Turkish Journal of Veterinary and Animal Sciences

http://journals.tubitak.gov.tr/veterinary/

Research Article

Turk J Vet Anim Sci
(2020) 44: 1155-1163
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doi:10.3906/vet-2006-24

Slaughter and carcass characteristics of Kıvırcık, Karacabey Merino, Ramlıç, German Black-Head Mutton × Kıvırcık and Hampshire Down × Merino crossbreed lambs reared under intensive conditions

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Received: 05.06.2020 • **Accepted/Published Online:** 12.11.2020 • **Final Version:** 18.12.2020

Abstract: This study aimed to determine the slaughter and carcass characteristics of five different meat-type lambs reared under intensive husbandry conditions. For this purpose, a total of 202 lambs—Kıvırcık (K, n = 51), Karacabey Merino (KM, n = 47), Ramlıç (R, n = 28), German Black-Head Mutton × Kıvırcık (GBK, n = 49), and Hampshire Down × Merino crossbreed (HM, n = 27)—were used to evaluate rearing performance. At the end of the rearing period, 10 male lambs of each breed were randomly selected to investigate slaughter and carcass characteristics. All lambs were housed in a single flock until the slaughtering period. An average of 600 g/lamb of concentrate feed, 100 g/lamb of alfalfa hay, and 300 g/lamb of vetches-wheat mixtures hay per day were given with ad libitum fresh water. While the average daily gain (ADG) of female K, KM, R, GBK, and HM lambs was 94.4, 165.2, 142.2, 109.0, and 160.0 g ($P < 0.001$); the male lambs' ADG was 167.3, 240.4, 180.5, 176.0, and 246.6 g, respectively ($P < 0.001$). Cold carcass weights of lambs in breeds were 19.12, 21.76, 16.80, 20.71, and 20.80 kg ($P < 0.001$); cold dressing percentages (CDP) were 47.39%, 47.55%, 44.86%, 47.41%, and 45.61% in K, KM, R, GBK, and HM, respectively ($P < 0.01$). It is concluded that Merino crossbreeds (KM and HM) had significantly more ADG and total weight gain when compared to K, R, and GBK. On the other hand, KM and GBK had higher CDP value while HM came forward for the loin eye area.

Key words: Meat-type breeds, rearing performance, carcass quality, image measurements, loin eye area

1. Introduction

In meat production systems, sheep producers and researchers mainly focus on increasing slaughter weight (SW). It is well known that even a small increase in SW may result in increased productivity ratio and creates more options to manipulate these rearing or fattening systems, which are supplemented with pasture or good-quality hay and commercial concentrate feed. Also, a manipulation that increases meat quality and quantity with an aim to increase productivity and incomes, considering consumer acceptance, is desirable in the meat production systems [1]. Crossbreeding practices of indigenous ewes with meat-type breeds and intensive lamb rearing after weaning are the most common practices to increase SW [2–4]. As previously reported, the age and weight of lambs at the slaughtering period are the main factors that affect the carcass in terms of meat quality and quantity [5].

In recent years, there has been a great interest in lean carcasses among the consumers with the recommendation of scientific studies and nutritional guidelines. The amount and site of fat in the carcass and/or carcass cuts and meat color play an important role in influencing customer decisions when purchasing fresh meat [6,7]. Many factors such as genotype, rearing system, nutritional regimen, and supplementation of plant-derived compounds can affect live weight gain and meat quality [8–11]. Also, it has been reported that with an increasing slaughter age and SW, carcass conformation became better with an increase in intramuscular fat and adiposity, especially on suckling and light meat lambs, e.g., Suffolk Down and Lecesse [12,13].

In the western part of Turkey, the current trends in rearing schemes for meat-type breeds are to keep lambs with their dams and to feed them with concentrated feed until they are weaned (approximately 10–12 weeks) [14]. If pasture allowance is adequate, lambs graze with their dams in the preweaning stage. A further 6–8-week feeding regimen is applied to lambs after weaning, with high-energy concentrated feed until the desired market

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weight is reached (approximately 40–45 kg) [15]. Merino (reproducing throughout the year, and early development) and indigenous Kıvırcık (good meat quality and flavor, disease resistance, thin tail structure, and marbling) and crossbreed derived from these breeds are widespread in order to meet the market demand [16,17]. Moreover, lamb meat producers of this region tend to have more than one genotype in their herd, mainly due to curiosity about their adaptation capability, growth rate, and rearing or fattening performance, such as Suffolk or Ramlıç (crossbreeding Rambouillet with Daglıç). Therefore, this study aimed to determine the slaughter and carcass characteristics of Kıvırcık (K), Karacabey Merino (KM), Ramlıç (R), German Black-Head Mutton × Kıvırcık (GBK) and Hampshire Down × Merino (HM) crossbreed lambs reared under intensive conditions in the Marmara Region.

2. Materials and methods

The present study was carried out from January to June 2018 in the experimental farm unit of Sheep Breeding Research Institute (Balıkesir, Turkey) under the institute conditions for rearing and management of the intensive system. The animal care and handling procedures were reviewed and approved by the Ethical Committee of the Sheep Breeding Research Institute (Approval number: 13360037). Lambs of the same breed were housed in separate barns with their dams until they were weaned. The restricted suckling program (twice a day, without milking) was applied to all lambs from 15 days of age to the weaning period with the supplementation of alfalfa hay and lamb starter feed in addition to their dam's milk. A total of 202 lambs, Kıvırcık (n = 51), Karacabey Merino (n = 47), Ramlıç (n = 28), German Black-Head Mutton × Kıvırcık (n = 49), Hampshire Down × Merino crossbreed (n = 27) lambs were selected to create a single flock after they were weaned and placed together in the same barn. Selected lambs for rearing program were later-born lambs, which were born within 10 days at the end of the lambing season, with an average of weaning at 90.5 ± 5.7 days (mean ± SD). Lambs received approximately 600 g/lamb of concentrate feed, 100 g/lamb of alfalfa hay, and 300 g/lamb of vetches-wheat mixtures hay per day with ad libitum freshwater and mineral licking blocks. They received the concentrate and roughages twice a day, at 09:00 and 16:30 at an equal amount. The chemical composition of concentrate and roughages used in this study were presented in Table 1.

Table 1. Chemical composition of concentrate and roughages.

Chemical composition	Alfalfa hay	Vetches-wheat mixtures	Concentrate
DM	874.9	894.9	894.4
CP	232.0	87.1	126.5
CA	145.1	56.6	94.3
EE	20.7	12.6	32.2
CF	203.8	418.6	96.6
NDF	354.3	635.9	399.0
ADF	230.0	466.8	129.5

DM: Dry matter (g/kg fed basis); CP: Crude protein (g/kg DM); CA: Crude Ash (g/kg DM); EE: Ether extract (g/kg DM); CF: Crude fiber (g/kg DM); NDF: Neutral detergent fiber (g/kg DM); ADF: Acid detergent fiber (g/kg DM).

At the end of the rearing period, 10 male lambs of each breed were randomly selected to investigate slaughter and carcass characteristics. Selected lambs were transferred to the institute's slaughterhouse and then fasted for 12 h with free access to freshwater and weighed before slaughtering. During two consecutive days, 50 lambs were slaughtered using standard commercial procedures. SW was recorded immediately before slaughter. After skinning, the noncarcass components (head, skin, feet, lungs, liver, heart, spleen, testicles, and gastrointestinal tract) were removed, and hot carcass weight (HCW, including kidneys and perinephric-pelvic fat) was recorded. After chilling at 4 °C for 24 h, the cold carcass weight (CCW) was recorded, and the dressing percentage was calculated from the ratio of both HCW and CCW to SW. Linear measurements were conducted using a flexible calibrated tape and caliper on the chilled carcass. After linear measurements were taken, the carcasses were separated into primal cuts (neck, shoulder, rack, loin, and leg) and weighed [18]. The loin eye parameters (area, perimeter, depth, width, and fatness) and body fatness were measured on both sides of the chilled carcass from photographs using the Fiji image measurement program (Version 1.52d), and their average values were used [19]. An example measurement taken from the left side of the carcass is given in Figure.

The effect of independent factors (breed and sex) on live body weight (1) and the effect of breed on each slaughter and carcass trait (2) were analyzed using the GLM procedure of Minitab [20] statistical package programs, and least-squares means were compared using Tukey's multiple comparison tests. The models used for the least-squares (LS) analysis were as follows:

$$Y_{ijk} = \mu + a_i + b_j + ab_{ij} + e_{ijk} \quad (1)$$

where Y_{ijk}: the observation of the kth animal within the ith breed of the jth sex; μ: overall mean; a_i: effect of the ith breed (i: K, KM, R, GBK, HM); b_j: effect of the jth sex (j: male, female), ab_{ij}: interaction between ith breed and jth sex, e_{ijk}: effect of the experimental error.

$$Y_{ij} = \mu + a_i + e_{ij} \quad (2)$$

where Y_{ij}: observed value; μ: overall mean; a_i: effect of breed type; e_{ij}: effect of the experimental error.

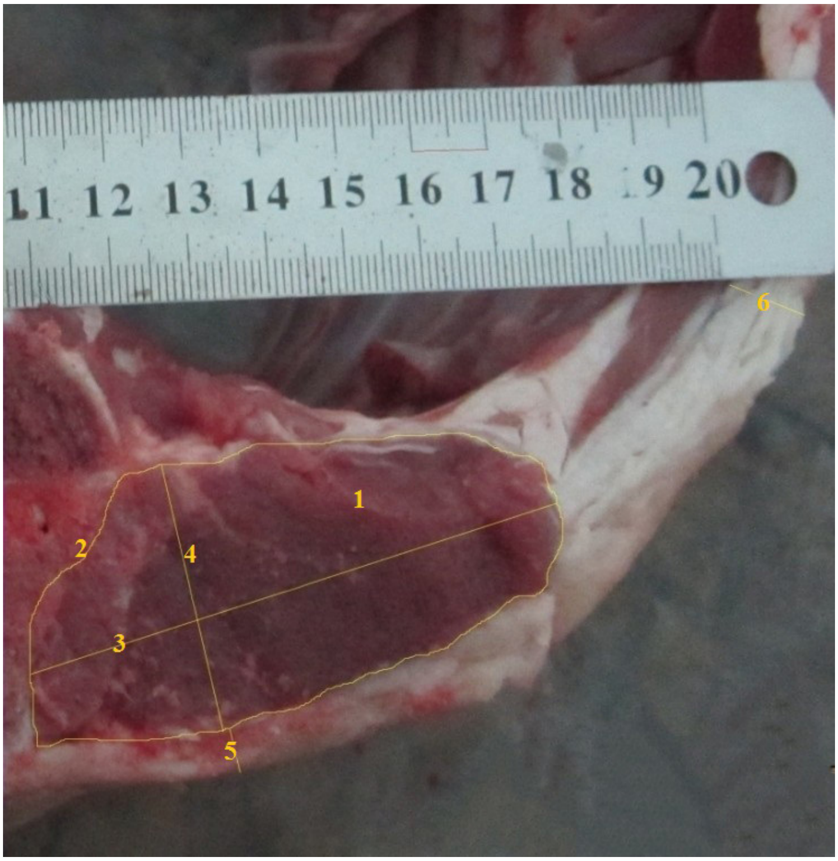

Figure. An example measurement from the left side of the carcass (1: loin eye area, 2: loin eye perimeter, 3: loin eye depth, 4: loin eye width, 5: loin eye fatness, 6: body fatness).

3. Results

The rearing performance data for different meat-type lambs are presented in Table 2. The differences between initial weight (IW), final weight (FW), total weight gain (TWG), and average daily gain (ADG) were statistically significant as expected ($P < 0.001$). The effect of breed and sex was significant ($P < 0.001$) on the studied traits, while the interaction between breed and sex was not significant ($P > 0.05$). The ADG and TWG values in these breeds varied in the ranges of 130.1–203.3 g and 6.28–9.76 kg, respectively. Specifically, male K lambs had lower ADG and TWG (167.3 g/day and 8.03 kg), whereas male HM lambs averaged higher values (246.6 g/day and 11.84 kg). Also, sex affected both ADG and TWG parameters, with male lambs averaging higher ADG and TWG ($P < 0.001$) compared to female lambs.

Carcass parameters of different meat-type lambs are shown in Table 3. The differences between breeds for chilling loss (CL) and the perimeter, depth, width, and fatness of the loin eye and body fatness (BF) were not significant ($P > 0.05$). On the other hand, the loin eye area (LEA) ($P < 0.05$); cold dressing percentage (CDP) and hot dressing percentage (HDP) ($P < 0.01$); and SW, HCW, and CCW ($P < 0.001$) showed significant breed-dependent differences.

The effects of breed on noncarcass components are given in Table 4. The differences between heart, spleen, omental and mesenteric fat, and other parts of red offal were not significant ($P > 0.05$). In contrast, head, kidney, and full stomachs ($P < 0.05$); skin, lungs, full and empty intestines ($P < 0.01$); feet, testicles, liver, empty stomachs, and kidney fat ($P < 0.001$) were affected by breed.

The effects of breed on linear carcass measurements are represented in Table 5. There were no significant differences observed in linear carcass measurements except for half carcass length ($P < 0.05$), carcass length, and chest depth of these breeds ($P < 0.001$). R lambs had lower carcass length, half carcass length, and chest depth values (69.25 cm, 67.80 cm, and 24.25 cm, respectively), whereas HM, KM, and K lambs had averaged higher values (76.60 cm, 72.35 cm, 26.35 cm, respectively).

Primal cuts of different meat-type lamb carcasses are sown in Table 6. The differences between neck proportion were breed-dependent ($P < 0.05$), whereas shoulder, rack, loin, and leg were not ($P > 0.05$).

Table 2. Rearing performance of different meat-type lambs.

		Breed										S				P		
Trait	S	*n*	K	*n*	KM	*n*	R	*n*	GBK	*n*	HM	*n*	M	*n*	F	Br	G	Br×G
IW^{x}, kg		*51*	30.71 ± 0.56^{b}	*47*	32.07 ± 0.58^{b}	*28*	27.38 ± 0.69^{c}	*49*	34.41 ± 0.56^{a}	*27*	32.03 ± 0.71^{ab}	*69*	32.71 ± 0.44^{a}	*133*	29.93 ± 0.343^{b}	***	***	NS
	M^{y}	*15*	32.73 ± 0.94^{ab}	*14*	33.66 ± 0.97^{ab}	*14*	28.16 ± 0.97^{cd}	*15*	35.53 ± 0.94^{a}	*11*	33.48 ± 1.10^{ab}							
	F^{y}	*36*	28.70 ± 0.61^{cd}	*33*	30.48 ± 0.63^{bc}	*14*	26.61 ± 0.97^{d}	*34*	33.29 ± 0.63^{ab}	*16*	30.58 ± 0.91$^{b\text{-}d}$							
FW^{x}, kg		*51*	36.99 ± 0.69^{b}	*47*	41.81 ± 0.72^{a}	*28*	35.13 ± 0.85^{b}	*49*	41.25 ± 0.70^{a}	*27*	41.79 ± 0.88^{a}	*69*	42.42 ± 0.54^{a}	*133*	36.37 ± 0.42^{b}	***	***	NS
	M^{y}	*15*	40.76 ± 1.16^{ab}	*14*	45.20 ± 1.20^{a}	*14*	36.82 ± 1.20$^{b\text{-}d}$	*15*	43.98 ± 1.16^{a}	*11*	45.31 ± 1.35^{a}							
	F^{y}	*36*	33.23 ± 0.75^{d}	*33*	38.41 ± 0.78^{b}	*14*	33.44 ± 1.20^{cd}	*34*	38.52 ± 0.77^{b}	*16*	38.26 ± 1.12^{bc}							
TWG^{x}, kg		*51*	6.28 ± 0.36^{b}	*47*	9.74 ± 0.37^{a}	*28*	7.75 ± 0.44^{b}	*49*	6.84 ± 0.36^{b}	*27*	9.76 ± 0.46^{a}	*69*	9.70 ± 0.28^{a}	*133*	6.44 ± 0.22^{b}	***	***	NS
	M^{y}	*15*	8.03 ± 0.60^{b}	*14*	11.54 ± 0.62^{a}	*14*	8.67 ± 0.62^{b}	*15*	8.45 ± 0.60^{b}	*11*	11.84 ± 0.70^{a}							
	F^{y}	*36*	4.53 ± 0.39^{c}	*33*	7.93 ± 0.40^{b}	*14*	6.83 ± 0.62^{bc}	*34*	5.23 ± 0.40^{c}	*16*	7.68 ± 0.58^{b}							
ADG^{x}, g		*51*	130.1 ± 7.4^{b}	*47*	202.8 ± 7.7^{a}	*28*	161.4 ± 9.1^{b}	*49*	142.5 ± 7.5^{b}	*27*	203.3 ± 9.5^{a}	*69*	202.2 ± 5.9^{a}	*133*	134.2 ± 4.6^{b}	***	***	NS
	M^{y}	*15*	167.3 ± 12.5^{b}	*14*	240.4 ± 12.9^{a}	*14*	180.5 ± 12.9^{b}	*15*	176.0 ± 12.5^{b}	*11*	246.6 ± 14.6^{a}							
	F^{y}	*36*	94.4 ± 8.1^{c}	*33*	165.2 ± 8.4^{b}	*14*	142.2 ± 12.9^{bc}	*34*	109.0 ± 8.3^{c}	*16*	160.0 ± 12.1^{b}							

^{x}The values with different letters (a, b, c) in the same row are statistically different ($P < 0.05$).
^{y}Levels not connected by the same letter for sex are significantly different ($P < 0.05$). Br: Breed, S: Sex, NS: Not Significant, ***: $P < 0.001$.
IW: Initial weight, FW: Final weight, TWG: Total weight gain, ADG: Average Daily gain, M: Male, F: Female, K: Kıvırcık, KM: Karacabey Merino, R: Ramlıç, GBK: German blackhead mutton × Kıvırcık, HM: Hampshire Down × Merino crossbreeds.

Table 3. Carcass parameters of different meat-type lambs.

Trait	K *(n=10)*	KM *(n=10)*	R *(n=10)*	GBK *(n=10)*	HM *(n=10)*	SEM	P
SW, kg	40.38^{bc}	45.73^{a}	37.30^{c}	43.70^{ab}	45.58^{a}	1.17	***
HCW, kg	19.58^{bc}	22.25^{a}	17.32^{c}	21.34^{ab}	21.43^{ab}	0.64	***
HDP, %	48.51^{ab}	48.63^{a}	46.27^{b}	48.84^{a}	47.01^{ab}	0.57	**
CCW, kg	19.12^{bc}	21.76^{a}	16.80^{c}	20.71^{ab}	20.80^{ab}	0.62	***
CDP, %	47.39^{a}	47.55^{a}	44.86^{b}	47.41^{a}	45.61^{ab}	0.59	**
CL, %	1.12	1.07	1.41	1.42	1.39	0.11	NS
LEA, cm^2	14.54^{b}	15.88^{ab}	16.45^{ab}	16.84^{ab}	18.02^{a}	0.79	*
LEP, cm	17.06	17.15	17.16	17.82	18.13	0.40	NS
LED, cm	2.95	3.17	3.35	3.40	3.40	0.17	NS
LEW, cm	6.45	6.51	6.43	6.58	6.70	0.23	NS
LEF, mm	5.32	4.23	5.35	5.38	5.31	0.46	NS
BF, mm	8.36	6.73	8.45	8.57	8.93	0.73	NS

SW: Slaughter weight, HCW: Hot carcass weight, HDP: Hot dressing percentage, CCW: Cold carcass weight, CDP: Cold dressing percentage, CL: Chilling loss, LEA: Loin eye area, LEP: Loin eye perimeter, LED: Loin eye depth, LEW: Loin eye width, LEF: Loin eye fatness, BF: Body fatness, K: Kıvırcık, KM: Karacabey Merino, R: Ramlıç, GBK: German Black-Head Mutton × Kıvırcık, HM: Hampshire Down × Merino crossbreeds, SEM: Standard error of means, NS: Not significant.
The values with different letters (a, b, c) in the same row are statistically different ($P < 0.05$), *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

Table 4. Noncarcass components of different meat-type lambs.

Trait	K *(n=10)*	KM *(n=10)*	R *(n=10)*	GBK *(n=10)*	HM *(n=10)*	SEM	P
Skin, kg	3.92^{b}	4.77^{a}	4.02^{ab}	4.36^{ab}	4.72^{a}	0.19	**
Head, kg	2.37	2.44	2.11	2.45	2.44	0.09	NS
Feet, kg	0.92^{b}	1.12^{a}	0.90^{b}	1.06^{a}	1.13^{a}	0.03	***
Testicles, g	315.5^{a}	278.7^{a}	171.0^{b}	352.5^{a}	275.0^{a}	22.3	***
Heart, g	267.5	303.4	243.0	282.5	287.0	16.2	NS
Lungs, g	564.5^{bc}	699.9^{ab}	550.0^{c}	$633.5^{a\text{-}c}$	735.5^{a}	35.8	**
Liver, g	727.0^{bc}	857.8^{a}	697.0^{c}	831.0^{ab}	812.0^{ab}	28.0	***
Spleen, g	127.5	144.9	93.5	125.5	106.0	14.7	NS
Kidney[1], g	127.0^{ab}	130.5^{a}	112.5^{b}	128.0^{ab}	123.5^{ab}	4.14	*
Full stomachs, kg	5.66^{b}	5.96^{ab}	5.56^{b}	6.42^{ab}	6.95^{a}	0.30	*
Empty stomachs kg	1.23^{b}	1.52^{a}	1.21^{b}	1.40^{ab}	1.50^{a}	0.06	***
Full intestine, kg	3.47^{b}	3.93^{ab}	3.45^{b}	3.43^{b}	4.17^{a}	0.15	**
Empty intestines, kg	1.95^{ab}	2.10^{ab}	1.86^{b}	1.90^{b}	2.20^{a}	0.06	**
Others, red offal, g	226.0	229.4	136.5	240.5	220.0	30.4	NS
Omental & mesenteric fat, g	494.5	459.5	513.5	429.5	369.5	51.0	NS
Kidney fat[1], g	229.0^{a}	162.5^{b}	156.0^{bc}	162.0^{b}	106.7^{c}	12.6	***

[1]weight after chilling at 4 °C for 24 h
K: Kıvırcık, KM: Karacabey Merino, R: Ramlıç, GBK: German Black-Head Mutton × Kıvırcık, HM: Hampshire Down × Merino crossbreeds. The values with different letters (a, b, c) in the same row are statistically different ($P < 0.05$). SEM: Standard error of means, NS: Not significant, *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

Table 5. Carcass linear measurements of different meat-type lambs.

Trait	K (n=10)	KM (n=10)	R (n=10)	GBK (n=10)	HM (n=10)	SEM	P
Carcass length, cm	73.60^{a}	75.15^{a}	69.25^{b}	74.25^{a}	76.60^{a}	0.97	***
Half carcass length, cm	71.40^{ab}	72.35^{a}	67.80^{b}	70.60^{ab}	72.00^{ab}	1.07	*
Pelvic limb length, cm	22.25	23.15	22.05	22.95	24.00	0.65	NS
Chest width, cm	16.85	18.00	16.60	17.30	17.55	0.41	NS
Chest depth, cm	26.35^{a}	26.05^{a}	24.25^{b}	25.25^{ab}	25.40^{ab}	0.37	***
Hindquarter length, cm	37.55	38.65	37.35	37.10	40.00	1.17	NS
Hindquarter perimeter, cm	55.40	59.70	53.15	57.10	52.17	2.73	NS

K: Kıvırcık, KM: Karacabey Merino, R: Ramlıç, GBK: German Black-Head Mutton × Kıvırcık, HM: Hampshire Down × Merino crossbreeds. The values with different letters (a, b) in the same row are statistically different ($P < 0.05$). SEM: Standard error of means, NS: Not significant, *: $P < 0.05$, ***: $P < 0.001$.

Table 6. Primal cuts of carcasses of different meat-type lambs.

Trait	K (n=10)	KM (n=10)	R (n=10)	GBK (n=10)	HM (n=10)	SEM	P
Neck, %	6.36^{a}	5.48^{ab}	5.90^{ab}	5.21^{b}	5.83^{ab}	0.25	*
Shoulder, %	29.76	29.64	29.66	31.17	28.43	1.49	NS
Rack, %	15.39	16.54	16.28	15.99	16.08	0.72	NS
Loin, %	14.69	14.41	13.44	14.88	12.36	0.69	NS
Leg, %	31.76	32.39	33.05	29.86	29.51	1.40	NS

K: Kıvırcık, KM: Karacabey Merino, R: Ramlıç, GBK: German Black-Head Mutton × Kıvırcık, HM: Hampshire Down × Merino crossbreeds. The values with different letters (a, b) in the same row are statistically different ($P < 0.05$). SEM: Standard error of means, NS: Not significant, *: $P < 0.05$.

4. Discussion

The findings related to rearing performance (IW, FW, TWG, and ADG) are presented in Table 2. Statistically significant differences were observed in IW and FW of those breeds, although they were weaned on the same day ($P < 0.001$). The ADG of HM and KM were higher than that of K, R, and GBK lambs. Also, male lambs gained 68.0 g more daily weight than female lambs per day and 3.26 kg more in total weight in the rearing period. According to Yılmaz et al. [21], one possible explanation of the ADG and TWG differences was the weight differences between male and female lambs at the beginning of the rearing period, which continued their significant effect during the rearing period. In contrast to the same researchers' findings [21], IW, FW, and ADG were significantly affected by genotype and sex in this study ($P < 0.001$). Research findings of Küçük et al. [22] and Rodríguez et al. [4] about genotype and sex effects on ADG and findings of Macit et al. [9] about genotype effect on IW and FW support our results.

Uğurlu et al. [23] underlined that although both HDP and CDP were important factors for determining carcass quality and meat production, CDP was the most preferred one due to reflecting market preferences. In this study, the highest HDP and CDP value was observed in GBK (48.84%) and KM (47.55%) lambs, respectively. On the other hand, R lambs had lower values, both for HDP (46.27%) and CDP (44.86%). The CCW and CDP values were reported to be 17.48 kg and 43.07% for Turkish Merino [21], 19.77 kg and 45.03% for Morkaraman, 19.99 kg and 45.80% for Kıvırcık × Morkaraman (G1) crossbreed [22], 22.10 kg and 48.94% for Akkaraman, 21.40 kg and 47.45% for Sakız × Akkaraman crossbreed [24], and 34.38 kg and 44.76% for Kıvırcık [25] lambs. The obtained results related to the CDP value from this study was similar to Sakız × Akkaraman crossbreed (except R and HM); higher than Turkish Merino, Morkaraman, Kıvırcık × Morkaraman (G1) crossbreed (except HM), and Kıvırcık; and lower than Akkaraman lambs. These results also indicate that CCW and CDP values of those meat-type lambs were satisfactory in the intensive rearing system. Differences such as breed type, IW, FW, suckling period, rearing duration, feeding regimen, and animal care might be the reason for CCW and CDP differences in the intensive rearing system.

In most of the carcass related studies, digital planimeter was used to evaluate loin eye area and perimeter [9,26,27]. On the other hand, biological-image analysis has become more popular in recent years, even in farm animals. For example, Esquivelzeta et al. [28] used an image processing technique in their longissimus dorsi (LD) ultrasound measurements to determine phenotypic relations later found in the slaughterhouse. In this study, the image processing technique was applied to the photograph of LD between 12th and 13th ribs in the slaughterhouse. The LEA was significantly affected by breed type ($P < 0.05$), and LEP was not ($P > 0.05$). The highest LEA (18.02 cm^2) and LEP (18.13 cm) values were found in HM lambs, whereas the lowest were found in K lambs (14.54 cm^2 and 17.06 cm, respectively) as presented in Table 3. LEA was reported as 15.75 cm^2 in Turkish Merino [21], 12.50 cm^2 in Akkaraman, 11.20 cm^2 in Sakız × Akkaraman [24], and 11.80 cm^2 in Awassi [29] lambs. The differences might be related to the dressing percentage and the measurement technique applied (planimeter vs. image processing).

In most developing and some developed countries, the producer is interested in certain qualitative and quantitative characteristics of noncarcass components due to their economic benefits [30]. Also, it has been shown that noncarcass components affect dressing percentage as lamb growth proceeds [31]. Therefore, assessment of noncarcass components is important in the meat production industry. In the present study, heavier kidney ($P < 0.05$), skin ($P < 0.01$), liver ($P < 0.001$), and stomach (empty) ($P < 0.001$) in KM lambs; lungs ($P < 0.01$), intestine (empty) ($P < 0.01$), and feet ($P < 0.001$) in HM lambs; testicles in GBK lambs ($P < 0.001$); kidney fat in K lambs ($P < 0.001$) were recorded.

Carcass linear measurements of different meat-type lambs are summarized in Table 5. Previous studies showed that linear carcass measurement gave some valuable information about confirmation of carcass and size [18,32]. R lamb carcasses had lower values for carcass length ($P < 0.001$), half carcass length ($P < 0.05$), and chest depth ($P < 0.001$) when compared to other meat-type breeds. Ekiz et al. [18] and Santos et al. [33] explained this situation via the differences between carcass weight and slaughtering age.

In this study, each whole lamb carcass was separated into five primal cuts, namely, neck, shoulder, rack, loin, and leg to minimize dissection error. While the neck proportion of carcasses was significantly affected by breed type ($P < 0.05$), shoulder, rack, loin, and leg proportion were not. Parallel to our research findings, Peña et al. [34] reported that sex had a significant effect on only the neck and back percentage.

In conclusion, Merino crossbreeds (KM and HM) had significantly more ADG and TWG when compared to K, R, and GBK. On the other hand, KM, GBK, and K had higher CDP values while HM came forward for LEA. Considering the consumers' preferences and market demands, Merino, Kıvırcık, and their crossbreeds are more suitable to produce lamb meat in the Marmara Region.

Acknowledgment

The present study was funded by the Republic of Turkey, Ministry of Agriculture and Forestry, General Directorate of Agricultural Research (Project No: TAGEM/HAYSUD/B/18/A4/P2/308).

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