Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

ISSN 1516-635X 2020 / v.22 / n.2 / 001-010

http://dx.doi.org/10.1590/1806-9061-2019-1246

Original Article

Effects of Lactobacillus Reuteri E81 Added into Rations of Chukar Partridges (Alectoris Chukar) Fed Under Heat Stress Conditions on Fattening Performance and Meat Quality

■Author(s)

Tekce E[I] https://orcid.org/0000-0002-6690-725X
Bayraktar B[II] https://orcid.org/0000-0002-2335-9089
Aksakal V[I] https://orcid.org/0000-0001-5701-0726
Dertli E[III] https://orcid.org/0000-0003-0318-0310
Kamiloğlu A[III] https://orcid.org/0000-0002-6756-0331
Çinar K[III] https://orcid.org/0000-0002-2253-2871
Takma Ç[IV] https://orcid.org/0000-0001-8561-8333
Kaya H[V] https://orcid.org/0000-0001-9024-8525
Gül M[VI] https://orcid.org/0000-0001-5477-1773

[I] Faculty of Applied Sciences, Bayburt University, Bayburt 69000, Turkey.
[II] Faculty of Health Sciences, Bayburt University, Bayburt 69000, Turkey.
[III] Faculty of Engineering, Bayburt University, Bayburt 69000, Turkey.
[IV] Faculty of Agriculture, Department of Animal Science, Biometry and Genetics Unit, Ege University, İzmir 35100, Turkey.
[V] Veterinary Department, Şiran Mustafa Beyaz Vocational High School, Gümüşhane University, 29600, Şiran / Gümüşhane, Turkey.
[VI] Animal Nutrition and Nutrition Disease, Atatürk University Erzurum, Turkey.

■Mail Address

Corresponding author e-mail address
Emre Tekce
Organic Agriculture Management, Faculty of Applied Sciences, Bayburt University, Bayburt 69000, Turkey.
Phone: +90 458-333-20-33
Email: vet_emre_tekce@hotmail.com

■Keywords

Chukar partridges (*Alectoris chukar*), Probiotic, Performance, Meat Quality, *Lactobacillus reuteri* E81.

Submitted: 25/December/2019
Approved: 17/March/2020

ABSTRACT

This study investigated the effects of the addition of *Lactobacillus reuteri* E81 (LRE) into rations of chukar partridges (*Alectoris chukar*) fed under heat stress (HS) conditions on fattening performance and meat quality. This study included 256 chukar partridges aged 1 day. The study comprised an adaptation period of 7 days and a fattening period of 35 days and included 8 different groups with 32 animals in each group. Each group was further divided into four subgroups with eight animals in each subgroup. At the end of the study, the best results in terms of fattening performance in the non-HS groups were obtained in the LRE 600 ppm group and in the HS groups, SLRE 200 ppm had the best effect on average live weight and average live weight increase, whereas SLRE 400 ppm had the best effect on FCR (p<0.05). The analysis of the samples collected from chukar partridges on day 21 showed that, there was no effect on the colour parameters and Thiobarbituric acid reactive substances (TBARS) level in the LRE in the HS and non- HS groups, whereas the meat pH level decreased in the SLRE 400 ppm group (p<0.05). The analysis of the samples collected on day 42 showed that there was no effect on colour parameters in the HS and non-HS groups. TBARS level decreased at the dose of LRE 200 ppm in the non-HS group, and the meat pH level decreased in both HS and non-HS groups (p<0.05).

INTRODUCTION

Global warming has become a major problem worldwide that adversely affects poultry yield. Poultry are homeothermic organisms that feel comfortable between 14°C and 27°C (Nardone *et al.*, 2010, Turk *et al.*, 2015). When the ambient temperature of a poultry house exceeds the thermoneutral levels, HS is exerted owing to the disruption of the balance between body temperature and heat emitted from the body to ensure hemostasis (Nardone *et al.*, 2010, Ezzat *et al.*, 2011). HS has an impact above 27°C and begins to exert its effect above 30°C (Turk *et al.*, 2015). Endocrine system disorder and electrolyte imbalance due to HS in poultry (Liu *et al.*, 2019, Nawab *et al.*, 2018) have adverse effects on fattening performance and intestinal microflora (Quinteiro-Filho *et al.*, 2010; Liu *et al.*, 2019) as well as meat quality (Lu *et al.*, 2017). In addition, reactive oxygen species (ROS) are formed because of increased levels of mitochondria and oxidative stress due to disruption of pro-oxidant/antioxidant balance. Such ROS metabolism results in lipid peroxidation and oxidative damages in protein and DNA structure (Sarıca *et al.*, 2015).

In recent years, owing to its low fat and high protein content (603 kJ/100 g and 240 g crude protein/kg dry matter, respectively), which is considered to be good for human health, partridge meat has become

a product of high economic value, primarily in the far east and also in many European countries (Fortin *et al.*, 2005; Vitula *et al.*, 2011). Cage systems are used in 90% of the partridge production in Europe and America. In some other countries, an alternative system, similar to the floor systems used for broiler chickens, is preferred with an aim to increase the production per unit area (Yıldız 2004; Alkan *et al.*, 2008). Research on different production systems (cage system vs. floor system) has shown that, while animals housed in cage systems reach higher body weights, the best results for meat quality are achieved with the floor system (Yamak *et al.*, 2016). It is indicated that partridge meat is juicy and of a pleasant colour and has a pH value ranging between 5.90-6.04 (Wen *et al.*, 2020). To date, the growth performance of partridges has been studied relatively less than that of other avian species. Available studies report that, the crude protein and energy requirements of partridges during the starter and grower phases of the fattening period are 20% and 15%, and 11.72 MJ/kg and 12.56 MJ/kg, respectively (Özek *et al.*, 2003; Ozek, 2006). In previous research on the growth performance of partridges, animals were determined to reach a body weight of 165 g with a feed intake of 366.8 g during a period of 0-5 weeks, and the feed conversion rate of these animals was calculated as 2.23 (Gülşen *et al.*, 2010; Khaksar *et al.*, 2014).

For many years, antibiotics were used to maintain growth performance and animal health. However, antibiotics have been prohibited for use in animal feed because of the risk of residues and resistance to bacteria (Yörük *et al.*, 2008; Habrun *et al.*, 2012; Tekce & Gül, 2016; Lajman *et al.*, 2017). As a result, various alternative substances have been used to protect animal health and increase yield. One of these alternative substances is probiotics. Probiotics are considered viable microorganisms that improve intestinal microflora and have positive effects on poultry health when taken at appropriate doses (Sivamaruthi *et al.*, 2019). It has been reported that probiotics improve fattening performance, (Mountzouris *et al.*, 2007; Shim *et al.*, 2010; Al-Fataftah & Abdelqader, 2014; Incharoen *et al.*, 2019), decrease mortality (Mountzouris *et al.*, 2007), increase activity of digestive enzymes (Wang & Gu, 2010), improve intestinal health by preserving intestinal microflora and synthesise vitamins (Awad *et al.*, 2009; Alkhalf *et al.*, 2010; Mountzouris *et al.*, 2010; Sen *et al.*, 2012), have antimicrobial properties (Pringsulaka *et al.*, 2015, de Melo Pereira *et al.*, 2018), maintain intestinal histology, decrease pH and release bacteriocins (Alkhalf *et al.*, 2010; Al-Fataftah & Abdelqader, 2014; Incharoen *et al.*, 2019), exert anticholesterol, antiobesity and antidiabetic effects (Nguyen *et al.*, 2007; Costabile *et al.*, 2017; Hu *et al.*, 2017; de Melo Pereira *et al.*, 2018), exert antiparasitic effects (Giannenas *et al.*, 2012), protect against cardiovascular risks (Costabile *et al.*, 2017), reduce stress (Zhang *et al.*, 2016), decrease foodborne bacteria (Khan & Naz, 2013) and exert positive effects on meat quality (Pelicano *et al.*, 2003, Wattanachant *et al.*, 2004).

The present study investigated the effects of *Lactobacillus reuteri* E81 (LRE) added at various doses (200, 400 and 600 ppm) into rations of chukar partridges (*Alectoris chukar*) fed under HS conditions on fattening performance (Body weight [BW], daily body weight increase [DBWG], feed utilisation ration [FCR] and feed consumption [FC) and meat quality.

MATERIALS AND METHODS

Animals, Experimental Design and Feed

The study included 256 male chukar partridges aged 1 day. The study comprised an adaptation period of 7 days and a fattening period of 35 days and was performed in 100 × 50 × 100 cm cages in the Poultry Unit of Bayburt University, Food, Agriculture and Livestock Application and Research Center. From day 7 of the study, live weights of animals were equally measured, and the animals were divided into eight groups (C, LRE 250, LRE 400, LRE 600, SC, SLRE 200, SLRE 400 and SLRE 600) with 32 animals in each group. From day 7, the animals were divided into two groups as non-stress group (25°C; C, LRE 250, LRE 400 and LRE 600) and HS group (37°C; SC, SLRE 200, SLRE 400 and SLRE 600) for 35 days. Each group was further divided into four subgroups with eight animals in each subgroup. The feeds used in the study were prepared by a private company operating in Erzurum, and their nutrient contents are shown in Table 1. After the feeds in front of the animals were weighed at the same time each day (18:00–19:00) and the basal diet feeds were measured, the probiotics were added at appropriate doses into the feeds and given to the groups other than the control groups. The probiotics used in the study were produced in Bayburt University Faculty of Engineering, Food Department Laboratories (4×10^{10} CFU/g). Nutrient analyses of the feeds used throughout the study were performed in accordance with the methods stated in AOAC (AOAC, 2005).

Table 1 – Basal diet ration nutrient content and analysis (g / kg).

Raw Material	Starter (0–14 d)	Grower (14–28 d)	Finisher (28–42 d)
Maize	52.70	54.60	58.12
Maize gluten feed	15.21	21.20	26.14
Soybean residue	26.35	18.90	10.65
Di-calcium phosphate	1.95	1.70	1.60
Calcium carbonate	1.18	1.10	1.04
Sodium chloride	0.31	0.31	0.31
Sodium bicarbonate	0.20	0.20	0.20
Salt	0.2	0.2	0.2
Methionine	0.50	0.50	0.44
Lysine	1.20	1.10	1.10
Vitamin–mineral premix[1]	0.20	0.20	0.20
ME (kcal/ kg)	3100	3150	3225
Crude protein (%)	24	22	20
Crude oil (%)	2.61	2.30	2.50
Ash (%)	5.19	4.63	3.85
Moisture (%)	13.20	13.20	13.20

The vitamin-mineral premix provided the following (per kg of diet): vitamin A, 6 000 IU; vitamin D3, 1000 IU; vitamin E, 15 mg/kg; vitamin K 2 mg/kg; vitamin B1, 3 mg; vitamin B2, 4 mg; vitamin B6, 4 mg; vitamin B10, 0.03 mg; calcium –D-pantothenate, 15 mg; folic acid, 1 mg; niacin, 25 mg; D-biotin, 0.115 mg; Mg 80 mg/kg; I, 0,15 mg/kg; Co, 0.2 mg/kg; Cu, 5 mg/kg; Fe, 60 mg/kg; Se, 1 mg/kg; Zn, 60 mg/kg.

Temperature, humidity and illumination of the poultry house

The overall temperature of the poultry house was kept constant at 32°C–33°C for the first 2 days and at 27°C–28°C for the next 5 days, and then, the stress groups were subjected to HS at 37°C and 75%–85% humidity, whereas the other groups were subjected to a temperature at 25°C and 55%–60% humidity. Throughout the study, all groups were subjected to illumination (60 W) for 24 hours. Chukar partridges were given fresh drinking water *ad libitum*. The general temperature in the pen was kept constant at 28-32°C for the first 2 days and at 27-28°C for the next 5 days of the experiment. Trial groups are divided into stress and stress-free starting from 7 days. Heating of the cluster was provided by means of 36 ± 1C sensitive thermostat appliances (TURKEY) connected to the central heating system for 7-42 days. Temperature and humidity values were measured with daily digital temperature-humidity meter (TFA Dostmann, Germany) thermometers placed at 4 different points of the coop to control the temperature in the coop. The room temperature of stress-free groups is designed to be 22 °C.

Performance parameters

Body weight (BW), body weight gain (BWG) and feed intake (FI) were measured at 7, 14, 21, 28, 35 and 42 days of age. FI of chukar partridges were recorded on subgroups basis, the uneaten feed was discarded and fresh feed replaced in feeders at the end of each day. The BW of the chukar partridges were recorded by weighing them weekly on digital precision scales with a sensitivity of 0.001 gr. Feed conversion ratio (FCR) was calculated as total FI (g) / total BWG (g). Mortality was recorded when it occurred.

Quality and Antioxidant Properties of Meat

At the end of the experiment, the above-mentioned parameters were applied for the cervical dislocation method of breast meat samples taken on the 21st and 42nd days from 3 randomly selected animals of each group, making 12 pieces and in total 96 male chukar partridges (*Alectoris chukar*). The analysis was conducted in the Bayburt University Food Engineering Department's Meat Technology Laboratory.

pH Determination

The pH determination of the breast meat was performed by using samples weighing 10 g that were mixed with 100 ml of distilled water and subjected to homogenization using ultra-turrax (IKA Werk7 T 25, Germany) for 1 min. The pH of the homogenate was measured with a pH meter (Mettler-Toledo AG, 8603 Schwerzenbach, Switzerland).

TBARS (Thiobarbituric Acid Reactive Substances) Value Determination

TBARS analysis was performed to determine the lipid peroxidation degree of the samples. The determination of TBARS value of the samples was performed by using the method given by Lemon (Lemon, 1975). The calculation of TBARS values was performed by using the absorbance values obtained with the help of the formula below and the results were given in mg MDA (Malondialdehyde) / kg.

TBARS = ((absorbance / k (0.06) x 2/1000) x 6.8) x 1000 / sample weight

Color Values Determination

The determination of Color values of samples (L *, a *, b *) were performed by using Chroma Meter (CR-400 Konika Minolta, Japan) colorimeter. Color measurements were evaluated according to the criteria set by the International Commission on Lighting (Commission Internationale De L'Eclairage). According to these criteria; L *; L * = 0, black; L * = 100 white (darkness / lightness); a *; + a * = red, -a * = green and b *; + b * = yellow, b * = blue indicates the intensity of the above-mentioned colors.

Statistical analysis

The parameters were all normally distributed, and the data expressed by means and standard errors. The statistical analyses of the diet and temperature effects on performance parameters, internal organ weights and meat quality were performed using the general linear model (GLM) that was given below.

$$Y_{ijk} = \mu + D_i + T_j + (D*T)_{ij} + e_{ijk,}$$

where: Y_{ijk} = an observation, μ = overall mean, D_i = Diet effect, T_i= Temperature effect, $(D*T)_{ij}$=the interaction effect and e_{ijk}=experimental error.

The Duncan's multiple comparison test was performed for group means with a significance level of 0.05 by IBM SPSS Statistics v25.

RESULTS

The effects of LRE added at various doses (200, 400 and 600 ppm) into rations of chukar partridges fed under HS conditions on fattening performance parameters (BW, DBWG, feed consumption and feed utilisation ratio [FCR]) are shown in Table 2. The analysis of the data obtained at the end of the study showed that the best results in terms of fattening performance in the non-stress groups (25°C) were obtained in the LRE 600 ppm group (p<0.05). In the HS groups (37°C), the SLRE 200 ppm and SLRE 400 ppm groups had the best results in terms of BW and DBWG and FCR, respectively (p<0.05).

The effects of the LRE on colour parameters (L*, a* and b*) and TBARS and pH levels of chukar partridges' meat from the analysis of data obtained at the end of the study are shown in Tables 3 and 4. The analysis of the samples collected on day 21 showed that the LRE had no effect on the L*, a* and pH levels in the non-stress groups (25°C), b* level increased in the LRE 200 ppm group and TBARS (mg malondialdehyde [MDA]/kg) level decreased in the probiotic groups compared with the control group (p<0.05). In the HS groups (37°C), there was no effect on the colour parameters and TBARS (mg MDA/kg) level, whereas the meat pH level was decreased in the SLRE 400 ppm group (p<0.05). The analysis of the samples collected on day 42 showed that there was no effect on colour parameters in the HS and non-stress groups compared with the control groups. TBARS (mg MDA/kg) level decreased at the dose of LRE 200 ppm in the non-stress groups, and the meat pH level decreased in both HS and non-stress groups (p<0.05).

Table 2 – Effect of LRE fattening performance added to the chukar partridges Ration Fed under stress.

		BW (g)		DBWG (g)		FC (g)		FCR (g/g)	
	N	25°C	37°C	25°C	37°C	25°C	37°C	25°C	37°C
Control	64	166.18^{b}	142.39^{b}	4.75^{b}	4.07^{b}	18.37^{a}	25.29^{a}	3.87^{a}	6.22^{a}
LRE 200 mg/kg	64	165.09^{b}	157.61^{a}	4.72^{b}	4.50^{a}	14.86^{c}	19.49^{b}	3.15^{c}	4.33^{b}
LRE 400 mg/kg	64	144.29^{c}	141.25^{b}	4.12^{c}	4.04^{b}	14.65^{b}	12.07^{d}	3.55^{b}	2.99^{d}
LRE 600 mg/kg	64	177.46^{a}	145.61^{b}	5.07^{a}	4.16^{b}	12.83^{d}	13.46^{c}	2.53^{d}	3.24^{c}
	SEM	1.57		0.05		0.11		0.05	
Main effect means diet									
Control		154.27^{b}		4.40^{b}		21.83^{a}		5.04^{a}	
LRE 200 mg/kg		161.35^{a}		4.61^{a}		17.17^{b}		3.74^{b}	
LRE 400 mg/kg		142.76^{c}		4.07^{c}		13.36^{c}		3.27^{c}	
LRE 600 mg/kg		161.53^{a}		4.61^{a}		13.14^{c}		2.88^{d}	
	SEM	1.11		0.03		0.08		0.04	
Temperature									
25°C		163.25		4.66		15.18		3.28	
37°C		146.71		4.19		17.58		4.19	
	SEM	0.78		0.02		0.06		0.03	
Source of variation (p-values)									
Diet		0.03		0.00		0.01		0.01	
Temperature		0.00		0.00		0.10		0.00*	
Temperature × Diet		0.00		0.01		0.03		0.02	

Body weight (BW), body weight gain (BWG) and feed intake (FI), Feed conversion ratio (FCR). Means within a column showing different superscripts are significantly different (p<0.05): least significance difference test was applied to compare means.* Significant at 0.05 level, ** Significant at 0.01 level, SEM = standard error of the mean.

DISCUSSION

The present study investigated the effects of LRE added at various doses (200, 400 and 600 ppm) into rations of chukar partridges fed under HS conditions on fattening performance (BW, DBWG and FCR), meat colour parameters (L*, a* and b*) and TBARS

Table 3 – Meat quality and color parameters 21st day**.**

		L*		a*		b*		TBARS (mg MDA/kg)		pH	
	N	25°C	37°C	25°C	37°C	25°C	37°C	25°C	37°C	25°C	37°C
Control	64	42.83	39.21	14.49	14.27	14.28^{a}	14.05	1.81	1.86	6.16	6.21^{b}
LRE 200 mg/kg	64	40.68	41.63	15.83	10.65	16.26^{a}	13.30	0.89	0.72	6.32	6.39^{a}
LRE 400 mg/kg	64	38.03	40.05	13.88	15.11	10.17^{b}	13.98	0.54	1.11	6.27	5.96^{c}
LRE 600 mg/kg	64	42.08	44.58	12.57	13.62	14.04^{a}	11.20	0.83	1.34	6.26	6.18^{b}
	SEM	2.59		1.69		0.88		0.27		0.05	
Main effect means diet											
Control		41.02		14.39		14.18^{ab}		1.83^{a}		6.19^{bc}	
LRE 200 mg/kg		41.15		13.24		14.78^{a}		0.81^{b}		6.35^{a}	
LRE 400 mg/kg		39.04		14.49		12.07^{c}		0.82^{b}		6.11^{c}	
LRE 600 mg/kg		43.33		13.10		12.62^{bc}		1.09^{b}		6.22^{b}	
	SEM	1.83		1.20		0.62		0.19		0.03	
Temperature											
25°C		40.90		14.19		13.69		1.02		6.25	
37°C		41.37		13.41		13.13		1.26		6.19	
	SEM	1.30		0.86		0.44		0.14		0.02	
Source of variation (*p*-values)											
Diet		0.46		0.77		0.02		0.01		0.00	
Temperature		0.80		0.52		0.39		0.24		0.07	
Temperature × Diet		0.64		0.23		0.01		0.48		0.00	

Means within a column showing different superscripts are significantly different ($p<0.05$): least significance difference test was applied to compare means.* Significant at 0.05 level, ** Significant at 0.01 level, SEM = standard error of the mean.

Table 4 – Meat quality and color parameters 42st day**.**

		L*		a*		b*		TBARS (mg MDA/kg)		pH	
	N	25°C	37°C	25°C	37°C	25°C	37°C	25°C	37°C	25°C	37°C
Control	64	46.58	57.64	22.66	15.99	22.84	20.58	0.28^{bc}	0.30	6.27^{a}	6.40^{ab}
LRE 200 mg/kg	64	52.01	55.29	18.76	19.21	21.60	24.68	0.18^{c}	0.36	6.20^{a}	6.25^{c}
LRE 400 mg/kg	64	50.81	55.18	17.87	15.06	22.91	25.02	0.42^{ab}	0.29	6.02^{c}	6.45^{a}
LRE 600 mg/kg	64	47.13	48.72	18.69	16.14	19.38	22.51	0.50^{a}	0.18	6.10^{b}	6.31^{bc}
	SEM	4.24		1.93		1.99		0.06		0.03	
Main effect means diet											
Control		52.11		19.33		21.71		0.29		6.34^{a}	
LRE 200 mg/kg		53.65		18.99		23.14		0.27		6.23^{b}	
LRE 400 mg/kg		52.99		16.47		23.98		0.35		6.24^{b}	
LRE 600 mg/kg		47.93		17.41		20.94		0.34		6.20^{b}	
	SEM	3.00		1.37		1.41		0.04		0.02	
Temperature											
25°C		49.13		19.49		21.68		0.34		6.15	
37°C		54.21		16.59		23.19		0.28		6.36	
	SEM	2.12		0.97		0.99		0.03		0.02	
Source of variation (*p*-values)											
Diet		0.55		0.43		0.45		0.46		0.00	
Temperature		0.11		0.05		0.30		0.14		0.00	
Temperature × Diet		0.70		0.36		0.50		0.00		0.00	

Means within a column showing different superscripts are significantly different ($p<0.05$): least significance difference test was applied to compare means.* Significant at 0.05 level, ** Significant at 0.01 level, SEM = standard error of the mean.

(mg MDA/kg) and pH levels. HS has serious effects on fattening performance in poultry and results in economic losses. HS has been reported to reduce feed intake (16.4%), BW (32.6%) and FCR (25.6%) in 42 days (Sohail *et al.*, 2012, Lara and Rostagno, 2013). It has been suggested that probiotics are an alternative to antibiotics to avoid these problems and have a positive effect on intestinal microflora and histology (Ahmad, 2006, Al-Fataftah & Abdelqader, 2014; Bitterncourt *et al.*, 2011). The studies on poultry have reported that the addition of probiotics to their feed under HS conditions have a positive effect on fattening performance (Khonyoung & Yamauchi, 2012; Sohail *et al.*, 2012; Al-Fataftah & Abdelqader,

2014; Incharoen *et al.*, 2019). Contrary to these studies, some studies have reported that it has no effect (Önol *et al.*, 2004; Asli *et al.*, 2007; Attia *et al.*, 2017). The analysis of data obtained at the end of the study showed that the best results in terms of fattening performance (BW, GCA, DBWG and FCR) in the non-stress groups (25°C) were obtained in the LRE 600 ppm group (p<0.05). In the HS groups (37°C), the SLRE 200 ppm group and the SLRE 400 ppm had the best results in terms of BW and DBWG and FCR, respectively (p<0.05). Although the results obtained in the present study were consistent with those of some studies (Khonyoung & Yamauchi, 2012; Sohail *et al.*, 2012; Al-Fataftah & Abdelqader, 2014; Incharoen *et al.*, 2019), some were not consistent (Önol *et al.*, 2004; Asli *et al.*, 2007, Attia *et al.*, 2017). It is considered that the difference between the literature data and the current study results is because of the type and doses of probiotics used and the duration of administration.

Poultry is an important source of animal protein and accounts for 30% of global meat consumption. Because the negative effects on meat quality would affect the acceptability of meat by the consumers, the physicochemical and sensory characteristics of the meat have attracted researchers' attention (Zheng *et al.*, 2014). There is a common view that the addition of probiotics may improve the quality of poultry meat (Al-Owaimer *et al.*, 2014; Park *et al.*, 2016). Some studies have shown that the addition of probiotics increased the pH level of poultry under HS conditions (Cramer *et al.*, 2018). However, in some studies, HS decreased the meat pH level (Yalcin *et al.*, 2005; Zhang *et al.*, 2012). On the other hand, in some studies, the addition of probiotics has been reported to increase the meat pH level (Pelicano *et al.*, 2003; Zheng *et al.*, 2014; Liu *et al.*, 2017), whereas in some other studies, it has been reported to have no effect on the pH level (Zhou *et al.*, 2010; Park & Kim, 2014, Park & Kim, 2015; Bai *et al.*, 2016a). In the present study, on day 21, there was no effect on pH in the non-stress groups, whereas pH was decreased in the SLRE 400 ppm group in the stress groups (p<0.05). However, on day 42, the pH level decreased in both groups (p<0.05). Although some findings of this study were consistent with those of some studies (Yalcin *et al.*, 2005; Zhou *et al.*, 2010; Zhang *et al.*, 2012; Park & Kim, 2014; Park & Kim, 2015; Bai *et al.*, 2016a; Lan *et al.*, 2017), some were not consistent (Pelicano *et al.*, 2003; Zheng *et al.*, 2014; Liu *et al.*, 2017; Cramer *et al.*, 2018).

Oxidative stress, considered a significant factor in various diseases, occurs when the balance of production system of free radicals and the antioxidant defence system are disturbed. Probiotics are of benefit for animal health because they suppress oxidative stress. In addition, they are used as feed supplements to improve the performance and antioxidant capacity of animals (Bai *et al.*, 2016b). Recently, the role of probiotics on lipid metabolism has been highlighted, which indicates that the fatty acid composition in poultry meat may be modified by probiotics (Abdulla *et al.*, 2018). In the present study, MDA was determined as an indicator of lipid peroxidation. Some studies on poultry have determined that the addition of probiotics has decreased TBARS and MDA levels (Kazemi *et al.*, 2019, Wu *et al.*, 2019). In another study, the animals were subjected to HS and probiotics, and HS increased TBARS level, whereas in the stress group administered with probiotics, TBARS level decreased (Cramer *et al.*, 2018). In the present study, on day 21, TBARS (mg MDA/kg) level decreased in the non-stress probiotic groups (p<0.05). However, there was no effect on TBARS (mg MDA/kg) level in the stress groups. On day 42, there was no effect on TBARS (mg MDA/kg) level in the stress groups, whereas it decreased in the non-stress LRE 200 ppm group (p<0.05). Based on these results and the literature, it may be suggested that HS causes oxidative damage in tissues and increases MDA level; however, the probiotics when added at a certain level improve this condition.

The majority of the consumers consider meat colour as the main criterion when buying meat (Karaoglu *et al.*, 2004, Bai *et al.*, 2016b). The probiotic supplementation to poultry feeds decreased the L* value in some studies (Pelicano *et al.*, 2003, Chen *et al.*, 2013); however, in other studies, it increased the colour parameters of meat (L*, a* and b*) (Zheng *et al.*, 2014) or had no effect on the colour parameters (L*, a* and b*) (Park & Kim, 2014, Park & Kim, 2015, Bai *et al.*, 2016a, Kim *et al.*, 2016, Lan *et al.*, 2017). In another study on poultry, HS and probiotic supplementation did not affect colour parameters (Cramer *et al.*, 2018). In the present study, there was no effect on L* or a* in the non-stress groups, whereas the b* level was increased in the LRE 200 ppm group (p<0.05). There was no effect on colour parameters on day 21 in the stress groups and on day 42 in both groups. It is considered that these differences between the literature data in pH, TBARS and colour parameter analyses to determine the meat quality are because of the type and doses of probiotics used and the duration of administration.

CONCLUSION

The LRE mixture added at various doses into rations of chukar partridges fed under HS conditions had a positive effect on the fattening performance and meat quality on days 21 and 42. The addition of LRE 200 ppm had a positive effect on the fattening performance in the stress groups, and it increased the b* level on day 21, but had no effect on it on day 42. Moreover, it had a reducing effect on TBARS and pH levels on days 21 and 42. Dietary probiotic supplementation was determined to improve the growth performance of chukar partridges raised under HS conditions. There is a need for further research on LRE, which has the potential to increase product quantity and quality by reducing the stress on poultry.

AKNOWLEDGMENT

This study was conducted pursuant to the approval (dated 12.11.2019 and numbered 2019/15) of the Local Ethics Board for Animal Experiments of Directorate of Veterinary Control Center Research Institute. This study was funded and supported by the scientific research projects commission of Bayburt University, Bayburt, Turkey (Project code: 2018/02–69001-02). The authors declare that they have no conflict of interest.

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