Tropical Animal Health and Production
https://doi.org/10.1007/s11250-019-01996-x

REGULAR ARTICLES

The effects of slaughter weight on chemical composition, physical properties, and fatty acid profile of *musculus longissimus dorsi* in Holstein bulls

Ertuğrul Kul[1] · Aziz Şahin[1] · Yüksel Aksoy[2] · Emre Uğurlutepe[1]

Received: 29 January 2019 / Accepted: 27 June 2019

Abstract
This study was conducted to investigate the effects of slaughter weight on chemical composition, physical properties, and fatty acid profile of *musculus longissimus dorsi* (MLD) in Holstein bulls. The bulls ($n = 20$) were divided into two slaughter weight groups as light (450–520 kg) and heavy (521–580 kg) according to body weights at slaughter. After resecting MLD from the carcass, its chemical composition, physical properties, and fatty acid profile were determined. The analysis showed that fat, ash, and cholesterol contents of MLD were significantly affected by slaughter weight ($P < 0.05$). Higher fat, ash, and cholesterol contents were determined in heavy bulls compared with light ones. However, the protein and moisture contents were not significantly different between slaughter weight groups in terms of pH, drip loss, and water holding capacity. With regard to meat color, the a^* was significantly higher in light bulls; however, the L^* and b^* values were similar in both slaughter weight groups. Of all fatty acids, only C:10 was found the highest in heavy bulls ($P < 0.05$). The n-6/n-3 ratio was significantly lower ($P < 0.05$) in light bulls compared with heavy ones. Consequently, the best results were obtained from light Holstein bulls in order to achieve better beef quality.

Keywords Holstein bull · Slaughter weight · Meat quality · *Musculus longissimus dorsi*

Introduction

Meat quality is an important criterion that influences consumer's decision for purchasing (Lukic et al. 2016). Meat quality is normally identified based on compositional quality, palatability of meat, and attractiveness of meat to consumers. The appearance of intramuscular fat content is the primary criterion for quality grading of beef and commonly called as marbling (Ustuner et al. 2017).

The principal objectives of beef production investigations are related to the need for a continuous improvement of slaughter and carcass traits, and also consumer meat quality preferences (Oler et al. 2015). The meat quality is determined by chemical, biochemical, and physical analysis. The meat quality can be, also, defined by the parameters including tenderness, leanness, and taste. Nowadays, in addition to its taste and convenience, safety and healthiness are considered important criteria (Çatıkkaş and Koç 2017). The color, acidity, and water holding capacity of meat are the basic quality characteristics for both consumers and food processing industry (Oler et al. 2015).

Health organizations have recommended to reduce total fat intake and saturated fatty acids (SFA), to increase polyunsaturated fatty acids (PUFA)/SFA, omega-3 (n-3)/omega-6 (n-6) ratio, and n-3 (Costa et al. 2006a). Protein and fat contents are also defined as meat quality criteria (Çatıkkaş and Koç 2017). Fat content and fatty acid composition of meat have been extensively studied due to its nutritional implications for human health (Alfaia et al. 2007). Cholesterol levels and fat compositions of the diet have become issues of great concern to consumers due to their possible effects on human health. Reduction of cholesterol intakes and total SFA plays important roles to prevent hypercholesterolemia and obesity and decrease the cancer (Costa et al. 2006b).

✉ Ertuğrul Kul
ertugrul.kul@ahievran.edu.tr

[1] Department of Animal Science, Faculty of Agriculture, University of Kırşehir Ahi Evran, Kırşehir, Turkey

[2] Department of Animal Science, Faculty of Agriculture, University of Eskisehir Osmangazi, Eskişehir, Turkey

Published online: 06 July 2019

In developed countries, a low PUFA/SFA ratio is one of the most important reasons of human mortality and is considered a major risk factor for cardiovascular diseases. Typical Western diets are characterized by a very high n-6/n-3 ratio, which supports the development of cardiovascular diseases, autoimmune diseases, inflammatory diseases, and cancer. Moreover, high n-6/n-3 and low PUFA/SFA ratios in meats contribute to the imbalanced fatty acid intake of consumers (Alfaia et al. 2007). A high n-6/n-3 ratio is also associated with increased risk of lifestyle diseases (Nogalski et al. 2014b).

The relationships among different production factors and carcass characteristics of beef cattle have been confirmed by many studies. Factors affecting meat chemical composition are cattle breed and genetic and environmental factors such as diet, age, gender, and slaughter weight (Irshad et al. 2013). Slaughter weight is considered one of the most important factors influencing meat quality. The optimum weight before slaughter is among the important factors affecting the quantity and quality of beef (Węglarz 2010). Młynek et al. (2006) found that carcass quality traits, meat tenderness, and color were significantly influenced by slaughter weight.

There has been limited information about meat quality traits in relation to specific slaughter weights in Turkey. Holstein cattle are bred mainly to produce milk and meat. The number of studies on meat quality in Holstein bulls raised in Turkey has been limited. Holstein cattle has become the most common cattle breed, with 5.5 million purebreds and 856 thousand crossbreeds (Ardıclı et al. 2018), and also is 78% of the European breeds in Turkey (Çatıkkaş and Koç 2017). As a result, Holstein cattle has been the basic breed for beef cattle production in Turkey; however, the detailed technical information on meat yield and quality has been limited. In the literature, there have been some studies evaluating carcass traits in Turkey's meat market, but these studies have been mostly conducted on limited sample sizes (Ardıclı et al. 2018). However, further studies have been needed to improve beef production in Turkey concerning high beef prices and its deficit in the sector. Therefore, in this study, the chemical composition, physical properties, and fatty acid composition of MLD obtained from the carcasses of Holstein bulls having different slaughter weights were investigated.

Materials and methods

Animals and meat samples

This study was conducted in a private beef cattle farm located in Kırşehir province in the Central Anatolian Region of Turkey (located at 38° 50′–39° 50′ north latitudes and 33° 30′–34° 50′ east latitudes) with an average altitude of 985 m above sea level. The annual temperature average of the location is 11.3 °C and ranges from 0.8 to 21.8 °C during winter and summer. In the present study, 20 Holstein bulls were used. The bulls were grouped as light (450–520 kg) and heavy (521–580 kg) slaughter weight at slaughterhouse.

The bulls were slaughtered by standard commercial slaughter procedures and not fed for 12 h prior to slaughter (TSI 1987). The animals were slaughtered 2–4 h after transportation and weighed in accordance with industrial standards by considering their welfare. The carcasses were kept in a freezer (+4 °C) for 24 h to conduct meat analyses. One day after slaughter, the meat samples were taken from *musculus longissimus dorsi* (MLD) between 11th and 13th ribs. The samples which were transported to the laboratory under cooling conditions (+4 °C) and packed in vacuum remained unchanged. The meat samples were stored at +4 °C for analysis; at − 20 °C for moisture, crude ash, protein, intramuscular fat; and at − 80 °C for drip loss (CL), fatty acid composition, cholesterol, and texture analyses.

Chemical and physical analysis

Ash, protein, and moisture contents were analyzed using the methods described by AOAC (1990). Fat contents were determined by the heat extraction method with an Ankom Extractor device (XT10, Spain) (Okeudo and Moss 2007).

Meat color measurements were carried out by a colorimeter (Konica Minolta CR-400, Japan) in 24 h after slaughter. After fat and connective tissues were removed, meat color was analyzed based on the mean of L^* (brightness), a^* (redness), and b^* (yellowness) values taken from five points of the samples.

Carcasses were chilled under commercial conditions (+4 °C) and pH was evaluated 24 h after slaughter using a portable pH meter (Testo 205) under a constant room temperature (Ramirez and Cava 2007). The pH meter was calibrated with standard buffer at 4.00 and 7.00. The measurements were taken at three locations and pH value was evaluated based on the mean of the three measurements.

Water holding capacity was determined by the filter press method (Grau and Hamm 1956). Meat sample (25 g) was ground in an Aura Type 103 (Turkey) brand mini chopper. The chopped sample (1 g) was placed between two filter papers, glass plates were placed above and below the filter papers, and then a weight (2.250 kg) was placed on them. The samples which were taken out of the filter papers 5 min later were weighed again (Barton-Gade et al. 1993). Then, the water holding capacity was calculated (Aksoy and Ulutaş 2016).

Drip loss was analyzed from the samples with approximately 20–25 g of MLD. Firstly, these samples were vacuumed and stored at +4 °C. They were taken from the vacuum pouches 3 days and 7 days later, dried without any pressure and weighed. Drip loss was calculated with the initial weight-to-final weight ratio (Bond and Warner 2007).

To determine the moisture content, approximately 5 g of meat was weighed in the drying containers, placed in the oven

at 105 °C, and kept in the oven for 12 h. Then, the cooled meat samples were weighed again and dry matter (%) was determined as the percentage of the ratio of the difference between the initial weight and the final weight to the initial weight.

Lipid samples (approximately 0.3–0.5 g) were taken from the lipid, cold-extracted, and were placed into closed glass tubes. Then, 33% KOH (0.3 mL) and 95% ethyl alcohol solution (3 mL) were added and the mixture was mixed and subjected to saponification in a water bath at 60 °C for 15 min. The tubes were cooled down. Distilled water (3 mL) and hexane (10 mL) were added and the mixed samples were kept for phase separation for 10 min. A 1-mL sample was separated from the hexane fraction into a test tube to determine cholesterol content. The hexane was removed using nitrogen gas. A FeCl3 stock solution was prepared with 840 mg FeCl3 and 10 mL concentrated glacial acetic acid, and 1 mL of this stock solution was increased to 100 mL with a concentrated glacial acetic acid, to prepare the FeCl3 working solution. Then, FeCl3 (1.5 mL) working solution was transferred and was mixed into a test tube. One milliliter of concentrated sulfuric acid was added 15 min later, and the samples were mixed for 1 min. The tubes were placed in the dark at room temperature for 45 min. The absorbance values were read at a 560-nm wavelength using a UNICAM UV/Vis spectrophotometer. The standard curves of cholesterol concentration were constructed and the data were expressed as the mg cholesterol/100 g (Rudel and Morris 1973).

Analysis of fatty acids

Fatty acid methyl esters (FAME) were applied by the ISO 12966-2:2011 method. The FAME was analyzed using a Perkin Elmer gas chromatograph (Auto system GLX, Shelton, CA, USA) model gas chromatograph. The FAME was separated on a SP™-2380 fused-silica capillary column (100 m × 0.25 mm i.d., 0.25 μm film thickness). The temperatures of the injector and detector were set at 250 °C and 260 °C, respectively. Helium was used as the carrier gas at 1 mL/min. Split ratio was set as 1:50. The column oven temperature was increased from 140 to 180 °C at 1 °C/min and 180 to 200 °C at 2 °C/min. The samples were stored at a final temperature of 200 °C for 8 min. Fatty acids were identified using the standard in a Supelco 37 FAME mixture (C4–C24) (Bellefonte, PA, USA). Fatty acid standards (Alltech) were determined by GC analysis to identify the peak retention times. The data were expressed as percentages (%) of the total FAME.

Statistical analysis

Statistical analyses were performed using the GLM procedure in SPSS version 17.0. Means were compared by independent sample *t* tests.

Results

The effects of different slaughter weights on chemical composition of *musculus longissimus dorsi* (MLD) in Holstein bulls are presented in Table 1. Slaughtered weight had significantly affected on fat, ash, and cholesterol contents ($P < 0.05$). The highest fat, ash, and cholesterol contents were observed in heavy bulls compared with light bulls. Slaughtered weight had no significant effect on moisture and protein content. Protein and moisture were higher in light bulls than heavy bulls, but the results were not statistically significant.

As seen from Table 2, pH value was similar for bulls slaughtered at light and heavy weights. Water holding capacity and drip loss (3 and 7 days) were not affected by slaughter weight. In terms of meat color, the *a** (redness) value was the highest in light bulls than heavy ones ($P < 0.05$). However, no differences between slaughter groups were found in the *L** (lightness) and *b** (yellowness) values.

Of all fatty acids, only C:10 was affected by slaughtered weight. The highest C:10 was determined in heavy bulls compared with light bulls ($P < 0.05$). None of the other fatty acid compositions were significantly affected by slaughtered weight (Table 3). Besides, effect of slaughtered weight on the n-6/n-3 ratio was significantly important ($P < 0.05$). The highest n-6/n-3 ratio was observed in heavy bulls. However, SFA, MUFA, PUFA, FA, PUFA/SFA, n-3, and n-6 were similar for bulls slaughtered at light and heavy slaughter weights (Table 4).

Discussion

Chemical composition

In this study, the heavy bulls at slaughter had a higher fat, ash, and cholesterol contents in their MLD ($P < 0.05$). No differences were found between slaughter weight groups in terms of moisture and protein contents. Fat deposits are energy storage

Table 1 Chemical composition of *M. longissimus dorsi* (MLD) of Holstein bulls in different slaughter weights

Chemical content (%)	Slaughter weight (kg)		SEM	*P*
	450–520	521–580		
Fat	5.53[b]	7.43[a]	0.548	*
Ash	0.95[b]	0.97[a]	0.003	*
Protein	24.33	22.59	0.556	ns
Moisture	71.89	70.54	1.073	ns
Cholesterol	65.56[b]	70.25[a]	1.405	*

The different superscripts in the columns means that *P* differs significantly ($P < 0.05$)

*$P < 0.05$; *ns*, not significant; *SEM*, standard error of means

Table 2 Physical properties of *M. longissimus dorsi* (MLD) of Holstein bulls in different slaughter weights

Physical parameters	Slaughter weight (kg)		SEM	*P*
	450–520	521–580		
pH	5.39	5.40	0.022	ns
Color: lightness (*L**)	41.20	39.07	0.923	ns
redness (*a**)	18.43[a]	16.55[b]	0.415	*
yellowness (*b**)	7.27	6.11	0.456	ns
Drip $loss_{3\ day}$	12.88	15.17	0.982	ns
Drip $loss_{7\ day}$	15.81	17.75	0.939	ns
Water holding capacity (%)	25.33	26.98	0.773	ns

The different superscripts in the columns means that *P* differs significantly ($P < 0.05$)

*$P < 0.05$; *ns*, not significant; *SEM*, standard error of means

mainly composed of triglycerides (Vieira et al. 2005). Fat content was also significantly higher in heavy bulls (7.43%) than light ones (5.53%) ($P < 0.05$, Table 1). These results were usually compatible with other study results (Bruns et al. 2004; Węglarz 2010; Nogalski et al. 2014b). Higher carcass fatness in heavy Holstein bulls was also confirmed by Maher et al. (2004). Protein content in heavy bulls was higher than light ones, which did not show any statistical significance. On the other hand, Węglarz (2010) determined higher protein content in light bulls during slaughtering ($P < 0.01$). Similar to the results of the present study, Zawadzki et al. (2015) reported that the bulls slaughtered at medium and heavy body weights had higher values of protein than bulls slaughtered at light body weight. On the other hand, Kim et al. (1996) reported that there was no significant difference in Holstein steer beef slaughtered at 17–19 months, except for moisture. Zawadzki et al. (2015) reported that moisture, ash, total lipids, and collagen were similar for bulls slaughtered at light, medium, and heavy body weights in 12-month-old crossbred.

Table 3 Fatty acid composition (*w*/*w*%) of *M. longissimus dorsi (MLD)* of Holstein bulls in different slaughter weights

Fatty acids	Slaughter weight (kg)		SEM	*P*
	450–520	521–580		
C10:0	0.04[b]	0.05[a]	0.002	*
C12:0	0.05	0.05	0.005	ns
C14:0	2.36	2.53	0.104	ns
C14:1	0.41	0.41	0.034	ns
C15:0	0.32	0.31	0.026	ns
C16:0	25.23	25.95	0.428	ns
C16:1	2.42	2.62	0.156	ns
C17:0	0.86	0.92	0.059	ns
C18:0	18.58	18.40	0.637	ns
C18:1n9t	0.86	0.89	0.111	ns
C18:1n9c	36.92	38.05	0.990	ns
C18:2n6c	2.66	2.74	0.176	ns
C:20	0.12	0.12	0.005	ns
C20:1	0.21	0.17	0.014	ns
C18:3n3	0.17	0.12	0.022	ns
C21:0	0.27	0.24	0.020	ns
C20:2	0.03	0.03	0.002	ns
C20:3n6	0.07	0.04	0.011	ns
C20:4n6	0.22	0.10	0.053	ns

The different superscripts in the columns means that *P* differs significantly ($P < 0.05$)

*$P < 0.05$; *ns*, not significant; *SEM*, standard error of means

Table 4 Total fatty acids (*w*/*w*%) of *M. longissimus dorsi* (MLD) of Holstein bulls in different slaughter weights

Total fatty acids	Slaughter weight (kg)		SEM	*P*
	450–520	521–580		
SFA	47.84	48.57	0.713	ns
MUFA	40.82	42.15	1.014	ns
PUFA	3.15	3.03	0.249	ns
FA	43.98	45.18	0.849	ns
PUFA/SFA	0.07	0.06	0.005	ns
n-3	0.24	0.16	0.032	ns
n-6	2.89	2.84	0.220	ns
n-6/n-3	14.27[b]	17.83[a]	0.971	*

The different superscripts in the columns means that *P* differs significantly ($P < 0.05$)

*$P < 0.05$; *ns*, not significant; *SEM*, standard error of means. *SFA*, saturated fatty acids; *MUFA*, monounsaturated fatty acids; *PUFA*, polyunsaturated fatty acids

Physical properties

The pH is closely related to meat quality traits such as texture, color, and water holding capacity (Aksoy and Ulutaş 2016). The meat pH has a high effect on color, which is considered by consumer preferences regarding quality indicators (Pogorzelska-Przybyłek et al. 2018). In this study, pH was measured 24 h after slaughter. The studies by Jeleníková et al. (2008) and Węglarz (2010) showed that no pH differences were observed between slaughtered weights, which was compatible with the results of the present study.

Meat color is one of the most important indicators of quality attributes that influence buying decisions of consumers (Bureš and Bartoň 2012; Cho et al. 2012; Nogalski et al. 2018) and satisfaction of meat products (Ustuner et al. 2017). Meat lightness is mostly correlated negatively with heme iron content (Chambaz et al. 2003). Consumers appear to prefer beef that is neither extremely pale nor dark (Ustuner et al. 2017). In the present study, the *a** value was shown to be

affected by slaughter weight in terms of meat color. However, the L^* and b^* values were not affected by slaughter weight groups (Table 2). These results were compatible with the data of Węglarz (2010), who observed that the meat from bulls slaughtered at lower weights (550 kg) had higher L^* (lighter color) and b* values compared with heavier animals (650 kg), but these differences were non-significant. Clausen et al. (2007) reported that slaughter weight significantly affected the color L^* and b^* of meat was significantly important ($P < 0.05$), and the meat from Holstein-Friesian bulls slaughtered at lower weights had higher values.

In addition to pH and color, water holding capacity is another aspect that influences the processing suitability of meat (Nogalski et al. 2018). Water holding capacity is correlated with pH and it was used to determine quality assessments of meat (Aksoy and Ulutaş 2016). In the present experiment, the concentrations of water holding capacity and drip loss (3 and 7 days) did not differ significantly between light and high slaughter weights. Increasing slaughter weight was not observed with increasing water holding capacity, which was confirmed by previous studies, too (Aksoy and Ulutaş 2016).

Fatty acid composition

The fatty acid composition plays an important role in human nutrition and prevention of disease (Cho et al. 2012). There were significant differences between the slaughter weight groups in terms of C:10 content ($P < 0.05$). The highest proportion of C:10 was found in heavy bulls (Table 3). No significant differences were observed between slaughter weight groups in terms of the other fatty acid composition, which was compatible with results of the study by Holló et al. (2001). These results were not compatible with the studies by Duckett et al. (1993) and Lengyel et al. (2003) who found that MUFA generally decreased with increasing slaughter weight. De Smet et al. (2000) determined that a higher proportion of SFAs and MUFAs and a lower proportion of PUFAs were related to increased fat content of bovine meat. Węglarz (2010) determined that the fat of bulls slaughtered at higher weights was characterized by significantly lower SFA and higher UFA levels. Moreno et al. (2008) detected that total fatty acid concentration and the concentrations of C12:0, C14:1, C16:0, C16:1, C18:0, total CLA, MUFA, and SFA increased with an increasing slaughter weight. The same authors also reported that an increasing slaughter weight decreased the concentrations of C15:0, C17:0, C18:0, C18:2, C18:3, C20:3n-6, C20:5, C22:6, C22:5, cis9, trans11 CLA, trans10, cis12 CLA, total CLA, PUFA, SFA, n-3, and n-6 and increased the proportion of C16:0 and C16:1.

The studies have showed that the major risk factors for cardiovascular diseases in humans are low n-3 and high n-6 intakes, thus, resulting in the increase of the n-6/n-3 ratio (Costa et al. 2006b; Stanley et al. 2007; Humada et al. 2012; Nogalski et al. 2014b, 2018; Pogorzelska-Przybyłek et al. 2018). The PUFA/SFA ratio is a nutritional index, commonly used to assess the nutritional value of fat for human diet (Alfaia et al. 2007; Humada et al. 2012; Nogalski et al. 2014a, 2018). According to the current nutritional recommendations, PUFA/SFA ratios in human diet should be above 0.45 and n-6/n-3 ratios should not exceed 4.0 (Alfaia et al. 2007). In view of the above guidelines, PUFA/SFA ratios were lower than the recommended values for healthy human diets. Also, the n-6/n-3 ratios were higher than healthy human nutrition (Table 4). The present study showed that n-6/n-3 was significantly greater in high slaughter weight than light slaughter weight. Similar to the results of the present study, previous studies (Moreno et al. 2008; Nogalski et al. 2014a, b) showed that the n-6/n-3 ratio was greater in heavy animals. Zawadzki et al. (2015) determined that SFA, MUFA, n-3, and n-6/n-3 ratio were similar for bulls slaughtered at light, medium, and heavy weights. The same study revealed that longissimus muscle from bulls slaughtered at medium slaughter weight had higher values of crude protein, FUFA, n-6, and PUFA/SFA ratio than bulls with light slaughter weight.

Conclusion

The present results showed that slaughter weight did not affect the moisture, protein, pH, drip loss, and water holding capacity of MLD of bull carcasses. However, fat, ash, and cholesterol contents were affected by slaughter weight and these contents were determined the lowest in the light slaughter group. The value of a^* in light slaughter weight was the highest or more red; whereas, the values L^* and b^* were not different in both slaughter groups. Of all fatty acid composition, only C:10 was the highest in heavy slaughter bulls. The values of the n-6/n-3 PUFA ratio were within the recommended limits for human diet. The n-6/n-3 ratio was lower in light slaughter weight compared with the high slaughter weight. According to the results of the present study, light bulls had better meat in quality. However, further studies are needed to improve the meat quality of Holstein bulls, which are well adapted to conditions in Turkey, by modifying the slaughter weight.

Acknowledgments We are grateful to Prof. Dr. Ahmet Şahin for his valuable assistance.

Funding information This work was financially supported by Kırşehir Ahi Evran University Scientific Research Projects Coordination Unit with project number: PYO-ZRT.4001.14.002.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Statement of ethical approval The study was approved by Kırşehir Ahi Evran University Local Animal Ethics Committee.

References

Aksoy, Y., Ulutaş, Z., 2016. Meat production traits of local Karayaka sheep in Turkey 1. The meat quality characteristic of lambs. Italian Journal of Food Science, 28(1), 131–138.

Alfaia, C.M., Castro, M.L., Martins, S.I., Portugal, A.P., Alves, S.P., Fontes, C.M., Bessa, R.J., Prates, J.A., 2007. Effect of slaughter season on fatty acid composition, conjugated linoleic acid isomers and nutritional value of intramuscular fat in Barrosã-PDO veal. Meat Science 75(1), 44–52.

AOAC, 1990. "Official Methods of Analysis" 15th ed. AOAC, Arlington

Ardıclı, S., Dıncel, D., Balcı, F., 2018. Evaluation of slaughter weights and carcass traits of bulls marketed in South Marmara Region of Turkey. Harran University Journal of the Faculty of Veterinary Medicine, 7(1), 45–50.

Barton-Gade, P.A., Demeyer, D., Honikel, K.O., Joseph, R.L., Puolanne, E., Severini, M., Smulders, F., Tonberg, E., 1993. Reference methods for water holding capacity in meat and meat product: procedures recommended by an OECD working group, 39th International Congress of Meat Science and Technology, 1–6 August 1993, Calgary, Canada, pp. 02.

Bond, J.J., Warner, R.D., 2007. Ion distribution and protein proteolysis affect water holding capacity of *longissimus thoracis et lumborum* in meat of lamb subjected to antemortem exercise. Meat Science, 75(3), 406–414.

Bruns, K.W., Pritchard, R.H., Boggs, D.L., 2004. The relationship among body weight, body composition, and intramuscular fat content in steers. Journal of Animal Science, 82(5), 1315–1322.

Bureš, D., Bartoň, L., 2012. Growth performance, carcass traits and meat quality of bulls and heifers slaughtered at different ages. Czech Journal of Animal Science, 57(1), 34–43.

Çatıkkaş, E., Koç, A., 2017. Fattening performance, carcass characteristics and beef quality of Holstein–Friesian, Brown–Swiss and Simmental bulls. Journal of Adnan Menderes University Agricultural Faculty, 14(1), 59–64.

Chambaz, A., Scheeder, M.R.L., Kreuzer, M., Dufey, P.A., 2003. Meat quality of Angus, Simmental, Charolais and Limousin steers compared at the same intramuscular fat content. Meat Science, 63(4), 491–500.

Cho, S., Kim, J., Kang, S., Kang, G., Seong, P., Park, K., Ki, K., Kim, H., Kim, C., Park, B., 2012. Physicochemical meat quality and sensory property of Holstein steer beef produced by different fattening periods. Korean Journal for Food Science of Animal Resources, 32(6), 749–755.

Clausen, I., Vestergaard, M., Børsting, C., 2007. Eating quality of meat from young bulls of different ages and fed in three different feeding systems. Proc. 53th International Congress of Meat Science and Technology, 5–10 August 2007, Beijing, China, pp. 2.

Costa, P., Roseiro, L.C., Alves, V., Partidário, A. Santos, C., 2006a. Histological profile and Fatty acid composition of Maronesa-PDO veal muscles. Revista Portuguesa de Ciências Veterinárias, 101(557–558), 95–102.

Costa, P., Roseiro, L.C., Partidário, A., Alves, V., Bessa, R.J., Calkins, C.R., Santos, C., 2006b. Influence of slaughter season and sex on fatty acid composition, cholesterol and a-tocopherol contents on different muscles of Barrosa˜-PDO veal. Meat Science, 72(1), 130–139.

De Smet, S., Webb, E.C., Claeys, E., Uytterhaegen, L., Demeyer, D.I., 2000. Effect of dietary energy and protein levels on fatty acid composition of intramuscular fat in double-muscled Belgian Blue bulls. Meat Science, 56(1), 73–79.

Duckett, S.K., Wagner, D.G., Yates, L.D., Dolezal, M.G., May, S.G., 1993. Effects of time on feed on beef nutrient composition. Journal of Animal Science, 71(8), 2079–2088.

Grau, R., Hamm, R., 1956. Die bestimmung der wasserbindung des fleisches mittles der premethode. Fleischwirtsch, 8, 733–736.

Holló, G., Csapó, J., Szűcs, E., Tözsér, J., Repa, I., Holló, I., 2001. Influence of breed, slaughter weight and gender on chemical composition of beef. Part 2. Fatty acid composition of fat in rib samples. Asian-Australasian Journal of Animal Sciences, 14(12), 1719–1723.

Humada, M.J., Serrano, E., Sañudo, C., Rolland, D.C., Dugan, M.E.R., 2012. Production system and slaughter age effects on intramuscular fatty acids from young Tudanca bulls. Meat Science, 90(3), 678–685.

Irshad, A., Kandeepan, G., Kumar, S., Ashish Kumar, A., Vishnuraj, M.R., Shukla, V., 2013. Factors influencing carcass composition of livestock: A review. Journal of Animal Production Advances, 3(5), 177–186.

Jeleníková, J., Pipek, P., Mitsuoshi, Miyahara M., 2008. The effects of breed, sex, intramuscular fat and ultimate pH on pork tenderness. European Food Research and Technology, 227(4), 989–994.

Kim, D.G., Jung, K.K., Sung, S.K., Choi, C.B., Kim, S.K., Kim, D.Y., Choi, B.J., 1996. Effects of age on the carcass characteristics of Hanwoo and Holstein steers. Korean Journal of Animal Science, 38, 268–274.

Lengyel, Z., Husvéth, F., Polgár, P., Szabó, F., Magyar, L., 2003. Fatty acid composition of intramuscular lipids in various muscles of Holstein–Friesian bulls slaughtered at different ages. Meat Science, 65(1), 593–598.

Lukic, M., Ivanovic, J., Starcevic, M., Djordjevic, J., Markovic, R., Baltic, M., 2016. Carcass performance of Simmental and Holstein Friesian beef cattle in Serbia. Meat Technology, 57(2), 95–101.

Maher, S.C., Mullen, A.M., Keane, M.G., Buckley, D.J., Kerry, J.P., Moloney, A.P., 2004. Decreasing variation in the eating quality of beef through homogenous preand post-slaughter management. Meat Science, 67(1), 33–43.

Młynek, K., Elminowska-Wenda, G., Guliński, P., 2006. The relationship between microstructure of Longissimus lumborum muscle and carcass quality of bulls slaughtered at three ages. Animal Science Papers and Reports, 24(1), 57–63.

Moreno, T., Keane, M.G., Noci, F., Moloney, A.P., 2008. Fatty acid composition of M. Longissimus dorsi from Holstein–Friesian steers of New Zealand and European/American descent and from Belgian Blue Holstein–Friesian steers, slaughtered at two weights/ages. Meat Science, 78(3), 157–169.

Nogalski, Z., Wielgosz-Groth, Z., Purwin, C., Nogalska, A., Sobczuk-Szul, M., Winarski, R., Pogorzelska, P., 2014a. The effect of slaughter weight and fattening intensity on changes in carcass fatness in young Holstein-Friesian bulls. Italian Journal of Animal Science, 13(1), 66–72.

Nogalski, Z., Wielgosz-Groth, Z., Purwin, C., Sobczuk-Szul, M., Mochol, M., Pogorzelska-Przybyłek, P., Winarski, R., 2014b. Effect of slaughter weight on the carcass value of young crossbred ('Polish Holstein Friesian' × 'Limousin') steers and bulls. Chilean Journal of Agricultural Research, 74(1), 59–66.

Nogalski, Z., Pogorzelska-Przybyłek, P., Sobczuk-Szul, M., Nogalska, A., Modzelewska-Kapituła, M., Purwin, C., 2018. Carcass characteristics and meat quality of bulls and steers slaughtered at two different ages. Italian Journal of Animal Science, 17(2), 279–288.

Okeudo, N.J., Moss, B.W., 2007. Intramuscular lipid ant fatty acid profile of sheep comprising four sex-types and seven slaughter weights produced following commercial procedure. Meat Science, 76(2), 195–200.

Oler, A., Głowińska, B., Młynek, K., 2015. Slaughter and carcass characteristics, chemical composition and physical properties of longissimus lumborum muscle of heifers as related to marbling class. Archives Animal Breeding, 58(1), 145–150.

Pogorzelska-Przybyłek, P., Nogalski, Z., Sobczuk-Szul, M., Purwin, C., Kubiak, D., 2018. Carcass characteristics and meat quality of Holstein-Friesian x Hereford cattle of different sex categories and slaughter ages. Archives Animal Breeding, 61(2), 253–261.

Ramirez, R., Cava, R., 2007. Carcass composition and meat quality of three different Iberian x Duroc genotype pigs. Meat Science, 75(3), 388–396.

Rudel, L.L., Morris, M.D., 1973. Determination of cholesterol using o-phthalaldehyde. Journal of Lipid Research, 14(3), 364–366.

Stanley, J.C., Elsom, R.L., Calder, P.C., Griffin, B.A., Harris, W.S., Jebb, S.A., 2007. UK Food Standards Agency Workshop Report: The effects of the dietary n-6:n-3 fatty acid ratio on cardiovascular health. British Journal of Nutrition, 98(6), 1305–1310.

TSI. 1987. "Turkish Standards Institute" TS 52737 Butchery Animals-Rules for Slaughtering and Carcass Preparation, Ankara, Turkey.

Ustuner, H., Yalcintan, H., Orman, A., Ardicli, S., Ekiz, B., Gencoglu, H., Kandazoglu, O., 2017. Effects of initial fattening age on carcass characteristics and meat quality in Simmental bulls imported from Austria to Turkey. South African Journal of Animal Science, 47(2), 194–201.

Vieira, C., Garcia, M.D., Cerdeno, A., Mantecon, A.R., 2005. Effect of diet composition and slaughter weight on animal performance, carcass and meat quality, and fatty acid composition in veal calves. Livestock Production Science, 93(3), 263–275.

Węglarz, A., 2010. Quality of beef from Polish Holstein-Friesian bulls as related to weight at slaughter. Annals of Animal Science, 10(4), 467–476.

Zawadzki, F., Rivaroli, D.C., Fugita, C.A., Valero, M.V., Do Prado, R.M., Jorge, A.M., Do Prado, I.N., 2015. Effect of the body weight on chemical and fatty acids composition of the longissimus muscle from young bulls, 61st International Congress of Meat Science and Technology, 23–28 August 2015, Clermont-Ferrand, France, pp. 1–5.