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Article

Effect of Feeding System, Birth Type and Gender on Carcass and Meat Quality of Karacabey Merino Lambs

Hulya Hanoglu Oral ^{1,*}, Pembe Dilara Kecici ², Firat Alaturk ³, Cemil Tolu ⁴, Bulent Ekiz ² and Ahmet Gokkus ³

¹ Department of Animal Sciences and Technologies, Muş Alparslan University, Faculty of Applied Sciences, Muş, Turkey; hanogluhulya@hotmail.com (H.H.O.)

² Department of Animal Breeding and Husbandry, Istanbul University - Cerrahpasa, Faculty of Veterinary Medicine, Istanbul, Turkey; dilara.kecici@iuc.edu.tr (P.D.K.); bekiz@iuc.edu.tr (B.E.)

³ Department of Field Crops, Faculty of Agriculture, Çanakkale Onsekiz Mart University, Çanakkale, Turkey; alaturkf@comu.edu.tr (F.A.); agokkus@yahoo.com (A.G.)

⁴ Department of Animal Science, Faculty of Agriculture, Çanakkale Onsekiz Mart University, Çanakkale, Turkey; cemiltolu@comu.edu.tr (C.T.)

* Correspondence: hanogluhulya@hotmail.com

Simple Summary: An economical animal production model, in which all the needs of the lambs can be met and they can reach the optimal slaughter weight in the shortest possible time, is the primary goal of all production models. Since production system is an important factor for carcass and meat quality, various production systems have been developed. In concentrate-based intensive systems, carcasses are tending to be fatter and reaches faster to optimal slaughter weight, while pasture-fed ones have more preferable fatty acid profile with more reddish color due to increased physical activity. In our study, we investigated the effects of feeding system, birth type, gender and birth year on carcass and meat quality of Karacabey Merino lambs. Gender and birth type effects on Karacabey Merino lambs exhibited expected results that single-borns have more muscle tissue than multiples, males have more muscle tissue than females, and females have more fatty carcasses. In conclusion, a pasture-based feeding system is thought to be more suitable for Karacabey Merino than stall feeding system, for those who prefer leaner and tender meat. However, it should not be ignored that stall fed lambs showed a better fattening performance in terms of conformation and fatness, in the same period.

Abstract: Fifty-eight Karacabey Merino lambs were used to evaluate the effects of feeding system (triticale pasture, oat pasture, or stall fed), birth type (single or multiple), gender (male or female) and birth year (2016 or 2017) on various carcass and meat quality characteristics. Stall lambs had higher conformation (CS) and fatness scores (FS), meat L* and h* values than both pasture groups, possibly as a result of higher fat content, while oat pasture lambs had the most tender meat. Single lambs had higher CS, FS and Longissimus thoracis muscle section area, while females had higher subcutaneous and non-carcass fat depositions, over their counterparts. Both single born lambs and 2016 born lambs had a higher meat a* and C* values than their counterparts. In conclusion, a pasture-based feeding system is thought to be more suitable for Karacabey Merino than stall feeding system, for those who prefer leaner meat and/or meat products. However, it should not be ignored that stall fed lambs showed a better fattening performance in terms of conformation and fatness, in the same period.

Keywords: feeding systems; concentrate fed; pasture lambs; Karacabey Merino

1. Introduction

The traditional lamb meat production model in Turkey is mostly based on natural pastures, in the form of extensive or semi-intensive systems. In these production systems, lambs usually reared with their mothers until slaughter to produce high quality meat with low costs. However, sheep milk and milk products are highly valuable and as a result of these production methods, it concludes with

low cheese production and low slaughter weights [1,2]. In addition to these outcomes, the inadequacy of pasture lands and the insufficient nutritional value of pastures to meet the needs of animals, and because it is easier to manage, intensive rearing has recently become widespread. In intensive lamb production, breeders tend to wean lambs in 45 days or 3 months old, depending on the need for milk or milk product manufacturing, supply them with high-energy concentrates, usually ad-libitum, to shorten the fattening period before slaughter [1].

An economical animal production model, in which all the needs of the lambs can be met and they can reach the optimal slaughter weight in the shortest possible time, is the primary goal of all production models. Since production system is an important factor for carcass and meat quality [2,3], numerous feeding models are used to achieve this goal. In concentrate based intensive or semi-intensive production systems, carcasses are tending to be fatter and reach optimal slaughter weight in shorter periods [4–6], while pasture fed ones has more preferable fatty acid profile [7–9] and a more reddish color due to increased physical activity in grazing [10,11]. On the other hand, as a result of being fatter, higher carcass yield [5,7,8], marbling and tenderness [3,12] with lighter meat color [5,8] can be observed in concentrate-based production systems.

Turkey has a remarkable number of sheep (45.18 million head), with being nearly 1/3 of the European Union (126.85 million head), and indigenous sheep breeds/genotypes constitutes nearly 92% of these sheep [13]. However, many crossbreeding studies were performed in the last century to improve both live weight and meat quality of the indigenous breeds. Karacabey Merino is one of them, which was obtained by German Mutton Merino and Kivırcık sheep in Karacabey State Farm, which is one of the best crossbreeds in Turkey in terms of meat development [14,15]. Therefore, there is a need for production system can be applied for fast and high quality meat production.

The aim of the study was to comparatively investigate the effects of feeding system (triticale pasture, oat pasture, or stall fed), birth type (single, multiple) and gender (female, male) on some carcass and meat quality characteristics of Karacabey Merino lambs.

2. Materials and Methods

2.1. Animals and production systems

The study was carried out at Bandırma Sheep Breeding Research Institute between 2015-2017. In order to obtain the animal materials of the study, purebred Karacabey Merino ewes were mated to purebred Karacabey Merino rams in August-September 2015 and 2016. The lambs were born in January-February of both years (2016-2017) and birth records were kept in detail (date of birth, birth type, gender, birth weight). Twelve ewes were allocated within each feeding group for each year. All ewes in the study were 3 years old when they gave birth to first group of lambs in 2016, and it was their 3rd pregnancy. Ewes were placed in predetermined feeding groups before the birth of lambs, and both ewes and the lambs in each study group were randomly selected. The feeding groups in the study were:

- a. Triticale pasture-based feeding system (TP): In this system, lambs were born and raised in the pasture with their mothers from birth until about 120 days of slaughter age (123.72 ± 2.84 days). The lambs were born in winter pasture and ad-libitum good quality alfalfa hay and concentrate feed were given to lambs after 10 days of age (starter feed containing 18% crude protein (CP) and 2700 kcal/kg metabolisable energy (ME), consisting of barley, corn, sunflower meal, marble powder, salt and vitamin-mineral mixture) in addition to their mother's milk. From the age of a month to slaughter, they were fed only with triticale pasture and their mother's milk. 15 lambs were born from 12 ewes in 2016 and 9 of them were slaughtered, and in 2017, 16 lambs were born from 12 ewes and 11 of them were slaughtered for the study.
- b. Oat pasture-based feeding system (OP): In this system, lambs were born and raised in the pasture with their mothers from birth until about 120 days of age (121.17 ± 2.79 days) when they were sent to slaughter. The lambs were born in winter pasture and ad-libitum good quality alfalfa hay

- and concentrate feed were given to lambs after 10 days of age (same starter feed was used in all groups) in addition to their mother's milk. From the age of a month to slaughter, they were fed only with oat pasture and their mother's milk. 14 lambs were born in 2016 from 12 ewes in this group and 9 of them were slaughtered, and in 2017, 17 lambs were born from 12 ewes and 12 of them were slaughtered for the study.
- c. Stall group (SG): The lambs in the stall group were reared intensively and were never had access to pasture during the study. Stall lambs were fed with mother's milk from birth, and from the age of 10 days, they were divided into groups at small paddocks, and ad libitum alfalfa hay (15.6% CP and 2160.40 kcal/kg ME) and lamb starter feed were provided them for the transition to creep feeding. The lambs were weaned when they reached the age of two months, and lamb grower feed containing 16% CP and 2600 kcal/kg ME was given in addition to ad libitum dry vetch grass (13.6% CP and 1410.40 kcal/kg ME) as roughage. In order to prevent the formation of urinary stones in lambs, 1% ammonium chloride was added to the lamb grower feed from two months of age. 18 lambs were born in 2016 from 12 ewes in this group and 9 of them were slaughtered, while 15 lambs were born from 12 ewes and 8 of them were slaughtered in 2017 for the study. The nutritional content of all pastures used in the study were presented in Table 1.

Table 1. The nutritional content of the pastures consumed by the lambs according to the years of the study.

Pastures	DM, %	CP, %	NDF, %	ADF, %	DOM, %	ME, kcal/kg
Winter pasture-2016	57.87	11.11	63.29	36.25	63.04	2.079
Triticale Pasture-2016	29.07	12.68	53.64	28.06	70.34	2.584
Oat Pasture-2016	26.77	12.89	52.66	26.73	71.28	2.626
Winter pasture-2017	71.87	9.20	63.41	38.35	61.66	1.995
Triticale Pasture-2017	31.38	14.06	53.63	34.11	66.09	2.390
Oat Pasture-2017	26.98	15.68	50.57	33.43	66.56	2.413

DM: Dry matter, CP: Crude protein, NDF: Neutral detergent fibre, ADF: Acid detergent fibre, DOM: Digestible organic matter, ME: Metabolisable energy.

In the second year of the project, the same feeding program was applied as in the first year. At the approximately 120 days of age, a total of 58 lambs (27 in 2016 vs 31 in 2017; 33 female vs 25 male; 31 single vs 27 multiple born lambs) were slaughtered to compare the carcass and meat quality characteristics according to their feeding systems.

2.2. Slaughtering of Lambs and Carcass Characteristics

Lambs were fasted for 12 hours prior to slaughter, with only access to ad libitum water, in accordance with the research institute's routine pre-slaughter procedures.

The slaughter of the lambs was carried out at the Bandırma Sheep Research Institute Slaughterhouse, without any stunning, immediately after the live weights were recorded. Following the bleeding process, the head, skin, feet and all internal organs were removed. In addition, full and empty weights of stomach and intestines, omental and mesenteric fat weights, and weight of gastrointestinal contents were recorded. In order to eliminate the additional variation that the amount of gastro-intestinal content would create in terms of carcass yield, after the gastro-intestinal contents were removed, the empty body weights were calculated. Immediately after the carcass dressing, the pH0 and carcass temperature were measured between the 12.-13. thoracic vertebrae with the help of a digital pH meter (T-205, Testo SE & Co. KGaA, Germany) from the longissimus thoracis (LT) muscle. The pH meter was calibrated with two different buffer solutions (pH:4 and pH:7), before the measuring of the first carcass in each sampling time. However, due to the temperature difference between cold storage and slaughterhouse's ambient temperature, pH meter was calibrated twice (both in room temperature and inside of the cold storage unit) before the first pH measurement for a more successful recording. Later, the hot carcass weights of all carcasses were recorded, and they were transferred to a cold storage unit at 4°C.

After the carcasses were kept in the cold storage for one day, conformation and fatness scores were given according to EUROP System [16,17] and the scores were converted to 1-15 scale [18] for statistical analysis. Following the scoring, the LT muscle pH₂₄ levels were measured from the same point where pH₀ measurement was made. Later, cold carcass weights were recorded, and cold carcass yields were calculated using empty body weight. Kidney knob and channel fat (KKCF), kidneys and tails were separated from the carcasses and the weights of these pieces were recorded. After all the carcasses were divided into right and left halves from the median line, a section was made between the 13th thoracic - 1st lumbar vertebrae of the right half carcasses, and the cross-sectional area of the LT muscle was drawn with the help of tracing paper, then the backfat thickness was recorded from the same section point with the help of a caliper [19]. Left halves of all carcasses were divided into 6 parts as the neck, shoulder, ribs (anterior rib + loin), flank, hind limb and tail using the method described by Colomer-Rocher et al. [20] and the weights of all parts were recorded.

2.3. Meat quality characteristics

In order to determine the meat quality characteristics, the Longissimus thoracis et lumborum muscle of the left half carcass were used. Meat color, express juice, drip loss, cooking loss and Warner Bratzler (WB) shear force measurements were carried out 5 days after slaughter in Istanbul University - Cerrahpaşa Faculty of Veterinary Medicine, Department of Animal Breeding and Husbandry Carcass and Meat Quality Laboratory. Samples were stored at 4°C until the day of analysis.

For drip loss analysis, approximately 80 grams of samples taken from LT muscle, and were weighed both before and after being hung in a polyethylene bag with a rope without touching the bag, and kept at 4°C for 24 hours. The drip losses of the samples were calculated as the percentage of the weight loss to the initial weight.

During express juice analysis, the “Modified Grau and Hamm” method of Beriain et al. [21] was applied. For this purpose, a 30-gram piece taken from LT muscle was separated from its fat and nerves, divided into 5-6 pieces with a total weight of 5 grams and placed between two filter papers. A weight of 2.250 kg was placed on the meat between the filter paper for 5 minutes and the liquid rate lost by the meat sample was calculated as % by weighing the filter papers used in the analysis at the end of 5 minutes.

A chromometer (CR 400, Minolta Co. Ltd.) measuring with L*, a*, b* coordinate system was used, and the standards reported by CIE [22] were applied during the measurements for meat color analysis, and D65 was chosen as the light source, while aperture size and observation angle were set as 8 mm and 2°, respectively. Chroma (C*) and hue (h*) values were calculated with the given formula; $C^* = [(a^*)^2 + (b^*)^2]^{1/2}$; $h^* = \tan^{-1}(b^*/a^*)$; described by Murray [23]. A sample of 4 cm thickness was taken from *M. longissimus lumborum*, 3 repeated 3 measurements (total of 9 measurements) were made from the lean parts of the sample's cross-sectional surface by means of a chromometer, and the average of the obtained values was calculated, and the color coordinates were accepted as measurement values. Color analysis of each sample was performed after 1-hour blooming. In this process, the samples were stored at 4°C and under continuous white light.

For cooking loss, 6-8 cm long samples taken from LT muscle were weighed before starting the analysis, then placed in heat-resistant polyethylene bags, vacuum packed and cooked in a water bath at 80°C for 45 minutes. Afterwards, they were removed from the water bath and cooled down under running water for 1 hour. Later than, the samples were taken out of their bags and dried with paper towels and their weights were recorded after cooking. Cooking loss (%) was calculated as the percentage of the difference between pre- and post-cooking weights to the initial weight. The cooking loss analysis were performed as one cooking batch per year.

In WB shear force analysis, the samples used in the cooking loss analysis were used and 6 sub-samples of 1 × 1 cm cross-section and 3 cm long were taken parallel to the muscle fibers for each sample. Warner-Bratzler blade connected to Instron 3343 (Illinois Tool Works Inc., USA) device was used to determine the peak shear force. The peak shear force value of the LT muscle of a lamb was determined by averaging the measurements obtained from all samples taken from the muscle.

2.4. Statistical analysis

General Linear Model (GLM) procedure was applied in SPSS 21.0 (SPSS, IBM, USA) package program in order to determine the effects of feeding system, birth year, birth type and gender on slaughter, carcass and meat quality characteristics of Karacabey Merino lambs. Feeding system (Triticale pasture (TP), Oat Pasture (OP), or Stall Fed (SG), year (2016 or 2017), birth type (Single or Multiple) and gender (Male or Female) factors were included as fixed effects in statistical models for all investigated parameters in the study. All two-way interactions were included to the models for all parameters. However, non-significant interactions were excluded from the models, using stepwise backward elimination. In case of significant interactions, one-way ANOVA was performed with Duncan's Multiple Range Test, in order to determine which difference between subgroups are significant. In addition, none of the interactions had significant effect on the percentages of carcass joints (in Table 3), therefore, they were not presented. Approximate F-ratio tests were conducted for all fixed factors for all parameters and $P < 0.05$ were accepted as the critical value threshold. Least significant difference was chosen for adjustment of multiple comparisons. The means and standard errors presented in the tables were the results from the models. The statistical model used in the analysis is given below:

$$Y_{ijkl} = \mu + a_i + b_j + c_k + d_l + e_{ijklm}$$

Y_{ijkl} : Estimation result of any trait

μ : Overall mean value

a_i : Fixed effect of feeding system (i: Stall, Triticale or Oat)

b_j : Fixed effect of birth year (j: 2016 or 2017)

c_k : Fixed effect of birth type (k: Single or Multiple)

d_l : Fixed effect of gender (l: Male or Female)

e_{ijklm} : Residual random error.

3. Results

3.1. Slaughtering characteristics

Birth weights and certain slaughtering characteristics of lambs in 3 different feeding groups are given in Table 2. The effect of the feeding group was significant on both conformation and fatness scores with omental mesenteric fat and KKCF percentages, and SG lambs had higher conformation, fatness, and omental mesenteric fat percentages over their counterparts, while TP lambs had lower KKCF percentage than the others. The effect of birth type on birth weight (BW), empty body weight (EBW), cold carcass weight (CCW), conformation score (CS), fatness score (FS) and Longissimus thoracis muscle section area (LTMSA) was significant, and it was determined that single born lambs had higher values for these characteristics. In addition, although females have lower birth weight and empty body weight than males, it has been observed that their carcasses have higher conformation and fatness scores, dressing percentage, omental mesenteric fat, and KKCF percentages.

The EBW, CS, FS, shrink loss (SL), dressing percentage (DP), omental-mesenteric fat (OMF), backfat thickness (BT), and KKCF were significantly affected from various interactions. Even though the effect of group was not significant on EBW, male SG lambs had higher than their female counterparts and both TP gender groups. However, the difference between them and OP lambs were not significant. Multiple interactions affected conformation score, resulting with male TP lambs, multiple born 2017 lambs, and OP lambs born in 2017 having the lowest conformation scores. Group $\times$ year and gender $\times$ year interactions were affected the fatness score, female TP had the lowest fatness scores, after the female OP lambs, resulting with all male groups and female SG had higher FS than them. In addition, male lambs born in both years was the fattiest ones, while 2017 born females had the leanest carcasses. Shrinkage loss of both pasture groups (TP and OP) in 2017 were higher than SG in 2016, however the difference between the rest of the groups were not significant. In the meanwhile, dressing percentage of single born female lambs were higher than all of their counterparts. The OMF, BT and KKCF were affected from group $\times$ year interaction, and similar to conformation and fatness scores, the internal fat and muscle accumulation of 2017 TP lambs were the lowest. In addition, SG in

2017 had the highest BT, while 2016 OP group had the highest KKCF percentage, except the difference between 2016 OP and 2017 SG group was not significant.

When the carcass joints of the lambs were investigated, the effect of the feeding group on the shoulder, flank, anterior rib and tail percentages was significant (Table 3). Carcasses of TP lambs had a higher shoulder percentage than the SG, while the difference between OP lambs and the others was not significant. SG lambs had a higher mean values compared to the TP lambs, in terms of flank and tail percentages. OP group had higher percentages for anterior ribs, compared to the TP group, but the difference between the TP and SG was not significant. However, the effect of birth type was only significant on kidney percentage and multiple lambs had a higher kidney percentage than singles. When the percentages of carcass joints were evaluated in terms of gender, males had a higher shoulder and kidney percentages than females, while females had higher loin percentages. In addition, none of the interactions affected the percentages of carcass joints significantly.

Table 2. Birth weight and certain slaughtering characteristics of lambs according to feeding group, birth type and gender.

	n	BW, kg	SA, days	EBW, kg	CCW, kg	CS	FS	SL, %	DP, %	LTMSA, cm ²	OMF, %	BT, mm	KKCF, %
Group													
Stall	17	5.30±0.15	127.07±3.05	33.91±1.11	19.17±0.70	8.39 ^a ±0.29	8.16 ^a ±0.25	2.91±0.24	56.93±0.46	16.30±0.84	1.08 ^a ±0.08	4.65±0.48	1.24 ^a ±0.10
Triticale	20	5.15±0.14	123.72±2.84	30.49±1.06	17.25±0.65	7.26 ^b ±0.28	6.51 ^b ±0.23	2.98±0.22	55.48±0.43	15.81±0.78	0.80 ^b ±0.08	3.11±0.45	0.75 ^b ±0.09
Oat	21	5.26±0.14	121.17±2.79	32.37±1.02	18.03±0.64	8.16 ^b ±0.27	6.87 ^b ±0.23	3.13±0.22	55.64±0.42	16.80±0.77	0.87 ^b ±0.07	3.35±0.44	1.20 ^a ±0.09
Birth Type													
Single	31	5.65±0.11	124.18±2.30	33.94±0.86	19.18±0.53	8.47±0.2	27.68±0.2	2.94±0.18	56.31±0.34	17.53±0.63	0.97±0.07	3.71±0.36	1.13±0.08
Multiple	27	4.82±0.12	123.80±2.46	30.57±0.90	17.12±0.57	7.40±0.4	26.69±0.2	3.08±0.19	55.73±0.37	15.08±0.68	0.83±0.07	3.69±0.49	1.00±0.08
Gender													
Male	25	5.41±0.13	124.16±2.58	33.62±0.94	18.62±0.59	7.37±0.5	26.87±0.2	3.36±0.20	55.20±0.38	16.67±0.71	0.72±0.08	3.17±0.41	0.86±0.08
Female	33	5.07±0.10	123.82±2.19	30.90±0.80	17.68±0.50	8.50±0.2	27.51±0.1	2.65±0.18	56.84±0.33	15.94±0.60	1.09±0.07	4.23±0.34	1.27±0.07
Overall mean		5.24±0.08	127.99±1.66	32.26±0.61	18.15±0.38	7.95±0.6	17.19±0.1	3.01±0.13	56.02±0.25	16.31±0.46	0.92±0.04	3.70±0.26	1.06±0.05
Significance													
Group		0.744	0.381	0.093	0.146	0.015	<0.001	0.786	0.054	0.656	0.041	0.056	0.001
Birth Type		<0.001	0.912	0.011	0.011	0.002	0.001	0.598	0.263	0.012	0.93	0.962	0.248
Gender		0.050	0.922	0.034	0.239	0.002	0.029	0.014	0.002	0.441	0.001	0.059	0.001
GR*G				0.027		0.027	-						
BT*Y						0.002	-						
GR*Y						0.010	<0.001	0.038			<0.001	0.002	<0.001
GE*Y						-	0.005						
BT*G									0.003				

n: Number of animals in a group, BW: Birth weight, SA: Slaughter age, EBW: Empty body weight, CCW: Cold carcass weight, CS: Conformation score, FS: Fatness score, SL: Shrinkage loss, DP: Dressing percentage, LTMSA: Longissimus thoracis muscle section area, OMF: Omental mesenteric fat, BT: Backfat thickness, KKCF: Kidney knob and channel fat percentage, GR: Group, BT: Birth type, GE: Gender, Y: Year. The results in the table are

presented as Least square means $\pm$ Standard errors. a, b: The difference between the mean values expressed with different letters in the same column for the feeding groups is statistically significant.

Table 3. Percentages of carcass joints according to feeding group, birth type and gender.

	n	Shoulder, %	Flank, %	Neck, %	Anterior rib, %	Loin, %	Hind Limb, %	Tail, %	Kidney, %
Group									
Stall	17	18.87 ^b $\pm$ 0.48	13.41 ^a $\pm$ 0.35	6.11 $\pm$ 0.24	16.47 ^b $\pm$ 0.39	8.24 $\pm$ 0.19	34.56 $\pm$ 0.54	0.53 ^a $\pm$ 0.03	0.60 $\pm$ 0.02
Triticale	20	20.69 ^a $\pm$ 0.45	12.07 ^b $\pm$ 0.32	6.29 $\pm$ 0.23	15.90 ^b $\pm$ 0.36	8.35 $\pm$ 0.18	34.95 $\pm$ 0.50	0.42 ^b $\pm$ 0.03	0.61 $\pm$ 0.02
Oat	21	19.15 ^b $\pm$ 0.44	12.69 ^{ab} $\pm$ 0.32	5.71 $\pm$ 0.22	17.62 ^a $\pm$ 0.35	8.19 $\pm$ 0.17	34.44 $\pm$ 0.49	0.43 ^b $\pm$ 0.03	0.63 $\pm$ 0.02
Birth Type									
Single	31	19.76 $\pm$ 0.36	12.86 $\pm$ 0.26	5.94 $\pm$ 0.18	16.46 $\pm$ 0.29	8.30 $\pm$ 0.14	34.52 $\pm$ 0.41	0.48 $\pm$ 0.02	0.59 $\pm$ 0.01
Multiple	27	19.38 $\pm$ 0.39	12.58 $\pm$ 0.28	6.13 $\pm$ 0.20	16.87 $\pm$ 0.31	8.21 $\pm$ 0.15	34.78 $\pm$ 0.44	0.44 $\pm$ 0.02	0.64 $\pm$ 0.02
Gender									
Male	25	20.24 $\pm$ 0.41	12.41 $\pm$ 0.29	6.04 $\pm$ 0.21	16.64 $\pm$ 0.33	8.04 $\pm$ 0.16	34.79 $\pm$ 0.46	0.43 $\pm$ 0.02	0.64 $\pm$ 0.02
Female	33	18.90 $\pm$ 0.35	13.03 $\pm$ 0.25	6.03 $\pm$ 0.17	16.69 $\pm$ 0.28	8.48 $\pm$ 0.14	34.50 $\pm$ 0.39	0.49 $\pm$ 0.02	0.59 $\pm$ 0.01
Overall mean		19.57 $\pm$ 0.26	12.72 $\pm$ 0.19	6.04 $\pm$ 0.13	16.66 $\pm$ 0.21	8.26 $\pm$ 0.10	34.65 $\pm$ 0.29	0.46 $\pm$ 0.02	0.61 $\pm$ 0.01
Significance									
Group		0.013	0.025	0.179	0.004	0.806	0.740	0.013	0.638
Birth Type		0.474	0.472	0.487	0.344	0.655	0.660	0.188	0.011
Gender		0.017	0.116	0.954	0.914	0.042	0.634	0.066	0.046

The results in the table are presented as Least square means $\pm$ Standard errors. a, b: The difference between the mean values expressed with different letters in the same column for the feeding groups is statistically significant.

3.2. Meat quality characteristics

The effect of the feeding group on the examined meat quality characteristics was only significant on WB shear force and the meat of OP lambs was the most tender ones (Table 4). In addition, 2016 born male and female lambs were being tender than their 2017 counterparts were observed as a result of the significant interaction effect. When the meat quality results were investigated in terms of birth type, only significant difference between the groups was for express juice, and single born lambs experienced higher water loss than multiple born lambs when exposed to pressure. Significant gender and gender $\times$ year interaction effect was observed on drip loss, and which indicated that male lambs lost more water during the analysis. Male lambs born in 2016 had the highest drip loss percentages, and followed by 2017 born males and both years' female lambs, respectively.

Table 4. Instrumental meat quality traits of lambs according to feeding group, birth type and gender.

	n	pH ₀	pH ₂₄	Drip loss, %	Express juice, %	Cooking loss, %	WBSF, N
Group							
Stall	17	6.26 $\pm$ 0.06	5.52 $\pm$ 0.03	1.68 $\pm$ 0.10	11.69 $\pm$ 0.36	32.62 $\pm$ 0.48	33.03 ^a $\pm$ 1.42
Triticale	20	6.31 $\pm$ 0.06	5.58 $\pm$ 0.02	1.57 $\pm$ 0.10	11.51 $\pm$ 0.34	32.35 $\pm$ 0.44	32.08 ^a $\pm$ 1.33
Oat	21	6.42 $\pm$ 0.06	5.53 $\pm$ 0.02	1.71 $\pm$ 0.10	10.93 $\pm$ 0.33	31.61 $\pm$ 0.45	28.05 ^b $\pm$ 1.33
Birth Type							
Single	31	6.38 $\pm$ 0.05	5.54 $\pm$ 0.02	1.68 $\pm$ 0.08	11.88 $\pm$ 0.27	32.20 $\pm$ 0.37	30.24 $\pm$ 1.16
Multiple	27	6.28 $\pm$ 0.05	5.56 $\pm$ 0.02	1.64 $\pm$ 0.08	10.87 $\pm$ 0.29	32.19 $\pm$ 0.38	31.86 $\pm$ 1.15
Gender							
Male	25	6.35 $\pm$ 0.05	5.56 $\pm$ 0.02	1.79 $\pm$ 0.09	11.56 $\pm$ 0.31	32.65 $\pm$ 0.41	32.65 $\pm$ 1.24
Female	33	6.31 $\pm$ 0.04	5.53 $\pm$ 0.02	1.52 $\pm$ 0.07	11.29 $\pm$ 0.26	31.74 $\pm$ 0.35	29.46 $\pm$ 1.02
Overall mean		6.33 $\pm$ 0.3	5.54 $\pm$ 0.01	1.66 $\pm$ 0.06	11.38 $\pm$ 0.20	32.19 $\pm$ 0.27	31.05 $\pm$ 0.80
Significance							

Group	0.113	0.127	0.526	0.277	0.280	0.027
Birth Type	0.145	0.944	0.719	0.016	0.990	0.333
Gender	0.610	0.336	0.020	0.690	0.100	0.053
GE*Y			0.026			0.011
GR*BT					0.017	

The results in the table are presented as Least square means ± Standard errors. GR: Group, BT: Birth type, GE: Gender, Y: Year, WBSF: Warner Bratzler Shear Force. a, b: The difference between the mean values expressed with different letters in the same column for the feeding groups is statistically significant.

In meat color measurements after 1-hour blooming, it was observed that the SG had higher lightness (L*), yellowness (b*) and hue (h*) values than the other groups, however, the difference between the OP in terms of b* value was not significant (Table 5). Single born lambs had higher redness (a*) and Chroma (C*) values than multiple born ones. Additionally, the effects of gender on meat color were not significant, however, the effect of gender × year interaction was significant and 2016 born males had redder meat than their counterparts (P<0.05).

Table 5. Meat color characteristics of lambs according to feeding group, birth type and gender.

	n	L*	a*	b*	C*	h*
Group						
Stall	17	41.51 ^a ±0.55	19.53±0.35	6.67 ^a ±0.32	20.67±0.40	18.90 ^a ±0.77
Triticale	20	39.04 ^b ±0.51	19.18±0.33	5.08 ^b ±0.30	19.90±0.37	14.77 ^b ±0.74
Oat	21	39.39 ^b ±0.50	19.92±0.33	5.84 ^{ab} ±0.30	20.83±0.37	16.28 ^b ±0.70
Birth Type						
Single	31	40.18±0.41	20.04±0.29	6.20±0.24	21.06±0.32	17.27±0.58
Multiple	27	39.78±0.44	19.05±0.28	5.53±0.26	19.87±0.32	16.03±0.62
Gender						
Male	25	40.34±0.46	19.50±0.31	6.05±0.27	20.50±0.34	17.24±0.65
Female	33	39.62±0.39	19.58±0.25	5.67±0.23	20.44±0.28	16.06±0.55
Overall mean		39.98±0.30	19.54±0.20	5.86±0.18	20.47±0.22	16.65±0.42
Significance						
Group		0.004	0.273	0.003	0.151	0.001
Birth Type		0.512	0.020	0.068	0.012	0.156
Gender		0.252	0.848	0.303	0.893	0.177
GE*Y			0.019		0.016	

The results in the table are presented as Least square means ± Standard errors. a, b: The difference between the mean values expressed with different letters in the same column for the feeding groups is statistically significant. GE: Gender, Y: Year. L*: Lightness, a*: redness, b*: yellowness, C*: Chroma, h*: hue angle.

4. Discussion

The primary objective of the study was to determine the effects of different feeding patterns on the carcass and meat quality of Karacabey Merino lambs slaughtered at the same age. The feeding group affected conformation and fatness scores with omental-mesenteric fat and KKCF percentages of Karacabey Merino lambs. Even though the CCW and EBW were similar among the feeding groups, the conformation and fatness scores of SG lambs were significantly higher than both pasture groups, which is consistent with Ekiz et al. [2], Borton et al. [4] and Priolo et al. [6]. As a result of the significant interaction effects, male TP lambs had the lowest conformation scores, while female TP lambs had the lowest fatness scores, indicating that even though the nutritional content between the pasture groups are similar, triticale groups has developed less muscle and fat tissue than their counterparts within the same feeding duration. Many studies reported that concentrate fed lambs had fatter carcasses from pasture lambs due to higher feed intake and lower physical activity [6,24]. Physical activity during grazing causes increased metabolism of lipid reserves to build muscle tissue, which results with lower carcass fatness, especially subcutaneous fat [10].

Many studies [2,6] indicated that grass/pasture reared lambs have more developed digestive system due to higher dry matter intake, which results with lower empty body weights, however, no significant differences were observed amongst the groups in the current study. Similar to them, Borton et al. [4] observed greater carcass weight in concentrate-fed lambs compared with forage-fed lambs, because of forage finishing systems increase digestive tract size and decrease external fat. However, there were no significant differences among feeding groups regarding EBW or CCW in the current study.

Feeding did not affect SL and DP significantly, however as a result of the interactions, SL of both pasture groups in 2017 were higher than concentrate-fed ones in 2017. Decrease in carcass surface area and subcutaneous fat percentage, as a result of low conformation and fatness scores of pasture groups, lowers the ability of preserving the moisture, which leads a high shrinkage loss, which is a similar result with Smith and Carpenter [25] and Joy et al. [26]. Dressing percentage of single females were the highest, even though their EBW were lower than the males, their conformation and fatness scores with DP that they had more developed carcasses than their counterparts, which is similar with Pérez et al. [27].

The lower KKCF percentages of TP lambs indicates that their counterparts have more developed carcasses in terms of carcass fatness, on the contrary to Karaca et al. [8], which reported that the effect of feeding system had no effect on KKCF. As the development of fat tissue begins later than muscle [6,29,30] the TP lambs were not finished their muscle development, when they were compared to their counterparts.

As an expected result, single born lambs had higher birth weight, EBW, CCW, conformation and fatness scores and LTMSA, which indicates that they are not only born heavier than their counterparts, but they also can grow more muscles in the same period [31]. Jucá et al. [32] reported that, EBW, CCW and LTMSA was higher in single born lambs, similar to our findings. Many studies reported that single born lambs grow faster and be heavier than multiple born lambs, and this is mainly due to having a non-competitive environment during gestation and not sharing the milk with a sibling [33–35].

Even though the males had higher birth weights, the differences between male and female lambs for CCW and LTMSA were not significant. However, female lambs had higher CS and FS, DP, OMF percentage, and KKCF percentages, which indicates that females have fattier carcasses (both subcutaneous and non-carcass fat). As many authors stated before [33,35,36], oestrogen hormone has a limited effect on both muscle and bone growth, however, it has a supportive effect on fat. In addition, higher fat content (both carcass and non-carcass) in females supports the fact that females mature faster and fatten faster than the males [37–39]. Horcada-Ibáñez et al. [40] reported that females had higher backfat thickness, omental fat, mesenteric fat, KKCF and intramuscular fat percentages over male lambs, as a result of females can deposit larger amounts of fat at the earlier period of growth.

When the carcass joints are commercially classified, loin rib, hind limb and anterior ribs are the 1st category cuts, shoulder/thoracic limb is secondary and flank and neck is the third [10]. Shoulder, hind limb and the ribs are the early developed carcass joints, as they are the primary body parts for the survival of the offspring. The feeding system effected the shoulder, flank, anterior rib and tail percentages of Karacabey Merino lambs. TP lambs had higher shoulder percentages, while OP lambs had higher anterior ribs percentages than their counterparts. On the other hand, SG lambs developed more of flank and tail, which are the least favorable carcass joints. Results indicate that OP and TP feeding systems contributed the growth of first and second category cuts, while concentrate feed helps to develop 3rd category carcass joints. Similar to ours, Murphy et al. [41] and Karaca et al. [8], observed higher shoulder percentage and leaner flanks in grazing lambs, than grazing + concentrate and concentrate-fed ones.

Birth type did not affect the primal joint size in a commercially important way, with multiple born lambs only having higher kidney percentage, similar to findings of Thatcher et al. [42]. Additionally, when the effect of gender was investigated, male lambs had higher shoulder and kidney percentages while females had higher loin percentage. On the contrary, Žgur et al. [43]

reported that male lambs had higher neck, chuck, shoulder percentages, while females had higher kidney fat, back and loin percentages. In addition, the differences between birth type groups in terms of shoulder, neck, rib, loin, leg were reported not significant by Jucá et al. [32], similar to the current study findings. The differences amongst the studies might be related with the breed, which has significant influence on development of the carcass joints [44,45].

The feeding programs used in the study had no effect on the ultimate pH (ranging between 5.52 to 5.58, within acceptable limits declared by Hedrick et al. [46]), which explains the lack of differences regarding investigated meat quality traits among feeding systems [3,5,28,47]. Also, Ripoll et al. [11] stated that even though 4 fattening systems with various grazing and concentrate levels were used, the ultimate pH values of lamb carcasses in those systems were similar. Slaughtering the lambs in the same day without transportation with same pre-slaughter conditions might be the key to this result, with creating the minimum pre-slaughter stress. Although, there are some studies [2,12,48] report that the feeding system has significant effect on ultimate pH. However, current results indicate that the feeding system had no effect, which is supported by Jucá et al. [32], Hopkins et al. [49] and Santos-Silva et al. [28] for lambs fed on pasture and particular feed supplements.

Express juice is a trait used for the amount of water lost by under pressure [21], which is usually related by the amount of fat storage in the body [8]. Because of the adipose tissue tend to store more water than muscle or bone, water holding capacity will be higher in the fattier carcasses and they will lose less water under pressure. Among the meat quality characteristics, a significant birth type effect was detected for only express juice, which might be a result of the single lambs having higher slaughter weights. Both Vergara et al. [50] and Ekiz et al. [51] found an increase in express juice of lambs with higher slaughter weights, which were related by lower carcass fatness, similar to our findings with single born lambs. However, this situation was reported as being breed and/or weight class specific in some cases [52]. In addition, Ekiz et al. [53] stated no significant effect of birth type on express juice of Kıvrıkcık lambs, being controversial with our findings.

It has been observed that females have lower DL and WBSF values, and therefore they have softer and juicier meat. This situation is an expected result of females having fattier carcasses than males due to their higher subcutaneous and internal fat caused by estrogen effect [38,39]. Significant gender influences on instrumental meat quality traits were also previously reported by Ruiz de Huidobro et al. [54] and Vergara and Gallego [47], however, both Olleta et al. [55] and Rodríguez et al. [39], reported no differences in water holding capacity between male and female lambs and they explained this situation with similar pH values observed in male and females.

The meat of stall group was lighter than both grazing groups at 1-hour blooming, might be a result of them being fattier than the grazing groups, since the adipose tissue allows the penetration of the light more than the muscle [56]. Both Priolo et al. [6] and Karaca et al. [8], reported higher lightness in SG than the grass ones, related to lower pH₂₄ values of the SG lambs. However, the pH levels of lambs from different feeding groups were similar in our study. Similar to our findings, Díaz et al. [5] also reported lighter meat color for SG lambs with similar ultimate pH values between concentrate-fed and pasture fed groups, which they explained it with different level of physical activity.

Increased physical activity in the pasture can increase the pigmentation, which can be observed as a higher a* (redness) value in meat [11,57]. However, the differences amongst the study groups were not significant with respect to the a* values, similar to Karaca et al. [8].

Both grazing groups showed lower yellowness (b*) values than concentrate fed SL, which contradicts with both Priolo et al. [6] and Carrasco et al. [58], since it is a more expected result because of the higher physical activity and carotenoids intake [11]. Karaca et al. [8] explained this situation with higher ultimate pH levels of pasture groups, which creates a detrimental effect on meat color. However, the slaughter weights and pH levels were similar in our study.

The effect of birth type was only significant on a* and C* values, single born lambs had higher values for both parameters. This was an expected outcome as a result of higher EBW, conformation and fatness scores of single-born ones. However, both Jucá et al. [32] and Greeff et al. [59] reported that birth type had no significant effect on redness, as a result of similar pH levels.

Meat color can be effected by the intermuscular fat content, due the penetration of the light being easier in adipose tissue [39,56]. Even though the fatness levels of female lambs were higher than males, the meat color of gender groups were similar. No gender effect on meat color was also reported by Rodríguez et al. [39], Santos et al. [60], Sañudo et al. [61], Vergara and Gallego [47], and Vergara et al. [50].

5. Conclusions

Results indicate that pasture based feeding systems contributed the growth of first and second category joints, while concentrate fed lambs develops more fat and less preferable carcass joints, such as flank and tail. In addition, oat pasture lambs had tender meat according to WB shear force, however, except for the characteristics related to subcutaneous and non-carcass fatness in the carcass, there was no significant difference between stall feeding and pasture feeding lambs. Additionally, the difference amongst pasture groups were not significant for nearly all characteristics investigated in the study, which indicates that oat and triticales are interchangeable feed supplies for Karacabey Merino lambs.

Gender and birth type effects on Karacabey Merino lambs exhibited expected results that single-borns have more muscle tissue than multiples, males have more muscle tissue than females, and females have more fatty carcasses.

In conclusion, a pasture-based feeding system is thought to be more suitable for Karacabey Merino than stall feeding system, for those who prefer leaner meat and/or meat products. However, it should not be ignored that stall fed lambs showed a better fattening performance in terms of conformation and fatness.

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