the other groups in the DPM ($P < 0.05$) (Table 5).

The effects of the addition of antioxidants to quail diets on the counts of microorganisms are presented in Table 6. Total aerobic mesophilic bacteria counts in the BSC, BSEC, and BSLA groups were found to be lower than in the BS and BSE groups ($P < 0.01$). Coliform counts in the BSC group were determined to be lower than those in the BSE group ($P < 0.05$). Lactic acid bacteria counts were found to be lower in quail muscles containing vitamin C and lipoic acid ($P < 0.01$) than in meat from quails whose diets contained vitamin E and E+C. Microbiological results of antioxidant addition with respect to sex are shown in Table 7.

Vitamin C added to the feed ration decreased the total aerobic mesophilic, coliform and lactic acid bacteria counts; and lipoic acid decreased the total mesophilic, aerobic and lactic acid bacteria counts. Vitamin E produced no effect (Table 6). Aksu et al. (2005) reported that total aerobic mesophilic bacterial counts were 3.99 and 3.83 log CFU/g in the breast and drumstick of broilers, respectively, and that lactic acid bacterial counts were 3.04 and 2.80 log CFU/g. Manousaridis et al. (2005) found out that the total aerobic mesophilic bacterial count was 3.4 log CFU per g and that the lactic acid bacterial count was 1.2 log CFU/g. Aksu et al. (2007) stated that the broiler lactic acid bacterial count was 3.62 CFU/g in male quails and that the broiler lactic acid bacterial count was log 3.47 CFU/g in female quails. Karpińska-Tymoszcyk (2007) also pointed out that the total aerobic mesophilic bacterial count was 2.6×10^5 CFU/g and the coliform bacterial count was 1.3×10^4 CFU/g in turkey meat. Saucier et al. (2000) found that lactic acid bacterial counts were 3.67 log CFU/g and 4.82 log CFU/g when they were kept in stock under different conditions; and that total aerobic mesophilic and coliform bacteria increased in chicken meat more than in turkey meat.

CONCLUSION

The antioxidants (vitamin E, vitamin C, lipoic acid) and antioxidant combinations (vitamin E+C) added to the feed rations did not have any significant effect on growth performance, but they decreased lipid oxidation in meat and modified the colour characteristics of meat in Japanese quails under heat stress. The effects on growth performance with increased amounts of antioxidants and a longer fattening period should be a focus of further studies.

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Received: 2009–06–05
Accepted after corrections: 2009–10–14

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Revised February 2010