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Meat quality traits of male Herik lambs raised under an intensive fattening system

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Abstract: The aim of the study was to determine certain meat quality traits of Herik lambs finished under the intensive husbandry conditions. Twenty single male lambs with an average final weight of 42 kg were used in the study. Concentrate feed and fresh water were given ad libitum, whereas 300 g of alfalfa per lamb per day was provided. At 24 h postmortem, the pH levels were 5.51, 5.63, and 5.24 for musculus longissimus dorsi, musculus semitendinosus, and musculus semimembranosus, respectively. The corresponding Warner–Bratzler shear force values ($P < 0.001$) of cooked meat were 3.359, 2.318, and 3.601 respectively. At 24 h postmortem, the L*(42.18) and a* (19.95) values of Herik lambs were near the acceptable values of L*(34–35) and a*(19.00). At 72 h postmortem, cooking loss and water holding capacity were 34.78% and 10.55%, respectively. Chemical composition traits, namely dry matter (26.35%), protein (22.21%), ether extraction (2.98%), and ash percentage (1.02%), were similar to those of other indigenous breeds. Consequently, these results indicated that the meat of Herik lambs may be suitable for sale after the lambs are raised under an intensive fattening system.

Key words: Heriks, lamb, pH, meat quality

1. Introduction

In sheep breeding, carcass quality studies focused on appropriate carcass weight in an effort to increase meat production during finishing and thus feed the increasing human population around the world. However, meat quality is also important. In developed countries, various studies on sheep and lambs have been conducted to determine meat quality (1–3).

The majority of the sheep population in Turkey consists of indigenous sheep breeds, which are source for meat production. As in developed countries, various studies were performed to determine the meat quality characteristics of indigenous breeds in Turkey (4–8). However, there have been no studies on the meat quality traits of some indigenous lambs.

The Herik sheep is one of the indigenous genetic sources in Turkey. Herik sheep are distributed around the intersection point of the coastline of the Black Sea (Samsun, Trabzon, Rize) and inner regions (Amasya, Sivas, Çorum). The Herik genotype is considered to be produced by irregular crossbreeding of the Akkaraman, which is a fat-tailed breed and is raised predominantly in Central Anatolia, with the Karayaka, which is a long-and thin-tailed breed raised predominantly along the eastern half of the Black Sea coast and in the inner regions (9). The Herik genotype has an approximately 1000 head population and it is under threat of extinction in Turkey (10).

pH is the most widespread criterion for meat quality due to its effect on the technological process, storage, and sensorial characters (11). The normal pH value at 24 h postmortem is important for meat quality, and pH values greater than 5.80 are regarded as undesirable (12). pH is closely related to tenderness, meat color, and water holding capacity (WHC), which have an important effect on consumer preference.

Tenderness, an important criterion for determining meat quality, has been measured via a sensory panel and a Warner–Bratzler shear force (WBSF) device. It has been reported that there is a positive relationship between pH and WBSF, and increasing pH adversely affects meat quality because meat with WBSF values exceeding 5.50 kg will be evaluated as tough by consumers (13). Devine et al. (14) reported that WBSF increased when ultimate pH was increased from 5.40 to 6.00. Some studies have reported a relationship between ultimate pH and tenderness, specifically a broad peak in tenderness when ultimate pH is in the range of 6.05 to 6.10 (15). In another study, there was no reported relationship between ultimate pH and tenderness (16).

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Meat color is the most important criterion that consumers use in determining the freshness of meat, and it thus influences their purchasing decisions. The acceptability threshold values for L* and a*, which are measured with a chroma meter, are 34–35 and below 19, respectively, for lamb meat (17). A study on consumer preference regarding the quality of lamb meat reported the general tendency acceptability on average meat color and acceptable meat color for 95% of consumers as 34.00 and 44.00 for L* and 9.50 and 14.50 for a*, respectively (18).

The WHC of fresh meat is an important quality trait because it affects both the productivity and quality of the end product. It has been reported that there is a relationship between accelerated pH decline and WHC. Low water holding capacity and unacceptably high purge loss are caused by accelerated pH decline (19,20).

The chemical composition of meat indicates its ability to provide sustenance. It has been reported that the chemical composition of meat is approximately 75% water, 20% protein, 5% lipid or fat, 1% carbohydrates, and 1% vitamin/minerals. Protein and fat are important nutrition sources for humans. Moreover, intramuscular fat is necessary for meat tenderness (21).

As a contribution to efforts to increase the efficiency of the Herik genotype in sheep breeding, the current study aimed to investigate the meat quality of Herik lambs raised under intensive finishing conditions and to compare their meat quality traits with those of other indigenous sheep breeds.

2. Materials and methods

The study was performed on a private farm, situated at 41°N and 36°E, in Samsun Province, Turkey, where the altitude is approximately 171 m. The average ambient temperature and humidity at the site were 22 °C and 76%, respectively, during the study. Fifty-five millimeters of rain fell during the study period. Twenty male lambs that were 2.5–3 months of age with an average live weight of 20 kg were used. The lambs were fed in groups and concentrate feed and fresh water were given ad libitum, whereas 300 g of alfalfa per lamb per day was provided. The area allocated for each animal was 0.7 m^2 (9). The study was approved by the Ethical Committee for Experimental Animals of Ondokuz Mayıs University (HADYEK 2014/37). The lambs were fattened with diet-1 until they reached 30 kg and with diet-2 until they reached a final weight of 42 kg. They were finished for an average of 105 days under intensive fattening after weaning. The chemical composition of the diets was analyzed according to the protocol provided by the Association of Official Analytical Chemists (22). The chemical compositions of the concentrate feed and alfalfa are presented in Table 1. The lambs were slaughtered to determine their meat quality traits, as well as pH, WBSF, meat color, WHC, cooking loss (CL), and chemical composition traits when lambs reached a final weight of 42 kg. The carcasses were chilled at +4 °C for 24 h. Thereafter, carcass pH was measured immediately after dressing, at 45 min, and 24 h after slaughter, with digital pH meter (Testo 205, Testo Inc., Sparta, NJ, USA). The pH measurement was performed on longissimus dorsi muscle between the 12th and 13th thoracic vertebrae (5).

The meat color, WHC, and CL were analyzed in fresh longissimus dorsi muscle samples. These samples were packaged under vacuum and then kept at 4 °C for 72 h. WBSF, moisture, dry matter, ash, and protein analyses were performed on frozen meat samples kept at –18 °C.

Table 1. Chemical composition of concentrate feed and roughage.

Chemical composition of diets	Diet-1	Diet-2	Roughage (dry alfalfa)
Dry matter (%)	92.19	91.86	91.77
Crude protein (%)	17.89	16.94	17.44
Crude cellulose (%)	8.07	10.60	29.18
Crude fat (%)	3.08	3.13	3.03
Crude ash (%)	5.72	7.87	10.45
ADF (%)	12.59	13.17	34.12
NDF (%)	44.82	46.21	48.23
Metabolic energy (kcal/kg)	2682.88	2497.35	2231.12

ADF: Acid detergent fiber; NDF: Neutral detergent fiber
Diet-1: Used from initial weight until lambs reached 30 kg live weight
Diet-2: Used from 30 kg live weight until lambs reached final weight of 42 kg

The meat color parameters were measured at 0 min, 45 min, 24 h, and 168 h on the cut surface of 2.5-cm-thick samples from the fat-free area of the MLD. During the storage period, samples were kept at 4 °C in polystyrene trays and wrapped with oxygen permeable PVC film to allow blooming. Nine color measurements were performed for each sample and the color coordinate value was determined by calculating the average of these nine measurements. Meat color was evaluated using the CIELAB color space. L* (lightness), a* (redness), and b* (yellowness) values were obtained using a Minolta CR 400 colorimeter (Minolta Camera Co., Osaka, Japan) with illuminant D65 as the light source (5).

WHC was determined at 72 h, after slaughter as described by Barton-Gade et al. (23). CL was determined at 72 h; the sample was weighed and then cooked in a water bath at 80 °C for 1 h, as per the method described by Honikel (24).

Longissimus thoracis muscle between the 5th and 13th ribs was used for WBSF determination. The meat samples were cooked in a water bath at 75 °C for 1 h as described by Hoffmann et al. (25). Bags containing the cooked samples were then cooled under cold running water for 1 h, and then the cooked samples were removed from their respective bags and dried with a paper towel. The cooked samples were used to determine shear force. Six subsamples (cut parallel to the muscle fibers with a cross section of 1 × 1 cm) were removed from each cooked sample. Shear force values of the subgroups were evaluated using Instron 3343 equipped with a WBSF device and an average of six subsamples was regarded as the WBSF value of the related sample (5).

The moisture, dry matter, ash content, intramuscular fat, and protein were measured according to the protocol provided by the Association of Official Analytical Chemists (22).

pH, pH change, heat change, and color parameters (L*, a*, b*) were analyzed with one-way ANOVA and determination of the significance of differences between the groups was done with Duncan's test. CL, WHC, dry matter, crude protein, ether extract, and crude ash were determined with descriptive statistics (SPSS, Chicago, IL, USA).

3. Results

3.1. pH and WBSF

Means and standard errors for pH and WBSF values are presented in Table 2. The initial pH values for the musculus longissimus dorsi (MLD), musculus semitendinosus (MST), and musculus semimembranosus (MSM) were 6.29, 6.27, and 6.59, respectively. The corresponding values for normal pH at 24 h postmortem were 5.51, 5.63, and 5.24, respectively. pH was not significantly affected by the muscle chosen, while WBSF ($P < 0.001$) was affected. The MST (2.31) was tenderer than the MLD (3.35) and MSM (3.60) in the present study. The highest accelerated pH decline ($P < 0.05$) and the lowest heat change range from 0 to 45 min ($P < 0.001$) were found for the MST.

3.2. Meat color

Means and standard errors for meat color of the MLD are presented in Table 3. Meat color parameters (L*, a*, b*) increased until 24 h postmortem. However, the meat color parameters at 168 h postmortem were lower than those at 24 h postmortem. Moreover, significant differences were determined at 0 min, 45 min, 24 h, and 168 h for a* ($P < 0.001$) and b* ($P < 0.001$), while no differences were determined at 0 min, 45 min, 24 h, or 168 h for L*.

3.3. WHC, CL, and chemical composition

The means and standard errors for the WHC, CL, and chemical composition of the lambs are presented in Table 4. CL and WHC at 72 h postmortem were 34.78% and

Table 2. The pH and WBSF value of muscles for Herik lamb ($\overline{X} \pm S\bar{x}$).

Characteristics		n	MLD	MST	MSM	P
pH	0 h	20	6.297 ± 0.064	6.279 ± 0.064	6.259 ± 0.064	-
	45 min	20	6.240 ± 0.072	6.346 ± 0.072	6.140 ± 0.072	-
	24 h	20	5.518 ± 0.156	5.636 ± 0.156	5.244 ± 0.156	-
pH change	0 h–45 min	20	0.057 ± 0.049^{ab}	-0.067 ± 0.049^{b}	0.120 ± 0.049^{a}	*
Heat change	0 h–45 min	20	9.60 ± 0.817^{a}	5.69 ± 0.817^{b}	3.09 ± 0.817^{c}	***
WBSF kg/cm^2		20	3.359 ± 0.147^{a}	2.318 ± 0.155^{b}	3.601 ± 0.155^{a}	***

-: nonsignificant, *: $P < 0.05$, ***: $P < 0.001$,

a, b, c: Different superscripts indicate significant differences in the same line.

MLD: musculus longissimus dorsi, MST: musculus semitendinosus, MSM: musculus semimembranosus

Table 3. Meat color traits for Herik lambs.

L*	n	$\bar{X} \pm S\bar{x}$	a*	$\bar{X} \pm S\bar{x}$	b*	$\bar{X} \pm S\bar{x}$
$(L^*)^0$	20	40.90 ± 0.33	$(a^*)^0$	18.23 ± 0.28^b	$(b^*)^0$	2.08 ± 0.16^a
$(L^*)^{1h}$	20	41.42 ± 0.32	$(a^*)^{1h}$	19.60 ± 0.43^c	$(b^*)^{1h}$	5.51 ± 0.45^b
$(L^*)^{24h}$	20	42.18 ± 0.28	$(a^*)^{24h}$	19.95 ± 0.40^c	$(b^*)^{24h}$	8.47 ± 0.22^c
$(L^*)^{168h}$	20	41.00 ± 0.67	$(a^*)^{168h}$	14.76 ± 0.49^a	$(b^*)^{168h}$	6.51 ± 0.53^b
P		-		***		***

a, b, c: Different superscripts indicate significant differences in the same line.

Table 4. Some meat quality traits for Herik lambs.

Characteristics	n	$\bar{X} \pm S\bar{x}$
Cooking loss 72 h	20	34.78 ± 0.79
Water holding capacity 72 h	20	10.55 ± 0.67
Dry matter	20	26.35 ± 0.33
Crude protein	20	22.21 ± 0.24
Ether extract	20	2.98 ± 0.10
Crude ash	20	1.02 ± 0.37

10.55%, respectively. Chemical composition traits, i.e. dry matter, protein, intramuscular fat, and ash percentage, were 26.35%, 22.21%, 2.98%, and 1.02%, respectively.

4. Discussion

4.1. pH

The normal pH value at 24 h postmortem is important for meat quality and values greater than 5.80 are regarded as undesirable (12). However, ultimate pH values of up to 6.00 are acceptable in terms of meat quality (26). pH values at 24 h postmortem were reported to be 5.66, 5.63, 5.63, 5.70, 5.69, and 5.71 for Turkish Merino, Ramlıç, Kıvırcık, Chios, Imroz (5), and Bafra (7), respectively. In the present study, pH values at 24 h postmortem were 5.518, 5.636, and 5.244 for the MLD, MST, and MSM, respectively. The pH values obtained from the current study were within the acceptable range. In addition, the pH values at 24 h postmortem were similar to those of other indigenous Turkish breeds.

4.2. WBSF and chemical composition

Tenderness is one of the most important textural characteristics in terms of consumer acceptance of meat. Tenderness is measured via a sensory panel and WBSF device. Meat samples having WBSF values exceeding 5.50 kg will be evaluated as tough by consumers (13). In the present study, WBSF values at 72 h postmortem were 3.359, 2.318, and 3.601 for the MLD, MST, and MSM, respectively. These results indicated that WBSF values of the MLD, MST, and MSM were lower than the acceptable value, that is 5.50 kg/cm^2. The WBSF values of Turkish Merino, Ramlıç, Kıvırcık, Chios, and Imroz (5), which are thin-tailed breeds, were reported to be 4.92 kg/cm^2, 5.05 kg/cm^2, 3.66 kg/cm^2, 4.01 kg/cm^2, and 3.88 kg/cm^2, respectively. The corresponding values for Awassi and Morkaraman (4), which are fat-tailed breeds, were reported to be 6.12 kg/cm^2 and 6.15 kg/cm^2, respectively. The values for various slaughter weights, from 30 kg until 40 kg in Karayaka (27) and Bafra (17), which are thin-tailed breeds, ranged from 4.51 to 5.18 kg/cm^2 and from 3.62 to 5.03 kg/cm^2, respectively. The WBSF values of Turkish Merino, Ramlıç, Kıvırcık, Chios, Imroz, and Bafra were obtained using the Warner–Bratzler shear device while that of Karayaka was obtained using the P36/R probe of a texture analyzer. The WBSF values for the MLD, MST, and MSM of Herik were similar to those of thin-tailed indigenous breeds.

It has been reported that the chemical composition of meat is approximately 75% water and 25% dry matter. The components of the dry matter are 20% protein, 3%–5% intramuscular fat, 1% carbohydrates, and 1% vitamin/

minerals (21). Protein, intramuscular fat, and ash were reported to be 20.13%, 2.41%, and 1.07%, respectively, given a mean slaughter weight of 40 kg in Karayaka (27), which is a thin-tailed breed. The corresponding values, given a mean slaughter weight of 55 kg in Awassi and Morkaraman (4), which are fat-tailed breeds, were 21.60%, 2.68%, and 1.11% and 20.78%, 2.63%, and 1.10%, respectively. A study on the quality of meat with Bafra, a thin-tailed breed, reported that protein, intramuscular fat, and ash were 22.21%, 2.98%, and 1.02%, respectively (7). These results indicate that the chemical composition of Herik lambs was much like those of other indigenous sheep breeds.

In the present study, ether extract was 2.80% for the MLD of Herik lambs. The WBSF value of the MLD was lower than the acceptable value, which is 5.50 kg/cm^2. Thus, some researchers reported that fat percentage in meat should be less 3% for optimum tenderness (21). It was determined that the MST was tougher than the MLD and MSM. The MST had the most accelerated pH decline and temperature change in the 0–45 min range. It was reported that accelerated pH decline, combined with a high temperature in the carcass, had an adverse impact on WBSF and tenderness (28). Therefore, the increase in WBSF values was attributable to accelerated pH decline combined with high temperatures in the carcass. Furthermore, these results supported the notion that accelerated pH decline, high temperatures in the carcass, and intramuscular fat have important effects on WBSF.

4.3. Meat color

Meat color, which is an important criterion for meat quality, influences the purchasing decisions of consumers. Hopkins (17) reported that the acceptability threshold values for L* and a*, which are measured with a chroma meter, are 34–35 and below 19, respectively, for lamb meat. Other studies regarding consumer preferences in terms of quality of lamb meat reported that general tendency acceptability on average meat color was 34.00 for L* and 9.50 for a*; also acceptable meat color for 95% of consumers was 44.00 for L* and 14.40 for a* (18). In this study, L*, a*, and b* values at 24 h were 42.18, 19.95, and 8.45 for Herik lambs raised under intensive finishing conditions (Table 2). The L* value of Herik was higher than the acceptable average but was lower than acceptable for the 95% of consumers value. Furthermore, the a* value was near the acceptable threshold value. Therefore, these results indicate that acceptable color characteristics for Herik lambs may not be difficult to achieve.

4.4. CL and WHC

CL and WHC are important meat quality traits because they affect productivity and quality of the final product. The CL values of Turkish Merino, Ramlıç, Kıvırcık, Chios, and Imroz (6) breeds, which are thin-tailed breeds, were reported to be 27.14%, 25.57%, 29.54%, 27.81%, and 28.91%, respectively, under intensive breeding conditions. The cooking yield values for Awassi and Morkaraman (5), which are fat-tailed breeds, were reported to be 68.26% and 67.87% (namely 31.74% and 32.13 for CL) respectively, under intensive breeding conditions. For various slaughter weights, from 30 kg until 40 kg, in Bafra (7) and Karayaka (27), which are thin-tailed breeds, CL values ranged from 27.35% to 31.54% and from 26.11% to 28.25%, respectively, under intensive breeding conditions. In the present study, the CL value of Herik lambs (34.78%) was higher than that of indigenous sheep breeds in Turkey. Therefore, these results indicate that the CL of Herik lambs raised under the intensive fattening system may be a disadvantage in terms of marketing their meat.

Under intensive breeding conditions, the WHC values of Turkish Merino, Ramlıç, Kıvırcık, Chios, and Imroz (5), which are thin-tailed breeds, were reported to be 10.44%, 10.51%, 12.21%, 10.15%, and 9.76%, respectively. The WHC values for Awassi, Morkaraman, Tuj, and Awassi × Tuj (6), which are fat-tailed breeds, were reported to be 7.56%, 7.14%, 8.18%, and 7.50%, respectively, under intensive breeding conditions. In the present study, the WHC value of Herik lambs (10.55%) was higher than those of fat-tailed breeds in Turkey. It was reported that carcasses with thick back fat insulated the meat and slowed down the cooling process (29). This result can be attributed to the back fat thickness of Herik lambs, which is a fat-tailed crossbreed.

Consequently, our study indicates that the meat quality of Herik male lambs was similar to that of indigenous sheep breeds in Turkey. Therefore, the meat of Herik lambs may be suitable for sale after the lambs are raised under intensive fattening.

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References

1. Beriain MJ, Horcado A, Purroy A, Lizaso G, Chasco J, Mendizabal JA. Characteristics of Lacha and Rasa Argonesa lambs slaughtered at three live weights. J Anim Sci 2000; 78: 3070-3077.
2. Díaz MT, Velasco S, Pérez C, Lauzurica S, Huidobro F, Cañeque V. Physico-chemicalcharacteristics of carcass and meat Manchego-breed suckling lambs slaughtered at different weights. Meat Sci 2003; 65: 1085-1093.

3. Santos VAC, Silva SR, Mena EG, Azevedo JMT. Live weight and sex effect on carcass and meat quality of “Borregoterrincho-PDO” suckling lambs. Meat Sci 2007; 77: 654-661.
4. Esenbuğa N, Macit M, Karaoğlu M, Aksakal V, Aksu **Mİ,** Yörük MA, Gül M. Effect of breed on fattening performance, slaughter and meat quality characteristics of Awassi and Morkaraman lambs. Livest Sci 2009; 123: 255-260.
5. Ekiz B, Yılmaz A, Özcan M, Kaptan C, Hanoğlu H, Erdoğan İ, Yalçıntan H. Carcass measurements and meat quality of Turkish Merino, Ramlıç, Kıvırcık, Chios and Imroz lambs raised under an intensive production system. Meat Sci 2009; 82: 64-70.
6. Esenbuga N, Yanar M, Dayıoglu H. Physical, chemical and organoleptic properties of lamb carcasses from four fat-tailed genotypes. Small Rum Res 2001; 39: 99-105.
7. Yakan A, Ünal N. Meat production traits of a new sheep called Bafra in Turkey 2. Meat quality characteristics of lambs. Trop Anim Health Prod 2010; 42: 743-750.
8. Yaralı E, Yılmaz O, Cemal İ, Karaca O, Taşkın T. Meat quality characteristics in Kıvırcık lambs. Turk J Vet Anim Sci 2014; 38: 452-458.
9. Akçapınar H. Sheep Breeding (in Turkish). 2nd ed. Ankara, Turkey: İsmat Printing Ltd. Şti; 2000.
10. Ertuğrul M, Dellal G, Soysal İ, Elmacı C, Akın O, Arat S, Barıtçı İ, Pehlivan E, Yılmaz O. Türkiye yerli koyun ırklarının korunması. Uludağ Üniversitesi Ziraat Fakültesi Dergisi 2009; 23: 97-119 (article in Turkish with an abstract in English).
11. Monin G. Recent methods for predicting quality of whole meat. Meat Sci 1998; 49: Supplement S231-S243.
12. Tejeda JF, Pena RF, Andres AI. Effect of live weight and sex on physico-chemical and sensorial characteristics of Merino lamb meat. Meat Sci 2008; 80: 1061-1067.
13. Shackelford SD, Morgan JB, Cross HR, Sawell JW. Identification of threshold levels for Warner-Bratzler shear force in beef top loin steaks. J Muscle Foods 1991; 2: 289-296.
14. Devine CE, Graafhuis AE, Muir PD, Chrystall BB. The effect of growth rate and ultimate pH on meat quality of lambs. Meat Sci 1993; 35: 63-77.
15. Purchas RW, Aungsupakorn R. Further investigations into the relationship between ultimate pH and tenderness for beef samples from bulls and steers. Meat Sci 1993; 34: 163-178.
16. Watanabe A, Daly CC, Devine CE. The effects of the ultimate pH of meat on tenderness changes during ageing. Meat Sci 1996; 42: 67-78.
17. Hopkins DL. Assessment of lamb meat colour. Meat Focus Intrenational 1996; 11: 400-401.
18. Khliji S, Van de Ven R, Lamb TA, Lanza M, Hopkins DL. Relationship between consumer ranking of colour and objective measures of colour. Meat Sci 2010; 85: 224-229.
19. Díaz MT, Velasco S, Caneque V, Lauzurica S, Ruiz de Huidobro F, Perez C, Gonzalez J, Manzanares C. Use of concentrate or pasture for fattening lambs and its effect on carcass and meat quality. Small Ruminant Research, 2002; 43: 257-268.
20. Díaz MT, Velasco S, Pérez C, Lauzurica S, Huidobro F, Cañeque V. Physico-chemical characteristics of carcass and meat Manchego-breed suckling lambs slaughtered at different weights. Meat Sci 2003; 65: 1085-1093.
21. Öztan A. Et Bilimi ve Teknolojisi. 5th ed. Ankara, Turkey: Filiz Publishing Ltd. Şti; 2005 (in Turkish).
22. AOAC. Official Methods of Analysis of AOAC International. 17th ed. Association of Official Analytical Chemistry, Maryland, USA; 2000.
23. Barton-Gade PA, Demeyer D, Honikel KO, Joseph RL, Puolanne E, Severini M, Smulders F, Tonberg E. Reference methods for water holding capacity in meat and meat products: procedures recommended by an OECD working group. In: Proceeding of 39th International Congress of Meat Science and Technology. Calgary, Canada: 1993.
24. Honikel, KO. Reference methods for the assessment of physical characteristics of meat. Meat Sci 1998; 49: 447-457.
25. Hoffman LC, Müller M, Cloete SWP, Schmidt D. Comparison of six crossbred lamb types: sensory, physical and nutritional meat quality characteristics. Meat Sci 2003; 65: 1265-1274.
26. Holmgren NL, Zobell DR. Reducing the incidence of cutting beef in junior livestock shows. http://extension.usu.edu/files/publication/AG_beef_2005-08.pdf.
27. Aksoy Y, Ulutaş Z. Meat production traits of local Karayaka sheep in Turkey 1. The meat quality characteristic of lambs. Ital J Food Sci 2016; 28: 131-138.
28. Devine CE, Payne SR, Peachey BM, Lowe TE, Ingram JR, Cook CJ. High and low rigor temperature effects on sheep meat tenderness and ageing. Meat Sci 2002; 60: 141-146.
29. Wiklund E, Sampels S, Manley TR, Pickova J, Littlehonn RP. Effects of feeding regimen and chilled storage on water-holding capacity, colour stability, pigment content and oxidation in red deer (*Cervus elaphus*) meat. J Sci Food Agric 2006; 86: 98-106.