

# Fattening performance, slaughter, carcass and meat quality traits of Karayaka lambs

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**Abstract** In order to verify the fattening performance, slaughter and carcass characteristics and to investigate the changes in some meat quality traits of Karayaka lambs weaned at 3 months of age, 39 lambs (23 males and 16 females) were used as experimental animals. The lambs were fed a concentrate mixture and alfalfa hay (120 and 168 g crude protein and 2,700 and 1,951 ME/kg, respectively) for a period of 60 days of fattening period. Male lambs were superior ( $p < 0.05$ ) to female lambs in terms of daily weight gain (270.4 vs. 205.4 g; SEM=9.46), hot and cold carcass weights (16.7 and 16.0 vs. 14.1 and 13.4 kg, respectively; SEM=0.35), intra-muscular fat ratios (1.9% vs. 2.5%; SEM=0.12) and dripping loss of semitendinosus muscle 3 days postmortem (8.1% vs. 10.2%; SEM=0.36). The relative weights of some organs, the meat quality traits (pH, cooking loss, shear force, CIELab colour characteristics) and proximate analyses (dry matter, protein and ash) of longissimus dorsi and semitendinosus muscle samples from lambs were not affected by sex ( $p > 0.05$ ). Dripping loss, pH and colour characteristics were affected by storage time ( $p < 0.05$ ). These results provide a basic understanding of performance and meat quality of Karayaka sheep which may have potentials in improving sheep production using an indigenous sheep breed in Turkey.

**Keywords** Sheep · Karayaka · Performance · Carcass components · Meat quality

## Introduction

Sheep meat is an important contribution to red meat production amounting to 20% of the total meat production of Turkey (TurkStat 2008), although the present meat production performances of native sheep breeds are far from optimal (Ekiz et al. 2009). There are some information in the literature on the performances of Turkish sheep breeds such as growth performance, physical, chemical and organoleptic properties of lamb carcasses, which they are essential to evaluate production characteristics of indigenous Turkish breeds, e.g. Awassi, Morkaraman and Kivircik lambs (Esenbuga et al. 2009; Ekiz et al. 2009). However, there have been insufficient and speculative information on fattening performance, slaughter, carcass and meat quality traits of Karayaka lambs. Slaughter lambs of native Turkish Karayaka breed are in demand throughout the year because it is believed that Karayaka is one of the most important breed among the native sheep breeds with high meat quality and also adaptation ability (Olfaz et al. 2005). Karayaka male lambs (136 g/day) and young rams (212 g/day; Olfaz et al. 2005) show low growth rates under intensive feeding conditions.

It is believed that Karayaka sheep originate from Asiatic mouflon that is *Ovis vignei* (Bilgemre 1943). They are raised on coastline of Black Sea Region with a total population of approximately one million sheep which is 3% to 4% of sheep population of Turkey (TurkStat 2008). They are well suited to the harsh climate, poor pasture and severe conditions that are the characteristics of the hills and uplands of the region. They are classified as a carpet-wool

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breed kept also for meat production. The body colour of Karayaka Sheep is white and there might be black and brown spots on head, ears, legs and body, and occasionally animals with black or brown body colour can be seen in some flocks. Karayaka sheep have long thin tail and also have got a cluster of wool on fore head (Fig. 1). The rams are usually horned and the ewes are usually polled. Due to their high adaptation ability to harsh environment and resistance to diseases, local sheep breeds such as Karayaka (Cankaya et al. 2009), Ovin Martinik (Marie-Magdeleine et al. 2009), West African Djallonké (Ouédraogo-Koné et al. 2009) and Kirdi (Ngwa and Tawah 2002) are important not only for preserving genetic diversity but also for sustainable rural development in developing or less developed parts or tropic and sub tropic geographical zones of the world.

Body weight change is a frequently recorded variable in animal research, as it is an important indicator of growth and fattening performance. Other measurements such as head, feet, pelt, liver, kidney, heart, rumen, small intestinal etc. weights are most commonly used in animal growth trials and since body weight fails to indicate the body composition of the animal. Colour, pH and drip and cooking loss are important meat quality characteristics that can affect consumer preferences. Indeed, sheep meat with a pale colour is preferred by consumers in some parts of the world (Carrasco et al. 2009). Variation in muscle colour is retained even through its conversion to meat and retail sale. Although a study has been made to assess meat quality of Karayaka rams at 12 months of age (Olfaz et al. 2005), there is no evidence about characteristics of meat colour (CIE  $L^*$ ,  $a^*$  and  $b^*$ ), pH and water-holding capacity evaluated by drip or cook loss as well as growth, carcass and digestive tract traits of Karayaka lambs. The suitability of Karayaka lambs for red meat production and especially sheep markets should be researched. On the other hand,



**Fig. 1** A picture showing Karayaka sheep

there is insufficient knowledge on influence of sex of lamb and meat storage time on meat quality. Accordingly, the objectives of the present study were to verify fattening performance, slaughter, carcass and meat quality traits of Karayaka lambs weaned at 3 months of age which may have potential in improving sheep production through the use of indigenous sheep breeds and to investigate the changes in colour characteristics, pH, water-holding capacity and nutrients (dry matter, ash, protein and fat) of longissimus dorsi (LD) and semitendinosus (ST) muscles of Karayaka lambs with the sex and meat storage time.

## Materials and methods

The study was carried out at the experimental farm of the Gaziosmanpasa University, Tokat, Turkey (40°31' N, 36° 53' E and 650 m above sea level) during May–June 2007. A total of 39 Karayaka male ( $n=23$ ) and female ( $n=16$ ) lambs born within 2 weeks were used in the study. Following the lambing, all lambs were kept with their mother in house until weaning. Starting from day 15 of lambing, ewes were allowed to pasture during day time and to suckle their lambs over the nights in house until weaning. Lambs were introduced at 2 weeks of age to a concentrated diet with good quality alfalfa fed to appetite. All lambs were held 1 day without feed and water for determination of live weight at the start and at the end of fattening. Fattening of the lambs started when they were at 90 days weaning age and finished when they reached 150 days age. The lambs were fed ad libitum concentrates containing 12% crude protein (Güven Yem A. Ş., Çorum, Turkey) and alfalfa hay during the fattening period. Water and mineral stone were freely available, and feed consumption was recorded daily. Chemical composition of experimental feeds is shown in Table 1.

At the end of fattening period, lambs were transported to an abattoir and measured fat thickness and loin thickness of eye muscle (LD muscle) by an ultrasonic linear prop (Falco Vet. Linear prop 8.0 MHz; Pie Medical Equipment Co., Maastricht, The Netherlands) as described by Ulutas et al. (2008). Live weights were measured before standard commercial slaughter procedure carried out. Warm carcass weights were measured after removing all internal organs. The pelt, head, feet, internal organs (spleen, lungs, liver and kidney), empty reticulo rumen and empty intestine were weighed (Balci and Orman 2008). In addition to weight of internal, pelvic and kidney fats, ST, semimembranosus, gastrocnemius muscles were isolated, and their weights were recorded (Esenbuga et al. 2009). Also just after the slaughter, a cross section from the mid-belly of the LD muscle was taken on a paper, and a muscle cross-sectional area was determined by a direct grid reading and

**Table 1** Chemical composition of experimental feeds (% on dry matter basis)

| Nutrient                                  | Concentrate | Alfalfa hay |
|-------------------------------------------|-------------|-------------|
| Dry matter                                | 90.0        | 88.4        |
| Crude protein                             | 12.0        | 16.8        |
| Ether extract                             | 4.9         | 1.6         |
| Crude fibre                               | 12.0        | 24.1        |
| Ash                                       | 9.0         | 9.6         |
| Metabolizable energy (kcal/kg dry matter) | 2,700       | 1,951       |
| Minerals                                  |             |             |
| Calcium                                   | 0.9         | 1.8         |
| Phosphor                                  | 0.5         | 0.4         |
| Sodium                                    | 0.3         | 0.1         |
| Potassium                                 | N/D         | 2.7         |
| Salt                                      | 1.0         | N/D         |
| Vitamins (IU/kg)                          |             |             |
| A                                         | 7,000       | N/D         |
| D <sub>3</sub>                            | 700         | N/D         |
| E                                         | 25          | N/D         |

N/D not determined

measurement of fat thickness over the LD muscle and loin thickness by digital caliper (Macit et al. 2002). Carcasses were chilled for 24 h at 4°C and reweighed to determine cold carcass weight.

The meat samples were taken from LD and ST muscles from the right of the carcasses after slaughter for physical and chemical analysis. These raw meat samples were analysed by AOAC (1990) procedures for dry matter, protein and ash. The protein content of muscles was determined as *N* (Kjeldahl method)  $\times 6.25$ . The intra-muscular fat content was measured by hot extraction method by Ankom extractor (Model XT10, Ankom Technology, Madrid, Spain) in petroleum ether refluxing for 80 min (Okeudo and Moss 2007). The protein, ash and intra-muscular fat content was determined as a percentage of dry (samples were retained 12 h at 105°C) muscle weight.

The pH value was determined using the meat pH meter with a puncture electrode (Testo 205, Lenzkirch, Germany) at 1 and 24 h postmortem (Olfaz et al. 2005). Meat colour as *L*\* (lightness), *a*\* (redness) and *b*\* (yellowness) value was determined using a chromometer (Konica Minolta CR-300, Minolta Co., Ltd., Osaka, Japan) at 1 and 24 h postmortem. Chroma (*C*\*, the square root of (*a*\*<sup>2</sup>+*b*\*<sup>2</sup>)) and hue angle (*H*°,  $\tan^{-1}(b^*/a^*)$ ) were also calculated (Olfaz et al. 2005). Colour difference ( $\Delta D$ ) was calculated using the following formula:  $\Delta D = [(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2]^{1/2}$ , where *L*<sub>1</sub>\*, *a*<sub>1</sub>\* and *b*<sub>1</sub>\* represent colour parameters measured at 1 h and *L*<sub>2</sub>\*, *a*<sub>2</sub>\* and *b*<sub>2</sub>\* represent colour parameters measured at 24 h postmortem in muscles

(Karacay et al. 2008). Muscle samples were weighed and vacuum-packaged in a sealed plastic bag under atmospheric pressure at 4°C. Then samples were stored at 4°C for 3 and 7 days and weighed, and drip loss percentage was calculated (Bond and Warner 2007). The samples were put in a plastic bag then cooked for 40 min in a water bath with at 70°C constant temperatures. The samples were then exposed to running water approximately 15 min to cool to room temperature (Bond and Warner 2007). The samples were weighed before and after cooking to determine percentage of cooking loss. Shear force values of cooked samples (cut parallel to the muscle fibres with a cross section of 2×2 cm) were determined (Bond and Warner 2007) using a Zwick texture meter (Model Z005, Zwick Roell, Germany). Mean pH, colour characteristics and shear force data from six measurements of each sample were used in the data analysis.

The statistical analysis was conducted on completely randomized design for fattening performances, eye muscle and slaughter traits and non-carcass components. Other traits were conducted on factorial experiment (2 sexes×2 storage times) on completely randomized design. Significant differences between means with respect to growth performance were tested by Tukey's multiple comparison tests. Minitab statistical software was used for analyses (Minitab 1998).

## Results and discussion

In the present study, some fattening performance and meat quality traits of Karayaka lambs were determined, which are essential to evaluate some production characteristics of lambs from indigenous Turkish Karayaka breed. The results of birth weight, initial weight, slaughter weight, daily weight gain, feed efficiency and eye muscle value of male and female lambs are presented in Table 2. Birth weights of male and female lambs were similar, but initial weight and slaughter weight of male lambs were heavier than female lambs (*p*<0.05). Such differences have been well documented by a number of other investigators (e.g. Macit et al. 2002).

One of the most important indicators of profitability of lamb production is the average daily live weight gain in fattening. The average daily weight gain of male lambs was higher (65 g) than that of female lambs (*p*<0.05). The results obtained from the present study on daily weight gain for Karayaka lambs especially male lambs were higher than several estimates at the same age reported in the literature, for example, some Turkish sheep breeds such as Awassi, Morkaraman and Kivircik lambs reported by Esenbuga et al. (2009) and Koyuncu and Kara Uzun (2009) and Bafra lambs which were developed by backcrossing between Chios and Karayaka (Yakan and Unal 2010).

**Table 2** Fattening performance, feed efficiency and eye muscle values of Karayaka lambs

| Traits                                               | Male   | Female | Combined | SEM  |
|------------------------------------------------------|--------|--------|----------|------|
| Fattening performance                                |        |        |          |      |
| Birth weight (kg)                                    | 3.9    | 3.8    | 3.9      | 0.09 |
| Initial weight (kg) at day 90                        | 19.3a  | 17.9b  | 18.8     | 0.39 |
| Slaughter weight (kg) at day 150                     | 35.6a  | 30.3b  | 33.4     | 0.72 |
| Daily weight gain (g) from days 90 to 150            | 270.4a | 205.4b | 243.7    | 9.46 |
| Feed efficiency <sup>a</sup>                         |        |        |          |      |
| Consumed concentrate feed (per kg gain)              | 4.9    | 6.5    | 5.7      | N/A  |
| Consumed roughage feed (per kg gain)                 | 0.6    | 1.0    | 0.8      | N/A  |
| Overall feed efficiency                              | 5.5    | 7.5    | 6.5      | N/A  |
| Feed conversion efficiency                           | 0.18   | 0.13   | 0.16     | N/A  |
| Eye muscle values                                    |        |        |          |      |
| Fat thickness (mm; ultrasonic measurement)           | 3.4    | 3.5    | 3.4      | 0.15 |
| Fat thickness (mm; caliper measurement)              | 3.6    | 3.7    | 3.6      | 0.12 |
| Loin thickness (mm; ultrasonic measurement)          | 20.5   | 22.1   | 21.2     | 0.52 |
| Loin thickness (mm; caliper measurement)             | 20.8   | 20.3   | 20.6     | 0.42 |
| Loin area (mm <sup>2</sup> ; ultrasonic measurement) | 74.3   | 77.8   | 75.7     | 4.34 |
| Loin area (mm <sup>2</sup> ; grid reading)           | 140.6  | 130.2  | 136.3    | 4.0  |

Means in rows with different letters are significantly different at  $p < 0.05$

SEM standard error of mean, N/A not applicable

<sup>a</sup> Statistical analyses between sexes in terms of food consumption have not been performed due to group feeding

Boggs and Merkel (1993) noted that average range of depth of fat (fat thickness) over the eye muscle and area of eye muscle should range between 5.08 and 12.7 mm and 38.1 and 91.4 mm<sup>2</sup> between 12th and 13th rib, respectively. In the present study, mean fat thickness and loin area values of Karayaka lambs obtained by ultrasonic measurements were below and within this reported range, respectively. Additionally, the areas of eye muscle which were measured with grid reading were similar with those of Bafra lambs (Yakan and Unal 2010). There were significant correlations between ultrasound and caliper measurements in terms of eye muscle fat thickness ( $r = 0.84 \pm 0.12$  for female and  $0.97 \pm 0.05$  for male;  $p < 0.05$ ).

Slaughter traits for Karayaka lambs are presented in Table 3. As a result of higher slaughter weight of male lambs, absolute weights of non-carass components and some organs of male lambs were also higher ( $p < 0.05$ ) than that of female lambs (data are not shown). However, proportion of non-carass components and some organs weights relative to slaughter weight were similar for male and female lambs. Absolute carcass weight but not relative carcass weight (46.9% for warm and 44.7% for cold carcass) was higher in male than female lambs ( $p < 0.05$ ). Observations in the present study for carcass weight and carcass yield of male Karayaka lambs were higher than the values for the same breed reported by Olfaz et al. (2005). Although chilling is one of the environmental factors which result in a considerable increase in the toughness of the meat, which is not reduced by maturing (Mushi et al. 2008), in the present study chilling loss of meat from male and female lambs was similar.

In general terms, females are more precocious than males (Rodríguez et al. 2008). Therefore, as female lambs grow, the proportion of fat on carcass was higher than male lambs, and as male lambs grow, they have more muscle mass when compared to female lambs (Rodríguez et al. 2008). At the end of fattening period in the present study, female lambs reached a lower body weight than the male lambs, but internal fat, pelvic fat and kidney fat proportions of female lambs were higher than that of male lambs ( $p < 0.05$ ). These observations are in agreement with the argument of Rodríguez et al. (2008).

Instrumental meat quality characteristics of Karayaka lambs are presented in Tables 4 and 5. In the present study, although carcass weight did differ between sexes, this effect was not reflected on studied meat quality traits, except for drip loss of the ST. This situation may result in the low correlation coefficients between many of the meat quality characteristics and lamb performance and carcass characteristics (Mushi et al. 2008). Meat quality traits, such as pH, dripping loss and CIELab colour characteristics were affected by storage time ( $p < 0.05$ ). The interactions of sex and storage time on any of the studied parameters were not significant, and thus, these were not shown in the tables. Therefore, the mean values of sexes for both muscles were pooled and are presented in all tables.

There is a slight tendency for males because they are more excitable, to have slightly higher pH values than females. No differences in final pH were reported by either Wojtysiak et al. (2010) between males and female Polish Longwool lambs or by Horcada et al. (1998) between male and female Lacha and Rasa Aragonesa lambs, confirming the results with

**Table 3** Weights and yields of carcass, yield of muscle and proportions of non-carcass components and organ weights of Karayaka lambs

| Traits                                  | Male  | Female | Combined | SEM   |
|-----------------------------------------|-------|--------|----------|-------|
| Carcass weight (kg)                     |       |        |          |       |
| Hot                                     | 16.7a | 14.1b  | 15.6     | 0.35  |
| Cold                                    | 16.0a | 13.4b  | 14.9     | 0.35  |
| Carcass yield (%)                       |       |        |          |       |
| Hot                                     | 47.2  | 46.4   | 46.9     | 0.62  |
| Cold                                    | 45.0  | 44.3   | 44.7     | 0.66  |
| Chilling loss (%)                       | 2.1   | 2.3    | 2.1      | 0.15  |
| Muscle (g/100 g body weight)            |       |        |          |       |
| ST muscle                               | 0.53  | 0.58   | 0.55     | 0.015 |
| SM muscle                               | 0.13  | 0.15   | 0.14     | 0.005 |
| GN muscle                               | 3.00  | 3.20   | 3.10     | 0.009 |
| Non-carcass parts (g/100 g body weight) |       |        |          |       |
| Head                                    | 5.4   | 4.7    | 5.1      | 0.25  |
| Pelt                                    | 12.5  | 12.4   | 12.5     | 0.21  |
| Feet                                    | 20.6  | 20.6   | 20.6     | 0.05  |
| Small intestine                         | 2.1   | 2.0    | 2.1      | 0.06  |
| Reticulo rumen                          | 2.7   | 2.9    | 2.8      | 0.09  |
| Internal fat                            | 0.9b  | 1.4a   | 1.1      | 0.06  |
| Pelvic fat                              | 0.36b | 0.61a  | 0.46     | 0.043 |
| Kidney fat                              | 0.16b | 0.35a  | 0.24     | 0.025 |
| Total fat                               | 1.4b  | 2.4a   | 1.8      | 0.12  |
| Organ weight (g/100 g body weight)      |       |        |          |       |
| Lung                                    | 1.4   | 1.3    | 1.4      | 0.04  |
| Liver                                   | 2.1   | 1.9    | 2.0      | 0.04  |
| Kidney                                  | 0.33  | 0.31   | 0.32     | 0.005 |
| Heart                                   | 0.43  | 0.43   | 0.43     | 0.008 |
| Spleen                                  | 0.20  | 0.19   | 0.20     | 0.007 |
| Testis weight (g)                       | 162.3 | N/A    | 162.3    | 0.61  |
| Ovarian weight (g)                      | N/A   | 0.90   | 0.90     | 0.01  |

Means in rows with different letters are significantly different at  $p < 0.05$

SEM standard error of mean, ST semitendinosus muscle, SM semi-membranosus muscle, GN gastrocnemius muscle, N/A not applicable

respect to the pH value of meat from Karayaka lambs. The main factor determining the quality of meat is its pH, which is related to biochemical processes during the transformation of muscle to meat. Consequently, changes in the pH during the postmortem period influence the organoleptic characteristics of the meat (Sañudo et al. 1998). Final pH results in a difference in water-holding capacity, assessed by drip loss or cooking loss. Indeed, a low pH is associated with poor water-holding capacity and a high pH is associated with poor shelf-life. Our result with respect to pH supports the idea that meat with a pH higher than 5.8 does not present a significant difference in water-holding capacity, irrespective of its

**Table 4** The pH value, drip loss, cooking loss and shear force of muscles from Karayaka lambs

| Traits                            | Muscle | Male  | Female | Combined | SEM  |
|-----------------------------------|--------|-------|--------|----------|------|
| pH                                |        |       |        |          |      |
| 1 h                               | LD     | 6.6   | 6.5    | 6.5A     | 0.04 |
|                                   | ST     | 6.6   | 6.6    | 6.6B     | 0.03 |
| 24 h                              | LD     | 5.6   | 5.6    | 5.6A     | 0.02 |
|                                   | ST     | 5.6   | 5.5    | 5.6B     | 0.01 |
| Drip loss (%)                     |        |       |        |          |      |
| 3 days                            | LD     | 8.4   | 9.2    | 8.8A     | 0.39 |
|                                   | ST     | 8.1b  | 10.2a  | 8.9B     | 0.36 |
| 7 days                            | LD     | 11.0  | 12.1   | 11.5A    | 0.35 |
|                                   | ST     | 11.2b | 13.5a  | 12.2B    | 0.42 |
| Cooking loss (%)                  | LD     | 23.0A | 24.5A  | 23.6     | 0.67 |
|                                   | ST     | 21.4B | 21.7B  | 21.5     | 0.56 |
| Shear force (kg/cm <sup>2</sup> ) | LD     | 3.6B  | 3.7B   | 3.7      | 0.09 |
|                                   | ST     | 4.3A  | 4.4A   | 4.4      | 0.12 |

Means in rows with different lowercase letters are significantly different at  $p < 0.05$ . Means in column with the same uppercase letters are significantly different at  $p < 0.05$

SEM standard error of mean, LD longissimus dorsi muscle, ST semitendinosus muscle

colour (Fogarty et al. 2000). The ultimate pH ranges for both LD and ST muscles are acceptable and within the normal pH ranges, assuming that an ultimate pH greater than 5.8 is regarded as undesirable (Tejeda et al. 2008). The pH values obtained from the current study were very similar to those of lambs from some Turkish sheep breeds such as Awassi, Morkaraman (Esenbuga et al. 2009), Ramlic, Kivircik, Chios, Imroz (Ekiz et al. 2009) and Bafra (Yakan and Unal 2010) slaughtered approximately at similar age but at different slaughter weight. The pH values measured at 1 h were higher than that at 24 h of LD and ST muscles ( $p < 0.05$ ; Table 4). The slaughter of an animal initiates biochemical changes in the muscle tissue. Anaerobic glycolysis produces a lactic acid build up, and therefore, this accumulation of lactic acid in postmortem muscle reduces the localized pH (Nagaraj et al. 2006). These authors have showed that the large variation in the pH fall in LD and ST muscles may be because of variations in glycolysis and accumulation of lactic acid within the carcass, resulting in a decline in muscle pH as observed in the present study.

The water-holding capacity, the ability of meat to retain its water during application of external forces such as cutting, heating, grinding or pressing, is an important attribute of meat quality. This property affects the retention of vitamins, minerals and salts, as well as the volume of water retained. Muscles that lose water easily are drier and lose more weight during refrigeration,

**Table 5** Colour characteristics of muscles from Karayaka lambs

| Traits                           | Muscles | Male | Female | Combined | SEM  |
|----------------------------------|---------|------|--------|----------|------|
| Lightness ( $L^*$ )              |         |      |        |          |      |
| 1 h                              | LD      | 34.5 | 34.9   | 34.7a    | 0.28 |
|                                  | ST      | 33.0 | 32.2   | 32.6b    | 0.24 |
| 24 h                             | LD      | 42.0 | 40.8   | 41.5a    | 0.47 |
|                                  | ST      | 40.0 | 38.3   | 39.3b    | 0.40 |
| Redness ( $a^*$ )                |         |      |        |          |      |
| 1 h                              | LD      | 17.8 | 18.5   | 18.1a    | 0.17 |
|                                  | ST      | 19.6 | 19.4   | 19.5     | 0.20 |
| 24 h                             | LD      | 19.7 | 19.7   | 19.7a    | 0.23 |
|                                  | ST      | 20.1 | 19.5   | 19.8     | 0.17 |
| Yellowness ( $b^*$ )             |         |      |        |          |      |
| 1 h                              | LD      | 4.3  | 4.4    | 4.3a     | 0.10 |
|                                  | ST      | 5.1  | 4.9    | 5.0b     | 0.09 |
| 24 h                             | LD      | 6.6  | 6.2    | 6.5a     | 0.17 |
|                                  | ST      | 6.7  | 6.5    | 6.7b     | 0.13 |
| Chroma value ( $C^*$ )           |         |      |        |          |      |
| 1 h                              | LD      | 18.3 | 19.1   | 18.6a    | 0.18 |
|                                  | ST      | 20.2 | 20.1   | 20.2b    | 0.22 |
| 24 h                             | LD      | 20.8 | 20.7   | 20.8a    | 0.25 |
|                                  | ST      | 21.2 | 20.6   | 21.0b    | 0.19 |
| Hue angle ( $H^\circ$ )          |         |      |        |          |      |
| 1 h                              | LD      | 13.5 | 13.5   | 13.5a    | 0.27 |
|                                  | ST      | 14.6 | 14.1   | 14.4b    | 0.23 |
| 24 h                             | LD      | 18.5 | 17.5   | 18.1a    | 0.34 |
|                                  | ST      | 18.6 | 18.4   | 18.5b    | 0.28 |
| Colour difference ( $\Delta D$ ) | LD      | 8.2  | 6.6    | 7.5      | 0.45 |
|                                  | ST      | 7.3  | 6.5    | 7.0      | 0.38 |

Means in column with the same letters are significantly different at  $p < 0.05$

SEM standard error of mean, LD longissimus dorsi muscle, ST semitendinosus muscle

storage, transport and marketing. The drip loss values in ST muscle but not in LD muscle from Karayaka male and female lambs were different ( $p < 0.05$ ). Horcada et al. (1998) found no effect of sex on water-holding capacity. However, Dawson et al. (2002) reported that carcasses from male lambs had a greater cooking loss than that from female lambs, and meat from male lambs had greater values for Warner–Bratzler shear force than that from female lambs. This contradiction between studies may be related to the negative correlations observed between Warner–Bratzler shear force and live-weight gain from birth to slaughter (Dawson et al. 2002) and to differences in determining method of shear force.

In the present study, cooking loss values of male and female lambs were not different. These results are in agreement with the results of Santos et al. (2007).

However, meat samples from LD had higher cooking loss compared with that from ST ( $p < 0.05$ ). Differences in cooking loss between muscles could be due to differences in fatness, since fatter muscles are expected to have more cooking loss. Therefore, our results with respect to shear force and cooking loss support the idea that meat tenderness and cooking loss differ among the different skeletal muscles (Sazili et al. 2008). Cooking loss values of Karayaka lambs were lower than those of lambs of Awassi, Morkaraman (Esenbuga et al. 2009), Ramlic, Kivircik, Chios, Imroz (Ekiz et al. 2009) and Bafra (Yakan and Unal 2010). As expected, drip loss of the 3-day conditioned both muscle samples was lower than that of the 7-day conditioned samples ( $p < 0.05$ ; Table 4). Indeed, Nagaraj et al. (2006) reported that there was a significant increase in drip loss of LD and ST muscles from goat at 3, 6 and 9 days of storage, respectively. Increased drip loss may be related to different factors, such as protein denaturation, sarcomere shortening and myosin denaturation (Nagaraj et al. 2006). Unfortunately, these were not investigated in the present study.

Tenderness is the most important textural characteristics of meat and has the greatest influence on consumer acceptance of meat. At the same age, meat from male is less tender than that from female lambs (Mushi et al. 2008). In the present study, no differences in meat tenderness, assessed by shear force, were found in the LD and ST muscle from male and female Karayaka lambs. This result agrees with the work of (Horcada et al. 1998), who found that there were no differences in meat tenderness of carcasses from male and female Rasa Aragonesa and Lacha lambs. This may be explained by either that slaughter weights were not sufficient for the collagen to be restructured or increases in muscle fat content may have counteracted any decrease in tenderness. The LD muscle had a lower ( $p < 0.05$ ) shear force value compared to the ST muscle which is likely due to a difference in the number of thermoresistant linkages between the collagen fibres, as the proportions of red and white fibres differ within the muscles and between muscles in different parts of the body (Horcada et al. 1998). This result is in agreement with a previous report by Sazili et al. (2005) who reported significant differences in shear force values between LD and ST muscles in growing lambs. Similar results were also reported Esenbuga et al. (2009). Tenderness values of LD muscle from Karayaka lambs in the present were similar to that of Kivircik (Ekiz et al. 2009) and Bafra lambs (Yakan and Unal 2010) but lower than those of Ramlic (Ekiz et al. 2009), Awassi and Morkaraman lambs (Esenbuga et al. 2009). Shear force values obtained from the present study were acceptable because they were lower than  $5.5 \text{ kg/cm}^2$  which were similar to those of Bafra lambs (Yakan and Unal 2010).

Colour is the main factor that consumers use to discriminate when buying lamb meat. Thus, the colour of meat has a great importance in the acceptance of meat by consumers at the point of purchase at market (Martínez-Cerezo et al. 2005). These parameters are influenced by biological and technological factors, the most important of which are live weight and diet composition, which affect the amount and composition of fat in different adipose tissues (Olfaz et al. 2005). Lamb meat with pale or pink colour is preferred by consumers of Turkey, where dark meat is very difficult to market (Esenbuga et al. 2009).

In the present study, mean lightness ( $L^*$ ), redness ( $a^*$ ) and yellowness ( $b^*$ ) values of LD and ST muscles from male and female lambs at 1 and 24 h postmortem and also  $L^*$ ,  $a^*$  and  $b^*$  decline between these two measurements were not significant ( $p>0.05$ ; Table 5). But the differences among storage time in terms of  $L^*$ ,  $a^*$  and  $b^*$  values were significant ( $p<0.05$ ; Table 5), which is likely because postmortem pH is one of the most important events in the conversion of muscle to meat due to its impact on meat colour (Carrasco et al. 2009). Similarly to the present study, no influence of sex on meat lightness was reported by Rodríguez et al. (2008). Wojtysiak et al. (2010) reported no significant differences in colour parameters between males, castrate males and females. Meat colour parameters of Awassi, Morkaraman (Esenbuga et al. 2009), Kivircik (Koyuncu and Kara Uzun 2009) and Bafra (Yakan and Unal 2010) lambs are generally similar to what was observed in the present study. The chroma ( $C^*$ ) and hue angles ( $H^\circ$ ) are more closely related to visual appearance. Young and West (2001) reported that  $a^*$  and  $H^\circ$  values are both good indicators of meat discoloration. These authors observed that the  $a^*$  values fell and  $H^\circ$  increased as discoloration progressed in beef during retail display. It was also noted that  $C^*$  drops and meat is seen as dull. In the present study,  $C^*$  and  $H^\circ$  values of LD and ST muscles from male and female lambs at 1 and 24 h postmortem and also  $C^*$  and  $H^\circ$  decline between these two measurements were not significant ( $p>0.05$ ; Table 5). But the differences among storage time in terms of  $C^*$  and  $H^\circ$  values were significant, and  $C^*$  and  $H^\circ$  values at 24 h were higher than that at 1 h ( $p<0.05$ ; Table 5).

Generally, there are negative correlations between carcass characteristics and ultimate pH, cooking loss, Warner–Bratzler shear force,  $L^*$  and  $H^\circ$  values and positive correlations between carcass characteristics and  $a^*$ ,  $b^*$  and  $C^*$  values (Dawson et al. 2002). However, no differences were found between sexes in terms of meat quality traits in the present study because proportions of dry matter, protein, ash of male and female lambs and muscle types were similar (Table 6). A similar result was also reported by Rodríguez et al. (2008).

**Table 6** Chemical composition of muscle from Karayaka lambs (% on dry matter)

| Traits             | Muscle | Male | Female | Combined | SEM  |
|--------------------|--------|------|--------|----------|------|
| Dry matter         | LD     | 24.8 | 25.3   | 25.0     | 0.16 |
|                    | ST     | 24.1 | 24.5   | 24.3     | 0.15 |
| Ash                | LD     | 1.1  | 1.1    | 1.1      | 0.03 |
|                    | ST     | 1.1  | 1.1    | 1.1      | 0.02 |
| Protein            | LD     | 20.1 | 19.8   | 20.0     | 0.40 |
|                    | ST     | 19.7 | 19.8   | 19.7     | 0.36 |
| Intra-muscular fat | LD     | 2.2b | 3.3a   | 2.7A     | 0.19 |
|                    | ST     | 1.9b | 2.5a   | 2.1B     | 0.12 |

Means in rows with different lowercase letters are significantly different at  $p<0.05$ . Means in column with different uppercase letters are significantly different at  $p<0.05$

SEM standard error of mean, LD longissimus dorsi muscle, ST semitendinosus muscle

### Concluding remarks

In the current study, carcass and meat quality characteristics of Karayaka male and female lambs were compared. The performance and meat quality parameters of Karayaka breed determined in this study are comparable to the other native sheep breeds of Turkey. The results of this study show that fattening performance of Karayaka lambs are quite acceptable if the optimum fattening conditions are provided. Meat quality characteristics of Karayaka breed and changes in quality parameters with the storage period are within the preferable range of consumers. This is particularly important due to the fact that Karayaka lamb meats are in demand throughout the year locally.

In the case of carrying out an improvement programme for the performance and meat quality of native sheep breeds of Turkey, the performance and meat quality of Karayaka breed reported in this study indicate that it may have implications in such local breeding programmes. These results presented here also provide a valuable input into the characterization of performance and meat quality of Karayaka breed which may have potential in improving sheep production in Turkey. The results of present study may indicate that future studies with Karayaka sheep breed should include selection studies in improvement programmes and responses to the improving fattening performance and meat quality with an increase in litter size.

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