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ORIGINAL ARTICLE

Sensory and texture profile analysis of meat from heifers and bulls of different breeds reared in plateau conditions

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Abstract

This experiment aimed to determine the effects of breed and sex on the sensory and instrumental characteristics of meat from heifers and bulls reared in plateau conditions. The groups consisted of 36 animals: Brown Swiss × Eastern Anatolian Red (BSEAR), Holstein Friesian × Eastern Anatolian Red (HFEAR), and Brown Swiss × Holstein Friesian (BSHF). Sensory scores differed significantly among breeds ($P<0.01$), with BSHF receiving the highest tenderness score (6.51 ± 0.194). The sensory analysis values determined for males were higher than those of samples belonging to females ($P<0.01$). Adhesiveness was significantly higher in HFEAR samples compared to the other groups (-0.018 ± 0.010, $P<0.05$). Cohesiveness was significantly higher in BSEAR and BSHF (0.609, 0.616 ± 0.021 respectively, $P<0.05$). Hardness, chewiness, and gumminess were significantly higher in females ($P<0.01$). There was no significant correlation between Texture Profile Analysis (TPA) and sensory parameters. The distribution of cumulative variance in Principal Componenet Analysis (PCA) showed extensive variation for breed and sex. In conclusion, this study provides insights that could be valuable for producing high-quality meat under plateau conditions.

Keywords Beef production · Meat quality · Principal componenet analysis · Plateau production

Introduction

Meat quality is primarily defined by traits that consumers find desirable, such as appearance, texture, and consistency (Lee et al. 2012), in general, textural structure and tenderness are considered the most important palatability trait (Warner et al. 2010). Therefore, as texture of meat could occure even more important than color or flavor (Saláková 2012), determination and dissemination of new production strategies based on consumer preference ranked among our priority justifications. Although in different regions have, partially, different meat production preferences, they have, generally, been overshadowed by feedlot systems due to commercial considerations. However, researchers and breeders need to identify alternatives to this monotype production model and industrialize methods of producing quality animal protein or meat, especially, by bringing the results obtained into the literature. Considering all these basic factors, this study was designed to comparatively evaluate of sensory and instrumental analyzes of beef meat on the basis of breeds and genders, which is a major deficiency in the literature. In addition, this study carries additional content in terms of

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originality and added value by being conducted for highland conditions.

Recently, the trend in consumer preferences has brought to the agenda the necessity of replacing the uniform rearing based on certain breeds in feedlots with production models based on confidential, material diversity and untouched resources such as plateau. Such preferences, which are on the agenda, create a reason to determine the texture characteristics of male and female beef produced in the plateau condition having reliable sources, where there is currently no literature information.

The researchers reported that texture and flavor values in beef mainly depend on characteristics of the animal such as breed, sex (Huff and Parrish 1993; Zembayashi et al. 1995 2011), rearing and feeding condition (Aalhus et al. 1992). On the other hand, studies were carried out to tenderize the meat of hard-meat animal breeds using some biochemical methods (Yayuan et al. 2022), as consumers were even willing to pay a premium for qualified, confidential and more tenderness meat (Boleman et al. 1997). In determining this character of meat the texture profile analysis (TPA) is widely used method, as well as sensory analysis. This test that has been used in both raw and cooked meat provides a set of variables defining the rheological characteristics of meat (Choe et al. 2016).

The purpose of this study was to determine the sensory and instrumental (TPA) values of young female and male cattle meat in order to produce qualified animal protein and meat in natural and reliable feed sources such as plateaus, to create new production models and to ensure profitable use of resources.

Materials and methods

Animals, study area and feeding

The study was carried out in Eastern Anatolian Agricultural Research Institute, 39°55′15.49″N, 41°17′12.90 E coordinates, and altitude of 1850 m in Türkiye. Animals comprised of 12 heads F_1 (6 male, 6 female) Brown Swiss × Eastern Anatolian Red (BSEAR), 12 heads F_1 (6 male, 6 female) Holstein-Friesian × Eastern Anatolian Red (HFEAR), 12 heads F_1 (6 male, 6 female) Brown Swiss × Holstein-Friesian (BSHF). Follow-up was initiated for fattening following birth. In calf period, they were fed with milk at 10% of birth weight, concentrate-I (dry matter (DM) 88.0%, crude protein (CP) 18.0%, ash 7.1) and, ad libitum, a hay (DM 92.26%, CP 10.13%, Acid Detergent Fiber (ADF) 39.55%, Neutral Detergent Fiber (NDF) 62.4%, ash 10.4%) under similar conditions in boxes individually and were weaned at 63 days of age. To 180 days from the weaning, the animals were fed 2 kg/day concentrate-II (DM 88.0%, CP 17%, ash 7.7%), ad libitum dry hay and oat (DM 30.0%, CP 11.30%, ADF 37.82%, NDF 54.0%, ash 8.98%) in equal mix. Then the animals were fed a ration consisting of dry hay, oat, fresh mowed green hay and concentrate. They were fed 4 kg/day/head concentrate-III (DM 90.25%, CP 16.45%, ash 9%) and ad libitum dry hay and oat until at the age of 16 months as a group. Until 20 months of age, they were fed with 4 kg/day/head concentrate-III, 2 kg/day/head dry oat and ad libitum fresh mowed green hay (DM 24.95%, CP 17.00%, ether extract (EE) 3.65%, ash 10.62%). The male and female animals were kept as a group in the paddocks which was size of 8 × 21 and 8 × 15 m, respectively. All animals were sent to slaughter at the age of 20 months.

Slaughtering and sampling

The animals were weighed on two consecutive days and then was dispatched to the slaughter. After the transportation, they were let to rest about 2 h, and then sent to slaughtering. This process was carried out in the Meat and Milk Institution abattoir which has a modern status. Carcasses were chilled for 24 h in cooling units at 4 °C. Then, the Longissimus dorsi (LD) was extracted from the left half carcass between the 6th and the 13th ribs and cut into two piece.

Samples preparation and sensory analysis

Meat samples for organoleptic testing and TPA analysis were cooked in a plastic bag, in a water bath at 90 °C until they reached an internal temperature of 70 °C as declared by Özlütürk et al. (2004). Cooking loss was calculated by dividing cooked weight by uncooked weight by recording uncooked and cooked weights of the samples. The cooked samples were portioned into sections of uniform dimensions (approximately 1 × 1 × 1 cm), and were randomly served to the panel members. Four male and four female panellists evaluated cooked samples for tenderness, juiciness, flavor and general acceptability on using a nine-rating scale (9 = extremely tender, 1 = extremely tough; 9 = extremely juicy, 1 = extremely dry; 9 = extremely strong flavor, 1 = extremely weak flavor; 9 = extremely high general acceptability, 1 = extremely less acceptability). Number of chews before swallow (NCBS) made according to describing was determined by the panel members.

Samples preparation and TPA tests

Meat samples for TPA analysis were cooked in a plastic bag, in a water bath at 90 °C until they reached an internal temperature of 70 °C as reported by Özlütürk et al. (2004). Cooked samples were subjected to texture profile analysis

(TPA) using a texture analyzer (TA.XTplus, Stable Micro Systems Ltd, Godalming, Surrey, U.K.) equipped with a cylindrical metal probe (35 mm) (P/35) using a 30 kg load cell. 20 mm cooked meat cubes were cut parallel to the longitudinal orientation of the muscle fiber. The muscle fiber axis of the cube was perpendicular to the movement of the probe, and the sample was twice compressed to 30% of its original height. TPA test was carried out under conditions 1.0 mm/s pre-test speed, 2.0 mm/s test speed, 2.0 mm/s post-test speed, 10.00 g trigger force, 5 s time. Texture parameters such as firmness, cohesiveness, springiness, adhesiveness and chewiness were calculated from a force– time graph. Firmness is the height of the 1st peak; adhesiveness is the first negative area; cohesiveness is the second positive area divided by the first positive area; springiness is the time of second bite divided by the time of first bite. Chewiness is a secondary instrumental property, resulting from the product of hardness, cohesiveness, and springiness, and defined as the energy required to masticate a solid food product to a state ready for swallowing.

Statistic analysis

Statistical analysis was performed by two-way Analysis of Variance (ANOVA) using General Linear Model (GLM) procedures in SPSS (SPSS 2020). The Duncan method was applied for comparison of subclass means when F - tests for main effects were significant. The data on the sensory analysis and TPA were analysed by a statistical model that included the effect of breed, sex, breed and sex interaction. The effects of breed and sex on measurements parameters were determined by the following model:

$$Y_{ijk} = m + A_i + B_j + (AB)_{ij} + e_{ijk}$$

where, Y_{ijk} is the value of the analyzed parameter, μ is population mean, A_i is the effect of breed (1, 2, 3), B_j is the effect of sex (1, 2), $(AB)_{ij}$ is the breed × sex interaction, and e_{ijk} is random error. Principal component analysis (PCA) was performed for the breed and sex as supplementary data to highlight the associations between the loadings of the variables. In this process, there was used the varimax rotation and centroids were plotted.

Results

Assessment of sensory tests

Although, meat in terms of physical have being generally assessed mechanical, its texture characteristics might not be meaningful if they are not corroborated by sensory testing (Ruiz de Huidobro et al. 2005). But it is important that panel is done by experienced people. The sensory analiysis and cooking loss of LD for the breed and sex were shown in Table 1. In the study, breeds showed no significant differences for cooking loss and sensory parameter (except tenderness) compared with each other ($P>0.05$). The tenderness exhibited significant differances in sensory testing referred to breed. BSHF had the highest value for tenderness ($P<0.01$).

Table 1 Least squares means and standard errors for sensory analyses and cooking loss in research

VS	Tenderness	Juiciness	Flavor	NCBS	GA	CL (%)
BSEAR	5.82^{b}	5.90	5.97	58.99	5.80	28.35
HFEAR	5.25^{c}	5.93	5.71	59.74	5.47	30.27
BSHF	6.51^{a}	5.75	6.03	60.18	5.87	29.23
s.e.	0.194	0.179	0.178	2.640	0.196	1.521
b.e. (*p* value)	<0.01	0.187	0.501	0.098	0.280	0.087
Male	6.84	6.24	6.30	49.70	6.20	26.18
Female	4.88	5.49	5.50	69.57	5.22	32.38
s.e.	0.164	0.14	0.143	2.10	0.158	1.242
g.e. (p value)	<0.01	<0.05	<0.01	<0.01	<0.01	<0.05
BSEAR × m	6.97^{b}	6.17^{ab}	6.50^{a}	49.42^{d}	6.35^{ab}	26.59^{c}
BSEAR × f	4.67^{c}	5.63^{b}	5.44^{b}	68.55^{b}	5.25^{b}	30.11^{b}
HFEAR × m	5.71^{bc}	6.08^{ab}	5.62^{b}	55.48^{c}	5.27^{b}	27.34^{c}
HFEAR × f	4.80^{c}	5.77^{b}	5.80^{ab}	64.00^{b}	5.66^{b}	33.20^{a}
BSHF × m	7.85^{a}	6.45^{a}	6.79^{a}	44.20^{d}	7.00^{a}	24.62^{c}
BSHF × f	5.16^{bc}	5.05^{c}	5.27^{b}	76.16^{a}	4.75^{c}	33.83^{a}
s.e.	0.274	0.250	0.247	3.65	0.274	2.151
b*g (*p* value)	<0.01	<0.05	<0.01	<0.01	<0.01	<0.01

VS, Variation source; BSEAR, Brown Swiss × Eastern Anatolian Red; HFEAR, Holstein Friesian × Eastern Anatolian Red; BSHF, Brown Swiss × Holstein Friesian; NCBS, Number of chews before swallow; GA, general acceptability; CL, Cooking loss; m, Male; f, Female; s.e, Standard error; b.e, Breed effect; g.e, Sex effect; b*g, Breed and sex interaction a-c: values that show with different letters in the same column are statistically different from each other

Table 2 Least squares means and standard errors for TPA in research

VS	Hard	Adhe	Cohe	Spri	Chew	Gumm
BSEAR	32.710	−0.032[b]	0.609[a]	0.693	14.596	20.183
HFEAR	39.792	−0.018[a]	0.541[b]	0.620	14.737	20.836
BSHF	37.823	−0.026[ab]	0.616[a]	0.692	16.685	23.013
s.e.	2.791	0.010	0.021	0.030	1.522	2.060
b.e. (p value)	0.178	<0.05	<0.05	0.164	0.555	0.597
Male	26.333	−0.025	0.575	0.652	10.185	14.782
Female	47.219	−0.026	0.602	0.684	20.494	27.906
s.e.	2.270	0.011	0.021	0.023	1.241	1.682
g.e (p value)	<0.01	0.867	0.366	0.368	<0.01	<0.01
BSEAR*f	40.692[b]	−0.030	0.652[a]	0.737	19.491	26.426
BSEAR*m	24.737[c]	−0.034	0.565[ab]	0.648	9.702	13.941
HFEAR*f	56.759[a]	−0.025	0.652[a]	0.733	21.336	28.866
HFEAR*m	22.825[c]	−0.028	0.579[a]	0.650	12.034	17.160
BSHF*female	44.208[a]	−0.022	0.501[b]	0.583	20.655	28.425
BSHF*male	31.438[b]	−0.014	0.580[ab]	0.658	8.819	13.247
s.e.	3.813	0.005	0.036	0.043	2.081	2.819
b*g (*p* value)	<0.05	0.491	<0.05	0.103	0.816	0.816

VS, Variation source; Hard, Hardness; Adhe, Adhesiveness; Cohe, Cohesiveness; Spr, Springiness; Chew, Chewiness; Gumm, Gumminess; BSEAR, Brown Swiss × Eastern Anatolian Red; HFEAR, Holstein Friesian × Eastern Anatolian Red; BSHF, Brown Swiss × Holstein Friesian; m, Male; f, Female; s.e, Standard error; b.e, Breed effect; g.e, Sex effect; b*g, Breed and sex interaction a-c: values that show with different letters in the same column are statistically different from each other

Table 3 Pearson correlation values among TPA and sensory testing parameters

	Hard	Adhe	Cohe	Spri	Chew	Gumm
Tenderness	0.068	−0.192	−0.039	−0.075	0.038	0.059
Juiciness	−0.091	−0.190	0.152	0.095	0.020	0.020
Flavor	−0.018	−0.122	0.417*	0.170	0.108	0.100
GA	0.082	−0.143	0.091	0.041	0.107	0.111
NCBS	0.164	0.181	0.084	0.105	−0.100	−0.105
CL	−0.150	0.111	0.097	0.080	−0.089	−0.085

NCBS, Number of chews before swallow; GA, General acceptablity; CL, Cooking loss; Hard, Hardness; Adhe, Adhesiveness; Cohe, Cohesiveness; Spri, Springiness; Chew, Chewiness; Gumm, Gumminess, *: $p<0.05$

The sex affected significantly tenderness ($P<0.01$), juiciness ($P<0.05$), flavor ($P<0.01$), NCBS ($P<0.01$), general acceptability ($P<0.01$) and cooking loss ($P<0.01$) values, in favour of male, meanwhile there was significant influence of breed and sex interaction on these parameters ($P<0.05$ to $P<0.01$).

Assessment of texture profile analysis (TPA)

The instrumental texture measurements of the Longissimus dorsi muscle for breed and sex, and their combinations were shown in Table 2. It was found that variation sources (breed and sex) significantly affected some instrumental texture parameters. On the other hand, the interactions between breed and sex were significantly in hardness and cohesiveness parameters, consequently the interpretation of the main effects was important. Hardness, chewiness, gumminess in meat samples of current study was affected by sex ($P<0.01$), but not breed. The breed affected significantly ($P<0.05$) adhesiveness and cohesiveness values, meanwhile there was no significant influence of sex on these parameters.

Correlation index for TPA and sensory testing

The correlation between the sensory and TPA parameters of beef samples were shown in Table 3. In this study, tenderness was lowly correlated with hardness, andchewiness, cohesiveness, springiness, chewiness and gumminess in TPA, these correlations were negatively with andchewiness, cohesiveness, springiness. Flavor had more correlation with the cohesiveness ($P<0.05$). In that vein, the correlation that was between hardness and cooking loss was also lowly and negatively.

The principal component analysis (PCA)

The Principal component analysis (PCA) aimed to obtain a reduced number of principal components (PC) which would explain the course of change of the parameters.

The graphs that multidimensional space based on breeds and sexes was reported in biplots for sensory analysis and TPA analysis (Figs. 1 and 2, respectively). Total variance explained for sensory analysis in BSEAR female was 74.33%. In this section, the PC1 possessed 50.29% of percentage variance, was mainly associated with juiciness, flavor, GA, NCBS parameters. All parameters (except GA) were associate positively PC1 and PC2. PC2 that was connected with tenderness and CL possessed 24.04%. Total variance explained for sensory analysis in BSEAR female was 74.33%. Tenderness, flavor and NCBS were positively associated with PC1 and PC2, but were negatively correlated PC2 with GA and CL.

While the first two principal components accounted for 66.31% of total variance (PC1 42.76%, PC2 23.54%) in HFEAR female, was formed 70.66% (PC1: 46.30%, PC2: 24.35) in male (Fig. 1). Sensory parameters and CL were placed the positive side of the y axis in both females and males, but correlated negatively juiciness with flavor, NCBS and GA in female. And it was assessed that had negative relation tenderness, CL with juiciness, flavor, NCBS, GA in males.

The total variance load of sensory analysis to the BSHF female and BSHF male were calculated, and the results were as follows: total variance for two main components: 72.43% and 76.35% (female and male, respectively), 53.89% and 18.54% (PC1 and PC2, respectively) in female, and 43.15% and 33.20% (PC1 and PC2, respectively) in male. All sensory parameters (except CL, GA for females and CL for males) were in positive side of the y axis.

It was explained that total variance for TPA analysis in BSEAR female was 85.25% (PC1: 52.90%, PC2: 32.74%). Springiness, chewiness, gumminess were positive side of x, y axis. These parameters correlated negatively hardness and cohesiveness, and were distance with adhesiveness (Fig. 2). All TPA parameters of males were positive side of y axis (PC1: 61.13%, PC2: 27.52%), but hardness, chewiness, gumminess correlated negatively others.

All parameters of TPA in HFEAR breed were positive side of abscissa axis (except adhesiveness for female and hardness for males). Main components of variance were for female and male 59.34%, 22.92% and 51.35% and 33.60% (PC1 and PC2 respectively).

Total variance explained for TPA in BSHF female was 88.16%. The PC1 possessed 64.39% of percentage variance, was mainly associated with chewiness, gumminess, hardness. The TPA parameters in males were positive side of x axis (except adhesiveness) (PC1: 58.21% and PC2: 19.85%).

Discussion

Assessment of sensory tests

Fed based on plateau condition for qualified meat production was associated with breed and sex, and effects on tenderness of these resources of variation was determined through sensory analysis. In the present study, it had significant differences among breeds for tenderness. These differences among breeds maybe be due to the within breed variability being high and that the subjective nature of evaluating sensory traits leading to greater variation in values (Conanec et al. 2021). Concerning for tenderness, showing similar results with our study was conducted the studies. An earlier study by Conanec et al. (2021) reported a significant effect of breed on the tenderness values of 15 European breeds, reared under as similar conditions as possible. In the same line, Canozzi et al. (2016) studied the effect of breed in commercial herds consisting of cattle and buffalo and concluded that breed has a significant effect on the tenderness of meat. Examining the tenderness feature of meat in terms of sex, similar to the present study, differences were significantly for tenderness compared sexes that fed a total mixed ration (TMR) composed of grass silage, concentrate I (to body weight of 300 kg) and concentrate II (at body weight above 300 kg) in a semi-intensive production system such as bulls, steers, heifers (Pogorzelska-Przybyłek et al. 2021). In contrast, in study by Canozzi et al. (2016) beef belong males had by greater tenderness than beef from females, but difference was not significant statistically. This result was not coherent our findings.

Concerning juiciness characteristic of meat samples, HFEAR, showing a higher value, was found to be more remarkable in terms of juiciness than BSEAR and BSHF, but differences were not significantly. Similar to our findings, an earlier study by Canozzi et al. (2016) reported no effect of raised in a pasture-feeding system on juiciness in meat of comparable such as cattle (5.60 for Angus and 6.02 for Brangus) and buffalo (5.75 for Bubalus) breeds. In the same line, Özlütürk et al. (2004) studied the values on juiciness in meat of breed in fed ad libitum access to concentrate and dry alfalfa during whole fattening period and concluded that breed had a significant no effect on the juiciness of meat. However, Conanec et al. (2021) recently reported more different results in the 15 European young bull breeds which were come from five European experimental stations and reared under as similar conditions as possible. They concluded result to be significant differences of juiciness values in meat of the breeds. In current study, the juiciness values were in range 5.49 (female) −6.24 (male) and showed higher values in samples provided from males. Whereas, literature report on this subject (Domenech et al. 2017), sex significantly did not

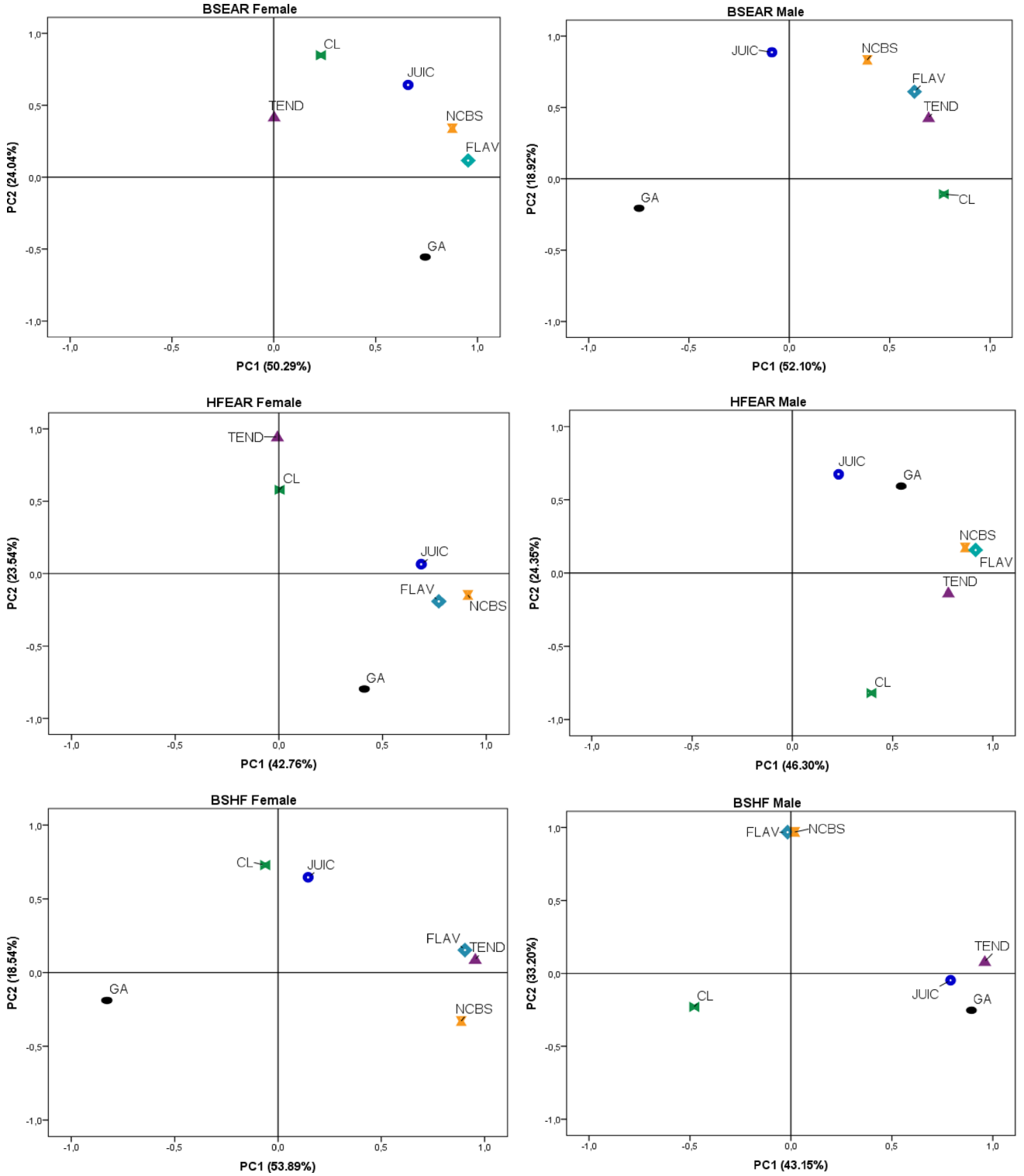


Fig. 1 Principal component analysis for sensory analyses. BSEAR: Brown Swiss × Eastern Anatolian Red, HFEAR: Holstein Friesian × Eastern Anatolian Red, BSHF: Brown Swiss × Holstein Friesian, TEND: tenderness, JUIC: Juiciness, FLAV: flavor, NBCS: number of chews before swallow, GA: general acceptability, CL: cooking loss

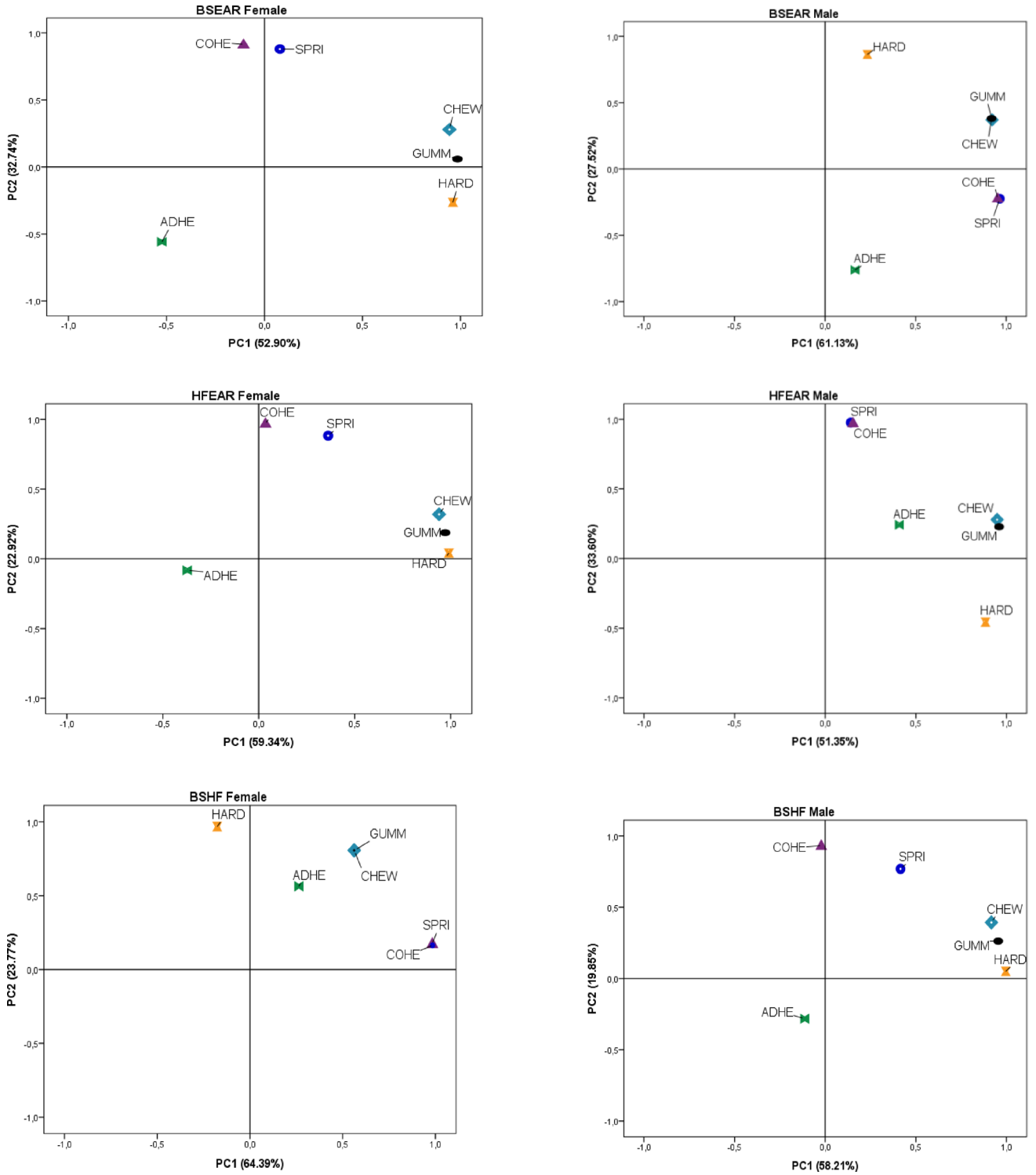


Fig. 2 Principal Component Analysis of Texture Profile Analysis (TPA) for breeds and sexes. BSEAR: Brown Swiss × Eastern Anatolian Red, HFEAR: Holstein Friesian × Eastern Anatolian Red, BSHF: Brown Swiss × Holstein Friesian, HARD: Hardness, COHE: Cohesiveness, ADHE: Adhesiveness, GUMM: Gumminess, CHEW: Chewiness, SPRI: Springines

affect the juiciness value of meat samples and the values were similar for males and females in commercially raised herds.

Studies to improve the flavor of beef meat by treatment with soy, yeast (Grasso et al. 2019) and similar flavor enhancers have a recent rising trend. However, the most acceptable of achieving this result is the one that occurs naturally, as we have adopted as a purpose in this study. In this study, the flavor values of meat samples obtained from different breeds did not show a statistically difference as analyzed by panelists. By contrast with, Conanec et al. (2021) studied the flavor variation of 15 European young bull breeds belong five European experimental stations and reported that with breed difference, the flavor in meat chenged, thereby concluding that flavor could been influenced by breed factor. Likewise, Özlütürk et al. (2004) reported a variation in the flavor of meat samples when the breed that fed with concentrate and ad libitim dry alfalfa became change. Studies including the effect of sex on the flavor value of meat in cattle through sensory analysis have currently not found. In this study, which we designed taking into consideration this issue, we could not include any literature discuss related to this issue.

Texture of the meat before chewing even though meat properties after intra-oral transformation affect, it depend on better its tendernes and juiciness (Mioche et al. 2002). This state is of great importance for consumption and digestion. Because, NCBS is effective on substantially reduces meal size in different weight adults (Zhu and Hollis 2014). There is currently, not much literature information available explaining the NBCS values of beef, either by breed or by sex. In the present study, there was no impact between breed and NBCS value, while there was a significant result with sex. Although this might be seen as a contrariety, in terms of being more flavor, it might be thought to be due to the fact that the panellists were more willing to chew tender and juicy meats. As to the relevance of the ıssue to the literature, contrary to our findings, Özlütürk et al. (2004) used different bulls such as Eastern Anatolian Red, Charolais and Simmental to obtain quality meat and reported significant difference in terms of NCBS among breeds that fed with concentrate and ad libitum dry alfalfa during experiment.

Considering consumer preferences into the meat production process can design better and acceptibilty product. In line, the visual impressions based on intrinsic and extrinsic cues, such as sensory characteristics and appearance of a product, can seen to be an important indicator that may explain beef quality expectations (Bello Acebrón and Calvo Dopico 2000). In the present study, the breed did not affect GA. In the present study, the breed did not affect GA. In the same line, Canozzi et al. (2016) compared different breeds that fed under pasture-feeding system conditions such as Angus (cattle), Brangus (catle) and Bubalus (buffalo) and reported no significant difference in the GA of breeds. In contrast, other researchers reported to be significan differences among Simmental, Charolais and Eastern Anatolian Red bulls that fed concentrate and ad libitum dry alfalfa during experiment (Özlütürk et al. 2004). Sex which is one of the most crucial factors for meat production reflects the sensory properties of the product. Hence considering of sex in terms of GA during manufacturing and processing is essential in the meat production sector. In current study, we observed between sexes that were significant differences for GA. Contrary, in a related investigation, Canozzi et al. (2016) used pasture characterized as grassy-woody savanna (native grassland) and observed no differeces between sexes for GA. In the same line, Domenech et al. (2017) determined the GA values for females and males that were reared to be commerical herd 4.60 and 4.56, respectively, and were not significant difference.

In the current study, cooking loss% was associated with sex, but not breed. There were findings relating breed to cooking loss, contrary to our results. Cafferky et al. (2019) examined Angus, Belgium Blue, Charolais, Hereford, Limousin, Parthenaise, Salers and Simmental bulls that fed ad-libitum concentrate diet with 3 kg of fresh hay for cook-loss% and found significance differences; alike, when comparing Nguni, Bonsmara and Angus bulls for cook-loss, Jama et al. (2008) found Nguni bulls to be significantly different. On the other hand, according to the results of the present study, it associated sex and cooking loss, and was seen to be having cooking loss% lower in males, and results were discussed with proper literatures. Cafferky et al. (2019) found sex effect between bulls and steers that fed 8 kg of concentrates and 5 kg of hay for cooking loss%, and the result, contrary to our findings, was higher in males. But, Pogorzelska-Przybyłek et al. (2021) were not noted a significant difference for cooking loss among bulls, steers and heifers thad fed a total mixed ration (TMR) composed of grass silage, concentrate I (to body weight of 300 kg) and concentrate II (at body weight above 300 kg) in a semi-intensive production system.

Assessment of texture profile analysis (TPA)

Basic mechanism that influence hardness of meat are meat proteins and water content in the muscles (Pematilleke et al. 2022). This mechanism can be shaped under the influence of some factors. It was not found directly reference for the effect of the cattle breed and sex, which were considered as a source of variation in this study, on the TPA hardness value. Thus, discussions were made according to the literature reports closest to the subject.

In the current study, for hardness, meat samples received similar values for breeds, indicating that breed did not significantly impact the hardness properties of meat. On the other hand, females showed higher value in hardness attribute compared to males, suggesting that sex had a

significantly effect on the hardness of meat. The effect of breed and sex on hardness were discussed with currently available literatures informations. Contrary to our findings, Ripoll et al. (2019) reported effect to be on hardness in cooked longissimus lumborum muscle of breed in different eight goat breeds reared by feding milk replacer or natural milk from thir dams in two or three farms per breed in their respective local areas. In the same line, it was determined effectively on meat hardness of breed in rabbits that fed ad libitum commercial complete pelleted feed with 10.2 MJ of metabolic energy, 16.5% during seven weeks by Kozioł et al. (2017). As for discussing this character in terms of sex, Kozioł et al. (2017) reported that fed ad libitum commerical complete pelleted feed, and housed in a battery system for commercial rearing of rabbits, in metal cages without litter, and concluded that no effected of sex on hardness of meat. This declaration was not coherent our result. Similary, significant differences were not found when comparing hardness values from of the muscle longissimus thoracis et lumborum of males and females lambs of Rubia de El Molar breed that reared in an intensive regime (Miguel et al. 2021).

Adhesiveness that is negative area under the base line between the two compressions cycles is relevant (Pematilleke et al. 2022) with loss of water and fat from meat (Vasanthi et al. 2007). Literature information that related with studies conducted on this ıssue was very limited. Therefore, there was almost no literature reporting directly the effects of breed and sex. In this context, the literature reports that could be evaluated as closest to the subject were discussed. This character might be influenced by breed, as in current study. Rippol et al. (2019) reported differences in adhesiveness of meat different goat breeds reared on two or three farms per breed in the irrespective local areas, supported our findings.

Cohesiveness that defined as a measure of the strength of internal bonds in a sample (Botinestean et al. 2016), and chewiness that is a product of hardness, cohesiveness and flexibility (Pematilleke et al. 2022), are instrumental analysis parameters with an integrated effect. We could not find any study about effect of cattle breed and sex on instrumental cohesiveness, springiness, chewiness and gumminess; therefore, we discussed the data with closest instrumental cohesiveness data currently available in literature. Concerning cohesiveness, our results was confirmed by findings a previous researche conducted with different goat breeds that fed with milk replacer and whole milk having different chemical composition by Ripoll et al. (2019) i.e. that breed factor made statistically significant effcet cohesiveness characteristic of meat. However, different results regarding the impact between breed and cohesiveness were also reported. Breed factor no significantly effected the cohesiveness value of meat in rabbit housed in a battery system for commercial rearing, in metal cages without litter (Kozioł et al. 2017). As for effect of sex factor, in the same study no effected the cohesiveness value of meat (Kozioł et al. 2017) and the notice promoted our findings.

In the current study, springiness characteristic belonging to meat samples were influenced by neither breed nor sex. In agreement with our results, Rubia de El Molar ovine breed reared in an intensive regime (Miguel et al. 2021) and different breed rabbits housed in a battery system for commercial rearing (Kozioł et al. 2017) did not indicate differences in springiness values of meat between breeds and sexes. It was, however, significantly the springiness differences among Florida, del Guadarrama, Majorera, Palmera, Payoya, Retinta, Tinerfeña and Verata goat breeds when considered results reported by Ripoll et al. (2019).

In this study, while the chewiness and gumminess related sex, they was not related with breed. These results were discussed with existing literature declarations. Kozioł et al. (2017), in a study conducted in order to determine effect of meat samples chewiness value in five rabbit breeds obtained no significant difference between sexes, contrary to our findings. In the same line, Miguel et al. (2021) studied the effect of sex in lamb of Rubia de El Molar ovine breed that fed in intensive regime, and had a no significant effect on the chewiness value of meat. On the other hand, Ripall et al. (2019) declared in eight goat breeds that fed milk replacer and whole milk had significant differences for chewiness of meat among breeds, contrary to our results.

Correlation index for TPA and sensory testing

Correlations obtained between sensory and instrumental texture parameters in meat are usually very low (Caine et al. 2003), as it are used such as TPA that imitate mastication (Guerrero and Guardia 1999). In the present study, a similar result was observed. But it was found that the correlation values between sensory analysis and instrumental analysis followed a genuine course. In previous work by Ruiz de Huidobro et al. (2005) texturometry on cooked cattle meat was studied, and they found that sensory hardness value was, in low degree, significantly correlated to TPA hardness value, contrary to our results. According to same team, TPA hardness, TPA springiness and TPA chewiness were negative and significantly correlated to sensory juiciness. This declaration, in our study, was only similar for value between TPA hardness and sensory juiciness. Unlike our findings, TPA hardness and TPA chewiness parameters alone were positively and significantly correlated to the number of chewings (Ruiz de Huidobro et al. 2005). According to Caine et al. (2003), hardness in TPA of left longissimus thoracis of beef carcasses was lowly negative correlated with sensory juiciness and flavor, but same parameter had lowly positive correlation with the sensory tenderness. Authors' declarations supported the

correaltion degrees determined between hardness with flavor and juiciness in the our study. While the authors found a low-grade negative correlation between cohesiveness and flavor, this value was moderately positive in our study. Pematilleke et al. (2022) studied the semitendinosus right and left muscles belonging to Black Angus and found that there was very high correlation between sensory hardness with TPA hardness and cooking loss, contrary to our findings belonging to same parameters. General acceptability values in the study were positively correlated to the following instrumental variates: hardness, cohesiveness, springiness, chewiness, gumminess. NCBS was correlated to hardness, adhesiveness, cohesiveness, springiness positvely, and to chewiness and gumminess negatively. But TPA parameters showed not much correlation to cooking loss that had some positive some negative value.

The graphs that multidimensional space based on breeds and sexes was reported heterogeneous distribution in biplots for sensory analysis. The coordinates of meat samples for sensory analysis indicate that meat obtained from breeds and sexes is located in the positive or negative part of the PC1 and PC2 factors. This show that meat from animals of different breeds and sexes is separated by texture and sensory characteristics, but also by CL. PC1 had high correlations with all attributes except ADHE and HARD for TPA in BSEAR female, while PC2 shown positive correaltions with all treats for BSEAR male. ADHE was highly and negatively correlated with PC1 in HFEAR female, while all the attributes were highly and positively correlated with the PC2 factor in HFEAR male. PC1 indicated positive correlations with all TPA attributes in BSHF female, but PC2 shown negative correlations with COHE and ADHE in males. The coordinates of meat samples shown that meat from different breeds and sexes placed heterogenic in the positive and negative parts of PC1 and PC2. This indicates that meat from animals of different breeds and sexes were separated by TPA traits.

Conclusion

Combining the TPA results with those from sensory evaluation analysis showed that breed had an effect on tenderness, adhesiveness, cohesiveness, sex had an effect on tennderness, juiciness, flavor, NCBS, GA, CL, hardness, chewiness, gumminess. The main indexes reflecting the texture of young female and male cattle in TPA were hardness, cohesiveness, springiness chewiness and adhesiveness, while in the sensory evaluation, generally, juiciness, flavor and NCBS. Analysis of the correlation between the TPA and sensory evaluation showed that hardness was negatively correlated with juiciness, flavor, cooking loss but was positively correlated with tenderness, NCBS, GA. In PCA analysis, two principal components were obtained from the TPA indexes and sensory evaluation indexes, and was difference cumulative variance contribution rates. It was determined that there was a significant lack of literature information on the effect of breed and sex on both TPA and sensory test parameters. This study provided a certain contribution to eliminating the lack of literature knowledge. However, other studies neede also in this area.

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Author contributions SY planned the research, collected data, performed statistical analyses and wrote it. MMK performed TPA and evaluated the results. AK, BB and UŞ collected and evaluated the data. Each author contributed equally to the revision process and gave their approval for the final version of the manuscript. Sadrettin Yüksel: planning the research, application of research, measurement and evaluation of data, construction of statistical analysis and writing of the article. Mehmet Murat Karaoğlu: Evaluating and conducting of instrumental analyzes (TPA). Alpay Karaçuhalılar: Application of research, measurement and evaluation of data, carrying out rechecks. Burcuhan Balta: Application of research, measurement and evaluation of data, carrying out rechecks. Usame Şimşek: Application of research, health checks of experimental animals, carrying out rechecks.

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Data availability Available upon request. The data of this study are transparent to all scientific platforms.

Code availability Not applicable.

Declarations

Conflict of interest The authors have declared no conflicts of interest.

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

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