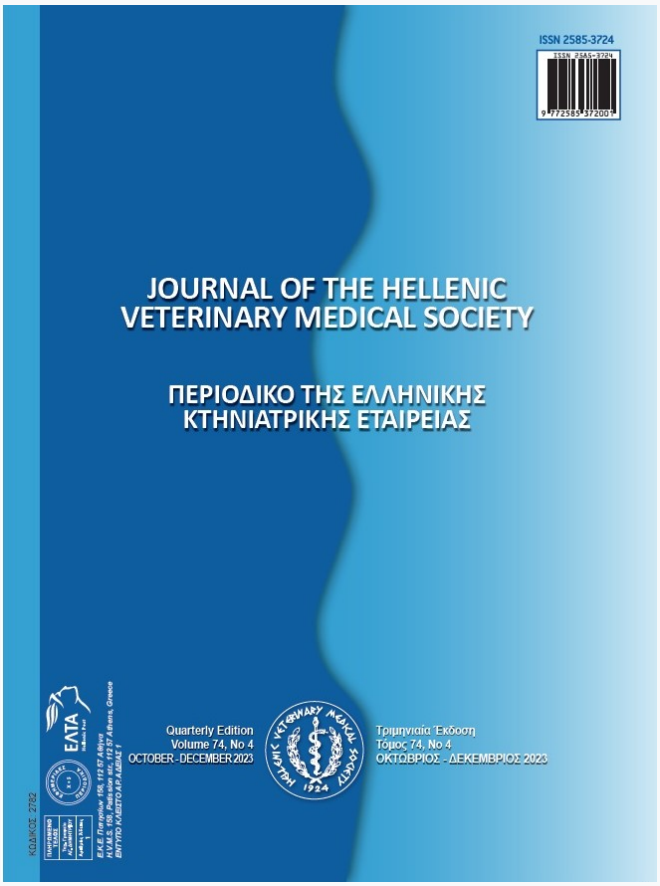
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# Effects of Slaughter Weight and Muscle Types on Carcass and Meat Quality Characteristics of Holstein Friesian Bulls

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**ABSTRACT:** The aim of this study was to determine the effects of slaughter weight and muscle types on carcass characteristics, chemical composition and meat quality characteristics of young Holstein Friesian bulls. For this purpose, 21 young bulls were assigned to three experimental groups based on their weight at slaughter called lighter (LSW) (470.4±32.5kg), medium (MSW) (540.8±10.9 kg) and heavier (HSW) (605.8±28.3 kg). Animals in the HSW group resulted in higher carcass weight, *Longissimuss dorsi* (LD) area, crude protein content, $pH_{24}$ value. On the other hand, L* and a* values color parameters and LD area per 100 kg carcass weight were significantly decreased with the increasing slaughter weight. The meat obtained from the LSW group was brighter and redder compared to the other two slaughter groups. Additionally, there was a decreasing trend in the proportion of the non-carcass components with increasing of the slaughter weight. However, increasing of the slaughter weight led to a significant increase in the carcass measurements such as thoracic depth, carcass length, length of the round as well as width of the round. Although the crude protein content was significantly affected by both slaughter weights and muscle types, only muscle types were also significant sources of variation in percentages of moisture and crude ash.

***Keywords*:** Carcass traits; Chemical composition; Meat color; Non-carcass components; Slaughter weight.

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## INTRODUCTION

In many parts of the world, meat forms an important part of a typical daily diet. It also contributes for providing nutrients such as protein, mineral, vitamin and fat, and these nutrients have considerable and beneficial effects on the well-being of the people. In 2020, the European Union produced 11.75 % of the global beef production, and was ranked third in the world with almost 6.8 million metric tons of carcasses (Anonymous, 2022). Turkey is the leading country in the EU regarding cattle population, and beef is the most consumed red meat in the country. Additionally, the share of cattle in total red meat production was reported to be 89.5% by Ozdemir and Yanar (2021).

In many European countries, dairy cattle breeds such as Holstein Friesian are the main sources of beef production, since the share of pure beef cattle breeds is small in the total cattle population. Holstein Friesian carcasses are mostly utilized as raw material for processing meat products since they are less valuable and cheaper (Nogalski et al., 2014a). Another problem encountered by beef producers is the low slaughter weight of Holstein Friesian, which adversely influences carcass and meat quality characteristics, such as a lower degree of conformation and a lower percentage of carcass dressing (Węglarz, 2010). Therefore, producers using dairy cattle breeds for beef production can't compete successfully on international beef markets.

Genetic (breed or genotype of animal) as well as non-genetic factors, such as diet, age at slaughter, sex, animal handling, and slaughter weight affect meat quality, acceptability, chemical composition, and physicochemical characteristics of carcass. Among the non-genetic factors, slaughter weight is noted as the most significant factor influencing meat quality properties and quantity of beef (Irshad et al., 2013).

Holstein Friesian cattle that are reared on elevated plains of eastern Turkey have distinctive morphological structures that are smaller in body weight and size than their counterparts raising in lowland countries of Europe (Bayram et al., 2004). Although body size of Holstein Friesian cattle raised in this region became smaller, these animals were quite well adapted to the harsh environmental conditions in the eastern region of the country. The reason laid behind that fact could be the ability of the breed to adapt to a wide range of climatic environments as indicated by Fanta (2017).

There is no information about the effects of different slaughter weights on carcass characteristics, chemical composition as well as meat quality characteristics of Holstein Friesian cattle raised in adverse geographic conditions of the eastern Turkey where has about 1500-2000 meters elevation from sea level. Therefore, this study was carried out to determine the effects of slaughter weights and muscle types on carcass characteristics, chemical compositions and meat quality attributes in young Holstein Friesian bulls.

## MATERIAL AND METHODS

The animal material of the research consisted of 21youngHolstein Friesian bulls were reared in the Food and Livestock Application and Research Center at Atatürk University, Erzurum, Eastern Turkey. The study was approved by the Chairman of the Ethics and Animal Welfare Committee of Faculty of the Agriculture at Atatürk University and the animals used in this research were treated in line with the present standards and regulations issued by the Ministry of Agriculture and Forestry of the Republic of Turkey. The animals were fed the same total mixed ration (TMR) during the fattening periodand group feeding was practiced for 280 days. TMR consisting of 30% dry hay and 70% concentrate on a dry matter basis was used for feeding of the animals. Chemical composition of the concentrate used in this study was 87.9% dry matter, 16.8% crude protein, 9.3% crude ash, 40.4% neutral detergent fiber, 21.1% acid detergent fiber, 2.9% ether extract. Dry hay contained 91.6% dry matter, 9.5% crude ash, 10.3% crude protein, 63.6% neutral detergent fiber, 39.1% acid detergent fiber, 3.3% ether extract.

After the fattening period was completed, bulls were transported to the Erzurum Meat and Milk Boardabattoir. Before slaughtering of the young bulls, they were allocated into three groups based on their weight at slaughter. The slaughter weight groups were called as lighter (n: 7, ranged from 400 to 538 and average: 470.4±32.5kg) (LSW), medium (n: 7, ranged from 520 to 563 and average: 540.8±10.9kg) (MSW) and heavier (n: 7, ranged from 589 to 658 and average: 605.8±28.3kg) (HSW). Slaughtering and post-slaughter processing in the abattoir was carried out in accordance with the regulations for slaughtering and carcass preparation of Turkish Standards Institute (TSI, 1987).

Immediately following the slaughter, hide, fore and hind shanks, head, lungs, heart, liver, spleen, tail, testis were removed and weighed, then carcass

measurements such as carcass length, thoracic depth, width of the round from medial side, length of the round as well as width of the round were also determined. The SEUROP beef carcass grading system was used to visually evaluate the fatness score (degree of fat cover) and the conformation score of each carcass by a trained meat grader. Quantities of the kidney, pelvic, and heart (KPH) fat was determined for each carcass following the slaughter, and percentage of KPH was calculated by dividing the KPH fat weight by the hot carcass weight that was recorded at about 1 h post-mortem.

The carcasses were cut along the spine into two half-carcasses, before they were chilled for 24 h at 4 °C. Dressing percentages of hot and cold carcasses were determined as percentage ratio of hot or cold carcass weights to live body weight at slaughter. After slaughter, the carcasses were cut at the 12th-13th rib interface. Marbling score, depth of fat at three equally spaced locations over *Longissimus dorsi* (LD) muscle and area of LD muscle cross-section were determined at the ribbing site.

Samples from the LD and *Gluteus medius* (GM) muscles were excised from the carcasses at 24 h post-mortem. The muscle portions were cut perpendicular to the muscle fiber into two pieces and used for chemical analysis and meat color parameters determination. Levels of moisture, ether extractable lipid, crude protein and ashin the raw meat samples were also determined (ISO14421978; ISO1443 1997; ISO937 1978; ISO9361989, respectively).

The pH and color parameters were measured at 24 h post-mortem on the LD and GM muscles. The pH measurements were performed on freshly cut surfaces of LD and GM muscles by direct probe using a SCHOTT, Lab Star pH meter. Color parameters [lightness ($L^*$), redness (a*), yellowness (b*) values] on the LD and GM muscles were determined objectively using a Minolta colorimeter device (CR-200, Minolta Co Osaka, Japan) after 30 min of exposure to the air. (Honikel, 1998). Tissue hue (H*) and chroma (C*) were calculated as $\tan^{-1}$(b*/a*) and respectively (McLaren, 1997). Finally, hue was converted from radians to degrees by multiplying $\tan^{-1}$(b*/a*) by (180/3.14) (McNamee et al., 2014).

**Statistical analysis**

The Kolmogorov-Smirnov test in SPSS statistical program version 20 was utilized to test the normality of data of the study. Since the data had normal distribution, the SPSS GLM procedure was used for statistical analysis of the data. Two different mathematical models were formed to analyze theeffects of fixed factors (SPSS, 2011). The data for carcass characteristics, proportions of the non-carcass components and carcass measurements were analyzed by one-way ANOVA. The mathematical model (1) used for ANOVA was as follows:

$$Y_{ij} = \mu + a_i + e_{ij} \qquad (1)$$

Data on the color characteristics and chemical composition were analyzed by two-way ANOVA. Since interactions between slaughter ages and muscle types were not statistically significant in the preliminary analysis, they were excluded from the mathematical models used in the final statistical analysis. The second mathematical model (2) used for ANOVA of data on meat color parameters, proximate analysis and meat textural characteristics was as follows:

$$Y_{ijk} = \mu + a_i + b_j + e_{ijkj} \qquad (2)$$

Where, Y represents each of the observations. μ is the least squares means while a, b respectively corresponded to the fixed effects of the slaughter weight (i=1, lighter; i=2, medium; i=3, heavier) and muscle types (j=1, LD; j=2, GM). The random residual effect was indicated by e.

Statistical comparisons among subclass means were carried out by Duncan's Multiple Range test available in SPSS statistical program when F-tests for main effects were significant.

## RESULTS

The least squares mean and standard errors for the carcass traits of young Holstein Friesian bulls in the LSW, MSW and HSWgroups are presented in Table 1.

Slaughter weights affected significantly ($P<0.01$) both hot and cold carcass weight. The differences between slaughter weight in terms of SEUROP fatness, and conformation scores as well as marbling scores were not statistically significant. Similarly, the percentages of hot and cold carcass dressing, kidney fat, and internal fat, as well as the marbling score, were not significantly affected by the slaughter weights. However, various slaughter weights had significant effect on total LD area and LD area per 100 kg carcass weight values.

Data concerning proportions of the non-carcass components of the bulls slaughtered at different weights are presented in Table 2. Slaughter weight had significant impact on the proportions of hide (P<0.01), head, liver and lungs (P<0.05) while the rest of the non-carcass components did not differ significantly by slaughter ages.

Least squares means and standard errors for carcass measurements are given in Table 3. All of the carcass measurements excluding width of the round from medial side were significantly (P<0.01) affected by slaughter weight groups.

In Table 4, least squares means and standard errors for the chemical composition of the LD and GM muscles of young bulls in LSW, MSW and HW groups are presented. Although the crude protein content was significantly affected by both slaughter weights and muscle types, only muscle types were also significant sources of variation in percentages of moisture and crude ash.

**Table 1.** Least squares means and standard errors for carcass characteristics of Holstein Friesian bulls

| | Slaughter Weights | | | |
|---|---|---|---|---|
| | LSW | MSW | HSW | P value |
| Hot Carcass Weight (kg) | 256.5±7.3$^{C}$ | 299.2±6.4$^{B}$ | 337.7±7.3$^{A}$ | 0.009 |
| Cold Carcass Weight (kg) | 252.7±7.1$^{C}$ | 295.2±6.3$^{B}$ | 332.2±7.1$^{A}$ | 0.005 |
| Hot Carcass Dressing Percentage (%) | 54.5±0.6 | 55.2±0.5 | 55.7±0.6 | 0.132 |
| Cold Carcass Dressing Percentage (%) | 53.7±0.5 | 54.5±0.5 | 54.8±0.5 | 0.170 |
| SEUROP Fatness Scores | 3.4±0.65 | 4.3±0.58 | 4.6±0.65 | 0.063 |
| SEUROP Conformation Scores | 11.28±0.84 | 10.57±0.74 | 10.22±0.84 | 0.182 |
| Marbling Scores | 1.57±0.34 | 1.71±0.38 | 1.89±0.34 | 0.069 |
| LD Area ($cm^2$) | 71.2±2.06$^{B}$ | 79.49±1.81$^{A}$ | 83.97±2.06$^{A}$ | 0.009 |
| Fat thickness over LD (mm) | 4.1±0.8 | 4.4±0.8 | 4.7±0.8 | 0.071 |
| LD Area per 100 kg Carcass Weight | 27.9±0.7$^{A}$ | 27.3±0.7$^{A}$ | 24.9±0.7$^{B}$ | 0.007 |
| Kidney Fat Percentage (%) | 0.89±0.06 | 0.89±0.06 | 0.81±0.06 | 0.172 |
| Internal Fat Percentage (%) | 0.80±0.09 | 0.66±0.08 | 0.83±0.09 | 0.093 |

$^{A, B, C}$: Values in rows with different letters differ significantly (P<0.01).

**Table 2.** Least squares means and standard errors for proportions of non-carcass components of the bulls

| | Slaughter Weights | | | |
|---|---|---|---|---|
| Non-carcass Components (%) | LSW | MSW | HSW | P value |
| Hide | 8.02±0.13$^{A}$ | 7.68±0.12$^{AB}$ | 7.38±0.13$^{B}$ | <0.001 |
| Head | 3.79±0.07$^{a}$ | 3.54±0.06$^{b}$ | 3.60±0.07$^{ab}$ | 0.045 |
| Fore and Hind Shanks | 2.02±0.06 | 1.96±0.05 | 2.01±0.06 | 0.085 |
| Testis | 0.18±0.01 | 0.16±0.01 | 0.16±0.01 | 0.172 |
| Tail | 0.25±0.01 | 0.24±0.01 | 0.22±0.01 | 0.274 |
| Liver | 1.71±0.11$^{a}$ | 1.33±0.10$^{b}$ | 1.37±0.11$^{b}$ | 0.034 |
| Lungs | 0.98±0.04$^{a}$ | 0.85±0.03$^{b}$ | 0.89±0.04$^{b}$ | 0.029 |
| Spleen | 0.19±0.01 | 0.18±0.01 | 0.17±0.01 | 0.093 |
| Heart | 0.47±0.01 | 0.45±0.01 | 0.43±0.02 | 0.167 |

$^{a, b}$: Values in rows with different letters differ significantly (P<0.05). $^{A, B}$: Values in rows with different letters differ significantly (P<0.01).

**Table 3.** Least squares means and standard errors for some carcass measurements of the Holstein Friesian bulls

| | Slaughter Weights | | | |
|---|---|---|---|---|
| Carcass Measurements (cm) | LSW | MSW | HSW | P value |
| Thoracic depth | 44.7±0.7$^{A}$ | 47.8±0.6$^{B}$ | 50.1±0.7$^{C}$ | 0.008 |
| Carcass length | 142.6±1.6$^{A}$ | 150.2±1.4$^{B}$ | 152.7±0.6$^{B}$ | 0.001 |
| Length of the round | 75.0±1.2$^{A}$ | 79.6±1.0$^{B}$ | 82.4±1.2$^{B}$ | <0.001 |
| Width of the round | 40.1±0.8$^{A}$ | 43.0±0.7$^{B}$ | 44.7±0.8$^{B}$ | 0.003 |
| Width of the round from medial side | 21.3±0.6 | 22.7±0.5 | 23.0±0.6 | 0.212 |

$^{A, B, C}$: Values in rows with different letters differ significantly (P<0.01).

**Table 4.** Least squares means and standard errors for the chemical composition of the LD and GM muscles of Holstein bulls slaughtered at three live weights.

| Chemical Composition | Slaughter Weights | | | | Muscle Types | | |
|---|---|---|---|---|---|---|---|
| | LSW | MSW | HSW | P value | GM | LD | P value |
| Crude protein (%) | 21.51±0.16$^{ab}$ | 21.38±0.14$^{b}$ | 21.91±0.16$^{a}$ | 0.045 | 22.02±0.13$^{A}$ | 21.18±0.13$^{B}$ | 0.001 |
| Ether extract (%) | 1.43±0.14 | 1.59±0.12 | 1.60±0.13 | 0.171 | 1.49±0.11 | 1.59±0.11 | 0.695 |
| Crude ash (%) | 1.13±0.01 | 1.11±0.009 | 1.12±0.01 | 0.265 | 1.09±0.008$^{A}$ | 1.14±0.008$^{B}$ | 0.008 |
| Moisture (%) | 75.93±0.22 | 75.92±0.19 | 75.37±0.22 | 0.573 | 75.40±0.17$^{a}$ | 76.08±0.17$^{b}$ | 0.050 |

$^{a, b:}$ Values in rows with different letters differ significantly (P≤0.05).$^{A, B:}$ Values in rows with different letters differ significantly (P<0.01).

**Table 5.** Least squares means and standard errors for $pH_{24}$ andmeat color parameters.

| | Slaughter Weights | | | | Muscle Types | | |
|---|---|---|---|---|---|---|---|
| | LSW | MSW | HSW | P value | GM | LD | P value |
| $pH_{24}$ | 5.52±0.03$^{a}$ | 5.57±0.03$^{ab}$ | 5.70±0.03$^{b}$ | 0.035 | 5.68±0.026$^{A}$ | 5.52±0.026$^{B}$ | 0.003 |
| **Meat color parameters** | | | | | | | |
| L* | 31.89 ±0.43$^{a}$ | 30.16±0.49$^{ab}$ | 29.18±0.49$^{b}$ | 0.048 | 29.31±0.38$^{A}$ | 31.51±0.38$^{B}$ | 0.002 |
| a* | 15.05±0.47$^{a}$ | 14.23±0.41$^{ab}$ | 13.55±0.47$^{b}$ | 0.039 | 13.54±0.37$^{A}$ | 15.0±0.37$^{B}$ | 0.007 |
| b* | 5.21±0.22$^{A}$ | 5.75±0.19$^{AB}$ | 6.04±0.22$^{B}$ | 0.001 | 5.84±0.17 | 5.50±0.17 | 0.226 |
| C* | 14.52±0.50$^{a}$ | 15.36±0.44$^{ab}$ | 16.22±0.50$^{b}$ | 0.028 | 16.10±0.40$^{A}$ | 14.63±0.40$^{B}$ | 0.002 |
| H* | 21.92 ±0.48 | 22.85±0.42 | 22.93±0.48 | 0.168 | 21.26±0.37$^{A}$ | 23.88±0.37$^{B}$ | 0.004 |

$^{a, b}$: Values in rows with different letters differ significantly (P<0.05). $^{A, B}$: Values in rows with different letters differ significantly (P<0.01). L*: lightness, scale 0 (black) to 100 (white); a*: redness, + a* (red) to - a* (green); b*: yellowness, + b* (yellow) to - b* (blue); C*: Chroma (Color intensity); H*: hue.

Least square means and standard errors for L*, a*, b*, C*, H*and $pH_{24}$ values were tabulated in Table 5. All of the color parameters except for H* value were significantly affected by slaughter weights. Moreover, muscle types also had significant (P<0.01) effects on meat color parameters such as L*, a*, C* and H* values. The pH values measured at 24 h post-mortem ($pH_{24}$) on the meat samples were also influenced significantly by slaughter weights (P<0.05) and muscle types (P<0.01).

## DISCUSSION

Cattle breeders in Turkey are paid on basis of carcass weight and dressing percentage. Therefore, cattle producers need to know the relationship between potential carcass weights and dressing percentages of their cattle slaughtered at different weights to maximize returns from their animals. The hot and cold carcass weights of the Holstein Friesian bulls in the HSW group, respectively, were 12.8% and 12.6% heavier than those in the MSW group, and 31.6% and 31.5 % higher than those in the LSW group (Table 1). Furthermore, the hot and cold carcass weights increased linearly and differed (P<0.01) among the slaughter weight groups, similar to the findings of the studies reported by Moreno et al. (2008), Węglarz (2010) and McNamee et al. (2014). Both hot and cold dressing percentages improved with increased slaughter weights, however, differences in the carcass dressing were not statistically significant. The results were comparable to the findings of McEwen et al. (2007) and Węglarz (2010). Meanwhile, slaughtering young bulls at higher weight has a slight effect on increasing the SEUROP fatness score and decreasing conformation score, which is in accordance with the results of the studies carried out by Bruns et al. (2004) and McNamee et al. (2014).

The LD muscle is a high value portion of a carcass and related to the lean meat content. In the current study, cross-sectional area of LD muscle and LD area per 100 kg carcass weight accompanied by an increase with slaughter weight (P<0.01) (Table 1). The LD area of the young Holstein bulls in the HSW group was 17.9 and 5.6% higher than that of the animals in the LSW and MSW groups, respectively. The significant effect of the slaughter weight on LD area was also observed in other studies carried out by Bruns et al. (2004) and Nogalski et al. (2014b).

There was an increasing trend in the intramuscular fat deposition in the LD muscle (marbling) as well

as fat thickness over LD in the present study as the slaughter weight increased. However, the differences in the carcass fat parameters among the LSW, MSW and HW groups were not significantly different. Likewise, an existing association between advancing slaughter weight and increasing of intramuscular fat content was also reported by McEwen et al. (2007) and Nogalski et al. (2014b).

Proportions of hide, head, liver and lungs to slaughter weight of the bulls in the LSW group were significantly higher than those of animals in HSW groups. Although the rest of the non-carcass components did not differ significantly among the slaughter weight groups, there was a decreasing trend in the proportion of the non-carcass components as the slaughter weight increased (Table 2).

Increasing of the slaughter weights of Holstein Friesian bulls resulted in a significant increase in the carcass measurements such as thoracic depth, carcass length, length of the round as well as width of the round (Table 3). The results are in agreement with the findings of Paris et al. (2015) who reported significant ($P<0.01$) increases in carcass length, round length and arm length of Holstein bulls with the increasing the slaughter weight.

Determination of the chemical composition of beef is essential for evaluation of the nutritional value of the meat. The effects of the slaughter weight on the percentages of the ether extract, crude ash and moisture contents, except for the percentage of protein, were not statistically significant (Table 4). Likewise, Zawadzki et al. (2015) reported that content of moisture, ash and total lipids of the LD muscle were comparable for bulls slaughtered at light, medium and heavy body weights. In the present study, high protein content was determined in the meat samples of the bulls in HSW group. The percentage of the protein of the meat from bulls in HSW group was 1.85% and 0.51% higher than those in LSW and MSW groups. Similar result was also reported by Zawadzki et al. (2015) who stated that the bulls in medium and heavy slaughter weight groups had greater ($P<0.01$) percentage of protein than those slaughtered at light body weight. However, Węglarz(2010) reported a higher protein content ($P<0.01$) in the meat of light bulls compared to heavy ones at slaughter. On the other hand, no significant difference in the proximate composition of the meat from Holstein steers slaughtered at different weights was noted by Kim et al. (1996) except for moisture content.

Types of muscles were a significant sources of variation in percentages of protein, ash and moisture content. The ash ($P<0.01$) and moisture ($P<0.05$) contents of the LD muscle were significantly higher than those of the GM muscle. However, the protein content of the GM muscle was significantly ($P<0.01$) superior to that of the LD muscle. In general, the findings regarding chemical composition of LD and GM muscles were found to be within the range of the results of Ozluturk et al. (2004) and Yuksel et al. (2009).

Meat quality characteristics, such as color, texture, and water holding capacity, are closely associated with the meat pH. The pH is most closely related with the L*, a* and b* values from the meat color parameters. In this study, pH was measured at 24 h post-mortem and significant differences were determined among the slaughter weight groups and the muscle types. The highest $pH_{24}$ was measured from meat samples obtained from animals in HSW group. The findings are in agreement with the results of the studies conducted by Węglarz (2010) and Sahin et al. (2021).The observed dissimilarities in pH between LD and GM muscles in the present study could be attributed to the difference in fiber type composition of the muscles as indicated by Anderson et al. (2012).

Appearance of the food determines how consumers perceive quality, and therefore it significantly affects purchasing decision. In the case of beef, meat color is a significant factor affecting visual evaluation and consumer appreciation as well as preference (Ainur et al. 2021). The consumers use discoloration as an indicator of freshness and wholesomeness, and any deviation from the bright cherry red color of beef influence adversely people's buying decision. Slaughter weight of cattle is also one of the factors influencing meat color attributes (Canto et al.2016).

In the present study, L* value (lightness) of the meat of Holstein Friesian bulls in HSW group were significantly lower than those of animals in LSW group, which means heavy bulls produced darker muscles than light bulls (Table 5). In other words, it is widely recognized that muscles of higher ultimate pH appears darker and generally related with a lower L* value. Likewise, results of several studies revealed that meat color becomes darker as slaughter weight increases (Clausen et al.2007; Bures and Barton 2012). Sañudo et al. (2000) postulated that increasing of the slaughter weight as well as age will increase pigment density which leads to the darker meat. Similarly, Dunne et al.(2004) reported a strong relation-

ship between the L* (r=0.23) and H* (r=0.32) values with myoglobin concentration. Additionally, the high $pH_{24}$ of the meat samples of young bulls in the HSW group could result in the development of the darker color of the animal's meat.

The a* value (redness) of the meat of the animals in LSW group was significantly (P<0.05) higher than that of cattle in HSW group. Therefore, the meat color of the young bulls in HSW group was more reddish than that of animals in LSW group. The finding could be attributed to the most highly negative association between ultimate pH and a* value as indicated by Page et al. (2001). It was compatible with the results of Dunne et al. (2004) and Sahin et al.(2021) who noted a decrease of a* value as slaughter weight increased.

In the current study, the b* value (yellowness) was found higher in HSW group in comparison to the LSW group. Similarly, Cerdeno et al.(2006) noted the greatest b* value for animals in heavier slaughter weight group compared to those in the light group (Page et al.2001). McNamee et al. (2014) also reported that Norwegian Red x Holstein Friesian crosses in heavy group had higher b* than those in light group.

Muscle type is another significant factor influencing meat color characteristics (Canto et al. 2016). In the present study, differences between LD and GM muscles in terms of all meat color parameters except for b* were statistically significant. The LD muscle had significantly (P<0.01) higher L*, a* and H* values than the GM muscle. In other words, the LD muscle was brighter and redder than GM muscle. This result could be attributed to different structural characteristics of the muscles which might affect the meat color, absorption or reflection of the light and allowing oxygen to penetrate. Furthermore, Kirchofer et al. (2002) reported that α-white fibers were mostly responsible for brightness (L* value), while β-fibers were responsible for red colors. Therefore, variations of the percentage of the two types of fibers existing in different muscles could also lead to differences in the color parameters. Moreover, the results obtained in the current study regarding effect of the muscle types on color parameters are in agreement with findings of studies reported by Aksoy et al. (2021) and Sahin et al. (2021).

## CONCLUSION

The present study revealed that Holstein Friesian bulls in the heaviest slaughter weight group were characterized by higher carcass weight, LD area, crude protein content, carcass measurements and $pH_{24}$ value. On the other hand, an increase in slaughter weight have accompanied by significant decrease in hardness value, L* and a* values from color parameters. Additionally, the carcasses of the animals in LSW group had brighter and redder color.

## ETHICS APPROVAL

This study was performed with ethical approval from the Local Ethics Committee of Ataturk University Faculty of Agriculture (Erzurum,Turkey; approval no. 2022/010).

## CONFLICT OF INTEREST

Authors declared that they have no conflict of interest.

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