Meat and Muscle Biology™

Influence of Finishing Systems on Carcass Characteristics, Composition, and Fatty Acid Profile of Bison Bulls

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Abstract: The objective of this study was to determine the influence of grain- and grass-finishing systems on carcass characteristics of bison bulls and proximate and fatty acid compositions of bison steaks. Bison bulls grazed native pasture until approximately 25 mo of age, then were randomly assigned to grain-finishing ($n = 98$) or grass-finishing ($n = 98$) treatments. Bulls were slaughtered at approximately 30 mo of age. Hot carcass weight (HCW), ribeye area, backfat thickness, kidney fat percentage, marbling score, and instrumental color (L^*, a^*, and b^*) of the ribeye and subcutaneous fat were recorded. Skeletal maturity, lean maturity, and fat color were subjectively scored. Strip loins were collected from a subsample of carcasses, fabricated into 2.5-cm steaks, and designated for proximate, cholesterol, or fatty acid analyses. Grain-finished bulls had greater ($P < 0.0001$) HCW, dressing percentage, ribeye area, backfat thickness, kidney fat percentage, and marbling score. The a^* and b^* values of the ribeye and a^* value of subcutaneous fat were greater ($P < 0.0001$), but the L^* and b^* values of subcutaneous fat were less ($P < 0.0001$) for grain-finished bulls. A greater proportion ($P < 0.001$) of grain-finished carcasses had moderately bright red lean color, whereas a greater proportion ($P < 0.0001$) of grass-finished carcasses had moderately yellow fat color. Steaks from grain-finished bulls had an increased percentage of crude protein ($P < 0.0001$), fat ($P < 0.0001$), and ash ($P = 0.0006$) content but less moisture ($P < 0.0001$). Steaks from grain-finished bulls had more ($P < 0.001$) cholesterol and palmitic, stearic, oleic, linoleic, and arachidonic acids in addition to more total fatty acids (mg/g of wet tissue). However, for total fatty acids, grass-finished steaks had a greater ($P < 0.0001$) percentage of polyunsaturated fatty acids. These data indicate that the finishing system influences the composition of bison bull carcasses as well as the nutrient profile of bison meat.

Keywords: bison, bull, carcass characteristics, composition, fatty acid, finishing system
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Introduction

Bison (*Bison bison*) were hunted to near extinction in North America in the 1800s (Marchello and Driskell, 2001). However, current numbers have rebounded to approximately 362,000 head in private, state, federal, and tribal herds (National Bison Association, 2023). This increase in bison numbers has led to an increase in the number of bison slaughtered annually (South Dakota State University, 2023), helping fill the growing demand for bison meat in the United States. Previous research investigating the meat characteristics of bison has shown that bison meat is leaner with an increased percentage of polyunsaturated fatty acids (PUFA) when compared to cattle finished in a similar system (Larick et al., 1989; Marchello et al., 1989; Koch et al., 1995). These nutritional benefits are of interest to consumers and can drive consumer demand for bison.

Bison producers utilize both grain- and grass-finishing systems. Previous research has shown that these diverse finishing systems cause variation in carcass characteristics, fatty acid composition, and cholesterol content of ruminants (Rule et al., 2002; Daley et al., 2010; Van Elswyk and McNeil, 2014). However, only a few studies have investigated the effects of the finishing system on bison carcass traits and composition. Janssen et al. (2021) reported that grain-finished bison heifers had greater live weight, hot carcass weight (HCW), dressing percentage, backfat thickness, and marbling scores than grass-finished heifers. Further, steaks produced from heifers in a grain-finished system had more cholesterol and total fatty acids but a decreased percentage of PUFA than steaks produced in a grass-finishing system (Janssen et al., 2021). A greater proportion of grain-finished heifers had a lean maturity characterized as "bright red," whereas more grass-finished heifers were characterized as "pale red." Grass-finished heifers also produced carcasses with more yellow backfat (Janssen et al., 2021). However, comparable carcass information is not available for grain- and grass-finished bison bulls. Rule et al. (2002) compared range (forage diet) versus feedlot-finished (grain diet) bison bulls and reported that samples from the *longissimus dorsi* muscle of range-finished bulls had increased levels of saturated fatty acids (SFA) and PUFA, but a lower proportion of total fatty acids and cholesterol. However, no carcass data were reported by Rule et al. (2002).

Both bison bulls and heifers are marketed for meat production in the United States, and bulls represent a greater proportion of the slaughter mix (South Dakota State University, 2023). López-Campos et al. (2013) compared bison bulls and heifers of unspecified finishing systems and reported bison bulls had increased HCW, decreased marbling scores, and decreased backfat thickness when compared to heifers. Given these inherent differences based on sex and the increased proportion of bison bulls slaughtered relative to heifers, research to evaluate the influence of finishing system on carcass outcomes and nutritional composition of bison bulls is warranted. Therefore, the objective of this study was to determine the influence of grain- and grass-finishing systems on carcass characteristics of bison bulls and proximate and fatty acid compositions of bison steaks.

Materials and Methods

Rearing and harvesting of bison were performed in accordance with relevant guidelines and regulations set forth by the United States Department of Agriculture (USDA). This study evaluated bison from commercial ranches and did not involve intervention by the research team; therefore, Institutional Animal Care and Use Committee (IACUC) approval was not necessary.

Animals, carcass evaluation, and longissimus lumborum collection

Bison bulls ($n = 196$) from a common source were allowed to graze native pasture in the Sandhills Ecoregion of Nebraska under free-range conditions from weaning until assignment to finishing treatments. When bulls were approximately 25 mo of age (mean body weight = 308 ± 3.0 kg), they were randomly assigned to one of 2 finishing treatments: grain-finished ($n = 98$; placed in an open lot with ad libitum access to prairie hay, alfalfa hay, and whole shell corn for 146 d prior to slaughter) or grass-finished ($n = 98$; bulls continued to graze native pasture for 146 d prior to slaughter). Further details about typical plant composition of these pastures, finishing methods, and facilities are described by van Vliet et al. (2023).

At approximately 30 mo of age, all bulls were transported (~608 kilometers) to a commercial harvest facility and harvested over 2 d. On the first day of slaughter, 50 head of grain-finished bulls and 49 head of grass-finished bulls were slaughtered. On the second day of slaughter, 48 head of grain-finished bulls and 49 head of grass-finished bulls were slaughtered. Hot carcass weight and kidney fat percentage were recorded. Kidney fat percentage was determined as the difference in carcass weight before and after the removal of the kidney knob. After an approximately 20-h chilling period, carcasses were ribbed between the 12th and 13th rib. Ribeye area, backfat thickness, marbling score, skeletal maturity, lean color, and external fat color were determined by USDA graders. Yield grades (YG) of bison bulls in this study were calculated according to the equation used to determine beef YG (based on the USDA beef YG equation; USDA-AMS Livestock, Poultry, and Seed Program, 2017). Skeletal maturity was subjectively scored based on the ossification percentage of the thoracic cartilage buttons and assigned a number that corresponded with ossification percentages as follows: 0%–24% (slight, 11), 25%–49% (moderate, 7), 50%–99% (hardbone, 5), and 100%–200% (extreme hardbone, −5). Lean maturity was subjectively scored based on the lean color of the exposed ribeye and assigned a number corresponding to a color description as follows: bright red (11), moderately bright red (7), slightly bright red (5), red (3), pale red (1), and dark cutter (0). The fat

color was subjectively scored based on the subcutaneous fat color and assigned a number that corresponded to fat color as follows: white (11), moderately white (7), slightly white (5), moderately yellow (3), and yellow (1). Additionally, objective color (CIE L^* [0 = Black, 100 = White], a^* [negative values = green, positive values = red], and b^* [negative values = blue, positive values = yellow]) of the exposed ribeye area and the subcutaneous fat of the carcass surface opposite the ribeye area were recorded using a handheld colorimeter (Chroma Meter CR 410, Konica Minolta, Inc., Tokyo Japan) according to instrumental meat color measurement guidelines described by King et al. (2023). The colorimeter was equipped with a 2° observer and 50 mm aperture and was calibrated using a standard white tile specific to the machine. A subsample ($n = 30$ per finishing system; 15 carcasses closest to the average HCW per treatment per slaughter day) was selected and transported to a commercial fabrication facility. Both *longissimus lumborum* muscles were removed from each subsampled carcass, vacuum packaged, and transported in a refrigerated trailer back to the South Dakota State University Meat Laboratory for steak fabrication and further analysis.

Longissimus lumborum fabrication and pH

Samples arrived at the South Dakota State University Meat Laboratory at 2 or 3 d postmortem. Ultimate pH was recorded at the posterior end of the *longissimus lumborum* muscle using a hand-held pH meter (Thermo-Scientific Orion Star, Beverly, MA; Model #A221 and Star A321 Portable pH probe). Following pH evaluation, samples were fabricated into 2.54-cm steaks from the anterior end of the *longissimus lumborum*. One steak was individually vacuum packaged and designated for proximate analysis. Another steak was individually vacuum packaged and designated for evaluation of cholesterol and fatty acid profile. Both steaks were stored at −20°C. Additional steaks were stored for use in other studies.

Proximate analysis

To determine proximate composition, samples were thawed slightly and trimmed of excess external fat and accessory muscles, chopped with a knife, submerged in liquid nitrogen, and powdered using a stainless-steel blender (Waring Products Division, Model #51BL32, Lancaster, PA). Homogenized samples were stored at −20°C in plastic bags (Whirlpack, Nasco, Fort Atkinson, WI) until chemical composition analyses. Moisture was determined using the method outlined by Mohrhauser et al. (2015). Proximate nutrient composition was determined using the method outlined by Janssen et al. (2021).

Cholesterol determination

Total cholesterol from muscle samples was extracted as described by Dinh et al. (2012) with modification in alkaline concentration and detection method. Briefly, 1 g of the powdered steak sample was saponified by 10-N KOH and extracted in toluene with the addition of 5α-cholestane as an internal standard. One milliliter of the toluene extract was pipetted into a 2-milliliter GC vial and injected directly into an Agilent 7890A GC system equipped with an HP-5ms Ultra Inert column (30 m x 250 µm x 0.25 µm), an autosampler, a split/split less injector, and an Agilent 5975C inert XL MSD with triple-axis mass detector. Cholesterol was separated at a 10-min isocratic temperature with helium as the carrier gas flowing at a constant rate of 1.5 milliliter/min. Inlet, transfer line, ion source, and quadrupole were heated at 300°C, 300°C, 230°C, and 150°C, respectively. Ionization was performed in an electron impact mode at 70 eV, and the detection of m/z 217/372 (5α-cholestane) and m/z 275/386 (cholesterol) was optimized in a selected ion monitoring mode and evaluated for mass centroid and dwell time. 5α-cholestane and cholesterol were identified by retention times, target ions (217 and 275, respectively), and ratios of target ions to qualifier ions (372 and 386, respectively) compared to those of authentic standards. Cholesterol was calculated by an internal standard calibration method and expressed as mg/100 g of fresh meat.

Fatty acid composition analysis

Fatty acids from muscle samples were extracted and derivatized as described by O'Fallon et al. (2007). Briefly, approximately 1 g of each powdered sample was weighed into a 20-milliliter flat-bottom borosilicate vial with Teflon®-lined screw-cap, to which tridecanoate methyl ester as internal standard, 10 N KOH, and methanol were added for saponification at 55°C in a water bath for 1.5 h. After cooling the vial in cold water, 24-N H_2SO_4 was added for direct transesterification at 55°C in the water bath for another 1.5 h. The fatty acid methyl esters (FAME) formed during esterification were extracted in hexane and transferred into a 2-milliliter amber gas chromatograph vial with a Teflon®-lined screw-cap. Vials were stored −20°C until determination by gas chromatography-mass spectrometry. The fatty acid composition was

determined by an Agilent 7890A gas chromatograph system equipped with a HP-88 capillary column (30 m x 0.25 mm x 0.20 µm), an autosampler, a split/splitless injector, and an Agilent 5975C inert XL MSD with triple-axis mass detector. The FAME were separated in a 20-min temperature-gradient program with helium as the carrier gas flowing at a constant rate of 1.5 milliliter/min. Transfer line, ion source, and quadrupole were heated at 250°C, 230°C, and 150°C, respectively. Ionization was performed in an electron impact mode at 70 eV. Ions were detected in a selected ion monitoring mode optimized for saturated fatty acids, monounsaturated fatty acids (MUFA), and PUFA. Fatty acid methyl esters were identified by comparing their retention times, target ions, and ratios of target ions to qualifier ions with those of authentic FAME standards. Fatty acid concentrations were calculated by an internal standard calibration method. The gravimetric concentration of each fatty acid (mg/g of muscle) was calculated according to Dinh et al. (2011) with correction by the molecular weight difference between FAME and their corresponding fatty acid. The total fatty acid concentration (microgram/gram of muscle) was used as an estimate of the intramuscular fat content (Wood et al., 2013). The percentage of each fatty acid based on total fatty acid was also calculated.

Statistical analysis

Live body weight, dressing percentage, carcass measurements, objective color, pH, proximate analysis, cholesterol content, and fatty acid profile data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Skeletal maturity, lean color, fat color, and YG measurements were analyzed using the GLIMMIX procedure of SAS for the main effect of finishing treatment. Separation of least-squares main effect means was performed using LSD with a Tukey's adjustment, and significance was assumed at an alpha level of ≤ 0.05. Carcass served as the experimental unit for all carcass and compositional analyses.

Results and Discussion

Carcass characteristics

There is currently no system for assigning yield or quality grades to bison in the United States; therefore, carcass measurements, YG, and marbling scores were calculated and assigned using the USDA beef grading standards. Bison typically vary in size due to their diverse genetic pool; a common practice for marketing bison bulls is harvesting at 408 to 544 kg, and heifers can be harvested as low as 363 kg (Anderson and Feist, 2015). Anatomy and confirmation of bison differs from cattle. Bison have 14 pairs of ribs, carry more weight in their forequarter, and deposit a larger proportion of subcutaneous fat over the rib primal (Koch et al., 1995). Bison also tend to finish at a lighter weight and have smaller ribeye areas compared to beef, although they often reach market readiness at a more advanced chronological age. Bison carcasses are also reported to have less intramuscular fat in the ribeye but greater backfat thickness compared to cattle (Koch et al., 1995). Bison bulls in the current study were harvested at approximately 30 mo of age, which falls within the age range (20–36 mo) reported by previous bison studies (Hawley, 1986; Marchello et al., 1989; Marchello et al., 1998; Marchello and Driskell, 2001; Rule et al., 2002; Galbraith et al., 2006; Janssen et al., 2021).

Live weight and carcass data are reported in Table 1. Grain-finished bulls had greater ($P < 0.0001$) live weight, HCW, dressing percentage, ribeye area, backfat thickness, kidney fat percentage, and marbling scores compared to grass-finished bulls. Carcass outcomes in this study are similar to findings of (Janssen et al., 2021) comparing the effects of grain- and grass-finishing systems on bison heifers. The carcass weights of grain-finished bulls in this study are within the range (266 kg to 318 kg) reported by USDA-AMS in the National Monthly Bison Report for young, grain-fed bulls (USDA-AMS, 2021). However, grass-finished bulls were lighter than USDA reports for grain-finished bulls but similar to HCW of bison heifers (229 kg) reported by López-Campos et al. (2013) and grass-finished heifers (226 kg) reported by Janssen et al. (2021). Dressing percentage of grain-finished bulls in the current study was 60.3%, which is similar to dressing percentage of bison steers (59.9%) reported by Hawley (1986) and grass-finished heifers (59.8%) reported by Janssen et al. (2021). Grass-finished bulls had a dressing percent of 55.9%, which is lower than other studies. This could be a response of grass-finishing resulting in less backfat and lighter muscling. The average ribeye area of grain-finished bulls was 65.1 cm^2, which is similar to the ribeye area of grain-finished heifers (64.6 cm^2) reported by Janssen et al. (2021), while grass-finished bulls had a ribeye area of 59.8 cm^2, which is similar to the ribeye area of bison steers (60.5 cm^2) reported by Hawley (1986). Grain-finished bulls had 0.91 cm of backfat, which is less than the backfat thickness of grain-finished bison heifers (2.16 cm) reported by Janssen et al. (2021). Grass-finished bulls had 0.25 cm of backfat,

Table 1. Least-squares means for the effect of finishing system on live weight and carcass characteristics of grain- or grass-finished bison bulls

Variable	GRAIN[1]	GRASS[1]	SEM[2]	*P* value[3]
Live weight, kg	480	414	2.706	<0.0001
Hot carcass weight, kg	289	232	1.907	<0.0001
Dressing percentage, %	60.3	55.9	0.179	<0.0001
Ribeye area, cm^2	65.1	59.8	0.569	<0.0001
Backfat thickness, cm	0.91	0.25	0.020	<0.0001
Kidney fat, %	2.56	0.97	0.057	<0.0001
Marbling score[4]	185	105	4.357	<0.0001
Yield grade[5]				
Yield grade 1, %	2.04	77.55	4.215	<0.0001
Yield grade 2, %	58.16	22.45	4.983	<0.0001
Yield grade 3, %	39.80	0.00	4.944	0.9678
Subjective skeletal maturity[6]				
Moderate	3.06	0.00	1.740	0.9739
Slight	96.94	100.00	1.740	0.9739
Lean maturity[6]				
Pale red, %	0.00	1.02	1.015	0.9761
Red, %	7.14	11.22	3.189	0.3275
Slightly bright red, %	57.14	75.51	5.000	0.0077
Moderately bright red, %	34.69	12.24	4.808	0.0004
Bright red, %	1.02	0.00	1.015	0.9761
Subjective external fat color[6]				
Yellow, %	0.00	3.06	1.740	0.9739
Moderately yellow, %	12.24	39.80	4.944	<0.0001
Slightly white, %	37.76	8.16	4.897	<0.0001
Moderately white, %	48.98	15.31	5.050	<0.0001
White, %	1.02	33.67	4.774	0.0002

[1]Treatments: GRAIN = bison bulls ($n = 98$) backgrounded on grain and finished for 146 d with ad libitum access to grass hay, alfalfa, and corn prior to slaughter. GRASS = bison bulls ($n = 98$) remained on native pasture until slaughter.

[2]Standard error of the mean.

[3]Probability of difference among least-squares means.

[4]Marbling score: 100 = Practically Devoid^0, 200 = Traces^0.

[5]Yield grade calculated according to USDA beef grading system.

[6]Subjective skeletal maturity, lean maturity, and external fat color assigned by USDA grader.

which aligns with the most common range of backfat thickness (<0.7 cm) for bison bulls of various ages reported by López-Campos et al. (2013). The kidney fat percentage of both grain- (2.56%) and grass-finished (0.97%) bulls was similar to that of grain- (2.56%) and grass-finished (0.89%) heifers reported by Janssen et al. (2021) for their respective finishing system. Grain- and grass-finished bulls had marbling scores of 184 and 105, respectively. Marbling scores for both finishing systems in this study would fall into the practically devoid (Standard) category of the USDA beef quality grading system.

To compare YG of bison bulls in this study, measurements were calculated according to the equation used to determine beef YG. A greater proportion ($P < 0.0001$) of grass-finished bulls were classified as YG 1 carcasses (77.55%) when compared to grain-finished bulls (2.04%). A greater proportion ($P < 0.0001$) of grain-finished bulls were classified as YG 2 (58.16%) when compared to grass-finished bulls (22.45%). Finishing system did not influence ($P > 0.05$) the proportion of carcasses in the YG 3 category, and there were no YG 4 or 5 carcasses in the study. This is similar to findings by Janssen et al. (2021) with the grass-finishing treatment producing leaner, higher yielding carcasses than grain-finishing. However, Janssen et al. (2021) reported bison heifers in YG categories of 2, 3, and 4. The increased YG of heifers compared to bulls in the current study can be attributed to differences in backfat thickness and carcass weight.

Aalhus et al. (2003) reported that bison heifers had greater backfat thickness and lighter carcass weights compared with bison bulls.

Carcass maturity and subjective external fat and lean color

Finishing system did not influence ($P > 0.05$) the proportion of bulls with moderate or slight skeletal ossification. No bulls were classified in the extreme hardbone or hardbone categories for skeletal maturity in this project. A greater percentage ($P = 0.0077$) of grass-finished bison bulls were classified as having slightly bright red lean compared to grain-finished bison bulls, while a greater percentage ($P = 0.0004$) of grain-finished bulls were classified as moderately bright red. The most common lean color classification for bison bulls regardless of finishing system was slightly bright red (57.14% and 75.51% for grain- and grass-finished, respectively), with the least common classification being pale red and bright red. There was no difference ($P > 0.05$) in the percentage of grain- and grass-finished bulls classified as pale red, red, or bright red for lean maturity.

An Increased percentage ($P = 0.0002$) of grass-finished bulls were classified with moderately yellow or white fat when compared to grain-finished bulls. This increase in yellow fat color of the grass-finished bulls is likely due to an increased amount of β-carotene within adipose tissue, which is known to cause a yellow color in fat when cattle are finished on forage (Yang et al., 2002; Kerth et al., 2007). It is also likely that the increase in grass-finished bison categorized as white for subjective fat color could be due to the extremely small amount of backfat present on most carcasses in this study resulting in evaluation of epimysial connective tissue, which has a bright white appearance. An increased percentage ($P < 0.0001$) of grain-finished bulls were classified as having slightly white or moderately white backfat when compared to grass-finished bison bulls. There was no difference ($P > 0.05$) in the percentage of grain- and grass-finished bulls classified as yellow for fat color.

Objective color and ultimate pH

Objective color scores and pH are reported in Table 2. The a^* and b^* values of the exposed ribeye surface and a^* values of the subcutaneous fat were increased ($P < 0.0001$) in the grain-finished bulls compared to grass-finished bulls. The L^* and b^* values of the subcutaneous fat were increased ($P < 0.0001$) for grass-finished bulls compared to grain-finished. The increased b^* value is indicative of a more yellow color, which supports the greater percentage of grass-finished bulls having a subjective fat color classified as moderately yellow. Finishing system did not influence ($P > 0.05$) L^* value of the lean surface. Janssen et al. (2021) also reported that a^* and b^* values of the lean tissue and a^* of subcutaneous fat were increased in

Table 2. Least-squares means for the effect of finishing system on objective color measurements and ultimate pH of grain- and grass-finished bison bulls

Variable	GRAIN[1]	GRASS[1]	SEM[2]	*P* value[3]
***Longissimus lumborum*[4]**				
L^*	36.07	35.93	0.203	0.6419
a^*	22.15	20.93	0.144	<0.0001
b^*	7.68	6.72	0.010	<0.0001
Subcutaneous backfat[5]				
L^*	74.27	76.01	0.256	<0.0001
a^*	3.80	2.52	0.161	<0.0001
b^*	15.17	18.62	0.258	<0.0001
Ultimate pH[6]	5.68	5.65	0.013	0.1393

[1]Treatments: GRAIN = bison bulls ($n = 98$) backgrounded on grain and finished for 146 d with ad libitum access to grass hay, alfalfa, and corn prior to slaughter. GRASS = bison bulls ($n = 98$) remained on native pasture until slaughter.

[2]Standard error of the mean.

[3]Probability of difference among least-squares means.

[4]Objective color measurement recorded on the exposed ribeye (*longissimus lumborum*) following approximately 30 min bloom time; L^*: 0 = Black, 100 = White; a^*: Negative values = green; Positive values = red; b^*: Negative values = blue; Positive values = yellow.

[5]Objective color measurement of subcutaneous fat recorded on the external surface of the carcass, opposite the exposed ribeye; L^*: 0 = Black, 100 = White; a^*: Negative values = green; Positive values = red; b^*: Negative values = blue; Positive values = yellow.

[6]Ultimate pH was measured at either 2 or 3 d postmortem from grain- ($n = 30$) and grass-finished ($n = 30$) *longissimus lumborum*.

grain-finished bison heifers, while L^* and b^* were increased in fat tissue of grass-finished bison heifers. While studies investigating bison color are limited, Koch et al. (1995) reported that bison muscles were darker in color compared to beef. Further, Hasan et al. (2021) reported that color deteriorates more rapidly in bison compared with beef packaged in aerobic conditions. A comparison of two bison muscles at different aging and retail display times revealed that bison *longissimus lumborum* was more color stable than the *psoas major* and highlighted the challenges of marketing fresh bison due to losses caused by color instability (Hasan et al., 2021). Finishing system did not influence ($P > 0.05$) the ultimate pH of bison *longissimus lumborum*, which is similar to finding reported by Janssen et al. (2021) for bison heifers finished in different systems.

Proximate chemical composition

Steaks from grain-finished bulls had increased crude protein ($P < 0.0001$), crude fat ($P < 0.0001$), and ash ($P = 0.0006$) content, while steaks from grass-finished bulls had increased moisture content ($P < 0.0001$; Table 3). These results are similar to findings by Janssen et al. (2021); however, no differences in ash content were reported between grass- and grain-finished bison heifers. Others have compared the influence of finishing system on the proximate chemical composition of bison and reported that ribeye steaks from grain-finished bison contained 22.1% crude protein, 2.4% crude fat, and 1.2% ash, which was elevated compared to steaks from grass-finished bison with 21.5%, 1.9%, and 1.14% protein, fat, and ash, respectively (Marchello et al., 1998; Marchello and Driskell, 2001). These previous studies also reported that ribeye steaks from grass-finished bison had a moisture percentage of 76.0%, while steaks from grain-finished bison contained 74.0% moisture, which supports the findings of the current study. While studies on bison meat composition are limited, comparison with beef suggests that bison is lower in intramuscular fat content, which may be related to a higher proportion of bison that are grass-finished and a general lack of selection for marbling (Janssen et al., 2021).

Cholesterol content

Steaks from grain-finished bison bulls had more ($P < 0.0001$) cholesterol than steaks from grass-finished bulls (Table 3). The cholesterol content of steaks for grain- and grass-finished bison were 63.2 and 53.5 mg/100 g, respectively. Other studies have reported cholesterol content of ribeye steaks or steaks from the *longissimus dorsi* of grain-finished bison to range between 48.3 and 62.0 mg/100g (Marchello et al., 1989; Koch et al., 1995; Marchello et al., 1998; Marchello and Driskell, 2001; Rule et al., 2002; Galbraith et al., 2006; Janssen et al., 2021). The reported cholesterol content of ribeye steaks or steaks from the *longissimus dorsi* of grass-finished bison ranges between 43.8 and 57.5 mg/100 g (Marchello and Driskell, 2001; Rule et al., 2002; Janssen et al., 2021). Several studies have investigated how finishing system affects cholesterol content of bison meat, and findings are similar to the current study, indicating that steaks from grain-finished bison, regardless of sex, have increased cholesterol content when compared to steaks from grass-finished bison. Rule et al. (2002) reported that steaks from the *longissimus dorsi* of grain-finished bison bulls had a cholesterol content of 54.1 mg/100 g, while steaks from grass-fed bulls had 43.8 mg/100 g of cholesterol. Janssen et al. (2021) reported that steaks from grain-finished bison heifers contained 54.3 mg/100 g of cholesterol compared to 51.4 mg/100 g in grass-finished heifers.

Consumers have become more health conscious since the turn of the century, especially when it pertains

Table 3. Least-squares means for the effect of finishing treatment on the proximate nutrient composition of *longissimus lumborum* steaks from grain- and grass-finished bison bulls

Nutrient	GRAIN[1]	GRASS[1]	SEM[2]	*P* value[3]
Moisture,%	75.47	77.36	0.113	<0.0001
Protein,%	21.45	20.56	0.138	<0.0001
Fat,%	1.54	0.74	0.051	<0.0001
Ash,%	1.28	1.21	0.013	0.0006
Cholesterol, mg/100 g	63.20	53.53	0.963	<0.0001

[1]Treatments: GRAIN = bison bulls ($n = 98$) backgrounded on grain and finished for 146 d with ad libitum access to grass hay, alfalfa, and corn prior to slaughter. GRASS = bison bulls ($n = 98$) remained on native pasture until slaughter.

[2]Standard error of the mean.

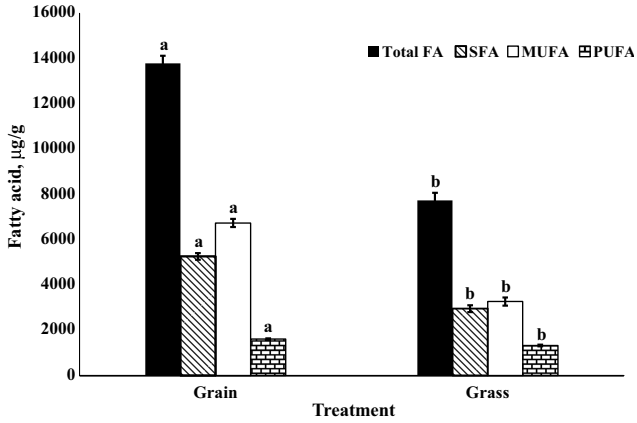
[3]Probability of difference among least-squares means.

to the fat and cholesterol content of their food. Increased cholesterol consumption is often perceived to increase the consumer's risk of atherosclerosis (Galbraith et al., 2006; Dinh et al., 2011). The USDA and US Department of Health and Human Services have released dietary guidelines defining "lean" meat as having less than 10 g of fat, 4.5 g or less of saturated fats, and less than 95 mg of cholesterol per 100 g (USDA/HHS, 2015). Therefore, according to this definition, bison meat across all studies cited, including the present study, would be classified as "lean."

Fatty acid profile

The majority of fatty acids evaluated (36 out of 56) were influenced ($P < 0.05$) by finishing treatment with the exception of C13:0 12-methyl, C14:0 12-methyl, C15:1 undifferentiated (UN:isomerization undetermined), C15:1 cis9, C16:0 15-methyl, C16:0 14-methyl, C16:1 cis9 14-methyl, C18:1 trans-11, C18:2 cis-12,15, C19:1 cis-10, C20:0, C21:0, C20:3UN, C20:2 cis-9,-12, C20:3 cis-8,-11,-14, C20:3 cis-11, -14,-17, C22:0, C22:4 cis-7,-10,-13,-16, C23:0, C22:6 cis-4,-7,-10,-13,-16,-19, BCFA (branch-chained fatty acid), and LCPUFA (long-chained PUFA) when reported on a mg/g raw tissue basis (Supporting Information Tables S1–S3). When reported as a percentage of total fatty acid, 44 of 56 fatty acids were influenced ($P < 0.05$) by finishing treatment except C8:0, C12:0, C16:1 cis-9 14-methyl, C18:1 UN, C18:2 trans-9,-12, C18:2 cis-12,-15, C21:0, C20:2 cis-11,-14, C20:2 cis-9,-12, C20:3 cis-8,-11,-14, C22:0, C22:4 cis -7, -10,-13,-16, and SFA (Supporting Information Tables S1–S3).

Steaks from grain-finished bison bulls had increased ($P < 0.0001$) total fatty acid, SFA, MUFA, and PUFA on a concentration basis (Figure 1). However, when analyzed as a percentage of total fatty acids, SFA were found to be similar ($P > 0.05$) between finishing treatments, while PUFA were increased ($P < 0.0001$) in grass-finished steaks compared to steaks from grain-finished bison (17.47% and 11.90%, respectively), and MUFA were increased ($P < 0.0001$) in grain-finished steaks compared to steaks from grass-finished bison (48.79% and 42.16%, respectively; Figure 2). Rule et al. (2002) and Janssen et al. (2021) also reported steaks from grass-finished bison to have an increased percentage of PUFA. However, in contrast to the current study they reported grass-finished steaks to have a greater percentage of SFA. Rule et al. (2002) also reported that steaks from grass-finished bulls contained increased PUFA compared to grain-finished bulls

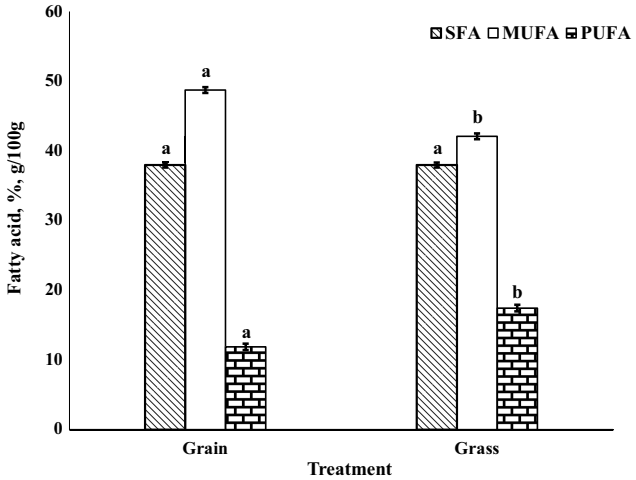


The SE bars represent the variation within each treatment. Within each fatty acid category, means without common letters (a-b) differ ($P < 0.0001$).

Figure 1. Least-squares means for the effect of finishing treatment on the fatty acid composition (µg/g wet sample basis) of steaks from grain- or grass-finished bison bulls. The SE bars represent the variation within each treatment. Within each fatty acid category, means without common letters (a, b) differ ($P < 0.0001$). FA = fatty acid; MUFA = monounsaturated fatty acid; PUFA = polyunsaturated fatty acid; SFA = saturated fatty acid.

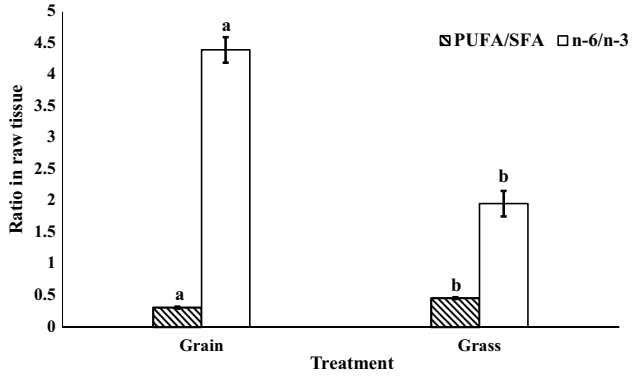
(16.5% and 10.7%, respectively) with percentages similar to the current study. In bison heifers, Janssen et al. (2021) also reported an increased percentage of PUFA in steaks from grass-finished heifers compared to grain-finished (20.5% and 13.7%, respectively). The increased percentage of PUFA in heifers compared to bull samples could be caused by the increased amount of intramuscular fat associated with steaks from heifers.

Steaks from grain-finished bulls had an increased ($P < 0.0001$) n-6 to n-3 ratio and a decreased



The SE bars represent the variation within each treatment. Within each fatty acid category, means without common letters (a-b) differ ($P < 0.0001$).

Figure 2. Least-squares means for the effect of finishing treatment on the fatty acid composition (%, g/100 g total fatty acids) of steaks from grain- or grass-finished bison bulls. The SE bars represent the variation within each treatment. Within each fatty acid category, means without common letters (a, b) differ ($P < 0.0001$). MUFA = monounsaturated fatty acid; PUFA = polyunsaturated fatty acid; SFA = saturated fatty acid.



The SE bars represent the variation within each treatment. Within each ratio, means without common letters (a-b) differ ($P < 0.0001$).

Figure 3. Least-squares means for the effect of finishing treatment on the ratio of PUFA to SFA and n-6 to n-3 of steaks from grain- or grass-finished bison bulls. The SE bars represent the variation within each treatment. Within each ratio, means without common letters (a, b) differ ($P < 0.0001$). PUFA = polyunsaturated fatty acid; SFA = saturated fatty acid.

($P < 0.0001$) PUFA to SFA ratio when compared to steaks from the grass-finished treatment (Figure 3). This is similar to results reported by Janssen et al. (2021) for bison heifers. Rule et al. (2002) also reported an increased n-6 to n-3 ratio in grain-finished bison bulls; however, no differences were found in the PUFA to SFA ratio. An n-6 to n-3 ratio between 2.5 and 5.0 and a PUFA to SFA ratio of approximately 2.0 have been reported to be the most beneficial in terms of potentially decreasing the risk of cardiovascular disease (Rule et al., 2002). While bison in this study, regardless of finishing system, had a PUFA to SFA ratio lower than 2.0 (0.31 and 0.46 for grain- and grass-finished, respectively), steaks from grain-finished bulls fell within the ideal n-6:n-3 range (4.40), and steaks from grass-finished bison bulls were below the range with an n-6 to n-3 ratio of 1.96. The n-6 to n-3 ratio for grass-finished bulls in the current study (1.96) is similar to the ratio reported by Rule et al. (2002) for grass-finished bulls (1.94). However, Rule et al. (2002) reported that grain-finished bulls had an n-6 to n-3 ratio of 5.73, which is higher than the findings of the current study. Janssen et al. (2021) reported that bison heifers had an increased n-6 to n-3 ratio at 5.74 and 4.64 for grain- and grass-finishing systems, respectively. This difference could be caused by sex, or the increased amount of fat contained within the steaks from heifers.

Conclusions

This study indicates that finishing system has an impact on the composition, carcass characteristics, and nutrient profile of meat from bison bulls. Bison bulls finished in a grain-based system had increased carcass weights, backfat thickness, ribeye area, and marbling scores when compared to bison bulls in a grass-finishing system. Finishing system also impacts the nutrient and fatty acid profile of bison meat. Grass-finishing resulted in steaks with decreased cholesterol content, percentage fat, and n-6:n-3 but increased PUFA:SFA when compared to steaks from grain-finished bison bulls. With these changes to carcass characteristics, composition, and nutrient profile, it could be beneficial for bison producers to recognize the influence of finishing system on product traits and use these differences to market desirable attributes of bison meat accordingly.

Acknowledgments

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Supporting Information Table 1. Least square means for the effect of finishing treatment on the saturated fatty acid composition of *longissimus lumborum* steaks from grain- or grass-finished bison bulls.

	(μg/g wet sample basis)				(%, g/100 g total fatty acids)			
Fatty Acids	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]	GRAIN1	GRASS[1]	SEM[2]	*P*-value[3]
C8:0	1.95	1.19	0.090	<0.0001	0.01	0.02	0.001	0.0933
C10:0	8.78	3.85	0.332	<0.0001	0.06	0.05	0.002	<0.0001
C11:0	0.36	0.15	0.023	<0.0001	0.00253	0.00187	0.000171	0.0078
C12:0	7.36	4.15	0.314	<0.0001	0.05	0.05	0.002	0.9170
C13:0 12-methyl	5.79	6.08	0.403	0.6143	0.04	0.08	0.003	<0.0001
C14:0	379.18	110.83	19.412	<0.0001	2.68	1.37	0.105	<0.0001
C14:0 13-methyl	18.55	26.70	1.299	<0.0001	0.13	0.34	0.001	<0.0001
C14:0 12-methyl	29.76	32.39	1.651	0.2648	0.21	0.42	0.012	<0.0001
C15:0	73.05	44.65	3.693	<0.0001	0.52	0.57	0.019	0.0396
C15:0 14-methyl	32.56	25.23	1.547	0.0014	0.23	0.32	0.010	<0.0001
C16:0	1183.46	684.66	28.089	<0.0001	8.59	8.91	0.093	0.0198
C16:0 15-methyl	64.62	67.42	2.476	0.4271	0.47	0.87	0.012	<0.0001
C16:0 14-methyl	24.64	23.29	1.102	0.3885	0.18	0.30	0.008	<0.0001
C16:0 3,7,11,15-tetramethyl	——	——	——	——	——	——	——	——
C17:0	259.37	117.18	11.934	<0.0001	1.84	1.50	0.052	<0.0001
C18:0	3333.06	1976.17	95.924	<0.0001	24.16	25.40	0.298	0.0046
C19:0	6.29	4.47	0.319	0.0002	0.05	0.06	0.002	<0.0001
C20:0	8.81	7.34	0.698	0.1356	0.06	0.09	0.005	0.0002
C21:0	0.17	0.08	0.045	0.1701	0.00123	0.0011	0.000828	0.8387
C22:0	0.12	0.16	0.107	0.7906	0.00090	0.00207	0.001136	0.4706
C23:0	0.05	0.11	0.032	0.1844	0.0037	0.0014	0.000419	0.0418
C24:0	——	——	——	——	——	——	——	——
Branched Chain Fatty Acid	178.00	182.41	7.894	0.6940	1.29	2.34	0.047	<0.0001

[1]Treatments: GRAIN = bison bulls (n = 98) backgrounded on grain and finished for 146 d with ad libitum access to grass hay, alfalfa, and a corn prior to slaughter. GRASS = bison bulls (n = 98) remained on native pasture until slaughter.

[2]Standard error of the mean

[3]Probability of difference among least square means

Supporting Information Table 2. Least square means for the effect of finishing treatment on the monounsaturated fatty acid composition of *longissimus lumborum* steaks from grain- or grass-finished bison bulls.

	(µg/g wet sample basis)				(%, g/100 g total fatty acids)			
Fatty Acids	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]
C14:1n9c	34.90	23.91	1.809	<0.0001	0.25	0.31	0.010	<0.0001
C15:1 (undifferentiated)	33.29	30.13	2.474	0.3705	0.25	0.39	0.028	0.0008
C15:1n9c	7.62	8.17	0.749	0.6066	0.06	0.11	0.007	<0.0001
C16:1n6c	58.98	51.59	2.094	0.0154	0.43	0.67	0.011	<0.0001
C16:1n9c	228.52	100.79	8.891	<0.0001	1.64	1.31	0.038	<0.0001
C16:1n7c	50.57	36.59	2.118	<0.0001	0.36	0.47	0.011	<0.0001
C16:1cis-9, 14-methyl	2.09	1.32	0.382	0.1566	0.01	0.02	0.004	0.7196
C17:1n10c	125.11	58.34	6.311	<0.0001	0.89	0.76	0.029	0.0020
C18:1n11t	145.03	150.95	14.696	0.7766	1.04	1.91	0.125	<0.0001
C18:1n9t	31.73	57.40	3.693	<0.0001	0.23	0.73	0.033	<0.0001
C18:1n9c	5657.15	2583.29	149.010	<0.0001	40.98	33.32	0.481	<0.0001
C18:1n11c	272.62	132.09	6.936	<0.0001	1.99	1.72	0.057	0.0018
C18:1 (undifferentiated)	——	——	——	——	——	——	——	——
C18:1n12c	11.81	0.30	0.863	<0.0001	0.08	0.00	0.005	<0.0001
C18:1n13c	21.51	8.04	1.136	<0.0001	0.15	0.101	0.007	<0.0001
C18:1 (undifferentiated)	19.31	10.02	1.039	<0.0001	0.14	0.13	0.006	0.2117
C19:1n10c	7.40	6.54	0.587	0.3059	0.05	0.08	0.004	<0.0001
C19:1 (undifferentiated)	8.44	0.00	0.605	<0.0001	0.06	0.00	0.003	<0.0001
C20:1n11c	25.65	11.92	1.635	<0.0001	0.18	0.15	0.011	0.0576
C22:1n13c	0.27	0.72	0.108	0.0045	0.0020000	0.009200	0.001245	0.0001
C24:1n15c	——	——	——	——	——	——	——	——

[1]Treatments: GRAIN = bison bulls (n = 98) backgrounded on grain and finished for 146 d with ad libitum access to grass hay, alfalfa, and a corn prior to slaughter. GRASS = bison bulls (n = 98) remained on native pasture until slaughter.

[2]Standard error of the mean.

[3]Probability of difference among least square means.

Supporting Information Table 3. Least square means for the effect of finishing treatment on the polyunsaturated fatty acid composition of longissimus lumborum steaks from grain- or grass-finished bison bulls.

	(μg/g wet sample basis)				(%, g/100 g total fatty acids)			
Fatty Acids	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]
C18:2n9,12t	13.20	6.13	0.852	<0.0001	0.09	0.08	0.006	0.0573
C18:2n9,12c	1023.99	666.39	18.851	<0.0001	7.56	8.77	0.241	0.0008
C18:2n12,15c	0.66	0.24	0.233	0.2115	0.00423	0.00247	0.001757	0.4799
C18:3n6,9,12c	10.01	4.07	0.659	<0.0001	0.07	0.05	0.006	0.0143
C18:3n9,12,15c	159.61	241.30	9.817	<0.0001	1.18	3.17	0.114	<0.0001
C18:2n9c11t	24.54	18.45	1.732	0.0157	0.18	0.24	0.013	0.0014
C18:3 (undifferentiated)	——	——	——	——	——	——	——	——
C18:2n10,12t	0.84	0.00	0.234	0.0140	0.01	0.00	0.002	0.0129
C20:2n11,14c	3.36	1.08	0.608	0.0103	0.02	0.01	0.006	0.2136
C20:3 (undifferentiated)	7.77	8.40	1.021	0.6636	0.06	0.11	0.010	0.0003
C20:2n9,12c	1.17	0.38	0.429	0.1999	0.008200	0.004533	0.003926	0.5116
C20:3n8,11,14c	0.57	0.49	0.363	0.8788	0.003800	0.006167	0.003549	0.6390
C20:3n11,14,17c	21.84	17.62	1.767	0.0946	0.16	0.23	0.018	0.0064
C20:4n5,8,11,14c	211.46	179.78	6.399	0.0009	1.57	2.37	0.078	<0.0001
C20:5n5,8,11,14,17c	50.39	77.74	4.473	<0.0001	0.37	1.02	0.053	<0.0001
C22:2n13,16c	——	——	——	——	——	——	——	——
C22:4n7,10,13,16c	3.59	2.01	0.627	0.0803	0.03	0.03	0.006	0.9804
C22:5n7,10,13,16,19c	57.25	83.39	5.247	0.0008	0.43	1.10	0.066	<0.0001
C22:6n4,7,10,13,16,19c	19.05	20.31	2.601	0.7327	0.14	0.27	0.026	0.0010
LCPUFA[4]	376.45	391.21	19.743	0.5991	2.80	5.15	0.234	<0.0001
n-3 PUFA[4]	308.81	440.62	14.517	<0.0001	2.29	5.80	0.179	<0.0001
n-6 PUFA[4]	1253.82	853.82	24.133	<0.0001	9.27	11.24	0.312	<0.0001
n-3 LCPUFA[4]	308.15	440.37	14.432	<0.0001	2.29	5.79	0.179	<0.0001
n-6 LCPUFA[4]	218.98	183.36	7.440	0.0013	1.62	2.41	0.084	<0.0001
LC n-3/n-3	0.74	0.42	0.019	<0.0001	0.74	0.42	0.019	<0.0001

[1]Treatments: GRAIN = bison bulls (n = 98) backgrounded on grain and finished for 146 d with ad libitum access to grass hay, alfalfa, and a corn prior to slaughter. GRASS = bison bulls (n = 98) remained on native pasture until slaughter.

[2]Standard error of the mean.

[3]Probability of difference among least square means.

[4]LC = long chain, PUFA = polyunsaturated fatty acid.