https://doi.org/10.17221/40/2024-CJAS

Effects of maize silage withdrawal from finishing ration on weight gain, carcass yield and beef quality of Holstein Friesian × Belgian Blue crossbred bulls

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Citation: Gündüz T., Çayiroğlu H. (2024): Effects of maize silage withdrawal from finishing ration on weight gain, carcass yield and beef quality of Holstein Friesian × Belgian Blue crossbred bull. Czech J Anim Sci, 69: 219–229.

Abstract: This study was practical work in a commercial beef cattle enterprise to offer beef producers different options in a total mixed ration (TMR) design. This study was conducted to determine the effects of withdrawing maize silage from TMR during the finishing period on weight gain, carcass yield and beef quality of meat in beef cattle. Fifty-two Holstein Friesian x Belgian Blue crossbred bulls were used in this study for 126 days. These bulls were divided into four feeding methods described as (*i*) no maize silage in TMR (C1), (*ii*) maize silage was withdrawn from TMR two months before slaughter (S1), (*iii*) maize silage was withdrawn from TMR one month before slaughter (S2), and (*iv*) maize silage was included in TMR until slaughter (C2). Results showed that the fattening performance of experimental bulls was not affected by treatments, except some colour parameters of the muscle. Also, its chemical composition, pH, water holding capacity, drip loss, thawing loss, cooking loss, shear force, thiobarbituric acid reactive substances and radical scavenging activity were not affected by treatments. To conclude, the withdrawal of maize silage from TMR did not affect fattening performance and meat quality, suggesting that there is no need to withdraw maize silage from TMR during the finishing period of fattening in beef cattle.

Keywords: carcass dressing; feeding; feed evaluation; *longissimus lumborum* muscle; meat quality

As a human diet, meat is an essential food that is rich in proteins, minerals, vitamins, and fatty acids. The colour (brightness), acidity (pH), tenderness, juiciness, water holding capacity (WHC), and texture of meats are important quality properties that affect the food processing industry and consumer preferences (Sahin et al. 2021). Especially, colour, juiciness, marbling level and taste have greater effects on consumer satisfaction (Hunt et al. 2016).

There are several factors that affect these meat quality parameters. It is well known that these factors can be classified as animal-related ones and others. While the former factors are breed, age and gender, the latter factors are environmental conditions such as management, handling, nu-

Supported by Scientific Research Projects Commission of Kırşehir Ahi Evran University as financial (ZRT.A4.18.015).

https://doi.org/10.17221/40/2024-CJAS

trition, animal's health status and other management procedures. These factors can affect the proportion of carcass components, meat quality, and its price. As nutritional factors, ingredients, roughage, concentrate or grains, and feed additives can affect beef quality. There are some reports that silage and roughage consumption improved meat colour andquality by increasing the vitamin E concentration in meat (Lee et al. 2009; Keller et al. 2022). The colour of fresh beef is one of the attributes based on which consumers make their decision about the purchase (Purslow et al. 2020). The most acceptable by consumers is bright, cherry-red beef, with a^* values equal to or higher than 14.5, L^* higher than 31.4 and b^* higher than 6.3 (Holman and Hopkins 2021). According to Nogalski et al. (2023), maize silage did not affect performance, carcass value or meat quality while He et al. (2018) found out that the increased amounts of maize silage in the diet of beef cattle may negatively affect beef characteristics. How dietary changes will affect meat quality has not yet been illustrated sufficiently in detail, especially by switching "from hay to silage or from silage to hay" in the fattening of beef cattle. Based on our personal observations in the field, since "brightness" is one of the meat colour parameters, there has been concern by beef keepers about the use of maize silage in finishing ration whether this may affect these parameters negatively or not. However, there has been no information about whether this practice has rational validity or whether it will affect the physicochemical properties of meat. Therefore, this study aimed to investigate the effects of withdrawing maize silage from TMR during the finishing period on fattening performance, carcass traits, and some physicochemical properties of meat in fattening cattle.

MATERIAL AND METHODS

Animals and caring

Our experimental protocols were approved by the Ethical Local Committee (Approval No. 27.12.2017/2). This study was conducted in a private feedlot enterprise in the Central Anatolian Region of Türkiye (located at 38°50'–39°50'N and 33°30'–34°50'E latitudes) at an altitude of 985 m above sea level.

Fifty-two Holstein Friesian × Belgian Blue crossbred bulls selected from the stock animals of the enterprise aged 18–20 months with pre-experiment average live weight of 570 ± 44.1 kg were used in the experiment. Their age was as what was entered in their birth records. Before the experiment, veterinary precautions were taken to protect the bulls from any internal and external parasites (deworming). The bulls having similar body weights were divided into four treatment groups. The feed ingredients with their nutritional contents are given in Table 1.

Having the same level of protein and energy to get daily 1.20 kg live weight gain, TMR formulations were made by using the ingredients such as feedlot concentrate, cracked barley, maize silage or lucerne hay, and wheat straw as given their proportions in Table 2, based on the nutritional requirements of finishing bulls (NRC 2000).

The experimental procedure is given in Table 3. The treatment groups each including 13 bulls and kept in a pen sized 104 m^2 were divided into four feeding methods described as (*i*) no maize silage in TMR (C1), (*ii*) maize silage was withdrawn from TMR two months before slaughter (S1), (*iii*) maize silage was withdrawn from TMR one month before

Table 1. Nutritional composition of feed ingredients used in TMRs (g/kg DM)

Feed ingredients	Wheat straw	Alfalfa hay	Maize silage	Cracked barley	Feedlot concentrate
Dry matter	910	820	320	880	880
Organic matter	872	882	825	975	926
Crude protein	50.5	180	173	125	161
Ether extract	19.8	15.9	69.1	23.9	72.7
Neutral detergent fibre	705	482	581	240	255
Acid detergent fibre	489	379	366	93	125
Crude ash	128	118	175	25	74
Metabolizable energy (MJ/kg DM)	6.51	8.34	10.1	12.3	12.2

DM = dry matter; TMR = total mixed ration

https://doi.org/10.17221/40/2024-CJAS

Table 2. Ingredients, crude protein, and metabolizable energy content of TMRs

Ingredients (g/kg of DM)	TMR–1	TMR–2
Wheat straw	43.3	36.3
Alfalfa hay	246	0
Maize silage	0	253
Cracked barley	348	348
Feedlot concentrate	348	348
Buffer ingredients[1]	5.41	5.41
Vitamin mineral yeast mix[2]	5.41	5.41
Marble powder	3.88	3.88
Crude protein (g/kg of DM)	146	145
Metabolizable energy (MJ/kg DM)	10.9	11.1

[1]67% NaHC03 + 33% MgO; [2]Vitamin and mineral and yeast mix (mg/kg, IU): 1 200 000 IU vitamin A, 240 000 IU vitamin D3, 100 mg vitamin E, 6.22 mg vitamin B7, 500 mg vitamin B1, 6 080 mg vitamin B3, 3 500 mg Mg, 50 mg Co, 5 000 mg Zn, 1 100 mg Cu, 5 650 mg Fe, 50 mg Se, 60 mg I, 32 000 mg Na, 15 277 mg Ca, 11 000 mg P, 3 × 10 CFU/g *Saccharomyces cerevisiae*

DM = dry matter; TMR = total mixed ration

slaughter (S2), and (*iv*) maize silage was included in TMR until slaughter (C2).

Before the experiment, the bulls were subjected to a 14-day adaptation period, while they were weighed at the end of this period after 12-h fasting. Following the adaptation period, the main experimental period lasted for 126 days. The bulls were fed *ad libitum* by considering 5% more of the feed amount they could consume daily. TMR was prepared daily using a feed wagon and provided to the bulls in two separate meals at 08:00 and 16:00. Additionally, fresh and clean water was provided *ad libitum*.

Individual feed intake of the bulls was determined daily but the feed intake for 14 days was evaluated. The experimental bulls were weighed individually before morning meals at fortnightly intervals. Each bull was considered as one replicate for body weight data. On these days, the bulls were subjected to 12 h of fasting before weighing. Animal welfare practices were taken into consideration during weighing. Based on the data obtained, the average daily live weight gains of the bulls were calculated. Based on fortnight data, the feed conversion ratio was calculated by dividing daily live weight gain by daily dry matter intake. Final body weights of the bulls were recorded at the conclusion of the fattening period.

Slaughtering, carcass yield and sampling

The bulls were taken to the slaughterhouse in a covered special vehicle approximately 12 h before slaughter. They were fasted during this period but allowed *ad libitum* access to water. The bulls were subjected to electrical stunning, being slaughtered within 30 seconds. The slaughtered bodies were labelled individually. Their head, feet, skin, and internal organs were separated, and the remaining carcasses were weighed, both hot and chilled. The hot carcass dressing percentage was computed by dividing the weight of the hot carcass, measured one hour post-slaughter, by the live weight prior to slaughter. Similarly, the cold carcass yield was determined by dividing the weight of the cold carcass by its slaughter weight.

Muscle samples were extracted from the *longissimus lumborum* (LL) muscle between the 11th and 13th rib on the left sides of the carcasses, from six bulls representing each treatment group. These samples were promptly transported to the laboratory for further analysis by using a cold chain box (maintained at 4 °C). Upon arrival, the meat samples were stored in a refrigerator at 4 °C for subsequent analysis, including moisture, ash,

Table 3. Experimental procedure

Treatment/day	1–70	71–98 (28 days)	99–126 (28 days)	127
C1	TMR without silage (TMR–1)			
S1	TMR containing silage (TMR–2)	TMR without silage (TMR–1)		slaughter
S2	TMR containing silage (TMR–2)		TMR without silage (TMR–1)	
C2	TMR containing silage (TMR–2)			

C1 = TMR without maize silage; C2 = TMR including maize silage offered until slaughter; S1 = TMR including maize silage offered to bulls until day 56 before slaughter; S2 = TMR including maize silage offered to bulls until day 28 before slaughter; TMR = total mixed ration

https://doi.org/10.17221/40/2024-CJAS

protein, intramuscular fat, pH, colour, WHC, drip loss, cooking loss, tenderness, thiobarbituric acid-reactive substances (TBARS) values, and radical scavenging activity. Additional samples were stored at –20 °C, specifically for TBARS value and frozen-thawing loss analysis (Sahin et al. 2021).

Chemical analysis

Feed and meat samples were analysed following the protocols outlined in AOAC (2000), which included the determination of dry matter (Method 934.01), ash (Method 942.05), and nitrogen (Method 988.05), using a nitrogen conversion factor of 6.25. The ether extract (EE) content of feeds was determined using the ANKOM XT15 Extraction System (AOCS 2005) while intramuscular fat contents of meat samples were determined by using the Soxhlet extraction method (AOAC Method 960.39). For feed samples, analyses of crude fibre (CF), acid detergent fibre (ADF, including residual ash), and neutral detergent fibre (NDF, post-α-amylase treatment and inclusive of residual ash) were carried out using an ANKOM 200 Fibre Analyser (ANKOM Technology Corp. Fairport, NY, USA) in accordance with Van Soest et al. (1991). Organic matter of samples was determined by subtracting the crude ash percentage from the dry matter percentage. Metabolizable energy (ME) of feeds was calculated by the formula provided by the Turkish Standards Institute (TSE 2004).

$$\mathrm{ME}\left(\frac{\mathrm{kcal}}{\mathrm{kg}}\mathrm{OM}\right) = 3\,260 + 0.455 \times (\mathrm{CP}) - 4.037 \times (\mathrm{CF}) + 3.517 \times (\mathrm{EE}) \quad (1)$$

The units of measure for ME, CP, CF, and EE are g/kg OM. The obtained values were converted to MJ/kg.

Physicochemical properties of the meat

Muscle pH was measured twice for each carcass, 1 h post-mortem ($pH_{1\,h}$) and 24 h post-mortem ($pH_{24\,h}$), from LL between the 11th and 13th rib, by using a pH meter (Testo 205) equipped with a piercing electrode (Kul et al. 2020). Muscle colour was determined by using the CIELab System Chroma Meter CR-410 (Konica Minolta, Japan) in chilled carcasses 24 h after slaughter. For this process, L^* (brightness/darkness), a^* (redness/greenness) and b^* (yellowness/blueness) values were measured from four different points of the meat and recorded (King et al. 2023). Chroma (C^*; saturation index) and hue angle ($h°$) were calculated by using the following equations:

$$(C)_{ab} = [(a)^2 + (b)^2]^{(1/2)} \quad (2)$$

$$(h°)_{ab} = \mathrm{arctangent}(\mathrm{b}/\mathrm{a}) \quad (3)$$

where:

C^* – saturation index;

$h°$ – hue angle;

a^* – redness/greenness;

b^* – yellowness/blueness.

The WHC of the LL muscle samples was determined by the filter-paper press method with some modifications (Aksoy et al. 2019). The meat sample (25 g) was placed between two filter papers (Whatman 1, No. 1001 125) on the ceramic surface and 2 250 g metal weight was placed on them. After 5 min, the samples were removed from the filter papers, weighed again. The difference between 25 g and the second weighing was determined as the amount of water removed, then its percentage in 25 g was defined as WHC.

Dripping loss and frozen–thawing loss values were determined as described by Aksoy et al. (2019). Accordingly, 50 g meat sample (W1) was vacuum-packed and stored at 4 °C for 7 days. On days 3 and 7, excess moisture was wiped out and the samples were weighed (W2). The drip loss value (%) was calculated according to the following equation:

$$\mathrm{Drip\ loss}(\%) = \left[\frac{\mathrm{W1} - \mathrm{W2}}{\mathrm{W1}}\right] \times 100 \quad (4)$$

where:

W1 – 50 g meat sample;

W2 – weighed samples.

To determine the frozen-thawing loss of meat, 50 g of meat sample (W1) was placed in vacuum bags and kept in a deep freezer at –20 °C for 120 h. At the end of this period, the samples taken out of the freezer were thawed at 4 °C for 12 h and weighed (W2). The frozen-thawing loss was calculated according to the following equation:

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$$\text{Thawing loss}(\%) = \left[\frac{W1 - W2}{W1}\right] \times 100 \quad (5)$$

where:
W1 – 50 g meat sample;
W2 – weighed samples.

The cooking loss and shear force were assessed following the procedure outlined by Sen et al. (2020). Accordingly, 40 g muscle samples (W1) underwent cooking by being placed in plastic bags and immersed in a water bath set at 70 °C for 40 minutes. Following the cooking process, the samples were cooled under running tap water for 60 minutes. Afterwards, the samples were taken out of the plastic bags and dried with paper towels, and weighed (W2) to measure the weight loss. The cooking loss was calculated according to the following equation:

$$\text{Cooking loss (\%)} = [(W1 - W2) / W1] \times 100 \quad (6)$$

where:
W1 – 40 g muscle sample;
W2 – weighed samples.

Samples to calculate shear force values were prepared by the same procedure as used for cooking loss determination. They were rested for 2 h after cooking and cut into pieces of 2-cm length and 2-cm^2 base with the muscle fibres parallel to the longitudinal axis. Measurements were done with a texture analyser (CT3, 50 kg, Brookfield Co., USA). Four shear tests were applied to each sample and the sensitivity was determined by averaging the results expressed in Newtons (N) (Sen et al. 2020).

The content of TBARS in the meat sample was determined as described in Kilic and Richards (2003). Based on the methodology outlined, the meat samples were stored at 4 °C for TBARS analysis on days 1, 3, and 7, and at –20 °C on day 21. For the analysis, 1 gram of muscle samples was homogenized with 6 ml of extraction solution using an Ultra-Turrax homogenizer for 15–20 seconds. The resulting homogenate was then filtered through Whatman Grade 40 filter paper. Following the filtration, 1 ml of filtrate was combined with 1 ml of TBA and vortexed, followed by heating at 100 °C for 40 min in a heated block. After cooling, the samples underwent centrifugation at 2 000 rpm for 5 minutes. Absorbance was measured at 532 nm against a blank containing 1 ml of TCA extraction solution and 1 ml of TBA solution. The TBARS value was calculated and compared with a standard curve prepared using 1,1,3,3-tetraethoxypropane. The results are expressed as mg of malondialdehyde (MDA) per kg of meat.

The free radical scavenging activity was measured according to the DPPH method of Sánchez-Moreno et al. (1998). A 5-g meat sample was mixed with 50 ml of 80% acetone and immediately homogenized for 10 minutes. The mixture was then filtered through Whatman No. 1 filter paper with the help of a Buchner funnel. The filter cake was again extracted with 80% acetone. The obtained filtrate was transferred to a rotary evaporator balloon, and the acetone was removed. The remaining aqueous extract was made up to 10 ml with 80% acetone, filtered, and immediately analysed. For the analysis, five test tubes were taken and 0.6 ml of DPPH radical solution was added to each. Different volumes (20-40-60-80-100 µl) of the sample extract were added to the test tubes. The tube content was made up to 6 ml with methanol. After mixing the tubes, they were incubated for 15 min in a dark environment at room temperature. For the witness sample, 0.6 ml of DPPH radical solution and 5.4 ml of methanol solution were added and incubated for 15 min at room temperature. At the end of this period, all samples were read in the spectrophotometer at a wavelength of 517 nm. The scavenging activity of the DPPH radical was calculated using the following equation:

$$\text{Radical scavenging activity \%} = \left[\frac{Abs_{blank} - Abs_{sample}}{Abs_{blank}}\right] \times 100 \quad (7)$$

where:
Abs_{blank} – absorbance of the blank;
Abs_{sample} – absorbance of the sample.

A curve was drawn with the absorbance values measured at different concentrations. In the $y = ax + b$ equation, the sample amount that halved the DPPH concentration was found in µg/ml, and 50% effective concentration (EC50) values were calculated.

Statistical analyses

The obtained data (performance and meat quality) were subjected to the General Linear Model

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Procedure of SPSS v17.0 for Windows. To ascertain differences between the treatment means, Duncan's multiple comparison test was applied within the same software.

RESULTS AND DISCUSSION

Performance

In our study, the withdrawal of silage from TMR during fattening did not produce any changes in the nutrient intake of bulls. The dry matter, organic matter, crude protein, ADF, and NDF intake of the bulls was not affected by any treatment ($P > 0.05$; Table 4). According to Table 4, there were no effects of any treatment on daily live weight gain, final live body weight, and total body weight gain across all treatments ($P > 0.05$). Furthermore, neither the final live body weight nor the total body weight gain was affected by the withdrawal of maize silage from TMR ($P > 0.05$). However, there was a significant difference between the treatment groups regarding the feed conversion ratio ($P < 0.05$). Bulls fed silage from the beginning to the end of fattening (C2) and bulls fed silage until one month before slaughter (S2) showed better feed conversion ratios ($P < 0.05$). In general, while some research has investigated the impact of feeding silage on the performance of beef cattle, there has been no study on the withdrawal of silage from TMR at different periods. He et al. (2018) stated that there was no significant difference in dry matter intake and body weight gain of cattle when maize stalk silage was replaced with maize silage. Sutherland et al. (2020) reported findings consistent with this, indicating that the intake of barley silage or maize silage had no impact on the dry matter intake and performance of the bulls. For bulls fed silage, the performance data obtained in this study are in line with the study of Nogalski et al. (2023).

Meat carcass traits and muscle chemical composition

There has been no information in the literature about the effects of silage withdrawal from TMR on meat quality characteristics in beef cattle. Studies on this subject have mostly focused on comparing the effects of different silage types. In the present study, neither the chemical composition nor dressing percentage of meat was affected by any treatment ($P > 0.05$; Table 5). In other words, withdrawing silage from TMR before slaughter did not influence the chemical composition of the muscles. These results showed that the withdrawal of maize silage from TMR during the last period of fattening and the addition of lucerne hay did not affect the chemical composition of the meat. Protes

Table 4. Effect of withdrawing maize silage from TMR on fattening performance

Parameters	C1	S1	S2	C2	SEM	Significance
Dry matter intake (g/d)	15 600	14 900	14 100	14 700	310	ns
Organic matter intake (g/DM/d)	14 300	13 600	12 900	12 600	295	ns
Crude protein intake (g/DM/d)	2 280	2 170	2 080	2 020	46	ns
ADF intake (g/DM/d)	2 970	2 810	2 670	2 590	62	ns
NDF intake (g/DM/d)	5 020	4 970	4 840	4 800	83	ns
Initial live body weight (kg)	556	581	579	566	6.022	ns
Final live body weight (kg)	717	741	748	731	7.455	ns
Daily live weight gain (g/d)[1]	1 273	1 258	1 308	1 293	8.627	ns
Total body weight gain (kg)	161	160	169	164	3.246	ns
Feed conversion ratio (kg DM intake/kg body weight gain)	12.3[a]	11.8[ab]	10.8[b]	10.8[b]	0.246	*

[1]This analysis was supported by repeated measurement analysis of SPSS statistical software; [a,b]Means in the same row with different superscripts differ significantly; *$P < 0.05$

ADF = acid detergent fibre; C1 = TMR without maize silage; C2 = TMR including maize silage offered until slaughter; DM = dry matter; NDF = neutral detergent fibre; ns = not significant; S1 = TMR including maize silage offered to bulls until remaining 56–d to slaughter; S2 = TMR including maize silage offered to bulls until remaining 28–d to slaughter

https://doi.org/10.17221/40/2024-CJAS

Table 5. Effects of withdrawing maize silage from TMR on carcass yield and chemical composition of *longissimus lumborum* muscle

Parameters	C1	S1	S2	C2	SEM	Significance
Meat carcass yield						
Hot carcass weight (kg)	391	398	415	407	5.001	ns
Chilled carcass weight (kg)	384	390	406	398	4.887	ns
Hot dressing percentage (%)	56.0	55.6	56.8	57.6	0.321	ns
Chilled dressing percentage (%)	54.9	54.4	55.6	56.4	0.319	ns
Chemical composition of *longissimus lumborum* muscle						
Moisture (%)	73.2	73.1	74.0	73.2	0.230	ns
Dry matter (%)	26.8	26.9	26.0	26.9	0.230	ns
Protein (%)	20.5	20.9	20.9	21.0	0.203	ns
Intramuscular fat (%)	1.27	1.35	1.22	1.27	0.021	ns
Ash (%)	2.19	2.01	2.24	2.25	0.036	ns

C1 = TMR without maize silage; C2 = TMR including maize silage offered until slaughter; ns = not significant; S1 = TMR including maize silage offered to bulls until remaining 56–d to slaughter; S2 = TMR including maize silage offered to bulls until remaining 28–d to slaughter

et al. (2018) reported that soybean and sorghum silage did not cause any difference in the chemical composition of lamb meat. Demirel et al. (2013) found that there was no impact on lamb carcass characteristics or meat quality when lambs were fed triticale and barley silage with or without inoculant. The chemical composition characteristics of muscle in this study resembled those reported for meat obtained from Holstein or its crossbred beef cattle by Manni et al. (2018) and Kul et al. (2020).

Physicochemical properties of meat

In general, the withdrawal of maize silage from TMR during the last period of fattening did not affect the physicochemical characteristics of the LL muscle, except L^*, b^*, and $h°$ (Table 6). One of the main factors determining meat quality is pH. After slaughter, anaerobic glycolysis causes the formation of lactic acid; thus, the lactic acid accumulated in the muscle reduces the pH. This process continues until the glycogen substrate is exhausted. This change in pH also influences the physicochemical properties of meat (Sen et al. 2010). In addition, the amount of lactic acid produced during silage fermentation affects the pH of meat in bulls. The higher silage lactic acid content results in lower meat pH (Tao et al. 2020). Lower pH is correlated with poor WHC and higher pH is related to the poor shelf life (Sen et al. 2010). Meats with an ultimate pH value greater than 5.80 are considered undesirable dark-coloured meats (He et al. 2018). The $pH_{24\,h}$ values determined in our study ranged from 5.55 to 5.71 ($P > 0.05$; Table 6). From this viewpoint, these values are acceptable. Lee et al. (2009) reported the ultimate pH of meat obtained from cattle fed grass and red clover silages as 5.50, and they concluded that the silage difference did not affect the ultimate pH. Similarly, Huuskonen et al. (2017) reported that the ultimate pH of meat was unaffected by silages derived from various plant species.

The meat colour is extremely important for the consumer's impression of the meat freshness (He et al. 2018; Aksoy et al. 2019; Sahin et al. 2021). Research has revealed that many factors (endogenous and exogenous ones) contribute to meat colour stability and biochemistry. One of them is the diet. In the present study, the L^*, a^*, b^*, and C^* values were found to be within the range reported for beef cattle by Zhang et al. (2021), with L^* value ranging from 24.3 to 41.3, a^* value ranging from 11.2 to 24.0, b^* value ranging from 4.1 to 12.5, and C^* value ranging from 11.9 to 26.6 (Table 6). However, in the present study, L^*, b^*, and $h°$ values of the muscle differed between the treatment groups; the S2 and C2 treatment groups showed higher L^* values than the others. Similarly, C2 group showed higher b^* and $h°$ values than the others (5.04 and 16.7, respectively). Accordingly,

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Table 6. Effects of withdrawing maize silage from TMR on physicochemical properties of muscle

Item	C1	S1	S2	C2	SEM	Significance
$pH_{1\,h}$	6.38	6.34	6.37	6.18	0.047	ns
$pH_{24\,h}$	5.66	5.55	5.59	5.71	0.044	ns
*L**, lightness	32.8^{b}	33.1^{b}	35.6^{a}	35.3^{a}	0.395	*
*a**, redness	16.0	16.6	17.0	16.8	0.237	ns
*b**, yellowness	4.21^{c}	4.93^{ab}	4.35^{b}	5.04^{a}	0.127	*
*C**, chroma	16.6	17.3	17.6	18.0	0.266	ns
h°, hue angle	14.7^{b}	16.6^{a}	14.2^{b}	16.7^{a}	0.342	**
Water holding capacity (%)	21.2	22.8	24.4	24.9	0.657	ns
Drip loss, 3rd day (%)	21.0	23.2	21.2	21.5	0.497	ns
Drip loss, 7th day (%)	24.7	25.6	23.3	25.7	0.444	ns
Frozen-thawing loss (%)	19.3	20.4	18.7	19.6	0.428	ns
Cooking loss (%)	42.1	36.1	38.0	40.8	0.954	ns
Shear force (N)	10.7	10.6	10.6	10.3	0.078	ns
TBARS 1st day	0.668	0.742	0.518	0.708	0.031	ns
TBARS 3rd day	0.740	0.800	0.600	0.712	0.030	ns
TBARS 7th day	0.697	0.788	0.640	0.647	0.028	ns
TBARS 21st day	0.618	0.440	0.457	0.652	0.030	ns
Radical scavenging activity (%)	2.22	2.32	2.51	2.35	0.073	ns

$^{a–c}$Means in the same row with different superscripts differ significantly; *P < 0.05, **P < 0.01

C1 = TMR without maize silage; C2 = TMR including maize silage offered until slaughter; ns = not significant; pH_{1h} = pH 45 min after slaughter; $pH_{24\,h}$ = pH 24 h after slaughter; S1 = TMR including maize silage offered to bulls until remaining 56–d to slaughter; S2 = TMR including maize silage offered to bulls until remaining 28–d to slaughter; TBARS = thiobarbituric acid reactive substances, mg malondialdehyde/kg

the muscles of bulls fed silage until slaughter had a lighter yellow colour compared with those of bulls fed lucerne until slaughter. This may be attributed to the lower carotenoid content of maize silage than that of lucerne hay. If this assumption is evidenced by further studies, lucerne should remain in TMR for beef cattle. In the literature, no study has examined the effects of lucerne hay and silage consumption on meat colour. However, some studies (He et al. 2018; Manni et al. 2018; Ku et al. 2021) have reported no difference in the LL muscle colour between grazing animals and animals consuming concentrated feed. Similarly, some studies (Huuskonen et al. 2017; Kennedy et al. 2018; Protes et al. 2018) have reported that different silage types do not make any difference in meat colour.

The WHC, drip loss, frozen-thawing loss, and cooking loss values have significant impacts on the yield and quality of meat products (Aksoy et al. 2019). In this study, no difference was found between treatments in WHC, dripping loss, frozen-thawing loss, and cooking loss values (P > 0.05; Table 6). These results suggest that withdrawing maize silage from TMR during the final fattening period will have a limited effect on meat WHC, dripping loss, frozen-thawing loss, and cooking loss parameters.

Shear force or tenderness is one of the key quality attributes used in the beef industry to assess meat quality and acceptability. The shear force value is affected by factors such as age, gender, intramuscular fat accumulation and post-slaughter processes of the animal from which the meat is obtained, as well as the characteristics of the testing device, cooking method, sample shape and size (Warner et al. 2021). This may also affect the sensory qualities of meat (Sen et al. 2020). Holman et al. (2020) reported the shear force threshold value for consumer acceptance of beef tenderness as < 42.6 N, and they reported that this value may vary depending on sample type, analytical methodology, and demographic characteristics of consumers. In this study, shear force values in cooked meat samples were found to be between 10.3 and 10.7 N,

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and there was no statistical difference between the treatments. In agreement with this study, no effect on tenderness or sensory meat quality parameters was observed in the studies of Rabelo et al. (2016) and Huuskonen et al. (2017).

Lipid oxidation is a major cause of deterioration in meat quality and it generally involves degradation of polyunsaturated fatty acids (Campo et al. 2006). It can also negatively affect the nutritional quality of meat as well as its sensory attributes (colour, odour, and flavour) (Dominguez et al. 2019). The limit value for TBARS in meat and meat products has been reported to be 2.00–2.50 mg/kg malondialdehyde (Dominguez et al. 2019). While Campo et al. (2006) reported the level ≥ 2.28 as an indicator of the unacceptability of TBARS, Hughes et al. (2014) stated that TBARS levels between 2.60 and 3.11 mg/kg MDA are acceptable for consumers. The TBARS values obtained in this study, including all treatment groups, were between 0.440 and 0.800 (Table 6). While TBARS values were numerically high on day 1, 3 and 7, these values decreased on day 21. This may be due to the longer storage time compared to others.

According to the DPPH method, the antioxidant capacity of meat obtained in this study was found to be between 2.22 and 2.51% (Table 6, $P > 0.05$). Antioxidants are compounds that stop or slow down oxidation reactions. These compounds neutralize free radicals and prevent them from causing damage to the body. They are usually gradually lost after slaughter during transformation into the meat muscle, processing or storage of meat products (Kumar et al. 2015). This adversely affects the shelf life of meat.

CONCLUSION

The current findings showed that withdrawing silage from the total mixed ration in the finishing period of fattening did not affect fattening performance, dry matter intake, daily live weight gain, hot and chilled carcass weights, and dressing percentages of the experimental bulls were unaffected during fattening. In addition, although there were some differences in colour parameters of the LL muscle, chemical composition, pH, water holding capacity, drip loss, thawing loss, cooking loss, tenderness, TBARS, and radical scavenging activity were not affected by bull feeding application. It can be suggested that beef producers can easily add maize silage to their beef cattle diets until the end of fattening, without compromising bull performance or meat quality. However, there is a need for more comprehensive studies with individual fattening of ruminants that includes other silage varieties.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgement

The authors wish to thank the Çağlayanlar Beef Cattle Farm Manager and Workers for their contributions to the supply of experimental animals and their help in conducting the study. This study was conducted as Tayfun Gündüz's master's thesis. We are grateful to Dr. Ahmet Şahin, for English editing, who has PhD degree from Leeds University, UK.

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Received: March 22, 2024
Accepted: June 21, 2024
Published online: June 28, 2024