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Carcass Yield, Non-Carcass Parts, Internal Organs and Meat Quality Characteristics of Karayaka Male Lambs with Different Birth Weight Fed Free-Choice Feeding

(Hasil Bangkai, Bahagian Bukan-Bangkai, Organ Dalaman dan Ciri Kualiti Daging Biri-biri Jantan Karayaka dengan Berat Kelahiran Berbeza Diberi Pemakanan Pilihan Sendiri)

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ABSTRACT

In order to investigate the changes in meat quality characteristics and some serum metabolites as well as carcass yield, non-carcass parts, internal organs of lambs as influenced by birth weight (BtW) and feeding system (FS), 28 Karayaka male lambs (150 days of age) obtained from four comparable groups that consisted of seven replicates according to a 2 × 2 factorial arrangement for 2 BtW (low, 4.1 ± 0.06 kg and high, 5.0 ± 0.09 kg) and 2 FS (total mixed ration, TMR and free choice feeding, FCF) were used. After weaning (90 days of age), lambs with low BtW and high BtW were fed individually a TMR ad libitum *or fed on the same ingredients (FCF) as that of TMR. The TMR was consisted of 80% of a compound feed and 20% of roughage based on a dry matter basis (140 g crude protein and 10.7 ME MJ/kg). The carcass weight and yield of lambs were not affected by the BtW, FS and BtWxFS interaction. The slaughter body weight, cold carcass weight and yield of FCF-fed lambs were higher than those of TMR-fed animals. The pH_{45} and shear force of semitendinosus muscle decreased and increased by the FCF systems, respectively. These results showed that BtW of lambs did not affect the studied parameter and that feeding system created more differences in terms of some parameters due to the fact that the FCF lead to improvement in carcass and some meat quality traits.*

Keywords: Cafeteria feeding; carcass weight; digestive tract; lamb meat; organ weights

ABSTRAK

Dalam usaha untuk mengkaji perubahan dalam ciri kualiti daging serta sesetengah metabolit serum serta hasil bangkai, bahagian bangkai, organ dalaman biri-biri kerana dipengaruhi oleh berat kelahiran (BtW) dan sistem memberi makan (FS), 28 biri-biri jantan Karayaka (usia 150 hari) diperoleh daripada empat kumpulan perbandingan yang terdiri daripada tujuh replikat mengikut aturan faktoran 2 × 2 untuk 2 BtW (rendah, 4.1 ± 0.06 kg dan tinggi, 5.0 ± 0.09 kg) serta 2 FS (jumlah campuran catuan, TMR dan pilihan pemakanan bebas, FCF) telah digunakan. Selepas cerai susu (usia 90 hari), biri-biri jantan dengan BtW rendah dan tinggi diberi makan TMR ad libitum *atau diberi bahan-bahan sama (FCF) seperti TMR secara individu. TMR tersebut terdiri daripada 80% sebatian makanan dan 20% hampas berdasarkan asas bahan kering (140 g protin gentian dan 10.7 ME MJ/kg). Berat bangkai dan hasil daripada biri-biri jantan tidak terjejas oleh interaksi BtW, FS dan BtWxFS. Berat badan penyembelihan, berat bangkai sejuk dan hasil biri-biri jantan diberi makan FCF adalah lebih tinggi berbanding haiwan diberi makan TMR. PH_{45} dan ricih daya otot separa tendon menurun dan meningkat masing-masing mengikut sistem FCF. Keputusan ini menunjukkan bahawa BtW biri-biri jantan tidak menjejaskan parameter yang dikaji dan sistem pemakanan mewujudkan lebih banyak perbezaan daripada segi parameter yang disebabkan oleh FCF membawa kepada peningkatan dalam bangkai dan sebahagian sifat kualiti daging.*

Kata kunci: Berat organ; berat bangkai; daging biri-biri; pemakanan kafeteria; saluran penghadaman

INTRODUCTION

The Karayaka, a native sheep breed, is reared under adverse conditions in the Black Sea region of Turkey. Slaughter lambs of native Turkish Karayaka breed are in demand throughout the year because it is believed that Karayaka breed is one of the most important breeds among the native sheep breeds with high meat quality and also adaptation ability (Olfaz et al. 2005; Sen et al. 2011; Sirin et al. 2011), although there are still insufficient and speculative information on slaughter, carcass and meat quality traits of Karayaka lambs.

Body weight (BW) changes until slaughter and BW at slaughter are frequently recorded variables in research, as they are important indicators of fattening performance and carcass weight. Other measurements such as non-carcass parts and gastrointestinal tract (GIT) and internal organ traits are most commonly used in lamb fattening trials, since the BW may fail to indicate the body composition and carcass yield of the animals (Olfaz et al. 2005). The effects of feeding system (FS) and birth weight (BtW) on carcass yield, non-carcass parts, internal organs and meat quality have been investigated in sheep (Carrasco et al. 2009;

Priolo et al. 2002; Sañudo et al. 1998). In these studies, however, no investigation on the combined effects of BtW and FS on these variables and on meat quality characteristics as well as growth, carcass and GIT traits in lambs was done.

Offering free-choice of feeds (free-choice feeding, FCF) may be a practical alternative that offers some advantages over conventional compound feeding of growing lambs. Indeed, studies evaluating the effects of FCF system or indicated that fattening sheep kept in a controlled environment can successfully select a diet of adequate intake from a suitable pair of feeds to match their nutritional requirements and had an improved the feed efficiency and growth rate similar or over those achieved with conventional feeding systems (Askar et al. 2006; Görgülü et al. 1996; Rodríguez et al. 2007; Sahin et al. 2003). Ebrahimi et al. (2007) and Ríos-Rincón et al. (2014) reported that when a single concentrate diet is allocated during the finishing period, dietary protein and energy levels had effects on carcass characteristics. Lambs which are heavier at birth are usually singles, males or offspring of ewes with both larger body sizes and good feeding conditions (Sirin et al. 2011). In a review related to choice feeding, it has been noted that differences between- and within-species may be resulted in differences in body size, morphology and physiology (Forbes 2007). However, no useful information is available on how different BtW of lamb on the FCF system affects carcass yield, non-carcass parts, internal organs and meat quality traits in fattening Karayaka male lambs. Indeed, the literature on diet selection in the growing animals mainly refers to animals with similar BW; studies performed with lambs which are BW based on BtW are scarce. In our previous study (Yıldırım et al. 2013), we found that FCF system can assist in enhancing the BW gain by promoting protein and energy intakes and improving the welfare of lambs with different BtW compared to total mixed ration (TMR) systems. Accordingly, the objectives of the study reported herein were twofold: Firstly, to compare the effects of lamb BtW and feeding system on characteristics of carcass, non-carcass parts and internal organs, but the main aimed was to investigate the changes in some meat quality characteristics of *longissimus dorsi* (LD) and *semitendinosus* (ST) muscles and selected serum metabolites in Karayaka male lambs as influenced by BtW and FS.

MATERIALS AND METHODS

ANIMALS AND DIET

The study was carried out at the experimental farm of the Gaziosmanpaşa University, Faculty of Agriculture, Tokat, Turkey situated at 40°31′N, 36°53′E and 650 m above sea level. The study was conducted complying with the EC 8 Directive 86/609/EEC and all animal procedures were approved by the local Ethical Committee of Gaziosmanpaşa University for Experimental Animals (specific authorization number: 032/2010). Long term average annual temperature and relative humidity in this region varies from 8.1 to 14.2°C and between 56% and 73%. The temperature of the experimental unit during the feeding trial (from July to August) varied from 19.5 to 30.5°C (average 25°C). The relative humidity was within a range of 70-76% during the same period (Yıldırım et al. 2013).

In this study, 28 Karayaka male lambs (150 days of age) obtained from four comparable groups that consisted of seven replicates according to a 2 × 2 factorial arrangement for 2 BtW (low, 4.1 ± 0.06 kg and high, 5.0 ± 0.09 kg) and 2 FS (TMR and FCF) were used. As reported by Yıldırım et al. (2013), after weaning (90 days of age), lambs with low BtW and high BtW were fed individually a TMR *ad libitum* or fed on the same ingredients (FCF) as that of TMR but each ingredient (barley, corn, wheat bran, soybean meal, alfalfa hay) was put in five separate troughs (5 L capacity) throughout the daily. The TMR was consisted of 80% of commercial compound feed and 20% of roughage based on a dry matter basis (Table 1) and was formulated to provide nutrient requirements for fattening by NRC (2007).

CARCASS, NON-CARCASS PARTS AND INTERNAL ORGANS MEASUREMENTS

Data on fattening performance and feeding behaviour of the study were published previously (Yıldırım et al. 2013). In this part of the study, it was determined the carcass yield, non-carcass parts, internal organs and meat quality traits of these lambs. At the end of fattening period (150 days of age), the animals were transferred to the slaughterhouse and were fasted for 12 h. Then they were weighed and were

TABLE 1. Nutrient composition of experimental ingredients and total mixed ration (*as fed*)

	DM (g kg^{-1})	CP (g kg^{-1})	NDF (g kg^{-1})	ADF (g kg^{-1})	ME (MJ kg^{-1})
Barley	900	110	190	70	11.9
Corn	880	82	250	110	12.6
Wheat bran	870	134	510	150	10.3
Soybean meal	900	460	150	100	11.5
Alfalfa straw	900	153	450	370	8.1
TMR	894	140	310	150	10.7

TMR: total mixed ration, DM: dry matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ME: metabolizable energy. The concentrate (per kg DM) in the TMR consisted of 416 g barley, 100 g corn, 200 g wheat bran, 62 g soybean meal, 200 g alfalfa straw, 15 g marble powder, 4 g dicalcium phosphate, 2 g salt and 1 g vitamin and mineral mixture. Each kg vitamin and mineral mixture provided 20 000 000 IU vitamin A, 3 000 000 vitamin D_3, 20 g vitamin E, 4 g vitamin B_1, 8 g vitamin B_2, 12 g vitamin B_5, 5 g vitamin B_6, 20 mg vitamin B_{12}, 200 g choline, 50 g Mn, 50 g Fe, 50 g Zn, 10 g Cu, 800 mg I, 150 mg Co, 150 mg Se slaughtered by severing the throat and major blood vessels in the neck. After removing all internal organs, hot carcass weights were measured and then chilled for 24 h at 4°C, and reweighed to determine cold carcass weight (Sen et al. 2011). Yields (dressing percentages) of hot and cold were calculated from the ratio of hot and cold carcass weights to slaughter weights, respectively. Head, pelt, fore and hind feet, internal fat, testes and internal organs (heart, liver, spleen, kidneys and lungs) were weighed. Whole GIT and various segments (stomach and small and large intestines) of the GIT were weighed before complete emptying and recorded as full weight. Then empty GIT, stomach and intestine weights were also weighed and recorded (Balci & Orman 2008). Small and large intestine lengths were measured (Steinheim et al. 2003).

MEAT QUALITY

In order to assess the meat quality traits such as Commission Internationale de l'Éclairage (CIE) colour values pH values, water-holding capacity (WHC) and shear force, the meat samples from LD and ST muscles were excised out of the right site of the carcasses after slaughter and then were vacuum packed, freeze-dried and stored at -20°C until further analysis. These meat quality parameters were performed as described by Sen et al. (2011) except for WHC. The pH values of ST and LD muscles were measured at 45 min (pH_{45}) and 24 h (pH_{24}) post-mortem by means of a pH meter equipped with a penetrating glass electrode (pH meter Metrohm® 704, Switzerland) and calibrated with pH 4.01 and 7.01 buffers (Mettler Toledo, Tampa, FL). The CIELab colour values (Hunt et al. 1991) of studied muscles representing lightness (L*), redness (a*), and yellowness (b*), were measured at 12 h post-mortem using a Minolta CR 300 Chroma Meter (Minolta Camera, Osaka, Japan). The samples were cooked (during 20 min) in a water bath at 70°C. Cooking loss was calculated as a percent difference between the pre-cooked and cooked weights. Shear forces, based on penetrometer readings, values of cooked samples (cut parallel to the muscle fibres with a cross section of 2×2 cm) were determined using a Warner-Bratzler device mounted on a Texture Analyzer® (TA XT2, England). Mean colour and pH values, cooking loss and shear force data from five measurements of each sample were used in the data analysis. Expressed juice or WHC of muscles was determined using a press technique explained by Oztan and Vural (1993) with a slight modification. A sample of 0.5 g for each muscle was placed on a filter paper (Whatman No. 1) and pressed for 20 min by a weight of 1 kg. The outline area of the expressible juice and the pressed meat film were measured using a Placom Digital Planimeter (Model KP-90, Sokkisha Planimeter Inc., Kanagawa, Japan). The WHC was calculated as meat film area-to-total juice area ratio.

BLOOD ANALYSIS

Before slaughter, blood samples were taken by jugular puncture. Within one hour of collection, the blood samples were centrifuged at 3000 rpm for 10 min. The serum was separated and stored at -20ºC until analysis. To determine the blood metabolites which are related directly to animal health (Bodas et al. 2012; Liu et al. 2012), the glucose and cholesterol concentrations of serum samples were analyzed using ready-to-use spectrophotometrical kits (Biomedical Systems, Barcelona, Spain) and the apparatus (UV-1601 Shimadzu, Japan).

STATISTICAL ANALYSIS

Individual lambs were considered as experimental units for all data. Data were analyzed using the GLM procedure (SPSS Inc. 2008, Release 17.0) and were studied by analysis of variance, according to a 2 × 2 factorial design, including the effects of BtW and FS and their interaction. Testing of significant differences was carried out according to the following mathematical-statistical model: Yij = μ + BtWi + FSj + (BtWxFS) ij + eij, where: Yij = value of the trait, μ = overall mean, BtWi = effect of birth weight (i = 1, 2), FSj = effect of feeding system (j = 1, 2), (BtWxFS)ij = combined effect of birth weight and feeding system and eij = random residual. The level at which differences were considered significant was $p<0.05$.

RESULTS AND DISCUSSION

The slaughter weight, carcass weight and dressing percentage of lambs in the present study were not affected by the BtW (Table 2). These characteristics of Karayaka male lambs in the present study were within the normal range (Olfaz et al. 2005; Sen et al. 2011; Sirin et al. 2011) and were also found to be comparable to the native sheep breeds such as Bafra (Yakan & Unal 2010), Awassi, Morkaraman (Esenbuga et al. 2009) and Kivircik (Gökdal et al. 2012) of Turkey. Although the BtW and FS have an impact upon slaughter weight, carcass weight and meat quality (Sañudo et al. 1998), the situation in the present study may be explained by the fact that the BW at the start of the fattening and the feed ingredients of the TMR and FCF were similar and the number of replicates per treatment was comparatively low. In the study of Sirin et al. (2011), Karayaka lambs with high BtW had higher BW and carcass weight compared to lambs with low BtW, contrary to the results reported for carcass weight in the present study. However, the differences in the BtW of lambs were not reflected in the BW at weaning (20.1 ± 0.92 *vs*. 21.1 ± 1.38 kg per lamb) and at slaughter (34.4 ± 3.13 *vs*. 35.1 ± 2.17 kg per lamb) ages. This result corroborated those obtained by Ocak et al. (2005) who reported the difference in the BtW of lambs from ewes offered different protein levels during late gestation was not reflected on the BW at weaning and slaughter. Growth performance of lambs from birth to weaning is considered as the most important factor in determining economic efficiency of a sheep breed (Ahmad et al. 2001; Mohammadi et al. 2013). The goal of feeding concentrate diets to growing lambs is to achieve maximum growth rates, better feed efficiency and improved carcass and meat characteristics (Bodas et

TABLE 2. Body weights and carcass weights of Karayaka male lambs with different birth weight fed total mixed ratio and free choice feeding

	Low BtW		High BtW			Significance		
	TMR	FCF	TMR	FCF	SEM	BtW	FS	BtWxFS
Body weight (kg per lamb)								
At birth	4.1	4.1	5.0	4.9	0.10	ns	*	ns
At slaughter	33.0	35.8	33.1	35.3	0.52			
Carcass weight (kg per lamb)								
Hot	14.1	16.6	14.2	15.3	0.29	ns	ns	ns
Cold	13.1	15.2	12.9	14.2	0.34	ns	*	ns
Carcass yield (Dressing percentage, %)								
Hot	42.8	46.3	43.0	43.3	0.99	ns	ns	ns
Cold	39.5	42.3	38.8	40.3	0.60	ns	*	ns

BtW: birth weight, TMR: total mixed ratio, FCF: free choice feeding, FS: feeding system, SEM: standard error of mean, *: Significant at $p<0.05$, ns: Not significant

al. 2007). In the present study, the slaughter weight, cold carcass weight and yield of FCF-fed lambs were higher than those of TMR-fed animals ($p<0.05$; Table 2). These results may be related to the fact that the FCF system increased the dry matter, energy and protein intakes. In the first part of the present study (Yıldırım et al. 2013), the daily weight gain, intakes of soybean meal and corn, dry matter, protein and energy of FCF-fed lambs were higher than those of TMR-fed lambs. Also FCF-fed lambs consumed less alfalfa hay, wheat bran and barley than TMR-fed lambs. This finding is in agreement with the idea that feed intake is regulated by dietary energy density in lambs (Ebrahimi et al. 2007; Ríos-Rincón et al. 2014). The results on the slaughter weight disagreed with the findings of other study (Sahin et al. 2003) who indicated that the slaughter weight did not differ between TMR- and FCF-fed lambs. This difference between the results of the previous study (Sahin et al. 2003) and the present study may be explained the fact that the FCF system enhanced the BW of lambs by promoting the protein and energy intakes and by improving the welfare of lambs compared to TMR system (Yıldırım et al. 2013). Therefore, the results of the present study support idea that the appropriate environmental and nutritional conditions important for the vital life support systems can be sufficient to allow extremely lambs with low BtW to survive and achieve growth (Greenwood et al. 2002).

In the present study, non-carcass parts and internal organ weights of Karayaka male lambs at 150 days of age were within previously reported range (Olfaz et al. 2005; Sen et al. 2011; Yakan & Unal 2010). The results regarding the slaughter traits of Karayaka male lambs are similar to those reported by Sirin et al. (2011) who noted that the BtW (2.68 kg vs. 4.05 kg) of Karayaka female lambs had no effect on those parameters. Our results with respect to absolute weights of non-carcass components and some organs of lambs may indicate that growth rates of Karayaka male lambs are not dependent on diet composition, since these variables were not affected by feeding systems, as reported by Olfaz et al. (2005). It is relevant to compare this figure with that found by Sahin et al. (2003) who found that TMR and FCF in Awassi lambs were not affect on hot carcass weight and dressing percentage. The fact that there were no differences between treatments in terms of internal organ weights indicate that lambs used in the present study had a similar metabolic rate, as reported by Absalan et al. (2011).

In animal feeding trials, weights and lengths of whole digestive system or its parts are used as a measure of feed utilization (Cañeque et al. 2003; Priolo et al. 2002). An increase in weight of the rumen and small intestine is an indication that they have a high function to improving the efficiency of feed utilization in animals (Priolo et al. 2002). The effect of feeding system on carcass yield may be the direct or indirect effect through a change in the intake and digestibility of the ingredients used in experimental diets. Indeed, the GIT of extensively produced animals are more developed, due to the higher intake of dry matter compared to intensively produced lambs (Priolo et al. 2002; Yıldırım et al. 2014a, 2014b). In the present study, relative weights of digestive tract ($p<0.05$) and stomach ($p<0.05$) and relative length of intestine ($p<0.05$) of TMR-fed lambs were higher than those of FCF-fed lambs (Table 3). These findings may be related to the body composition of lambs can be modified by increased energy and protein intakes (Ebrahimi et al. 2007; NRC 2007; Ríos-Rincón et al. 2014). Therefore, these results indicated that the FCF system did not affect the functions of the GIT traits to improving the efficiency of feed utilization in lambs although FCF system promoted the protein and energy intakes of lambs (Yıldırım et al. 2013).

The well-developed GIT of lamb resulted in production system will be decreased the dressing percentage of the animal (Priolo et al. 2002). Lambs with lower carcass yield may be heavier in terms of full stomach and intestine due to fact that the gastrointestinal content influenced carcass yield (Ríos et al. 2011). However, the TMR system increased the full GIT and stomach weight, but dressing percentage was not affect (Table 3). The increase in the GIT traits of TMR-fed lambs may be related to internal organ and non-carcass parts weights, since the relative lungs ($p<0.05$)

TABLE 3. Relative weights (g or cm per 100 g body weight) of carcass, non-carcass components and internal organ of Karayaka male lambs with different birth weight fed total mixed ratio and free choice feeding

	Low BtW		High BtW			Significance		
	TMR	FCF	TMR	FCF	SEM	BtW	FS	BtW x FS
Non-carcass parts	6.2	6.1	6.5	6.2	0.08	ns	ns	ns
Head	13.9	14.3	13.7	16.2	0.48	ns	ns	ns
Pelt	2.6	2.8	2.8	2.9	0.04	ns	ns	ns
Fore and hind feet	22.4	18.3	21.4	18.7	0.59	ns	*	ns
Full GIT	5.5	5.4	5.5	5.1	0.12	ns	ns	ns
Empty GIT	13.6	9.9	11.5	11.4	0.50	ns	*	ns
Full stomach	2.5	2.5	2.5	2.4	0.04	ns	ns	ns
Empty stomach	8.1	8.3	9.9	7.9	0.64	ns	ns	ns
Whole intestine	3.6	3.5	3.4	3.5	0.11	ns	ns	ns
Empty intestine	114.0	103.4	113.8	104.6	2.60	ns	*	ns
Intestine length	0.4	0.8	0.6	0.5	0.04	ns	ns	ns
Internal fat								
Internal organs								
Spleen	0.1	0.2	0.1	0.2	0.01	ns	ns	ns
Kidneys	0.2	0.3	0.3	0.3	0.01	ns	ns	ns
Heart	0.4	0.4	0.4	0.4	0.01	ns	ns	ns
Lungs	1.4	1.2	1.3	1.2	0.03	ns	*	ns
Liver	1.8	1.6	1.7	1.6	0.03	ns	ns	ns
Testes	0.3	0.5	0.3	0.4	0.03	ns	*	ns

BtW: birth weight, TMR: total mixed ratio, FCF: free choice feeding, FS: feeding system, GIT: gastrointestinal tract, SEM: standard error of mean, *: Significant at $p<0.05$, ns: Not significant.

and testicles ($p<0.05$) weights of lambs increased and decreased by TMR system, respectively, compared to the FCF system (Table 3).

Instrumental meat quality characteristics, serum glucose and cholesterol concentrations of Karayaka lambs are presented in Table 4. Many factors, such as inherent characteristics of the sheep and long- or short-term environmental conditions until (housing system, feeding systems & level) or immediately before slaughter (pre-slaughter capture & loading) may affect the carcass yield and meat quality. Factors which affect meat quality have been well documented by a number of other investigators (Carrasco et al. 2009; Priolo et al. 2002; Sañudo et al. 1998). External appearance (colour) and colour consistency of lamb meat are important attributes by which consumers will select sheep products for purchase and how they ultimately assess the final quality of the product at consumption. Although FCF-fed lambs had a higher slaughter and carcass weights than that for TMR-fed lambs (Table 2), this effect was not reflected on studied meat quality traits except for pH_{45} and shear force of the ST muscle (Table 4). This situation may result in the low correlation coefficients between some meat quality characteristics, such as ultimate pH, WHC, Warner-Bratzler shear force and a* value and carcass characteristics, such as cold carcass weight and yield (Dawson et al. 2002). Unfortunately the correlations among these parameters were not investigated in the present study.

The pH_{45} ($p<0.05$) and shear force ($p<0.05$) of the ST decreased and increased by the FCF systems, respectively (Table 4). The effect of BtW × FCF interaction on the shear force of LD muscle was not significant ($p>0.05$). Therefore, our results with respect to pH and shear force support the idea that meat tenderness, assessed by shear force and pH differ among the different skeletal muscles (Esenbuga et al. 2009; Sen et al. 2011). Moreover changes in shear force of the muscles may be resulted in negatively impact of pH value on the texture of the meat. In the present study, the pH value and shear force of muscles from Karayaka male lambs at 150 days of age were within range reported previously (Olfaz et al. 2005; Sen et al. 2011; Sirin et al. 2011), whereas the WHC of these muscles were lower than WHC values reported by these authors. This contradiction between studies may be related to the negative correlations observed between Warner–Bratzler shear force and BW changes and to differences in determining method of shear force (Dawson et al. 2002). The lack of dietary effect on pH values agrees with the observation made on Assaf lambs fed *ad libitum* commercial concentrates and barley straw or whole grain and protein supplement (Rodríguez et al. 2008). In the present study, there were no differences due to the BtW and FS or their interaction in any of the meat technological parameters recorded, e.g. pH_{45} and pH_{24}, confirming to suggestions of Díaz et al. (2002) and Sañudo et al. (1997). As reported herein, Carrasco et al. (2009) found similar pH values (5.54 to 5.59) of meat in lambs fed with different FS. However, Olfaz et al. (2005) reported that differences in pH were recorded due to greater glycogen concentrations in Karayaka growing rams fed high energy diets compared with lambs on low energy diet. The meat pH, which is related to biochemical processes during the transformation of muscle to meat, is main factor determining the quality of meat (Sen et al. 2011) and consequently, the organoleptic characteristics of the meat during the post-mortem period are influenced by changes in the pH (Sañudo et al. 1998). A low pH is associated with poor WHC and a high pH is associated with poor shelf-life because final pH results in a difference in the WHC (Sen et al. 2011). However the effects of studied factors on pH values were not reflected in the WHC in the present study. The result with respect to pH_{24} supports the idea that meat with a pH higher than 5.8 does not present a significant difference in the WHC and tenderness (Fogarty et al. 2000; Sen et al. 2011). Thus, the changes in pH values were within the range acceptable for lamb meats (Carrasco et al. 2009; Sen et al. 2011).

Meat colour is one of the most important components of the visual meat quality used by the customers in selecting quality meat (Martínez-Cerezo et al. 2005). No differences were found between treatments in terms of CIELab values (Table 4). The CIELab values of meats from Karayaka (Olfaz et al. 2005; Sen et al. 2011) and Bafra (Yakan & Unal 2010) lambs were generally similar to what was observed in the present study. Therefore, meat quality characteristics of Karayaka breed are within the preferable range of consumers and this is also particularly important due to the fact that Karayaka lamb meats are in demand throughout the year locally (Sen et al. 2011). The CIELab values for all treatments in the current study would be considered excessively pink bright and were within ranges reported by Díaz et al. (2002) and Sañudo et al. (1997). Indeed, sheep meat with a pale colour is preferred by consumers in some parts of the world (Carrasco et al. 2009).

Our results with respect to the serum glucose and cholesterol concentrations (Table 4) indicate that all lambs had normal physiological and healthy status because there was not found a significant differ between treatments in terms of blood metabolites which are related directly to animal health (Bodas et al. 2012; Liu et al. 2012). Also the serum glucose and cholesterol concentrations were within the serum reference values for healthy Karayaka sheep (Nisbet et al. 2006).

CONCLUSION

It is concluded that BtW of lambs did not affect the carcass yield, non-carcass parts, internal organs and meat quality traits and that feeding system created more differences in terms of some parameters due to the fact that the FCF lead to improvement in carcass and some meat quality traits. Indeed, results on non-carcass components and some organs weights of lambs indicate that these characteristics of Karayaka male lambs are not dependent on diet composition and the BW at birth of lambs. Therefore, Karayaka male lambs with different BtW should be

TABLE 4. Colour characteristics (CIELab), pH, water holding capacity (expressed juice), shear force values of *Longissimus dorsi* and *Semitendinosus* muscles and serum glucose and cholesterol concentrations of Karayaka male lambs with different birth weight fed total mixed ratio and free choice feeding

	Low BtW		High BtW			Significance		
	TMR	FCF	TMR	FCF	SEM	BtW	FS	BtW x FS
Longissimus dorsi muscle								
L* (lightness)	46.21	46.02	46.97	45.78	0.660	ns	ns	ns
a* (redness)	17.81	17.81	17.76	17.85	0.484	ns	ns	ns
b* (yellowness)	5.60	5.30	5.31	5.12	0.216	ns	ns	ns
Expressed juice (%)	43.44	43.94	42.59	44.78	1.339	ns	ns	ns
Shear force (kg per cm^2)	1.48	1.23	1.34	1.38	0.048	ns	ns	ns
Semitendinosus muscle								
L* (lightness)	48.13	44.22	47.87	46.02	0.686	ns	ns	ns
a* (redness)	17.99	19.65	19.76	19.77	0.703	ns	ns	ns
b* (yellowness)	4.69	5.44	5.27	5.96	0.739	ns	ns	ns
Expressed juice (%)	42.46	43.60	43.21	43.85	0.544	ns	ns	ns
Shear force (kg per cm^2)	1.14	1.18	1.15	1.33	0.058	ns	*	ns
pH_{45}	6.45	6.31	6.46	6.37	0.062	ns	*	ns
pH_{24}	5.58	5.52	5.53	5.56	0.023	ns	ns	ns
Serum parameters (mg dL^{-1})								
Glucose	40.00	51.00	34.67	41.67	5.328	ns	ns	ns
Cholesterol	90.00	103.67	91.33	96.00	8.097	ns	ns	ns

BtW: birth weight, TMR: total mixed ratio, FCF: free choice feeding, FS: feeding system, SEM: standard error of mean, *: Significant at $P < 0.05$, ns: Not significant.

fattened, taking into account demands and prices for carcass weight in different markets, because the response in terms of yield and quality parameters of the mutton can vary depending on the feeding system until slaughter.

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