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Carcass and meat quality characteristics of lambs reared in different seasons

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Abstract. Thirty-six Kivircik male lambs were used to determine the effects of rearing season (winter rearing – WR; spring–summer rearing – SSR; and autumn rearing – AR) on carcass and meat quality characteristics. Average daily gain in the period 0–134 days, final weight, cold carcass weight and real dressing percentage were higher in WR lambs than lambs from SSR and AR groups. Furthermore, SSR and AR lambs did not show significant differences for these traits ($P > 0.05$). WR lambs had the highest values in terms of back fat thickness, subjective carcass fatness score and fat percentage in pelvic limb, which gives information about the carcass fatness. Final meat pH, expressed juice and meat lightness 1 h after cutting were higher for SSR lambs than for WR and AR lambs. SSR lambs had the lowest scores in terms of flavour intensity, flavour quality and overall acceptability in the sensory evaluation panel. In conclusion, WR lambs yielded better carcass quality than SSR and AR lambs. When the rearing season is to be decided, the higher carcass quality of WR lambs and the lesser appreciation of meat of SSR lambs by consumers should be considered.

1 Introduction

Sheep breeding in Turkey is usually performed by the use of native breeds and also using traditional methods – which are similar to many countries in the Middle East. Sheep in the traditional production system proliferate according to natural breeding period and lambs suckle their dams until the slaughter age (Ekiz et al., 2012). Generally, lambs are slaughtered at 4–5 months of age or breeders apply a proper fattening programme after weaning to increase slaughter live weight of lambs depending on market demand. Therefore, lambs can usually be supplied to the market at predetermined times of the year.

The meat quality is influenced by consumer demand. Red meat consumers tend to prefer meat of grazed lambs, considering that such lamb meat is much healthier, tastier and more natural than meat from concentrate-based production systems (Font i Furnols and Guerrero, 2014). Butchers and restaurants which cater for high-income consumers demand high-quality lamb meat throughout the year. For this reason, some farmers apply synchronization programmes in order to supply meat as demanded by the market year round. According to the natural breeding programme, lambs are usually born in winter and are kept with their dams in sheepfold until spring as the pasture conditions are not suitable for lamb grazing in this period. But pasture conditions change with the season. Thus, farmers who aim to obtain lambs in other seasons take advantage of pasture and graze their lambs to provide for their nutritional needs. Therefore, the feeding system of lambs changes according to the rearing season.

The feeding system and husbandry conditions which change with rearing season may affect lamb growth performance (Santos-Silva et al., 2002; Joy et al., 2008; Ekiz et al., 2013) and influence the carcass and meat quality characteristics of lambs (Priolo et al., 2002; Joy et al., 2008; Carrasco et al., 2009; Ekiz et al., 2012). Previous studies have indicated that lambs fed with concentrate diet generally have higher carcass weight (Díaz et al., 2002; Priolo et al., 2002), dressing percentage and fatness level (Díaz et al., 2002; Ekiz et al., 2012, 2013) than lambs grazed on pasture. Studies also show that meat from lambs grazed on pasture is tougher and darker (Priolo et al., 2002; Cañeque et al., 2003; Ekiz et al., 2012) than meat from concentrate-fed lambs.

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Table 1. Means ± SE (standard errors) for birth weight, final live weight and average daily gain in lambs reared in different seasons.

Characteristics	WR*	SSR*	AR*	P value
Birth weight, kg	4.29 ± 0.27	4.19 ± 0.19	4.01 ± 0.12	0.631
Final weight, kg	$28.00^a \pm 1.39$	$21.66^b \pm 0.61$	$21.85^b \pm 0.99$	< 0.001
ADG[d], g	$176.99^a \pm 10.27$	$130.42^b \pm 4.27$	$133.09^b \pm 7.22$	< 0.001
Slaughter age	134.67 ± 1.05	134.00 ± 1.19	133.75 ± 0.51	0.787

[a,b] Means in the same line with different superscripts are significantly different. [d] ADG, average daily weight gain from birth to 134 days of age. * WR: winter rearing; SSR: spring–summer rearing; AR: autumn rearing.

The aim of this study is to determine the carcass and meat quality of Kivircik lambs reared in autumn, winter and spring–summer seasons in relation to the feed sources of these seasons.

2 Material and methods

The Ethics Committee of Istanbul University approved the experimental protocol of the current study (Approval number: 2015/05).

2.1 Animals and experimental design

The study was conducted at the sheep farm of Istanbul University (during the 2015–2016 breeding season). The herd was separated into three groups at the beginning of the breeding season and Eazi-Breed™ CIDR (controlled integral drug release) were used to synchronize ewes in each mating period (May, February, October). A total of 36 Kivircik male lambs raised in different seasons (autumn, 12 lambs; spring–summer, 12 lambs; winter, 12 lambs) were used in the research. The rearing seasons of lambs investigated in the current study are as follows:

a. *Spring–summer-reared lambs (SSR)*: lambs were kept with their mothers in the sheepfold for the 2 months following birth. In addition to mother's milk, lambs were fed with 500 g concentrate per day (87.7 % dry matter, 17.15 % crude protein, 4.8 % crude fat, 6.4 % crude cellulose, 7.96 % crude ash, 10.15 % neutral detergent fibre (NDF), 24.56 % acid detergent fibre (ADF), 0.82 % calcium, 0.5 % phosphorus and 2650 kcal kg^{-1} metabolizable energy (ME)) per lamb and ad libitum access to alfalfa hay (87.8 % dry matter, 12.88 % crude protein, 2.33 % crude fat, 37.3 % crude cellulose, 9.85 % crude ash, 43.89 % NDF, 58.79 % ADF and 1843 kcal kg^{-1} ME) after 2 weeks of age in a different pen which lambs can pass but mothers cannot, in the sheepfold. Lambs were grazed on natural pasture together with their dams during the daytime (09:00–16:00) from the beginning of June to slaughter age.

b. *Autumn-reared lambs (AR)*: the feeding system of AR lambs was similar to the SSR group; however, these lambs were grazed on natural pasture with their dams in the daytime from the beginning of October to slaughter age.

c. *Winter-reared lambs (WR)*: these lambs were born in middle November and kept with their dams until slaughter age in the sheepfold. In addition to mother's milk, lambs were fed with 500 g concentrate per day per lamb and ad libitum access to alfalfa hay after 2 weeks of age in a different pen which lambs can pass but mothers cannot, in the sheepfold.

The pasture was natural and composed of (on dry matter basis) 52 % Gramineae (*Festuca* spp. and *Lolium* spp.), 22 % Leguminosae (mainly *Trifolium* spp., *Medicago* spp. and *Vicia* spp.) and 26 % other families (mainly *Conium* spp., *Geranium* spp., *Viola* spp., *Rumex* spp. and *Plantago* spp.) (Ekiz et al., 2013). Lambs in all experimental groups were weighed on a fortnightly basis and were slaughtered at the average age of 134 days (Table 1).

2.2 Slaughter procedure, carcass characteristics and dissections

At the end of the each rearing season (March, August, December) 12 Kivircik male lambs were brought to the experimental abattoir of Istanbul University Veterinary Faculty, and were kept in the lairage pen (4 × 5 m) for 2 h. After lairage, lambs were weighed and then slaughtered after electrical stunning. After the removal of non-carcass components, lamb carcasses were chilled at 4 °C for 24 h and then carcass weights were recorded. Commercial dressing percentage was calculated based on pre-slaughter live weight, while real dressing percentage was calculated based on empty body weight (EBW). Subjective fatness and conformation scores were given by using the European system (EUROP) as described by Johansen et al. (2006). Subcutaneous fat colour was measured from tail root with a Minolta CR 400 colorimeter (Minolta Camera Co., Osaka, Japan) using CIELAB colour space (L^*, a^*, b^*) as described by Ekiz et al. (2012). Carcasses were split into two halves and the left side of each carcass was separated into five joints according to the methodology described by Colomer-Rocher et al. (1987). Longissimus dorsi (LD) muscle section area and back fat thickness were measured as described by Boggs and

Merkel (1993). In order to estimate carcass composition the left pelvic limb was used. After carcass jointing, pelvic limbs were vacuum-packed and then put into deep freeze (−18 °C) until the day of dissection. The day before dissection, pelvic limbs were thawed at 4 °C for 24 h. Each pelvic joint was dissected into muscle, bone, subcutaneous fat, intermuscular fat and other tissues by the dissection method described by Fisher and De Boer (1994).

2.3 Meat instrumental quality

In order to be used in meat quality analyses LD muscle was removed from left side of the carcasses at 24 h post-slaughter and were packed. Meat samples were taken after 72 h ageing process at 4 °C in refrigerator. For sensory evaluation, meat samples were packed under vacuum, frozen and kept at −18 °C until panel evaluation.

The pH of longissimus dorsi was measured immediately after dressing (pH_0) and at 24 h after dressing (pH_{final}) from the muscle between the 12th and 13th thoracic vertebrae using a digital pH meter (Testo 205, Testo AG, Lenzkirch, Germany). Drip loss was estimated by the ratio of weight loss to initial weight after meat samples were stored for 24 h at 4 °C in refrigerator (Honikel, 1998). Expressed juice was determined by modified Grau and Hamm pressure method (Beriain et al., 2000). To determine cooking loss, the meat samples were put into heat-resistant polyethylene bags and were cooked in a water bath at 80 °C for 45 min and then cooled under running water. Cooking loss was estimated by means of percentage of weight loss of the cooked samples to initial weight (Honikel, 1998). Six sub-samples cut parallel to the muscle fibres with a cross section of 1 × 1 cm were prepared from each cooked sample to measure tenderness (Ekiz et al., 2012) with an Instron Universal Testing Machine (model 3343, Instron Corp., Norwood, MA, USA). Meat colour was determined on LD muscle at 1 and 24 h after cutting on cut surface with a Minolta CR 400 colorimeter (Minolta Camera Co., Osaka, Japan) using CIE (1976) standards as described by Ekiz et al. (2012).

2.4 Meat sensory evaluation

Meat samples, which were served to the panellists, were prepared according to the methodology described by Ekiz et al. (2012). Panel evaluation was carried out in four sessions and in each session three sub-samples from each group were served to the panellist. Sensory characteristics of cooked samples were assessed by seven panellists using an eight-point category scale described by Sañudo et al. (1998). The panellists assessed lamb odour intensity, tenderness, juiciness, flavour intensity, flavour quality and overall acceptability (scale 1 = no odour, extremely tough, extremely dry, no flavour, dislike flavour extremely and dislike extremely; scale 8 = very strong lamb odour, extremely tender, extremely juicy, very strong flavour, like flavour extremely and like extremely) (Sañudo et al., 1998).

2.5 Statistical analyses

In order to determine the effect of rearing season on carcass and meat quality characteristics, one-way ANOVA was performed using the SPSS 13 statistical package (SPSS Inc, Chicago, Illinois, USA). Data for meat colour parameters were re-analysed by adding the slaughter weight as a covariate into the statistical model. General linear model analyses were performed to analyse the data for sensory characteristics. The model used to analyse data for sensory characteristics included the fixed effects of feeding system, session, panellist and also significant two-way interactions between these main effects. Pearson correlation analysis in the SPSS 13 statistical package was applied in order to obtain coefficients of correlation among sensory characteristics.

3 Results

The effects of rearing season on lamb growth performance are presented in Table 1. Lambs' slaughter ages in all groups in the research were similar as a result of the experimental plan. The average daily weight gain from birth to 134 days and final live weight were significantly higher in WR lambs than in AR and SSR lambs, while AR and SSR lambs had similar values for these traits.

The effects of the rearing season on carcass quality characteristics and fat colour parameters are shown in Table 2. WR lambs presented higher empty body weight, carcass weight, real dressing percentage and back fat thickness than their SSR and AR counterparts. However, there were no significant differences between SSR and AR groups in terms of these traits. Moreover, WR lambs had the highest score in subjective carcass fatness while SSR lambs had the lowest score for the same trait. Rearing season had no significant influence on carcass fat colour parameters except fat lightness (L^* value) and hue angle. The lowest lightness and hue values were observed in the SSR lambs, while there were no significant differences between WR and AR lambs with regard to these traits. Mean values of pelvic limb composition are presented in Table 3. Rearing season had a significant effect on lean, bone and fat percentages in different levels. SSR lambs presented higher lean and bone percentages and lower subcutaneous and intermuscular fat percentages than their WR and AR counterparts. The lean / fat ratio was significantly higher in SSR lamb carcasses than other experimental groups.

Mean values of meat pH, drip loss, cooking loss, expressed juice and Warner–Bratzler (WB) shear force values are shown in Table 4. Rearing season had no significant effect on pH_0, drip loss, cooking loss and WB shear force. While meat from SSR lambs had higher pH_{final} and expressed juice values than those of other groups, there were no significant

Table 2. Means ± SE for certain carcass quality characteristics and fat colour parameters of lambs reared in different seasons.

Characteristics	WR	SSR	AR	P value
Empty body weight, kg	$23.38^a \pm 1.01$	$15.55^b \pm 0.50$	$17.61^b \pm 0.89$	< 0.001
Carcass weight, kg	$12.62^a \pm 0.64$	$7.51^b \pm 0.28$	$8.63^b \pm 0.56$	< 0.001
Commercial dressing, %[d]	$45.14^a \pm 0.81$	$36.27^c \pm 0.64$	$39.41^b \pm 0.81$	< 0.001
Real dressing, %[f]	$53.77^a \pm 0.57$	$48.18^b \pm 0.44$	$48.63^b \pm 0.74$	< 0.001
Shrinkage loss, %	$2.51^c \pm 0.10$	$4.13^a \pm 0.10$	$2.84^b \pm 0.13$	< 0.001
LD muscle section area, mm^2	$9.97^a \pm 0.46$	$8.90^{a,b} \pm 0.43$	$8.16^b \pm 0.49$	0.030
Back fat thickness, mm	$0.85^a \pm 0.15$	$0.24^b \pm 0.03$	$0.26^b \pm 0.14$	0.001
Conformation score (1–15)	$5.42^a \pm 0.29$	$4.67^{a,b} \pm 0.19$	$4.25^b \pm 0.39$	0.031
Fatness score (1–15)	$5.50^a \pm 0.15$	$2.33^c \pm 0.23$	$3.17^b \pm 0.32$	< 0.001
Fat colour parameters				
Fat lightness (L^*)	$72.38^a \pm 0.56$	$66.96^b \pm 1.29$	$73.49^a \pm 0.62$	< 0.001
Fat redness (a^*)	4.21 ± 0.33	4.61 ± 0.40	4.37 ± 0.30	0.718
Fat yellowness (b^*)	5.02 ± 0.46	4.23 ± 1.22	5.45 ± 0.48	0.558
Chroma (C^*)	6.59 ± 0.52	6.88 ± 0.95	7.06 ± 0.46	0.883
Hue angle (H^*)	$49.76^a \pm 2.01$	$29.16^b \pm 9.49$	$50.33^a \pm 2.48$	0.021

[a,b,c] Means in the same line with different superscripts are significantly different. [d] Commercial dressing: cold carcass dressing based on pre-slaughter live weight. [f] Real dressing: cold carcass dressing based on empty body weight.

Table 3. Means ± SE for pelvic limb composition of lambs reared in different seasons.

Characteristics	WR	SSR	AR	P value
Pelvic limb weight, kg	$2.09^a \pm 0.10$	$1.28^b \pm 0.05$	$1.47^b \pm 0.09$	< 0.001
Composition of pelvic limb				
Lean, %	$58.83^b \pm 0.80$	$66.00^a \pm 0.62$	$60.07^b \pm 0.53$	< 0.001
Bone, %	$19.75^c \pm 0.30$	$23.48^a \pm 0.51$	$21.38^b \pm 0.70$	< 0.001
Subcutaneous fat, %	$11.11^a \pm 1.02$	$1.23^c \pm 0.38$	$7.40^b \pm 1.08$	< 0.001
Intermuscular fat, %	$5.12^a \pm 0.42$	$2.81^b \pm 0.45$	$5.25^a \pm 0.57$	0.001
Total fat, %	$16.23^a \pm 0.90$	$4.04^c \pm 0.81$	$12.65^b \pm 1.17$	< 0.001
Other tissues[d], %	$3.14^b \pm 0.30$	$4.43^a \pm 0.19$	$3.30^b \pm 0.21$	0.001
Evaporation losses, %	2.05 ± 0.10	2.05 ± 0.15	2.58 ± 0.29	0.101
Lean / bone ratio	2.98 ± 0.05	2.83 ± 0.06	2.84 ± 0.09	0.234
Lean / fat ratio	$3.79^b \pm 0.29$	$25.33^a \pm 4.75$	$5.35^b \pm 0.65$	< 0.001

[a,b,c] Means in the same line with different superscripts are significantly different. [d] Major blood vessels, tendons, larger nerves and lymph nodes.

differences between WR and AR lambs considering these traits. Results for meat colour parameters of LD muscle at 1 and 24 h after cutting are presented in Table 5. The differences among rearing season in terms of meat lightness (L^*) and redness (a^*) were significant at 1 and 24 h after cutting, while feeding system had no significant effect of yellowness values. SSR lambs had higher lightness values than those of WR and AR lambs at 1 h and that of WR lambs at 24 h. However, WR lambs had higher redness values in LD muscle at 1 and 24 h after cutting. Meat obtained from WR lambs had greater Chroma values than those of SSR and AR lambs at 1 and 24 h, while it had lower hue angle values than the other two groups at 24 h after cutting. The effects of slaughter weight, as a covariate, on meat lightness (L^*) and redness (a^*) values were significant ($P < 0.05$ and $P < 0.01$ respectively). On the other hand, the effect of the rearing season becomes insignificant when slaughter weight is added the statistical model as a covariate, except for $(a^*)_{24\,\mathrm{h}}$ values.

The effects of rearing season on meat sensory characteristics are presented in Table 6. There were no significant differences between treatments in terms of odour intensity, tenderness and juiciness in meat samples ($P > 0.05$). But the lowest scores were given to meat samples from SSR lambs for flavour intensity, flavour quality and overall acceptability by panellists in the sensory panel. Moreover, there was positive and significant correlation between flavour quality and over-

Table 4. Means ± SE for pH, drip loss, cooking loss, expressed juice and Warner–Bratzler (WB) shear force values of longissimus dorsi muscle of lambs reared in different seasons.

Characteristics	WR	SSR	AR	P value
pH_0	6.52 ± 0.07	6.48 ± 0.04	6.35 ± 0.04	0.072
pH_{final}	$5.78^b \pm 0.04$	$5.97^a \pm 0.03$	$5.70^b \pm 0.03$	< 0.001
$pH^d_{0-24\,h}$	$0.74^a \pm 0.08$	$0.51^b \pm 0.05$	$0.65^{a,b} \pm 0.05$	0.043
Drip loss, %	2.78 ± 0.40	3.08 ± 0.32	2.61 ± 0.21	0.575
Cooking loss, %	24.70 ± 0.70	27.40 ± 1.00	24.09 ± 1.16	0.050
Expressed juice, %	$9.64^b \pm 0.80$	$13.28^a \pm 0.83$	$8.12^b \pm 0.34$	< 0.001
WB shear force, kg	5.79 ± 0.53	4.66 ± 0.25	4.79 ± 0.65	0.239

^{a,b} Means in the same line with different superscripts are significantly different. ^{d} pH decline between 0 min and 24 h post mortem ($pH_0 - pH_{24\,h}$).

Table 5. Means ± for meat colour parameters of longissimus dorsi muscle of lambs reared in different seasons.

Characteristics	WR	SSR	AR	P value
Colour parameters at 1 h				
$(L^*)_{1\,h}$	$37.38^b \pm 0.69$	$41.65^a \pm 0.76$	$39.32^b \pm 0.59$	< 0.001
$(a^*)_{1\,h}$	$18.44^a \pm 0.36$	$16.49^b \pm 0.32$	$16.22^b \pm 0.46$	< 0.001
$(b^*)_{1\,h}$	4.12 ± 0.45	3.47 ± 0.40	3.12 ± 0.15	0.157
$Chroma_{1\,h}$	$18.94^a \pm 0.42$	$16.90^b \pm 0.35$	$16.53^b \pm 0.46$	< 0.001
Hue $angle_{1\,h}$	12.36 ± 1.23	11.79 ± 1.24	10.93 ± 0.52	0.631
Colour parameters at 24 h				
$(L^*)_{24\,h}$	$40.55^b \pm 0.69$	$42.85^a \pm 0.56$	$42.12^{a,b} \pm 0.42$	0.023
$(a^*)_{24\,h}$	$17.89^a \pm 0.49$	$16.20^b \pm 0.27$	$14.47^c \pm 0.28$	< 0.001
$(b^*)_{24\,h}$	6.22 ± 0.36	6.63 ± 0.26	6.66 ± 0.16	0.437
$Chroma_{24\,h}$	$18.96^a \pm 0.54$	$17.52^b \pm 0.32$	$15.94^c \pm 0.26$	< 0.001
Hue $angle_{24\,h}$	$19.04^c \pm 0.89$	$22.20^b \pm 060$	$24.78^a \pm 0.68$	< 0.001

^{a,b,c} Means in the same line with different superscripts are significantly different.

all acceptability ($P < 0.01$) and flavour intensity and overall acceptability ($P < 0.01$) according to the Pearson correlation results (Table 7).

4 Discussion

4.1 Lamb growth performance

WR lambs were slaughtered at higher slaughter weight than their SSR and AR counterparts although all lambs were at similar ages in the research. These differences in final live weight might be explained by the nutrient sources depending on the season. Supporting the current results, various studies (Karim et al., 2007; Joy et al., 2008; Ekiz et al., 2013) showed that lambs fed concentrate diet in sheepfold had higher growth rate than lambs fed on pasture. Growth rate increases with rising proportion of concentrate in the diet (Santos-Silva et al., 2002). Also, great energy deprivation might occur because of increasing physical activities and basal metabolism due to grass consumption in their diet for pasture-fed lambs (Díaz et al., 2002). In the current study, energy needs of SSR and AR lambs increased as they were grazed together with their dams.

4.2 Carcass quality

WR lambs had higher empty body weight, dressing percentage and back fat thickness. The increased dressing percentages of WR lambs might be explained by the higher fatness in their carcasses. Supporting the current study, various authors (Díaz et al., 2002; Cañeque et al., 2003; Karim et al., 2007; Ekiz et al., 2012) reported higher fatness level in lambs fed concentrate in sheepfold than lambs fed on pasture and concomitant dressing percentage increase. Peña et al. (2005) also reported an increase in fatness level of carcass with increasing slaughter weight of lambs. In this study there are differences between rearing groups in terms of slaughter weight of lambs which were slaughtered at the same age – WR lambs had the highest slaughter weight compared with other groups. Back fat thickness of concentrate-fed lambs' carcasses were also higher than that of pasture-fed lambs. Feeding with high-energy nutrition and less physical activity

Table 6. Means ± SE for meat sensory characteristics of lambs reared in different seasons.

Characteristics	WR	SSR	AR	P value
Lamb odour intensity	4.52 ± 0.14	4.24 ± 0.14	4.60 ± 0.14	0.168
Tenderness	4.93 ± 0.18	4.67 ± 0.18	5.18 ± 0.18	0.139
Juiciness	4.41 ± 0.13	4.43 ± 0.13	4.63 ± 0.13	0.421
Flavour intensity	4.67[a] ± 0.13	4.29[b] ± 0.13	4.80[a] ± 0.13	0.015
Flavour quality	5.10[a] ± 0.13	4.62[b] ± 0.13	5.04[a] ± 0.13	0.020
Overall acceptability	5.07[a] ± 0.15	4.56[b] ± 0.15	5.07[a] ± 0.15	0.024

[a,b] Means in the same line with different superscripts are significantly different.

Table 7. Coefficient of correlation among for meat sensory characteristics.

Characteristics	Tenderness	Juiciness	Flavour intensity	Flavour quality	Overall acceptability
Odour intensity	0.27	0.147	0.518**	0.292	0.130
Tenderness	–	0.631**	0.597**	0.784**	0.825**
Juiciness		–	0.397*	0.634**	0.693**
Flavour intensity			–	0.628**	0.576**
Flavour quality				–	0.946**

* $P < 0.05$ and ** $P < 0.01$.

might be the cause of the stored fat in carcasses of WR lambs which were fed with concentrate in addition to their mothers' milk in the sheepfold.

WR lambs had highest mean values in terms of subjective fatness score, subcutaneous fat percentage and total fat percentage in pelvic limb which provide information about carcass fatness. Several authors who have investigated the effects of feeding/management system on carcass quality (Díaz et al., 2002; Priolo et al., 2002; Ekiz et al., 2012) also reported less developed fat depots for pasture-raised lambs when compared with sheepfold lambs as a result of increasing physical activity or lower energy intake in grazing lambs. Díaz et al. (2002) noted that increased physical activity in pasture-raised lambs bring about less carcass fatness of lambs as a result of the increased mobilization of reserve lipids to form muscle tissue. Similarly, Carrasco et al. (2009) observed lower total carcass fat in grazing lambs caused by lower proportion of subcutaneous fat than in lambs which had free access to concentrate.

Increasing mean values of the fat b^* value represent the rising yellowness of carcass. Yellow fat is not generally appreciated by consumers worldwide (Priolo et al., 2002). The differences in subcutaneous fat colour might be due to carotenoids which are stored in fat depots in pasture lambs (Joy et al., 2008; Carrasco et al., 2009). However, the feeding system did not affect the subcutaneous fat b^* values (between 4.23 and 5.45) in the current study. Priolo et al. (2002) observed that carcasses which had subcutaneous fat b^* values above 22 were easily distinguished from the other carcasses by the naked eye. According to this fact, yellowness values for subcutaneous fat in the current study were not as high as to be rejected by consumers.

Weights of carcass cuts rise with increasing slaughter weight (Majdoub-Mathlouthi et al., 2013). Higher pelvic limb weights in WR lambs were the result of the higher final weights in the current study. Furthermore, increased slaughter weight causes a change in carcass composition, which appears as a decrease in lean ratio and an increase in the fat ratio, especially subcutaneous fat, in the carcass (Díaz et al., 2002; Santos-Silva et al., 2002; Majdoub-Mathlouthi et al., 2013). On the other hand, differences between two grazing groups (SSR and AR) in terms of lean and bone percentages in pelvic limb were probably caused by different fatness levels due to grazing conditions.

4.3 Meat instrumental quality

Final pH value is the main indicator of meat quality commercially and has effects on instrumental meat quality characteristics such as texture, meat colour and water holding capacity. It also affects meat sensory characteristics (Miller, 2002). Werdi Pratiwi et al. (2007) reported that pH values higher than 6.0 are related to lower meat quality. In the current study, final pH values obtained for lambs from treatment groups varied between 5.70 and 5.97, which might be considered within the desired range for quality meat.

Meat juiciness was detected measuring water-holding capacity by using expressed juiciness, cooking loss and drip loss analyses. In these analyses, meat from SSR lambs had lower water-holding capacity as it lost more water than meat from WR and AR lambs. Similarly, several authors (Cañeque et al., 2003; Santos-Silva et al., 2002) who compared different management/feeding systems reported lower water-holding capacity for pasture lambs.

Hopkins et al. (2006) reported that tenderness (shear force values) and intramuscular fat level were significant predictors of the consumer sensory traits. Meat tenderness can be affected by the structure of the connective tissue, carcass fatness and collagen levels of meat (Sañudo et al., 2000; Díaz et al., 2002). Rearing season did not affect the meat tenderness, which was assessed by WB shear force in the current study. The results of shear force analysis suggest that meat from SSR lambs was as tender as the meat from the other groups.

Meat colour is not an important eating characteristic, but it is a major factor for the initial selection of meat by consumers (Beriain et al., 2000). Consumers mostly prefer light or pink lamb meat in Turkey, as is also the case in other Mediterranean countries (Ekiz et al., 2012). Priolo et al. (2001) noted that meat colour may be influenced by various factors such as carcass fatness, final pH, physical activity, slaughter age, carcass weight and intramuscular fat content.

Numerous authors (Díaz et al., 2002; Priolo et al., 2002; Cañeque et al., 2003) reported darker meat from pasture-fed lambs compared to concentrate-fed counterparts and they explained this difference by the physical activity and greater blood pigment concentration of animals raised on pasture. Ekiz et al. (2013) also reported darker meat colour for lambs raised on pasture compared to lambs raised on concentrate-based system and they explained this result as a combined effect of carcass fatness, slaughter age and final pH. Contrary to previous reports, WR lambs fed on a concentrate-based diet had darker meat colour at 24 h after cutting than SSR and AR counterparts which were fed a pasture-based diet in the current study. These differences could be explained by the higher pre-slaughter live weight of WR lambs. Meat colour became darker (decreasing L^* value) and had a lower yellowness value (decreasing b^* value) with increasing slaughter weight (Santos-Silva et al., 2002). Furthermore, Beriain et al. (2000) noted that darker meat colour is connected with increasing muscle myoglobin concentration which rises with slaughter weight or age. Indeed, the effect of slaughter weight on meat colour parameters was significant according to the results of covariance analyses. Moreover, if slaughter weight was included in the statistical model, rearing season had no significant influence on meat colour which indicates that effects of slaughter weight and rearing season overlap for determination of meat colour.

4.4 Meat sensory evaluation

Lamb odour intensity and tenderness perception of panellists were not influenced by rearing season in the present study. The lack of differences among treatment groups in terms of tenderness score is consistent with the result of WB shear force analysis.

Meat preferences of consumers are associated with socio-economic factors, ethics or religious beliefs and tradition (Font i Furnols and Guerrero, 2014). For instance, a highly preferred meat flavour in one culture, region or country may be perceived as less preferable or unacceptable in another (Schreurs et al., 2008). Red meat consumers generally tend to think that meat from pasture raised lambs is more tasty and healthy as these lambs grow in a natural environment and consume less concentrate feed when compared with lamb meat from sheepfold raised lambs (Font i Furnols and Guerrero, 2014). Yet panellists gave the highest flavour and overall acceptability scores to meats from WR and AR lambs in the present study. Supporting the current results, Font i Furnols et al. (2009) observed that EU consumers preferred lamb meat from concentrate or mixed systems (concentrate and pasture) to meat of lambs fed only on pasture. Furthermore, Sañudo et al. (2000) and Muela et al. (2010) reported that meat from fattier carcasses had higher flavour intensity.

Overall acceptability scores given to lamb could be reflection of the meat tenderness, flavour intensity and quality perception of panellists (Ekiz et al., 2012). In particular, flavour which can be the determining feature in acceptance or rejection of the meat, is an important aspect for consumer preferences (Schreurs et al., 2008). The highest scores in terms of flavour intensity and quality were given to meat from WR and AR lambs, while there were no significant differences in tenderness scores among whole groups. This is also supported by Pearson correlation results which are positive and significant between flavour quality and overall acceptability and flavour intensity and overall acceptability in agreement with the results reported by Ekiz et al. (2012) and Font i Furnols et al. (2009).

5 Conclusions

We found that growth rate, empty body weight, carcass weight, dressing percentages and pelvic limb weight decrease in the pasture-raised lambs in spring–summer and autumn. On the other hand, WR and AR lambs had higher values in terms of certain carcass fatness parameters (subjective fatness score, intermuscular, subcutaneous and total fat percentage in pelvic limb) than SSR lambs. Furthermore, results of sensory analyses indicate that meat from WR lambs had similar flavour intensity, flavour quality and overall acceptability scores as meat from pasture-raised lambs in autumn (AR). The results of the current study indicate that WR lambs yield better carcass quality than SSR and AR lambs, and meat of SSR lambs is least appreciated by consumers.

Data availability. The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Author contributions. HY and BE conceived and designed the experiment; HY coordinated the research project; HY, BE, OK, ND, PDA and AY performed the experiments; HY and BE analysed the data; ND and PDA helped in drafting of the tables; and HY wrote the paper.

Competing interests. The authors declare that they have no conflict of interest.

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