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Slaughter and carcass characteristics, and meat quality in Holstein Friesian, Eastern Anatolian Red and crossbreed (F_1) bulls fed at high altitude

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ABSTRACT

The study aimed to determine the slaughter traits, carcass characteristics and meat quality of Eastern Anatolian Red (EAR), Holstein Friesian (HF) and their crossbreed (F_1) bulls to provide a different systematic structure to red meat production for sustainable meat production. The present research applied the rearing and feeding method commonly used in the region. The experiment was conducted at a high altitude, and comprised in total of 10 Eastern Anatolian Red (HFEAR) bulls, 6 Holstein Friesian (HF) bulls and 6 Holstein Friesian × Eastern Anatolian Red (HFEAR) bulls (Eastern Anatolian Red dams sired by Holstein Friesian) crossbred bulls that had 15-month ages. The objective for slaughter age in the experiment was 20 months (150 days) which is the average slaughter age for beef bulls. The slaughter and carcass characteristics and carcass measurements were determined by the measurement and weighing. Marbling score, fat thickness over *longissimus dorsi* (FatT), carcass conformation (CarC), fat cover score (FCS), colour (L*, a*, b*) and organoleptic traits (tenderness, juiciness, flavour) were determined in the *longissimus dorsi* (LD) muscle from carcass representative of the experimental bulls. The results indicated that initial weight (InW), final weight (FW), hot carcass weight (HoW), dressing (Drs%), head weight (HeW), four feet weight (FFW), hide weight (HiW), kidney weight (KidW), liver weight (LivW), pelvic fat weight (PFW), pH, carcass length (CarL), round length (RoL), round width (RoW) were associated with breed ($P < 0.01$). Significant differences were determined among fat thickness over LD (FaT, $P < 0.05$), *longissimus dorsi* area (LDA, $P < 0.05$), carcass conformation (CarC, $P < 0.05$), fat cover score (FCS, $P < 0.05$), L* ($P < 0.01$), a* ($P < 0.01$). At the same time, there were no significant marbling scores, pH, or b* differences among breeds ($P > 0.05$). HF bulls had a greater total weight gain (TWG) ($P < 0.01$), average monthly weight gain (AMWG) ($P < 0.05$), average daily weight gain (ADWG) ($P < 0.01$) and sensory analysis (except flavour) ($P < 0.05$) in comparison to the EAR bulls. Contrary to the prejudice that was no suitable material for fattening at high altitudes; fattening performance, carcass characteristics and meat quality values of cattle obtained by crossbreeding Holstein Friesian and local breed bulls were found to be at standard level, in this study.

Keywords: beef production, Holstein Friesian, Eastern Anatolian Red, crossbreeding, location effect, meat quality

INTRODUCTION

The foundation of important strategies in beef and milk production today is productivity and sustainability, which involves consideration of the proper definition of production goals, supply of suitable materials, and genetic variation. Many countries in the world have adopted systems that include both production and functional traits such as calving ease and adaptation to environmental conditions as in Finland, Sweden, Norway and Denmark (Juga et al., 1999). A sustainable production system is one of the important parts of the regional livestock sector and provides an essential source of credible production. The products from certain breeds selected from available resources and sustainable breeding goals may become more desirable to the consumer than products from casually selected breeds (Sorensen et al., 2008). Thus, consumers have generally evaluated animal products produced in high-altitude areas with this understanding (Coner et al., 2008).

The eastern region of Türkiye consists of high-altitude meadows and pastures where heat stress, which may negatively affect animal production (Gutiérrez-Lizarazo and Báez-Sandoval, 2020), is not experienced. The Eastern Anatolian Red (EAR) breed is also an indigenous breed adapted to the marginal areas (Yüksel, 2019). Although this breed has a preferable potential in terms of feed conversion, fattening performance and meat quality characteristics (Yüksel et al., 2012; Özlütürk et al., 2004), it does not compete for fattening performance with European-origin breeds (Özlütürk et al., 2004). Notwithstanding, the meat yield character of Holstein Friesian, which has higher meat yield potential than native breeds or some combined productivity breeds, has been ignored due to some prejudices. Whenas, the breed has had satisfactory fattening performance in intensive conditions according to research (Yüksel et al., 2009).

The efficient use of resources and improvement strategies are important for the bottleneck, which is frequently, experienced in terms of red meat in some regions of the world. Thus, prestigious studies that aim at increasing the productivity of native breeds are important in many countries in the World (Pesonen and Huuskonen, 2015).

This study aimed to determine the slaughter, carcass and meat quality characteristics of EAR, HF and their crossbreed (F_1) bulls in order to give a systematic structure to red meat production under high-altitude regional conditions. Thus, it would contribute to both the solution of some prejudices about Holstein breeding at high altitudes and the sustainability of local breeds.

MATERIALS AND METHODS

Animals, feeding and housing

The study was carried out in Erzurum (Türkiye), at 39°55′15.49″N, 41°17′12.90 E, and at an altitude of 1,850 m. The region has a continental climate, large pasture and plateau areas, and a diversity of cattle and sheep. A significant part of the population lives in rural areas, and livestock is the main production branch of this region. The experiment was conducted at a high altitude and comprised in total of 10 HFEAR bulls, 6 HF bulls and 6 HFEAR bulls (Eastern Anatolian Red dams sired by Holstein Friesian, F_1) crossbred bulls that had 15-month ages. Based on an assumption that the alpha error was 0.15 at the beta error being 0.85, at least 6 animals per group were needed to have a statistical significance when the hot dressing was 50% higher in the final of the study.

The animals, which spent the winter period in a closed barn, were taken to the paddocks (8 × 15 m), in groups by breeds, outside as of the beginning of May. By weighing after a two-week adaptation period, they fed on the ration program determined as from mid-May. The concentration was kept constant throughout the study. The study lasted for 150 days by applying the feeding program that was adopted widely by rearers ratio of 4 kg/day concentrate and ad libitum dry hay, oat and wheat straw. The bulls were weighed at monthly intervals. The chemical composition of the feeds offered throughout the experimental period is presented in Table 1.

Table 1. Feed components used in the study

Components	Concentrate	Grass hay	Oat hay	Wheat straw
DM (%)	90.2	92.2	30.0	91.2
CP (%)	16.4	10.1	11.3	3.5
CA (%)	9.0	10.4	8.9	7.6
ADF (%	10.5	39.5	37.8	50.1
NDF (%)	22.7	62.4	54.0	67.7

Measurements and analytical methods

The animals whose final weights (FW) were determined by weighing on two consecutive days were dispatched to the abattoir which was 30 minutes away. After resting 2.5 – 3 hours in abattoir lairage, and bulls were then slaughtered at 20 months of age.

The slaughter process was carried out in the official abattoir (Meat and Milk Institution) in Erzurum province. Following slaughter, head, hide, front + hind feet, kidneys, liver and pelvic fat were removed and weighed. Hot weight (HoW) was measured and thus the dressing was determined. Some carcass measurements including carcass length (CarL), round length (RoL), and round width (RoW) were measured with the help of a tape measure (Yüksel et al., 2009). The ribbing site was at the 12th - 13th rib interface. After chilling at 4 °C for 24 h, the carcasses were ribbed, scored and graded by two trained carcass evaluators (USDA, 1989). Carcass conformation (CarC) evaluation was made according to the SEUROP procedure (USDA, 1989). This scale ranged from 1 to 18, three digits apart (S: super, E: excellent, U: unrivalled, R: right, O: ordinary, P: poor). Fat cover score (FCS) was in five classes ranging from 1 to 15, three-digit intervals (1: lean, 2: low-fat, 3: mid-fat, 4: fatty, 5: very fat (USDA, 1989). The cross-section of the *longissimus dorsi* muscle, whose projection was recorded on millimetric measuring paper, was area scanned by computer and the LDA was calculated in square centimetres. Fat thickness over LD (FaT) was determined by measuring with a millimetre ruler the depth of the fat at three equally spaced locations over the *longissimus dorsi* muscle. Also marbling score was detected at the same site, ranging from 1 to 6 (1 = slight, 2 = small, 3 = modest, 4 = moderate, 5 = slightly abundant, 6 = abundant). At the 24th hour, the pH values were measured on LD surfaces by probe using a SCHOTT, Lab Star pH meter. Minolta colourimeter device (CR-200, Minolta Co, Osaka, Japan) was used to measure Commission Internationale l' E Clairage lightness (L*), redness (a*) and yellowness (b*) on the LD (Honikel, 1998). For organoleptic analysis for samples, they used nine-point hedonic scales (1 = extremely tough to 9 = extremely tender; 1 = extremely dry to 9 = extremely juicy; 1 = extremely weak flavour to 9 = extremely strong flavour). The cooked samples were cut into cubes (2×2×2 cm) and served to eight panellists with a cup of water. Panellists independently evaluated each meat sample for the degree of tenderness, juiciness and flavour intensity of meat tissue.

Statistical analysis

The ANOVA was performed to evaluate the effect of breed (genotype) on carcass characteristics and meat quality traits, using the GLM procedure (SPSS, 2020). The results were shown as the least squares mean. Duncan's test method was applied for the comparison of subclass means when F-tests for the main effect were significant.

RESULTS

The dressing values obtained in some studies for low altitudes (30 to 900 m) as a part of this study are presented in Table 2.

Table 2. Hot carcass dressing percentage of HF and their crossbreeds reared at low altitude

Breed	Age (mo)	Feeding style	Hot dressing (%)	Reference
Holstein	12 - 15	int	55.8 - 59.3	Akcan et al (1989)
Holstein	12 - 18	int	57.2 - 57.9	Koç and Akman (2003)
Friesian	6 <	int	57.21	Alçiçek et al (2003)
Holstein crossbred (Pi × F)	6 <	int	61.05	Alçiçek et al (2003)
Holstein crossbred (Pi × F)	6 <	int	60.09	Alçiçek et al (2003)
Holstein	5- 15	int	57.6 - 58.2	Koçak et al (2004)
Holstein Friesian	15 - 20	int	52.51	Çatıkkaş and Koç (2017)
Holstein Friesian	18 <	dc	53.78	Ardıclı et al (2018)
Holstein crossbred	18 <	dc	53.46	Ardıclı et al (2018)
Holstein	10 - 12	int	51.95	Ünlü and İpçak (2021)

Pi: Piemontese, F: Friesian, mo: month, int: intensive, dc: different condition

The dressing values obtained under different environmental conditions at low altitudes were close in terms of altitude the high altitude values for the Holstein breed (51-53%), except for intensive feeding.

The body weight gain and the slaughter traits of the experimental animals are given in Table 3 and Table 4, respectively. The InW of the HF bulls was higher than that of the EAR and HFEAR bulls ($P < 0.01$). The FW and TWG values of the HF bulls were higher than those of the EAR and HFEAR bulls ($P < 0.01$). The 3rd mo AMWG value of the HF bulls was higher than that of the EAR and HFEAR bulls ($P < 0.05$), but the 1st mo, 2nd mo, 4th mo and 5th mo values were, statistically, similar values that of the EAR and HFEAR bulls. In addition, the ADWG score of the HF bulls was higher than that of the EAR and HFEAR bulls ($P < 0.01$).

Differences in the HoW among the experiment bulls that were slaughtered were statistically significant ($P < 0.01$). The HoW value of the HF bulls was higher than the other. The value of Drs% from the EAR bulls was 53,14%, which was 51,87% and 48,20% higher than those from the HF and HFEAR bulls, respectively ($P < 0.01$).

There were significant differences in the weight of the head among experiment groups ($P < 0.01$). The HF bulls had the highest value, and EAR had also the lowest. There was the same trend for four feet weight. The HiW value was higher in the HF bulls than in the EAR and HFEAR bulls ($P < 0.01$). However, in the HFEAR bulls the KidW was higher than that in the EAR and HF bulls ($P < 0.01$). Furthermore, The LivW value was higher ($P < 0.01$) from HF and HFEAR than from EAR bulls. Regarding the yields of PFW value, all the breeds differed significantly from each other ($P < 0.01$). It was almost twice of HFEAR in EAR and HF. In the HFEAR bulls, the CarL value was 105.0, and higher than that in the EAR and HF bulls ($P < 0.01$). The values of RoL and RoW 85.66 and 44.50, respectively were higher in the HF bulls than in the EAR and HFEAR bulls ($P < 0.01$).

Carcass characteristics, meat quality and sensory values are given in Table 5. The marbling score did not demonstrate a statistically significant difference among breeds. However, when the FaT was compared among breeds, a significant effect was observed ($P < 0.05$) for breeds, with higher values for EAR bulls (Table 5). The mean LDA of HF and HFEAR was greater than in EAR bulls and were significantly different ($P < 0.05$).

Table 3. Body weight gains for the experimental animals (Mean ± SE)

Traits	EAR	HF	HFEAR	F	*P*-value
InW (kg)	171.70 ± 8.61[b]	220.41 ± 11.11[a]	196.00 ± 11.11[ab]	6.10	0.009
FW (kg)	279.70 ± 8.60[c]	378.16 ± 11.10[a]	329.00 ± 11.10[b]	25.03	0.001
TWG (kg)	109.02 ± 4.66[b]	157.57 ± 4.72[a]	132.94 ± 5.21[ab]	16.21	0.002
AMWG (kg)					
1st mo	18.30 ± 2.06[b]	28.06 ± 3.61[a]	24.31 ± 1.11[a]	3.88	0.022
2nd mo	20.77 ± 2.68[b]	32.25 ± 0.00[a]	25.88 ± 2.01[ab]	4.26	0.001
3rd mo	23.21 ± 2.00[b]	32.41 ± 2.99[a]	25.98 ± 2.16[b]	4.31	0.031
4th mo	23.00 ± 1.99[b]	33.00 ± 3.63[a]	27.11 ± 2.61[ab]	3.95	0.001
5th mo	23.74 ± 2.09[b]	31.85 ± 2.99[a]	29.66 ± 2.10[a]	5.26	0.020
ADWG (g)	726.21 ± 26.01[c]	1.041 ± 27.01[a]	891.26 ± 18.11[b]	57.23	0.003

EAR: Eastern Anatolian Red, HF: Holstein Friesian, HFEAR: Holstein Friesian × Eastern Anatolian Red, InW: initial weight, FW: final weight, TWG: total weight gain, AMWG: average monthly weight gain, mo: month, ADWG: average daily weight gain, SE: standard error, a-c: values reported with different letters on the same line are statistically different.

Table 4. Slaughter traits and carcass measurements for the experimental animals (Mean ± SE)

Traits	EAR	HF	HFEAR	F	P
HoW (kg)	148.76 ± 5.24[b]	196.36 ± 6.77[a]	158.66 ± 6.77[b]	15.92	0.001
Drs (%)	53.14 ± 0.49[a]	51.87 ± 0.63[a]	48.20 ± 0.63[b]	19.10	0.001
HeW (kg)	11.04 ± 0.23[c]	15.55 ± 0.30[a]	12.50 ± 0.37[b]	67.68	0.001
FFW (kg)	5.19 ± 0.20[c]	7.86 ± 0.26[a]	6.66 ± 0.32[b]	31.88	0.001
HiW (kg)	24.2 ± 0.92[b]	30.36 ± 1.30[a]	24.04 ± 1.19[b]	8.59	0.002
KidW (g)	648.00 ± 99.40[b]	960.00 ± 128.32[ab]	1295.00 ± 128.32[a]	8.05	0.003
LivW (kg)	3.98 ± 0.20[b]	5.61 ± 0.26[a]	5.50 ± 0.37[a]	14.58	0.001
PFW (g)	1414.00 ± 94.13[a]	1563.33 ± 121.52[a]	761.66 ± 121.52[b]	12.82	0.001
CarL (cm)	93.50 ± 1.74[b]	99.16 ± 2.25[b]	105.00 ± 2.25[a]	289.37	0.001
RoL (cm)	63.50 ± 1.15[c]	85.66 ± 1.49[a]	81.50 ± 1.49[b]	65.06	0.001
RoW (cm)	35.33 ± 1.11[c]	44.50 ± 1.44[a]	40.00 ± 1.44[b]	10.11	0.001

EAR: Eastern Anatolian Red, HF: Holstein Friesian, HFEAR: Holstein Friesian × Eastern Anatolian Red, HoW: hot weight, Drs: Dressing(%), HeW: Head weight, FFW: four feet weight, HiW: Hide weight, KidW: kidney weight, LivW: Liver weight, PFW: Pelvic fat weight, CarL: Carcass length, RoL: round length, RoW: round width, SE: standard error, a-c: different letters in the same row are statistically different.

Table 5. Carcass characteristics and meat quality values for the experimental animals (Mean ± SE)

Traits	EAR	HF	HFEAR	F	P
Marbling	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00	-	-
FatT (mm)	5.18 ± 0.04[a]	4.40 ± 0.05[ab]	3.27 ± 0.05[b]	3.41	0.050
LDA (cm^2)	57.57 ± 2.80[b]	70.00 ± 3.02[a]	64.50 ± 3.70[ab]	4.57	0.030
CarC	2.60 ± 0.35[b]	4.50 ± 0.45[a]	4.33 ± 0.45[a]	7.39	0.004
FCS	2.60 ± 0.18[ab]	3.00 ± 0.23[a]	2.00 ± 0.23[b]	4.53	0.025
pH	6.20 ± 0.07	5.97 ± 0.09	6.32 ± 0.09	3.29	0.059
L*	35.70 ± 0.55[a]	31.89 ± 0.75[b]	30.50 ± 0.70[c]	52.90	0.001
a*	15.82 ± 0.57[a]	14.41 ± 0.78[a]	11.44 ± 0.73[b]	11.18	0.001
b*	4.03 ± 0.53	4.33 ± 0.72	3.8 ± 0.67	0.11	0.894
Tenderness	5.82 ± 0.92[b]	6.16 ± 0.71[a]	6.02 ± 0.17[a]	5.26	0.034
Juiciness	5.76 ± 0.32	5.84 ± 0.91	5.78 ± 0.61	4.68	0.098
Flavour	6.15 ± 0.61[a]	5.98 ± 0.78[b]	6.50 ± 0.06[a]	7.99	0.022

EAR: Eastern Anatolian Red, HF: Holstein Friesian, HFEAR: Holstein Friesian × Eastern Anatolian Red, CarC: Carcass conformation, FCS: fat cover score, FatT: fat thickness over *longissimus dorsi*, LDA: *Longissimus dorsi* area, L*: brightness, a*: redness, b*: yellowness, SE: standard error, a-c: different letters in the same row are statistically different.

The CarC values of HF and HFEAR bulls were like and obtained greater values than EAR ($P < 0.01$). The FCS after 24 hours of slaughter did differ significantly among the breeds ($P < 0.05$) and the value of HF bulls was higher than others. The pH value tended to be higher in HFEAR bulls than in EAR and HF bulls. However, the differences among breeds were not significant ($P > 0.05$). There were significant differences ($P < 0.01$) in the flavour of EAR bulls for L* as well as a* value, but the HF had a similar value with EAR for a*. On the other hand, the breed had no significant effect on the b* value of the *longissimus dorsi*. HF and HFEAR bulls had high values for tenderness ($P < 0.05$), and EAR and HFEAR bulls had also high values for flavour ($P < 0.05$) (Table 5).

DISCUSSION

Previous studies involving different production systems showed that production with low-yielding breeds made it impossible to achieve sustainable production (Özlütürk et al., 2004). Based on this, this study was carried out to determine the state at high altitudes for productive beef production of the three breeds. In the current research, the InW weights of the breeds were different from each other and these differences are reflected also in the FW and HoW. In agreement with our finding with InW, FW and HoW, Özdemir and Yanar (2021) reported differences in InW, FW and HoW among Young Group, Middle Aged Group and Older Group Holstein bulls fattened with a 65% concentrate and 35% dry hay during 258 days. Whereas, Pesonen et al. (2012) showed that when Aberdeen Angus, Limousin and Aberdeen Angus × Limousin bulls having different InW were compared, variation was not found in FW. In the current study, EAR bulls had the lowest TWG, AMWH and ADWG. Compared with HF and HFEAR bulls, low TWG, AMWG and ADWG values of EAR bulls might be ascribed to the breed's genetic and slow growth character. Özlütürk et al. (2004) supported the findings of this study and reported that EAR bulls had lower total weight gain compared to Charolais and Simmental crossbred bulls. ADWG of the HF breed had the highest value ($P < 0.01$) among breeds, and the result of the present study was in accordance with the findings reported for Holstein bulls by Öztürk and Yanar (2021).

Percent Drs observed for EAR and HF breeds in the present study was in line with the observations reported by Çatıkkaş and Koç (2017), Ardıclı et al. (2018), Ünlü and İpçak (2021) based on results of HF determined in low altitude. However, Akcan et al. (1989), Alçiçek et al. (2003), and Koç and Akman (2003) observed that the Drs% of Holstein and their crossbreed bulls were high from current study results when the studies were in low altitude. This status illustrated, likely, variable caring and nutrition methods at the enterprise level considered to the different location conditions.

The results of the current study are in contrast with Özdemir and Yanar (2021) who found no effect on head percentage values among age groups for Holstein bulls, and Akbulut and Tüzemen (1994) who found no effect on head weight among breeds. However, Rahnefeld et al. (1983) reported that a difference in head percentage values explained by sex was observed for cross-beef cattle. The highest value breed for FFW was the HF, which was significantly different from EAR and HFEAR breeds. In a study carried out by Oh et al. (2008), the breed had a significant influence on FFW weight, with Jeju native cattle × Charolais × Brahman bulls having a higher value according to other breeds of bulls examined. This result was consistent with our findings. Differences in FFW weights in Holstein bulls were attributed to live weight, with weightier having a higher value than lightweight animals (Akcan et al., 1989). Consistent with Koç and Akman (2003), who reported that live weight was significant for FFFW weights. The hide weight of the HF breed was declared higher, compared to the pure Brown Swiss breeds, by some studies (Akbulut and Tüzemen, 1994). Similarly, it could be concluded that the difference in hide weight between Simmental and Charolais crosses was due to breed from the data reported by Özlütürk et al (2004). Similar findings were also reported for Jeju native cattle, Jeju native cattle × Charolais × Brahman and Jeju native cattle × Charolais × Brahman breeds by Oh et al. (2008). The indication of researchers for hide weight was status supporting our study finding. In this study, the value relating to KidW weights of experimental bulls showed trends that were associated with breed, pointing to HFEAR bulls having an overall higher value, relative to others within the study. Similarly, Oh et al. (2008) reported that the highest value of the KidW of 25% Jeju native cattle × 50% Charolais × 25% Brahman bulls among three breeds. Ünlü and İpçak (2021) reported that HF bulls had higher KidW than Angus. These determinations based on breed coincided with our results. It was reported that Holstein bulls had higher liver weights compared to Angus bulls (Ünlü and İpçak, 2021) and 25% Jeju native cattle × 50% Charolais × 25% Brahman had higher LivW compared to other breeds (Oh et al., 2008). These results determined based on breeds support our findings. In the current study, findings for the PFW were consistent with the findings of Musa et al. (2021), who reported that there were differences among Arsi, Borona, HF cross and Harar breeds. Similar results were reported for Angus, Simmental, Angus x Simmental and Simmental x Hereford breeds by Miller and Cross (1987). However, it was reported from data indicated by Özlütürk et al. (2004) that there was a difference in the PFW value among Charolais, Simmental, and EAR crosses. Akbulut and Tüzemen, (1994) also reported not a positive relationship between PFW and breed.

In the present study, while values of HF and EAR bulls were similar, HFEAR bulls had lengthier CarL. The differences in CarL might be attributed to the crossbreeding. In a study by Oh et al. (2008), the breed had a significant influence on CarL, with 25% Jeju native cattle × 50% Charolais × 25% Brahman bulls having almost over 8% the CarL relative to Jeju native cattle and 62.5% Jeju native cattle × 25% Charolais × 12.5% Brahman breed bulls examined in their study. On the other hand, Özlütürk et al. (2004) found that EAR was lower than Charolais and Simmentals, and Alçiçek et al. (2003) found that Friesians higher than Piemontese, Limousin × Friesians. In this study, the breed is associated with both RoL and RoW. Our results were in agreement with Özlütürk et al. (2004) who observed a significant difference in RoW among breeds. Findings relating breed to round measurements were some studies conflicting. Alçiçek et al. (2003) examined three different breeds for leg length and leg width and found no significance;

however, when comparing New Zealand, European/ American, and Belgian Blue × Holstein - Friesian bulls for these characteristics, Keane (2003) found New Zealand bulls to be significantly different. The study findings showed no significant difference in marbling score in terms of the bulls examined which was in agreement with numerous studies (Özlütürk et al., 2004; Ito et al., 2012). FatT was higher for local breed EAR bulls in comparison with pure breed HF and crossbreed HFEAR bulls. The differences found among breeds in FatT value were in line with those observations found by Ito et al. (2012) for the Caracu, Canchin, Aberdeen Angus × Canchin and Charolais × Caracu breeds. In contrast, it was not found breeds effect among Charolais, Simmental and EAR (Özlütürük et al., 2004) and Arsi, Borona, HF-cross, and Harar bulls (Musa et al., 2021). In the present study, the LD area was significantly, different among the breeds. The differences observed among breeds may be attributed to having higher FW and HoW of bulls. Similar trends regarding LD area values and breed effect were shown by Ito et al. (2012) who studied Caracu, Canchin, Aberdeen Angus × Canchin and Charolais × Caracu breeds, and Özlütürk et al. (2004) who studied Charolais, Simmental and EAR breeds. This study indicated that the change in CarC value was associated with the breed. In this study, findings were higher than results reported for New Zealand, European/American dairy and Belgian Blue, HF bulls by Keane (2003), but were lower than the declaration made by Hollo et al. (2012) and Ito et al. (2012).

FCS was lower than the values reported by Keane (2003) and Hollo et al. (2012), who determined a significant effect based on breed, but was similar to the findings reported by Tagliapietra et al. (2018). The pH did not, significantly, differ among breeds. A similar explanation was declared for Aberdeen Angus, Limousin, Aberdeen Angus × Limousin (Pesonen et al., 2012) and Angus, Belgium Blue, Charolais, Hereford, Limousin, Parthenaise, Salers and Simmental bulls (Cafferky et al., 2019).

The L* value making a significant difference was the highest for EAR bulls, whereas the lowest one was measured for HFEAR. Contrary to this result, Aberdeen Angus, Limousin, Aberdeen Angus x Limousin (Pesonen et al., 2012), Angus, Belgium Blue, Charolais, Hereford, Limousin, Parthenaise, Salers, Simmental (Cafferky et al., 2019), Angus, Holstein (Ünlü and İpçak, 2021) and Friesian, Piemontese × Friesian and Limousin × Friesian (Alçiçek et al., 2003) bulls had no significant values. Similarly to current study findings Pesonen et al. (2012) reported a significant difference for a* among breeds, and Aberdeen Angus x Limousin bulls was the highest in comparison with the other breeds. However, a* and b* parameters were not significant among breeds in some studies (Alçiçek et al., 2003; Pesonen et al., 2012; Cafferky et al., 2019; Ünlü and İpçak, 2021).

Differences in *Longissimus thoracis* tenderness, juiciness, and flavour value of Holstein Friesian × Hereford, Holstein Friesian × Limousin and Holstein Friesian × Charolais crosses were not significant in some studies. This declaration was not consistent with current study results. However, it was inferred from results declared by Ünlü and İpçak (2021) that there was a significant difference in flavour between Holstein and Angus and was not for juiciness. Özlütürk et al. (2004) reported significant differences in tenderness and flavour for Eastern Anatolian Red, Simmental × Eastern Anatolian Red and Charolais × Eastern Anatolian Red bulls in *Longissimus dorsi* but the difference in juiciness was not significant. Also, Diler et al. (2023) found that Holstein young bulls had higher tenderness values but not similar juiciness and flavour as the old group. In the study, purebred Holstein performed, generally, better in sensory analysis than other breeds.

CONCLUSION

In conclusion, the Drs% of HF and HFEAR bulls raised at high altitudes were generally similar to those at low altitudes. Breed had a significant effect on slaughter traits such as FW, HoW, Drs, HeW, FFW, HiW KidW, LivW, PFW, on carcass measurements such as CarL, RoL, RoW, on carcass characteristics CarC, FCS, FatT, LDA, and on meat quality such as L*, a*, b*. With respect to breed, HF had the highest FW, HoW, Drs, HeW, FFW, HiW and moderate KidW, HFEAR had the highest CarL, while EAR scored the highest for FatT, L* and b*. Contrary to some prejudices, this study supports the hypothesis that HF and their crossbred had meat production potential under high altitude environmental conditions.

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