2022

Effect of Finishing System and Animal Age on Carcass Traits and Nutritional Profile of Bison Bulls

Clay Newton
South Dakota State University, claynewton55@gmail.com

EFFECT OF FINISHING SYSTEM AND ANIMAL AGE ON CARCASS TRAITS AND NUTRITIONAL PROFILE OF BISON BULLS

By

CLAY NEWTON

A thesis submitted in partial fulfillment of the requirements for the

Masters of Science

Major Animal Science

South Dakota State University

2022

THESIS ACCEPTANCE PAGE

Clay Newton

This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Amanda Blair
Advisor Date

Robert Thaler
Department Head Date

Nicole Lounsbery, PhD
Director, Graduate School Date

ACKNOWLEDGEMENTS

Thank you to my advisor, Dr. Amanda Blair for guiding me through graduate school. The decision to stay at SDSU was in large part due to her and her passion to help her graduate student achieve their goals. Also, thank you for opening up your home and family to not only me, but everyone who makes the journey west river. Thank you to Dr. Kyle Grubbs for always welcoming students into your office to discuss duties or questions we may have, and also always bringing cards to pass the time. Thank you to Dr. Keith Underwood for not only answering questions, but always giving new questions to dig into to further my understanding of all aspects of meat science. Thank you to Dr. Carter Kruse and Dr. Krista Ehlert for taking the time to serve on my graduate committee. Thank you to the Turner Institute of Ecoagriculture. Without them or their funding this project would have not been possible. Thank you to Brush Meat Processors and Rocky Mountain Natural Meats for working with our meat group and allowing us to enter your processing facilities to conduct carcass data collection. Thank you to Dr. Thu Dinh and all the students within his lab group at Mississippi State University for helping us with the fatty acid analysis and cholesterol determination. Thank you to Dr. Kristi Cammack and Dr. Ken Olson for helping further my understanding of statistical analysis and allowing me to always ask questions. Thank you to the meat lab crew at SDSU. Thank you to the meat lab manager, Adam Rhody, and all undergraduate students that helped in the completion of this research. Also, thank you to all the meat science graduate students who I have worked closely with over the past two years: including Erin Gubbels, Trevor DeHaan, Lydia Hite, Harlee Brauckmuller, Austin and Sam Egolf,

Jessica Janssen, and Dr. Chris Bakker. Thank you to my family and friend for supporting me in my work over the last couple years, even if what I was saying seemed like a foreign language to you. Finally, thank you to my wife, Caroline Newton. You have always supported me in the late nights and long hours of this project and everything else that came with graduate school. I cannot wait to do the same as you pursue your own educational goals.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

EFFECT OF FINISHING SYSTEM AND ANIMAL AGE ON CARCASS TRAITS AND NUTRITIONAL PROFILE OF BISON BULLS

CLAY NEWTON

2022

The objectives of this thesis project were to 1) evaluate the influence of grain- and grass-finishing systems on carcass characteristics, proximate composition, nutritional profile, and fatty acid composition of bison bull meat, and 2) evaluate the influence of animal age on carcass characteristics of bison bulls. For objective 1, bison bulls were allowed to graze native range in north-central Nebraska until approximately 26 mo of age, when they were randomly assigned to either grain-finishing (n = 98; in an open lot with ad libitum access to prairie hay, alfalfa hay and corn for 95 d prior to slaughter) or grass-finishing (n = 98, on pasture until slaughter). Bulls were harvested at approximately 29 mo of age over a two-day period. Carcass measurements were recorded and strip loins were collected from a subsample of carcasses for compositional analyses. Finishing system influenced the characteristics of bison bull carcasses as well as the nutrient profile of bison meat. Grain-finished bulls had heavier hot carcass weights, larger ribeye areas, increased backfat thickness, while grass-finished steaks had decreased fat content, and cholesterol. Grass-finished steaks also had an increased proportion of poly unsaturated fatty acids compared to grain-finished steaks, which could have potentially meaningful implications to consumer health. For objective 2, bison bulls from a common herd were allowed to graze native range in north-central

Nebraska and harvested at two chronological endpoints: Young bulls (n=98) were slaughtered at 29 mo of age; and Mature bulls slaughtered at 36 mo of age following use in the breeding herd. Mature bulls were slaughtered over a one-day period in June 2020, and young bulls were harvested over a two-day period in November of 2020 and carcass measurements were recorded at harvest. Age at slaughter influenced carcass characteristics of bison bulls. Mature bulls had heavier hot carcass weights, larger ribeye areas, and greater marbling, while young bulls had increased backfat. Mature bulls were more likely to have ribeye lean color classified as pale red or red and fat classified as yellow or moderately yellow, while Young bulls were more likely to have ribeye lean color classified as slightly bright red.

CHAPTER 1: LITERATURE REVIEW: The American Plains Bison

Introduction

Bison are a large ruminants that are native to the North American plains and savannas, historically ranging from Alaska to northern Mexico and extending east to the Atlantic Coast and Florida (Pickering, 2015). Over hunting and disease brought by settlers and domesticated livestock in the 1800's diminished the wild population in North America from between 30 to 75 million head to less than 300 by 1900 (Pickering, 2015). In the late 1800's a small group of ranchers recognized the need to save some of the remaining herds and men including Michel Pablo, C.J. "Buffalo" Jones, Charles Goodnight, and Scotty Philip began raising bison calves in captivity creating the first private bison herds in the United States (Galbraith et al., 2014). In the early 1900's beef producers sought to incorporate cold weather heartiness into domesticated cattle and experimented by crossing bison and cattle creating hybrids called beefalo or cattlo (Koch et al., 1995). This practice did not gain much traction however, and was largely discontinued due to fertility issues of the male offspring (Jones, 1907).

As a result of the conservation efforts made by many ranchers and the United States government, bison are no longer considered endangered. It is estimated that there are roughly 400,000 bison residing in North American between private, tribal, state, and federal herds (NBA, 2021a). Of this number, about 90% are being raised in private herds. The National Bison Associates seeks to continue the resurgence of bison in North America and announced the Bison 1 Million initiative in 2017 (NBA, 2021b).

Through this restoration campaign the Association set an ambitious goal of increasing bison numbers to over one million within a decade.

Bison meat is a considered a niche product that claims a greater monetary value in the marketplace and demand is growing within the United States (Galbraith et al., 2014). From the first full year of reporting in 2018, the number of bison harvested has grown from 51,595 to 66,093 by the end of 2021 and is expected to continue growing in 2022 (USDA-AMS, 2021). However, there are challenges to bison meat production that affect the quality and consistency of the product (Galbraith et al., 2014). Expanded understanding of the relationship between production practices and meat characteristics would benefit not only bison ranchers and processors, but also ensure consumers receive a high quality, consistent product.

Bison Management and Finishing Systems

Bison are native to North America and are therefore have adapted to the climate and naturally occurring feedstuffs available on this continent. The fact that bison are well adapted to many regions of the United States can provide certain economic advantages, such as lower cost of production, because bison are able to utilize poor quality forages (Galbraith et al., 2014). However, there are also challenges raising a recently domesticated species. For example, bison have a larger flight zone and a stronger herd instinct than cattle, which can cause challenges during handling and transport. Fences must be built taller and stronger, both in the pasture and around handling facilities. Chutes are larger and may include a crash gate for added protection of the animals and handlers. A crash gate is a metal enclosure in the front of the area on

a chute where the animal's neck is caught during processing. The purpose of a crash gate is to stop the animal long enough to close the head gate around the neck for the bison to be processed (Lammers, 2011).

General management of bison also differs from traditional cattle production in the United States. Bison typically are not de-horned like cattle and bulls are rarely castrated, which can lead to added aggression and challenges with meat quality. Bison go through a 'rut' or mating season that can last from early July to late September (Flocchini, 2015). This seasonal mating pattern results in the birth of the majority of bison calves between the months of April and June. Reproduction technologies such as artificial insemination and estrus synchronization are not commonly used in bison production. Calves are generally raised beside their dam until they are weaned at approximately six months of age. After weaning calves are typically placed into a separate pasture to continue growing. Bison designated for meat production will enter a finishing phase between one and two years of age depending on the finishing system utilized.

When raising an animal for meat production, producers have to decide which finishing system best fits their facilities, business model, and marketing goals. Two common finishing systems for bison are intensive (feeding a high energy, low forage diet, typically in a feedlot or confinement facility), and extensive (allowing animals to graze pasture or range and consuming a forage-based diet). These systems are also referred to as grain- and grass-finishing respectively (Anderson and Feist, 2015; Steenbergen, 2015). Many bison producers choose to utilize an extensive system,

(grazing on a pasture) as it is viewed as a more “natural” way to finish bison and evokes the nostalgia of bison roaming on the open prairie. Bison are also better suited to digest fiber more thoroughly than cattle and are therefore better at utilizing high fiber feedstuffs (Anderson, 1997). When bison are finished in an intensive feedlot or confinement setting, certain adaptations are recommended to ensure the animals do not harm themselves, others, or handlers. Compared to cattle, bison require more square feet per animal, stronger and taller fences, and a longer adaptation period to the confinement situation and high concentrate diet (Anderson and Feist, 2015). Bison share some similarities to cattle when placed on a high concentrate diet. Average daily gain increases and bison develop a thicker layer of firmer, whiter, subcutaneous fat compared to bison that have been grass-finished, which have softer, yellower fat. However, bison tend to eat less grain and grow slower in the feedlot than cattle (Anderson, 1997). Bison also tend to consume less feed than beef cattle of the same weight (Steenbergen, 2015). Koch et al. (1995) reported that bison had a lower average daily gain (0.77 kg/d) compared to Hereford cattle (1.13 kg/d). However, this decreased consumption allows the animal to have more efficient digestion because of reduced passage rate of the feedstuff (Steenbergen, 2015). Bison also require more time to reach their mature physical size compared to cattle, generally resulting in an older animal at harvest. Most cattle finish between 13 and 20 months of age, whereas most bison are between 18 and 30 months before they are harvested (Steenbergen, 2015; NBA, 2021b). While bison require more days to finish, their live weight at harvest is

generally lighter than cattle ranging between 430 kg – 567 kg for bulls (NBA, 2021c) and 330 kg – 446 kg for heifers (Rutley and Aalhus, 2003; Janssen et al., 2021).

Research has demonstrated that finishing systems can also influence carcass characteristics of bison. Janssen et al. (2021) compared grain- and grass-finished bison heifers and reported that grain-finished heifers had heavier live weight (446 kg vs. 378 kg) and hot carcass weight (281 kg vs. 226 kg), larger ribeye area (64.6 cm^2 vs. 57.5 cm^2), increased backfat thickness (2.16 cm vs. 0.89 cm), a greater percentage of kidney pelvic and heart fat (2.6% vs. 0.9%), and an increased marbling score (389 vs. 244). It was also reported that 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'. However, comparable information is not available for grain- and grass-finished bison bulls.

Seasonal Intake Patterns

Bison are ruminants that have become well adapted to surviving winters on the northern plains. Similar to many wild ruminants such as elk and deer, bison will alter their daily activity patterns in response to seasonal fluctuations in forage availability and ambient temperature (Rutley and Hudson, 2001) as evidenced by a reduction of feed intake and activity in the winter (Anderson, 1997). During winter both mature and growing bison will fall into a "winter slump." Huntington et al. (2019) categorize this as a time when bison will voluntarily reduce intake. This change in diet is not only observed when bison are grazing forages, but also occurs in a confined feeding setting. When provided a choice, research has shown that bison will choose to consume a less nutrient

dense diet containing a greater proportion of roughage compared to concentrates in the winter (Anderson, 1997). Anderson (1997) conducted a study to determine quantities of different feedstuffs consumed by bison bulls throughout a year and reported that bison will modify the amount hay they consume in response to the season. During the winter bison consumed more hay compared to the fall (5.23kg/d and 3.76kg/d, respectively), and Anderson (1997) suggested that increased intake of hay during the winter may be an evolutionary response as a way of increasing body heat through ruminal fermentation. While the bison consumed more hay in the winter period compared to the fall, they did not consume more total feed in the winter compared to the fall. The additional hay consumption was offset by a decreased consumption of concentrate (Anderson, 1997).

In the warmer months bison increase their body condition and growth by increasing total feed intake (Church et al., (1999). In a two year study Church et al. (1999) reported that bison bulls consume more total feed in the summer (16.0-16.4 kg/day and 12.4-14.1 kg/day for years 1 and 2, respectively) than in the winter (7.2-10.0 kg/day and 11.5-13.9 kg/day for years 1 and 2, respectively). They also reported bison bulls gained more weight in the summer (1.13 ± 0.04 kg/d) than in winter (0.71 ± 0.05 kg/d). Anderson (1997) reported similar results with bison gaining more in the spring, summer, and fall compared to the winter, even when feed was readily available. While the phenomenon of the winter slump is supported by the literature, the cause is not fully understood and reports are conflicting. Anderson (1997) reported an extreme inefficiency in feed conversion over the winter resulted in decreased average daily gain.

However, Church et al. (1999) reported that feed efficiency of bison bulls was similar between seasons but the increased feed intake in the summer resulted in an increase in average daily gain compared to winter. The majority of feeding trials researching the effect of the winter slump on bison have found decreased voluntary feed intake to be the primary reason for decreased gain or loss of weight regardless of finishing system (Huntington et al., 2019).

Supplemental feeding over the winter months has been evaluated as a method of preventing the loss of weight caused by the winter slump. While additional supplementation has been reported to lessen the effect, it also reduced the compensatory growth that bison experience in the spring. Although, the animals gained better over the winter when supplemented, the reduced gain in the spring resulted in similar overall body weights (Huntington et al., 2019).

Apart from of the biological mechanism regulating this seasonal response, the winter slump is one of the distinct traits of bison and should be considered in management and marketing decisions. The superior performance of bison in the warmer months suggest an advantage to finishing and harvesting bison in the summer and fall as opposed to winter. Seasonal changes in intake patterns make it difficult to consistently finish and market bison at the optimal weight and condition on a year-round basis. Unlike finishing beef cattle, it is difficult to alter rations or placement dates to target a certain season or market because bison are prone to lose weight and condition during the winter regardless of how much feed is available to them.

Bison Carcass Characteristics and Meat Composition

Both bison bulls and heifers are marketed for meat production in the United States However, bulls represent the greatest proportion of the slaughter mix (USDA-AMS, 2021). As mentioned, the bison industry does not routinely castrate males leaving them intact throughout the entire growing and finishing process. Bulls will finish at a greater weight when compared to heifers, while also having less external fat (Rutley and Aalhus, 2003; Lopez-Campos et al., 2013).

While chronological age of an animal could be known, after slaughter, physiological age is used as the final determination for age of an animal. Physiological age can also be referred to as maturity. As an example, maturity of a beef carcass is determined by the degree of ossification of the thoracic buttons and lean color of the exposed ribeye muscle where the carcass is ribbed. As an animal ages, cartilage ossifies into bone (Gerrard and Grant, 2003). Lean tissue color also becomes darker and more red as an animal ages as the concentration of myoglobin in the muscle increases (Gerrard and Grant, 2003). The primary reason for determining the age of a carcass is related to palatability of the meat. As an animal ages, the concentration of connective tissue in muscle increases, which will make the meat from an older animal tougher than that of a young animal (Gerrard and Grant, 2003). While research investigating the impact of bison age or maturity on carcass and meat quality traits is limited, Lopez-Campos et al. (2013) evaluated the influence of physiological age of bison bulls and heifers on carcass characteristics and reported no influence on meat traits due to ossification group.

The anatomy of a bison carcass differs from a beef animal, which can create challenges with fabrication of bison carcass. The distinctive hump of the bison is created by a longer thoracic process of the thoracic vertebrae, which requires a larger splitting saw to divide or 'split' the carcass in half (Galbraith et al., 2014). Bison also have 14 ribs per side compared to the 13 in a beef carcass. Bison hide varies in thickness from front to rear with the anterior section of the hide being thick and heavy, whereas the hide of covering the posterior of the animal is very thin. Processors must take special care to not puncture the thinner hide of the hindquarter (Galbraith et al., 2014). While beef carcasses typically have their weight distributed approximately 50:50 between the forequarter and hindquarter, bison carry the majority of their weight in their forequarter (Peters, 1958). Hawley (1986) reported that the hindquarter represented roughly 46% of total carcass weight of bison steers compared to 54% of the weight in the forequarter.

Bison are typically slaughtered at a lighter weight than cattle regardless of sex. This lighter live weight at slaughter results in decreased hot carcass weights. In a study utilizing bison heifers, Janssen et al. (2021) reported average live weights of grain-finished heifers to be 446 kg and grass-finished heifers were 378 kg, while hot carcass weights were 281 kg and 226 kg for grain and grass finished heifers, respectively. In a study with 30 month old bison steers, Hawley (1986) reported average live weights of 444 kg and corresponding hot carcass weights of 277 kg. Koch et al. (1995) fed bison bulls to a slaughter weight of 431 kg resulting in a hot carcass weight of 269 kg. While bison are finished to a lighter weight than cattle, the dressing percent or weight of the

carcass after the head, hide, and offal is removed compared to live weight, is similar to cattle. Janssen et al. (2021) reported that grain-finished bison heifers had a dressing percent of 63.1% whereas grass-finished dressed at 59.8%. Hawley (1986) reported an average dressing percentage of 59.9% for bison steers and Koch et al. (1995) reported a dressing percent of 62.6% for bison bulls.

Bison tend to have a ribeye area close to 60 cm^2 compared to cattle who averaged approximately 90 cm^2 in the most recent National Beef Quality Audit (Boykin et al., 2017). Hawley (1986) reported bison steers had an average ribeye area of 60.5 cm^2 and Janssen et al. (2021) found grain-finished bison heifers had an average ribeye area of 64.6 cm^2, while grass-finished heifers had an average ribeye area of 57.5 cm^2. Bison show a tendency to carry fat primarily over their rib section as well as having a large internal fat depot over their kidneys (Hawley, 1986). Hawley (1986) described that the surface of the ribs of a bison carcass were extremely lean and the hips lacked finish, however the level of fat over the ribeye exceeded 1.5 cm in thickness. It is hypothesized that this difference in fat cover could be an adaptation as an energy depot and/or as protection from the cold environment (Koch et al., 1995). Koch et al. (1995) reported that bison had more fat cover (2.2 cm) over the rib primal when compared to Hereford cattle (0.8 cm) and bison x Charolais hybrids (1.0 cm). Janssen et al. (2021) reported that grain-finished heifers had greater backfat (2.2 cm) comparted to grass-finished heifers (0.9 cm). While few studies have evaluated marbling in bison trends suggest that bison are similar to beef in that females tend to deposit more intramuscular fat than males. Janssen et al. (2021) and Lopez-Campos et al. (2013) reported marbling scores for bison

heifers of 389 and 368 respectively, while Koch et al. (1995) and Lopez-Campos (2013) reported marbling scores of 319 and 289, respectively for bison bulls when comparing similar finishing styles.

Proximate analysis can be utilized as a method to determine the proportion of water, protein, fat, and ash or vitamins and minerals in a meat sample. Galbraith et al. (2006) investigated the composition of ribeye samples *(Longissimus thoracis)* from bison bulls and reported protein at 21.3%, total fat at 3.3% and moisture at 73.7%. Lopez-Campos et al. (2013) reported that steaks from the striploin (*Longissimus lumborum*) of bison bulls had a higher percentage of moisture compared to heifers (73.6% and 72.3%, respectively). However, heifers had greater fat content than bulls (3.8% and 2.2%, respectively). No differences were reported between bull and heifer samples for protein content (22.4% and 22.4%, respectively; (Lopez-Campos et al., 2013). Janssen et al. (2021) reported that striploin samples (*Longissimus lumborum*) from grain-finished bison heifers were 74.1% moisture, 21.4% protein, 3.2% fat and 1.1% ash, whereas grass-finished heifers had increased moisture (75.9%) content but less protein (21.0%), and fat (1.9%), with no difference reported for ash content (1.1%). Marchello et al. (1989) averaged samples from the longissimus muscle of bulls and heifers and reported 74.5% moisture, 21.7% protein, 1.9% fat, and 1.2% ash.

North American's have become more health conscious since the turn of the century, especially when it pertains to the fat and cholesterol content of their food (Galbraith et al., 2006). This health-conscious trend is likely driving some consumers to purchase grass-fed proteins. Promotion of animal health and well-being, environmental

stability, and/or desire for meat products with a modified nutritional profile with specific focus on lower total fat content and a more healthful fatty acid profile are of interest to many consumers (Van Elswyk and McNeil, 2014). Similarly, bison is promoted and sought by consumers as a lean meat due to a lack of intramuscular fat and greater levels of polyunsaturated fatty acids (PUFA) in relation to saturated fatty acids (SFA) (Rule et al., 2002). This has been a large part of the bison industry's marketing platform as bison meat has become more readily available to consumers. The increased levels of PUFAs, the low total fat content, and ratio of omega-3 to omega-6 fatty acids under 5 can appeal to a health conscious consumer (Rule et al., 2002). However, research investigating the influence of bison feeding strategies on fatty acid profile and cholesterol level in bison meat is limited.

Fatty acids are a major component of lipids and are incorporated into esters including triglycerides (Lobb and Chow, 2008). A triglyceride is comprised of a glycerol backbone with three fatty acids bound to it. Fatty acids are classified and named by their carbon chain length and number of double bonds or saturation. Fattcids are broken down into three categories, saturated, monounsaturated, or polyunsaturated. Saturated fatty acids contain no double bonds. Monounsaturated fatty acids contain one double bond along the carbon chain that can be either a cis or trans linkage. For a cis linkage, the hydrogen atoms are on the same side of the double bond and a trans linkage has the hydrogen atoms on opposite sides of the double bond. This difference in placement of the hydrogen atoms changes the shape of the fatty acid. A cis double bond with have a bend in the carbon chain, while the trans double bond will have a straight

carbon chain (Lobb and Chow, 2008). Polyunsaturated fatty acids contain two or more double bonds (Lobb and Chow, 2008). Polyunsaturated fatty acids also include the omega-6 (n-6) and omega-3 (n-3) families, which are considered essential fatty acids to humans as they cannot be synthesized in the body (Rubio-Rodríguez et al., 2010). Omega-3 fatty acids have been extensively researched due to the role they play in human health. Well known effects of increasing omega-3 fatty acids in the diet include reducing the risk of cardiovascular disease and rheumatoid arthritis as well as having the potential to reduce other inflammatory disease such as asthma or bowel diseases. Increased levels of omega-6 fatty acids have traditionally been associated with increasing Inflammation in the human body. This may be caused by omega-6 fatty acids inhibiting the anti-inflammatory properties of omerga-3 fatty acids (Innes and Calder, 2018). The n-6 family is the most common within PUFAs with the n-3 family being less prevalent.

The fatty acid composition of domesticated red meat species is primarily composed of SFA with decreasing levels of MUFA and PUFA. However, fatty acid profile can be influenced by animal diet. Regardless of finishing system, approximately one-third of the SFA in beef is stearic acid (Van Elswyk and McNeil, 2014). Red meat from domesticated animals like beef, pork, and lamb has an intermediate level of MUFAs with PUFAs making up the smallest percentage of the total fat content. However, most bison meat regardless of finishing system has a fatty acid profile more similar to that of non-domesticated species like elk, deer, and antelope where the greatest proportion of fatty acids is made up of MUFAs, followed by SFAs, and the smallest fraction being PUFAs

(Marchello et al., 1989; Marchello et al., 1998; Cordain et al., 2002; Galbraith et al., 2006; Janssen et al., 2021). However, Marchello and Driskell (2001) reported that the fatty acid profile of grain-finished bison follow the trend of red meat from domesticated species with SFAs making up the greatest proportion of fatty acids in meat, however other studies have not come to the same conclusion.

A few studies have evaluated the fatty acid profiles of bison meat. Galbraith et al. (2006) reported that the ribeye (*Longissimus thoracis*) from grain-finished bison bulls contained 3.31g/100g of total fat, 1.08g/100g SFA, 1.15g/100g MUFAs, 0.17g/100g PUFAs, and 0.01g/100g trans-fat. In a study evaluating bison heifers Janssen et al. (2021) reported that striploins (*Longissimus lumborum*) from grain-finished heifers contained 1.09g/100g of SFA, 1.61g/100g MUFA, and 0.41g/100g PUFA. Whereas grass-finished heifers were reported to have 0.70g/100g SFAs, 0.84g/100g MUFAs, and 0.36g/100g PUFAs. Marchello et al. (1989) evaluated the fatty acid profile of bison bulls and heifers as a percentage of total fat and reported SFA at 43.3%, MUFAs at 45.1%, and PUFAs at 11.7% in *longissimus* muscle tissue. When comparing grain- and grass-finished bison heifers Janssen et al. (2021) reported SFA at 34.7%, MUFA at 51.6%, and PUFA at 13.8% for grain-finished heifers and SFA at 36.4%, MUFA at 43.1%, and PUFA at 20.5% in grass-finished heifers on a percent of total fatty acid basis. In bison heifers, grain fed animals were reported to have a higher n6:n-3 ratio when compared to grass finished heifers (5.74 and 4.64, respectively; Janssen et al., 2021). Rule et al. (2002) detected a greater difference in the n6:n3 ratio of grain- and grass-finished bison bulls. Grain-finished bulls had an n-6:n-3 ratio of 5.73 whereas grass finished bulls had a ratio of 1.94. The ratio of

n-6:n-3 is often discussed in relation to the health benefits of the meat. Meat with a low n-6:n-3 ratio is reported to have anti-atherogenicity and anti-inflammatory effects that can help reduce the incidence of coronary artery disease with the ideal ration for n-6:n-3 omega fatty acids falling between 2.5 and 5.0 (Rule et al., 2002).

Many consumers are aware that there is a potential connection between plasma cholesterol concentration and atherosclerosis, or the buildup of plaque, cholesterol, and other substances on the arterial wall. The 2010 dietary guidelines for Americans recommends that less than 300mg/d of cholesterol be consumed. This has since been changed, with new recommendations indicating consumers take in as little dietary cholesterol as possible. Lean meat is defined 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). Often consumers make decisions regarding which food to eat based upon its cholesterol content (Dinh et al., 2011).

Marchello and Driskell (2001) and Marchello et al. (1998) compared the nutrient levels of meat from grain- and grass-finished bison bulls. They reported that across multiple cuts grain- and grass-finished bulls had a cholesterol content of 66mg/100g and 65mg/100g, respectively. Rule et al. (2002) evaluated the cholesterol content of *longissimus dorsi* muscle from bison bulls and reported that cholesterol was lower in range finished bulls (43.8mg/100g) compared with bulls finished in a feedlot (54.1mg/100g). Bison bulls finished on a free choice ration including 70-80% rolled barley and 20-30% straw had cholesterol levels of 48.27mg/100g in the *longissimus dorsi* muscle (Galbraith et al. (2006). In a study evaluating bison heifers finished either

on native rangeland or in a feedlot setting with free choice access to prairie hay and a concentrate mixture of corn and dried distillers grains, Janssen et al. (2021) reported that grain-finished heifers had an increase cholesterol content (54.31mg/100g) compared with those finished on pasture (51.41mg/100g). These studies indicate that bison meat fits into the category of lean meat and can have positive consumer health implications. They also show that finishing system plays a role in total fat content, fatty acid profile concentration, and amount of cholesterol within the meat with grain finished bison having increased total fatty acids, cholesterol content and, n-6/n-3 ratio.

Differentiating Bison Carcass Value

The United States does not have a formal bison grading system, therefore bison are ungraded and marketed as a game or "exotic" species, whereas in Canada, bison are marketed through a grading system as a means to standardize carcass and quality consistency (Galbraith et al., 2014). The Canadian bison grading system was developed in the early 1990's as a variation of their cattle grading system and was officially adopted in 1995 with nine grades across three different maturity classes (Lopez-Campos et al., 2013; Galbraith et al., 2014). Further revisions to the original grading system were made in 2007 leading to the 10 quality grades bison are currently marketed under including: A1, A2, A3, A4, B1, B2, B3, D1, D2, D3 distributed across two maturity classes (Galbraith et al., 2014). In the 2007 revision the three maturity groups were reduced to two, youthful (Class I), having ossification of the 9^{th} 10^{th} and 11^{th} thoracic buttons of less than 80% and mature (Class II) with greater than 80% ossification. Carcasses are sorted into a maturity class and further differentiated based upon conformation, color and

firmness of the fat, lean color, and firmness, as well as exterior fat thickness (Galbraith et al., 2014). Unlike beef, marbling is not used in determining quality grades of bison.

The United States does not have a grading system for bison carcasses. However, many processors choose to segregate carcasses based upon finishing systems (grass or grain finishing). There is currently no segregation based upon sex, marbling, or exterior fat thickness. This could potentially pose challenges with the growing demand for bison as Lopez-Campos et al. (2013) found greater differences in carcass characteristics, and tenderness between sex than from animals of different age ranges. Bison bulls had greater hot carcass weight, increased shear force values, and decreased marbling when compared to heifers. To keep up with growing demand for bison more research is necessary to understand bison meat and its characteristics to provide consumers with a repeatable, enjoyable eating experience.

While the body of bison research is growing, studies comparing the effect of different finishing systems on carcass traits and nutritional composition of bison bulls are limited. The lack of grading standards for product differentiation, the fact that bison producers utilize different finishing systems, the mixture of heifers and bulls marketed, and the harvest of animals at various ages contributes to product variation. Work to characterize these variations has the potential to increase product consistency and consumer acceptability and demand. Therefore, the objectives of this thesis project were to:

1. Determine the influence of finishing system (grass-finished vs. grain-finished) on carcass traits and meat quality

2. Characterize the nutritional profile of meat from bison bulls
3. Determine the influence of animal age (29 mo. vs. 36 mo.) on carcass traits of bison bulls.

Literature Cited

Anderson, V., and M. Feist. 2015. The Bison Producers' Handbook a Complete Guide to Production and Marketing. 5th ed. National Bison Association.

Anderson, V. M., B. 1997. Influence of season and diet on feedlot performance of Bison. Professional Animal Scientist 13:14-17

Boykin, C. A., L. C. Eastwood, M. K. Harris, D. S. Hale, C. R. Kerth, D. B. Griffin, A. N. Arnold, J. D. Hasty, K. E. Belk, D. R. Woerner, R. J. Delmore, Jr., J. N. Martin, D. L. VanOverbeke, G. G. Mafi, M. M. Pfeiffer, T. E. Lawrence, T. J. McEvers, T. B. Schmidt, R. J. Maddock, D. D. Johnson, C. C. Carr, J. M. Scheffler, T. D. Pringle, A. M. Stelzleni, J. Gottlieb, and J. W. Savell. 2017. National Beef Quality Audit–2016: In-plant survey of carcass characteristics related to quality, quantity, and value of fed steers and heifers1. J. Anim. Sci. 95(7):2993-3002. doi: 10.2527/jas.2017.1543

Bureš, D., and L. Bartoň. 2012. Growth performance, carcass traits and meat quality of bulls and heifers slaughtered at different ages. Czech J. Anim. Sci 57(1):34-43.

Church, J. S., R. J. Hudson, and B. D. Rutley. 1999. Performance of American bison (Bos bison) in feedlots. J. Anim. Feed Sci. 8(4):513-523. (Article)

Cordain, L., B. A. Watkins, G. L. Florant, M. Kelher, L. Rogers, and Y. Li. 2002. Fatty acid analysis of wild ruminant tissues: evolutionary implications for reducing diet-related chronic disease. European Journal of Clinical Nutrition 56(3):181-191. doi: 10.1038/sj.ejcn.1601307

Cross, H. R., J. D. Crouse, and M. D. MacNeil. 1984. Influence of Breed, Sex, Age and Electrical Stimulation on Carcass and Palatability Traits of Three Bovine Muscles1. J. Anim. Sci. 58(6):1358-1365. doi: 10.2527/jas1984.5861358x

Daley, C. A., A. Abbott, P. S. Doyle, G. A. Nader, and S. Larson. 2010. A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. Nutr. J. 9:12. (Review) doi: 10.1186/1475-2891-9-10

Dinh, T. T., L. D. Thompson, M. L. Galyean, J. C. Brooks, K. Y. Patterson, and L. M. Boylan. 2011. Cholesterol content and methods for cholesterol determination in meat and poultry. Comprehensive reviews in food science and food safety 10(5):269-289.

Dinh, T. T., L. D. Thompson, M. L. Galyean, J. C. L. Brooks, and M. L. Boylan. 2012. Determination of total cholesterol in meat and poultry by gas chromatography: Single-laboratory validation. Journal of AOAC International 95(2):472-488.

Flocchini, J. 2015. The Bison Producers' Handbook a Complete Guide to Production and Marketing.

Galbraith, J., A. Rodas-Gonzalez, O. Lopez-Campos, M. Juarez, and J. Aalhus. 2014. Bison meat: Characteristics, challenges, and opportunities. Animal Frontiers 4:68-73.

Galbraith, J. K., G. Hauer, L. Helbig, Z. Wang, M. J. Marchello, and L. A. Goonewardene. 2006. Nutrient profiles in retail cuts of bison meat. Meat Science 74(4):648-654. doi: https://doi.org/10.1016/j.meatsci.2006.05.015

Gerrard, D., and A. Grant. 2003. Principles of Animal Growth and Development.

Hawley, A. W. L. 1986. Carcass Characteristics of Bison (bison-bison) Steers. Canadian Journal of Animal Science 66(1):293-295. doi: 10.4141/cjas86-030

Huntington, G., M. Woodbury, and V. Anderson. 2019. Invited Review: Growth, voluntary intake, and digestion and metabolism of North American bison. Appl. Anim. Sci. 35(2):146-160. (Review) doi: 10.15232/aas.2018-01798

Innes, J. K., and P. C. Calder. 2018. Omega-6 fatty acids and inflammation. Prostaglandins, Leukotrienes and Essential Fatty Acids 132:41-48.

Janssen, J., K. Cammack, J. Legako, R. Cox, J. K. Grubbs, K. Underwood, J. Hansen, C. Kruse, and A. Blair. 2021. Influence of Grain- and Grass-Finishing Systems on Carcass Characteristics, Meat Quality, Nutritional Composition, and Consumer Sensory Attributes of Bison. Foods 10(5)doi: 10.3390/foods10051060

Jones, C. 1907. Breeding cattelo. Journal of Heredity (1):161-165.

Kerth, C., K. Braden, R. Cox, L. Kerth, and D. Rankins Jr. 2007. Carcass, sensory, fat color, and consumer acceptance characteristics of Angus-cross steers finished on ryegrass (Lolium multiflorum) forage or on a high-concentrate diet. Meat Science 75(2):324-331.

Koch, R. M., H. G. Jung, J. D. Crouse, V. H. Varel, and L. V. Cundiff. 1995. Growth, Digestive Capability, Carcass and Meat Characteristics of Bison-Bison, Bos-Taurus, and Bos x Bison. J. Anim. Sci. 73(5):1271-1281. (Article)

Kopuzlu, S., N. Esenbuga, A. Onenc, M. Macit, M. Yanar, S. Yuksel, A. Ozluturk, and N. Unlu. 2018. Effects of slaughter age and muscle type on meat quality characteristics of Eastern Anatolian Red bulls. Archives Animal Breeding 61(4):497-504.

Lammers, D. J. 2011. Evaluation of Facilities Design and Methods of Handling Bison.

Larick, D. K., B. E. Turner, R. M. Koch, and J. D. Crouse. 1989. Influence of Phospholipid Content and Fatty Acid Composition of Individual Phospholipids in Muscle from Bison, Hereford and Brahman Steers on Flavor. J. Food Sci. 54(3):521-526. doi: https://doi.org/10.1111/j.1365-2621.1989.tb04641.x

Lobb, K., and C. K. Chow. 2008. Fatty acid classification and nomenclature. Fatty acids in foods and their health implications 3:3-5.

Lopez-Campos, O., J. L. Aalhus, J. Galbraith, I. L. Larsen, M. Juarez, B. Uttaro, and W. M. Robertson. 2013. The relation of carcass physiological maturity to meat quality in the Canadian Bison Grading System. Canadian Journal of Animal Science 94(1):55-62. doi: 10.4141/cjas2013-047

Marchello, M., and J. Driskell. 2001. Nutrient composition of grass- and grain-finished bison. Great Plains Research 11:65-82.

Marchello, M., W. Slanger, M. Hadley, D. Milne, and J. Driskell. 1998. Nutrient Composition of Bison Fed Concentrate Diets. Journal of Food Composition and Analysis 11(3):231-239.

Marchello, M., W. Slanger, D. Milne, A. Fischer, and P. Berg. 1989. Nutrient composition of raw and cooked *Bison bison*. Journal of Food Composition and Analysis 2(2):177-185.

NBA. 2021a. Bison 1 Million. (Accessed September 13 2021).

NBA. 2021b. Bison by the Numbers. https://bisoncentral.com/bison-by-the-numbers/ (Accessed Sep 13 2021).

NBA. 2021c. Raising Bison. https://bisoncentral.com/raising-bison/ (Accessed 10/30/2021 2021).

Peters, H. 1958. A feedlot study of bison, cattalo and Hereford calves. Canadian Journal of Animal Science 38(1):87-90.

Pickering, R. 2015. The Bison Producers' Handbook a Complete Guide to Production and Marketing.

Rubio-Rodríguez, N., S. Beltrán, I. Jaime, M. Sara, M. T. Sanz, and J. R. Carballido. 2010. Production of omega-3 polyunsaturated fatty acid concentrates: A review. Innovative Food Science & Emerging Technologies 11(1):1-12.

Rule, D. C., K. S. Broughton, S. M. Shellito, and G. Maiorano. 2002. Comparison of muscle fatty acid profiles and cholesterol concentrations of bison, beef cattle, elk, and chicken. J. Anim. Sci. 80(5):1202-1211. (Article)

Rutley, B. D., and J. Aalhus. 2003. Determination of carcass characteristics of finished bison heifers. .

Rutley, B. D., and R. J. Hudson. 2001. Activity budgets and foraging behavior of bison on seeded pastures. Journal of Range Management 54(3):218-225. doi: 10.2307/4003237

Steenbergen, J. 2015. The Bison Producers' Handbook a Complete Guide to Production and Marketing. 5th ed. National Bison Association.

USDA-AMS. 2021. USDA Monthly Bison (Carcass and Cuts). https://mymarketnews.ams.usda.gov/viewReport/2827 (Accessed Dec 2 2021).

U.S. Department of Health and Human Services and U.S. Department of Agriculture (USDA/HHS). 2015. Dietary Guidelines for Americans. https://health.gov/sites/default/files/2019-09/2015-2020_Dietary_Guidelines.pdf.

Van Elswyk, M. E., and S. H. McNeil. 2014. Impact of grass/forage feeding versus grain finishing on beef nutrients and sensory quality: The U.S. experience. Journal of Meat Science 96:535-540.

Yang, A., M. Brewster, M. Lanari, and R. Tume. 2002. Effect of vitamin E supplementation on α-tocopherol and β-carotene concentrations in tissues from pasture-and grain-fed cattle. Meat Science 60(1):35-40.

CHAPTER 2: CARCASS CHARACTERISTICS, PROXIMATE COMPOSITION, NUTRITIONAL PROFILE, AND FATTY ACID PROFILE OF GRAIN- AND GRASS-FINISHED BISON BULLS

Introduction

Bison (*bison bison*) were hunted to near extinction in North America in the 1800's (Marchello and Driskell, 2001), however current numbers have rebounded to roughly 400,000 head in private, state, federal, and tribal herds (NBA, 2021). This increase in bison numbers has led to an increase in the number of bison slaughtered yearly (USDA-AMS, 2021), helping to fill the growing demand for bison meat. Previous research investigating the meat characteristics of bison have shown that bison meat is leaner with increased levels of polyunsaturated fatty acids (PUFAs) 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, which have been reported to cause variation in carcass characteristics, cholesterol content, and the fatty acid profile of beef (Rule et al., 2002; Daley et al., 2010; Van Elswyk and McNeil, 2014). However, studies investigating the effects of finishing system on bison carcass traits and composition are limited. Janssen et al. (2021) compared grass- and grain-finished bison heifers and reported that grain-finished heifers had greater live weight, hot carcass weight, dressing percentage, backfat thickness, and marbling scores when compared to grass-finished heifers. Grain-finishing produced steaks with increased cholesterol and total fatty acids, but reduced levels of PUFA (as a percentage of total lipid) compared

with grass-finishing (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 vs. feedlot finished 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 was reported by Rule et al. (2002)

Both bison bulls and heifers are marketed for meat production in the U.S. and bulls represent the greatest proportion of the slaughter mix (USDA-AMS, 2021). Lopez-Campos et al. (2013) compared bison bulls and heifers of unspecified finishing systems and reported bison bulls had increased hot carcass weights, decreased marbling scores, and decreased backfat 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 profile of bison bulls is warranted. Therefore, the objective of this study was to characterize the influence of finishing system (grain- or grass-finished) on carcass characteristics and nutritional composition of bison bulls.

Materials and Methods

Animals, Carcass Evaluation, and Striploin Collection

Prior to treatment allocation bison bulls (*Bison bison*; n = 196) were allowed to graze native rangelands in the Sandhills Ecoregion of Nebraska. When bulls were approximately 26 mo of age, they were randomly assigned to one of two finishing treatments: Grain-finishing (n = 98; placed in an open lot with ad libitum access to prairie hay, alfalfa hay and whole shell corn for 130 d prior to slaughter) or Grass-finishing (n = 98, continued to graze on pasture until slaughter).

Bulls were transported to a commercial harvest facility when they were approximately 29 mo of age and slaughtered over a two-day period. On the first slaughter day 50 grain-finished and 49 grass-finished bulls were harvested. On the second day 48 grain-finished and 49 grass-finished bulls were harvested. Live weight was recorded at the harvest facility. Hot carcass weight was recorded and kidney, pelvic, and heart fat percentage was determined as the difference in carcass weight before and after removal of the kidney knob. Following an approximately 20 hr chilling period, carcasses were ribbed between the 12^{th} and 13^{th} rib and ribeye area, backfat thickness, marbling score, skeletal maturity, subjective lean color, and subjective fat color were evaluated by United States Department of Agriculture (USDA) graders. Skeletal maturity was evaluated based upon the ossification percentage of the thoracic cartilage buttons and assigned a score corresponding with the ossification percentages as follows: 0-24% (slight), 25-49% (moderate), 50-99% (hardbone) and 100+% (extreme hardbone). Subjective lean color was scored based upon the lean color of the exposed ribeye and assigned a score based upon a color description as follows: bright red , moderately bright red, slightly bright red, red, pale red, and dark cutter. Fat color was scored based

upon the external fat color of the subcutaneous fat color opposite the ribeye as follows: white, moderately white, slightly white, moderately yellow, and yellow. Instrumental color (L*, a*, and b*) values of the exposed ribeye area at the 12th rib break and the subcutaneous fat of the carcass surface opposite the ribeye were also collected using a handheld Minolta colorimeter (Model CR-410, Minolta Corp., Ramsey, NJ; 50 mm diameter measuring space; D_{65} illuminant).

Both striploins (*M. longissimus lumborum*) were collected from a subsample of carcasses (n=60; 30 carcasses closest to the treatment average hot carcass weight). Striploins were vacuum packaged and transported in a refrigerated trailer to the South Dakota State University Meat Laboratory for fabrication and further analysis.

Striploin Fabrication and pH

Striploin samples arrived at the South Dakota State University Meat Laboratory at 2- or 3-days postmortem depending upon kill date. Striploins were removed from vacuum packaging, trimmed of external fat, and fabricated into 2.54-cm steaks. Steaks were individually vacuum packaged and assigned for analysis. The most anterior steak from the left side of the animal was designated for proximate analysis and frozen at 4 days postmortem. The second most anterior steak from the left side of the animal was utilized for determination of cholesterol content and fatty acid profile and frozen at 4 days postmortem. Remaining steaks were designated for analysis associated with other projects. Ultimate pH was recorded at the posterior end of the striploin using a handheld pH meter (Thermo-Scientific Orion Star, Beverly, MA, Model# A221 and Star A321 Portable pH probe).

Proximate Analysis

To determine the proximate composition, striploin steaks were slightly thawed and trimmed of external fat, accessory muscles, and connective tissue. Once trimmed, steaks were minced with a knife, placed in liquid nitrogen, and powered using a stainless-steel blender (Waring Products Division, Model # 51BL32, Landcaster, PA). Homogenized samples were stored at -20 ^{o}C in plastic bags (Whirlpack, Nasco, Fort Atkinson, WI) until chemical composition analyses was performed. To determine ash and moisture percentage, duplicate powered samples were weighed (~3 g) into dried aluminum tins (FischerBrand, Pittsburgh, PA, Cat. # 08-732-101), and dried in an oven (Precision Scientific, Winchester, VW, Cat.# 51220159) at 101 ^{o}C for 24 hours. Dried samples were placed into a desiccator (Scienceware, Wayne, NJ, Cat.# 420320000) and weighed after cooling a minimum of 1 hour. Moisture content was calculated as the difference between pre- and post-drying sample weights and expressed as a percentage of the pre-dried sample weight. Samples were then put into a muffle furnace (Fisher Scientific Co., Pittsburgh, PA, Model Series# 10-650) at 500 ^{o}C and ashed for 24 hours. Samples were allowed to cool to ~150 ^{o}C then placed into a desiccator to cool for an additional hour, then reweighed. Proximate ash content was calculated as the difference between pre- and post-ashed sample weights and expressed as a percentage of the pre-ashed sample weight.

Protein content was determined by weighing duplicate powdered samples (~250 mg) into crucibles. Samples were then subjected to dumas combustion by a nitrogen analyzer (Rapid Max N Exceed, Elementar, Hanau, Germany, Serial# 29161032). Percent

protein content was determined based on the protein factor (6.25) multiplied by the percent nitrogen detected in each sample.

Percent crude fat was determined using the ether extract method outlined by Mohrhauser et al. (2015). Powdered samples (~5 g) were weighed into dried aluminum tins (FischerBrand, Pittsburgh, PA, Cat.# 08-732-101), and dried in an oven (Precision Scientific, Winchester, VW, Cat.# 51220159) at 101 ^{o}C for 24 hours. Dried samples were placed into a desiccator (Scienceware, Wayne, NJ, Cat.# 420320000) and weighed after cooling for a minimum of 1 hour. Dried samples were then extracted with petroleum ether in a side-arm Soxhlet extractor (ThermoFischer Scientific, Rockville, MD) for a 60-hour reflux period, then placed under a laboratory hood to evaporate at room temperature for 4 hours, followed by drying in an oven at 101 ^{o}C for 4 hours. Dried and extracted samples were placed in a desiccator to cool for 1 hour, and then reweighed. To calculate the proximate intramuscular fat content the difference between pre- and post-extraction sample weight was determined and expressed as a percentage of the pre-extraction sample weight.

Cholesterol Determination

Total cholesterol from muscle samples was extracted as described by Dinh et al. (2012) with modifications in alkaline concentration and detection method. Briefly, meat (1 g) was saponified by 10-N KOH and extracted in toluene with the addition of 5α-cholestane as an internal standard. One mL of the toluene extract was pipetted into a 2-mL 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/splitless

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 mL/min. Inlet, transfer line, ion source, and quadrupole were heated at 300, 300, 230, 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) were optimized in a selected ion monitoring mode (SIM) 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/100g 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, samples were trimmed of all external fat and connective tissues and homogenized in liquid nitrogen to a finely divided power. Approximately 1 g of each sample was weighed into a 20-mL 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-mL amber GC vial with a Teflon®-lined screw-cap. Vials were stored −20 °C until determination by gas

chromatography – mass spectrometry (GC-MS). The fatty acid composition was determined by an Agilent 7890A GC system equipped with a HP-88 capillary column (30 m × 0.25 mm × 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 mL/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 was detected in a selected ion monitoring mode (SIM) optimized for saturated, monounsaturated, and polyunsaturated fatty acids. 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. (2010) with correction by the molecular weight difference between FAME and their corresponding fatty acid. The total fatty acid concentration (µg/g of muscle) was used as an estimate of the intramuscular fat content (Wood et al. 2013). The normalized percentage of each fatty acid based on total fatty acid was also calculated.

Statistical Analysis

Live body weight, dressing percent, carcass measurements, objective color, proximate analysis, cholesterol content, and fatty acid profile data were analyzed using the MIXED procedures of SAS (SAS Inst. Inc., Cary, NC). Yield grade, subjective skeletal maturity, subjective lean color, and subjective fat color were analyzed using the

GLIMMIX procedures 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 was used as the experimental unit for all carcass and composition 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, yield grade, and marbling scores were calculated using the USDA beef grading standards. Anatomy and confirmation of bison differs from cattle. Bison have 14 pairs of ribs, carrying more weight in their forequarter (or chuck on a carcass), 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 compared to beef, although they often reach market readiness at a more advanced chronological age. This lighter finished weight results in lighter hot carcass weight and a smaller ribeye area compared to cattle. Bison carcasses are also reported to have less intramuscular fat (marbling) in the ribeye but greater backfat thickness compared to cattle (Koch et al., 1995). Bison bulls in the current study were harvested at approximately 29 months of age, which falls within the average age range (20 - 36 months) 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 weights and carcass data are reported in Table 2-1. Grain-finished bulls had greater ($P < 0.0001$) live and hot carcass weights, dressing percentage, ribeye area,

backfat thickness, kidney, pelvic, and heart fat, 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 hot carcass weights of bison heifers (229 kg) reported by Lopez-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.

The ribeye area of grain-finished bulls was 65.1 cm^2, which is similar the ribeye area of grain-finished heifers (64.6 cm^2) reported by Janssen et al. (2021) while grass-finished bulls had a ribeye are 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, which aligns with the most common range of backfat thickness (<0.7 cm) for bison bulls of various ages reported by Lopez-Campos et al. (2013). The kidney, pelvic, and heart fat 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 category of the USDA beef quality grading system.

To compare yield grades (YG) of bison bulls in this study measurements were recorded and evaluated according to the equation used to calculate beef yield grades. 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 no 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 yield grade categories of 2, 3, and 4. The increased yield grades of heifers compared to bulls in the current study is likely due to differences in backfat thickness and carcass weight.

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 ($P < 0.01$) of grass-finished bison bulls were classified as having slightly bright red lean compared to grain-finished bison bulls, while a greater percentage ($P < 0.001$) of grain-finished bulls were classified as moderately bright red.

The most common 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 ($P < 0.001$) 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 silver skin (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 2-2. 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 greatest 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 grain-finished bison, while L* and b* were increased in fat tissue of grass-finished bison. Finishing system did not influence ($P > 0.05$) the ultimate pH of bison striploins, 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 ($P < 0.001$) crude protein, crude fat, and ash content, while steaks from grass-finished bulls had increased moisture content ($P < 0.0001$; Table 2-3). 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.

Cholesterol Content

Steaks from grain-finished bison bulls had increased ($P < 0.0001$) cholesterol content when compared to steaks form grass-finished bulls (Table 2-3). The cholesterol content of steaks for grain- and grass-finished bison were 63.2 and 53.5 mg/100g 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/100g (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 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/100g 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 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 United States has 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

Fatty acid data are reported in Tables 2-4 to 2-11. The majority of fatty acids evaluated were influenced ($P < 0.05$) by finishing treatment with the exception of C13:0 12methyl, C14:0 12methyl, C15:1 UN, C15:1 cis9, C16:0 15methyl, C16:0 14methyl, C16:1 cis9 14methyl, C18:1 trans11, C18:2 cis12,15, C19:1 cis10, C20:0, C21:0, C20:3 UN, C20:2 cis 9,12, C20:3 cis8,11,14, C20:3 cis11,14,17, C22:0, C22:4 cis7,10,13,16, C23:0, C22:6 cis4,7,10,13,16,19, BCFA, LCPUFA when reported on a mg/g raw tissue basis and C8:0, C12:0, C16:1 cis9 14methyl, C18:1 UN, C18:2 trans9,12, C18:2 cis12,15, C21:0, C20:2 cis11,14, C20:2 cis9,12, C20:3 cis8,11,14, C22:0, C22:4 cis 7,10,13,16, and SFA when reported on a percentage of total fatty acid basis.

While steaks from grain-finished bison bulls had increased SFAs, MUFAs, and PUFAs on a concentration basis (Table 2-7), when analyzed as a percent of total fatty acids (Table 2-11), SFAs were found to be similar between finishing treatments while PUFAs were increased in grass-finished steaks and MUFAs were increased in grain-finished steaks. Rule et al. (2002) and Janssen et al. (2021) also found steaks from grass-finished bison to have an increased percentage of PUFAs. However, in contrast to the current study they reported grass-finished steaks to have a greater percentage of SFAs.

Steaks from grass-finished bison had an increased percentage of PUFAs compared to steaks from grain-finished bison, 17.47% and 11.90%, respectively (Table 2-11). Rule et al. (2002) also reported that steaks from grass-finished bulls contained increased PUFAs compared to grain-finished bulls (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 PUFAs in steaks from grass-finished heifers compared to grain-finished (20.5% and 13.7%, respectively). The increased percentage of PUFAs 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 ($P < 0.0001$) PUFA to SFA ratio when compared to steaks from the grass-finished treatment (Table 2-7). 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, found no differences in the PUFA:SFA ratio. An n-6:n-3 ratio between 2.5 and 5.0 and a PUFA:SFA ratio of approximately 2.0 has 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: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), while steaks from grass-finished bison bulls were below the range with an n-6:n-3 ratio of 1.96. The n-6:n-3 ratio for grass-finished bulls in the current study is similar to the n-6:n-3 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/n-3 ratio of 5.73 which is higher than the findings of the current study. Janssen et al. (2021) reported bison heifers had an increased n-6: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.

Conclusion

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 when compared to bison bulls in a grass-finishing system. Finishing system also impacted the nutrient and fatty acid profile of bison meat. Grass-finishing resulted in steaks with decreased cholesterol content, percent 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.

Literature Cited

Daley, C. A., A. Abbott, P. S. Doyle, G. A. Nader, and S. Larson. 2010. A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. Nutr. J. 9:12. (Review) doi: 10.1186/1475-2891-9-10

Dinh, T. T., L. D. Thompson, M. L. Galyean, J. C. Brooks, K. Y. Patterson, and L. M. Boylan. 2011. Cholesterol content and methods for cholesterol determination in meat and poultry. Comprehensive reviews in food science and food safety 10(5):269-289.

Dinh, T. T., L. D. Thompson, M. L. Galyean, J. C. L. Brooks, and M. L. Boylan. 2012. Determination of total cholesterol in meat and poultry by gas chromatography: Single-laboratory validation. Journal of AOAC International 95(2):472-488.

Galbraith, J. K., G. Hauer, L. Helbig, Z. Wang, M. J. Marchello, and L. A. Goonewardene. 2006. Nutrient profiles in retail cuts of bison meat. Meat Science 74(4):648-654. doi: https://doi.org/10.1016/j.meatsci.2006.05.015

Hawley, A. W. L. 1986. Carcass Characteristics of Bison (bison-bison) Steers. Canadian Journal of Animal Science 66(1):293-295. doi: 10.4141/cjas86-030

Janssen, J., K. Cammack, J. Legako, R. Cox, J. K. Grubbs, K. Underwood, J. Hansen, C. Kruse, and A. Blair. 2021. Influence of Grain- and Grass-Finishing Systems on Carcass Characteristics, Meat Quality, Nutritional Composition, and Consumer Sensory Attributes of Bison. Foods 10(5)doi: 10.3390/foods10051060

Kerth, C., K. Braden, R. Cox, L. Kerth, and D. Rankins Jr. 2007. Carcass, sensory, fat color, and consumer acceptance characteristics of Angus-cross steers finished on

ryegrass (Lolium multiflorum) forage or on a high-concentrate diet. Meat Science 75(2):324-331.

Koch, R. M., H. G. Jung, J. D. Crouse, V. H. Varel, and L. V. Cundiff. 1995. Growth, Digestive Capability, Carcass and Meat Characteristics of Bison-Bison, Bos-Taurus, and Bos x Bison. J. Anim. Sci. 73(5):1271-1281. (Article)

Larick, D. K., B. E. Turner, R. M. Koch, and J. D. Crouse. 1989. Influence of Phospholipid Content and Fatty Acid Composition of Individual Phospholipids in Muscle from Bison, Hereford and Brahman Steers on Flavor. J. Food Sci. 54(3):521-526. doi: https://doi.org/10.1111/j.1365-2621.1989.tb04641.x

Lopez-Campos, O., J. L. Aalhus, J. Galbraith, I. L. Larsen, M. Juarez, B. Uttaro, and W. M. Robertson. 2013. The relation of carcass physiological maturity to meat quality in the Canadian Bison Grading System. Canadian Journal of Animal Science 94(1):55-62. doi: 10.4141/cjas2013-047

Marchello, M., and J. Driskell. 2001. Nutrient composition of grass- and grain-finished bison. Great Plains Research 11:65-82.

Marchello, M., W. Slanger, M. Hadley, D. Milne, and J. Driskell. 1998. Nutrient Composition of Bison Fed Concentrate Diets. Journal of Food Composition and Analysis 11(3):231-239.

Marchello, M., W. Slanger, D. Milne, A. Fischer, and P. Berg. 1989. Nutrient composition of raw and cooked *Bison bison*. Journal of Food Composition and Analysis 2(2):177-185.

NBA 2021. Bison by the Numbers. https://bisoncentral.com/bison-by-the-numbers/ (Accessed Sep 13 2021).

Rule, D. C., K. S. Broughton, S. M. Shellito, and G. Maiorano. 2002. Comparison of muscle fatty acid profiles and cholesterol concentrations of bison, beef cattle, elk, and chicken. J. Anim. Sci. 80(5):1202-1211. (Article)

Van Elswyk, M. E., and S. H. McNeil. 2014. Impact of grass/forage feeding versus grain finishing on beef nutrients and sensory quality: The U.S. experience. Journal of Meat Science 96:535-540.

USDA-AMS. 2021. USDA Monthly Bison (Carcass and Cuts). https://mymarketnews.ams.usda.gov/viewReport/2827 (Accessed Dec 2 2021).

U.S. Department of Health and Human Services and U.S. Department of Agriculture (USDA/HHS). 2015. Dietary Guidelines for Americans. https://health.gov/sites/default/files/2019-09/2015-2020_Dietary_Guidelines.pdf.

Yang, A., M. Brewster, M. Lanari, and R. Tume. 2002. Effect of vitamin E supplementation on α-tocopherol and β-carotene concentrations in tissues from pasture-and grain-fed cattle. Meat Science 60(1):35-40.

Table 2-1. Least squares means for 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	1.906	<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, pelvic, and heart 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[7]				
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[8]				
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 130 days with ad libitum access to grass hay, alfalfa, and a corn prior to slaughter. GRASS = bison bulls (n=98) remained on pasture until slaughter
[2]Standard error of the mean
[3]Probability of difference among least square 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 assigned by USDA.
[7]Subjective lean maturity assigned by USDA.
[8]Subjective external fat color assigned by USDA.

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

Variable		Grain[1]	Grass[1]	SEM[2]	*P*-Value[3]
Lean tissue [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 pasture and finished for 130 days with ad libitum access to grass hay, alfalfa, and corn concentrate prior to slaughter. GRASS = bison bulls (*n* = 98) remained on pasture until slaughter.
[2] Standard error of the mean.
[3] Probability of difference among least square means.
[4] Objective color measurement recorded on the exposed ribeye 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-days postmortem from grain- (n = 30) and grass- (n = 30) finished striploins.

Table 2-3. Least square means for the effect of finishing system on the proximate nutrient composition of raw tissue from the *longissimus dorsi* of grain- and grass-finished bison bulls.

Nutrient	Grain[1]	Grass[1]	SEM[2]	*P*-value[3]
Moisture, %	75.45	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/100g)	63.20	53.53	0.963	<0.0001

[1] Treatments: GRAIN = bison bulls (*n* = 30) backgrounded on pasture and finished for 130 days with ad libitum access to grass hay, alfalfa, and corn concentrate prior to slaughter. GRASS = bison bulls (*n* = 30) remained on pasture until slaughter.
[2] Standard error of the mean.
[3] Probability of difference among least square means.

Table 2-4. Least square means for the effect of finishing system on the saturated fatty acid composition (µg/g wet sample basis) of raw tissue from bison *longissimus dorsi* of grain- or grass-finished bison bulls.

Fatty Acids	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]
C8:0	1.95	1.19	0.090	<0.0001
C10:0	8.78	3.85	0.332	<0.0001
C11:0	0.36	0.15	0.023	<0.0001
C12:0	7.36	4.15	0.314	<0.0001
C13:0	5.79	6.08	0.403	0.6143
12methyl				
C14:0	379.18	110.83	19.412	<0.0001
C14:0	18.55	26.70	1.299	<0.0001
13methyl				
C14:0	29.76	32.39	1.651	0.2648
12methyl				
C15:0	73.05	44.65	3.693	<0.0001
C15:0	32.56	25.23	1.547	0.0014
14methyl				
C16:0	1183.46	684.66	28.089	<0.0001
C16:0	64.62	67.42	2.476	0.4271
15methyl				
C16:0	24.64	23.29	1.102	0.3885
14methyl				
C16:0	—	—	—	—
3,7,11,15				
tetramethyl				
C17:0	259.37	117.18	11.934	<0.0001
C18:0	3333.06	1976.17	95.924	<0.0001
C19:0	6.29	4.47	0.319	0.0002
C20:0	8.81	7.34	0.687	0.1356
C21:0	0.17	0.08	0.045	0.1701
C22:0	0.12	0.16	0.107	0.7906
C23:0	0.05	0.11	0.032	0.1844
C24:0	—	—	—	—

*Fatty acids present in minimal amounts that were undetected by gas chromatography analysis.

[1] Treatments: GRAIN = bison bulls (*n* = 30) backgrounded on pasture and finished for 130 days with ad libitum access to grass hay, alfalfa, and corn concentrate prior to slaughter. GRASS = bison bulls (*n* = 30) remained on pasture until slaughter.

[2] Standard error of the mean.

[3] Probability of difference among least square means.

Table 2-5. Least square means for the effect of finishing system on the monounsaturated fatty acid composition (µg/g wet sample basis) of raw tissue from bison *longissimus dorsi* of grain- or grass-finished bison bulls.

Fatty Acids	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]
C14:1 cis9	34.90	23.91	1.809	<0.0001
C15:1 UN	33.29	30.13	2.474	0.3705
C15:1 cis9	7.62	8.17	0.749	0.6066
C16:1 cis6	58.98	51.59	2.094	0.0154
C16:1 cis9	228.52	100.79	8.891	<0.0001
C16:1 cis7	50.57	36.59	2.118	<0.0001
C16:1 cis9 14methyl	2.09	1.32	0.382	0.1566
C17:1 cis10	125.11	58.34	6.311	<0.0001
C18:1 trans11	145.03	150.95	14.696	0.7766
C18:1 trans9	31.73	57.40	3.693	<0.0001
C18:1 cis9	5657.15	2583.29	149.010	<0.0001
C18:1 cis11	272.62	132.09	6.936	<0.0001
C18:1 UN	—	—	—	—
C18:1 cis12	11.81	0.30	0.863	<0.0001
C18:1 cis13	21.51	8.04	1.136	<0.0001
C18:1 UN	19.31	10.02	1.039	<0.0001
C19:1 cis10	7.40	6.54	0.587	0.3059
C19:1 UN	8.44	0.00	0.605	<0.0001
C20:1 cis11	25.65	11.92	1.635	<0.0001
C22:1 cis13	0.27	0.72	0.108	0.0045
C24:1 cis15	—	—	—	—

*Fatty acids present in minimal amounts that were undetected by gas chromatography analysis.

[1] Treatments: GRAIN = bison bulls (*n* = 30) backgrounded on pasture and finished for 130 days with ad libitum access to grass hay, alfalfa, and corn concentrate prior to slaughter. GRASS = bison bulls (*n* = 30) remained on pasture until slaughter.

[2] Standard error of the mean.

[3] Probability of difference among least square means.

Table 2-6. Least square means for the effect of finishing system on the polyunsaturated fatty acid composition (µg/g wet sample basis) of raw tissue from bison *longissimus dorsi* of grain- or grass-finished bison bulls.

Fatty Acids	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]
C18:2 trans9,12	13.20	6.13	0.852	<0.0001
C18:2 cis9,12	1023.99	666.39	18.851	<0.0001
C18:2 cis12,15	0.66	0.24	0.233	0.2115
C18:3 cis6,9,12	10.01	4.07	0.659	<0.0001
C18:3 cis9,12,15	159.61	241.30	9.817	<0.0001
C18:2 cis9 trans11	24.54	18.45	1.732	0.0157
C18:3 UN	—	—	—	—
C18:2 trans10,12	0.84	0.00	0.234	0.0140
C20:2 cis11,14	3.36	1.08	0.608	0.0103
C20:3 UN	7.77	8.40	1.021	0.6636
C20:2 cis9,12	1.17	0.38	0.429	0.1999
C20:3 cis8,11,14	0.57	0.49	0.363	0.8788
C20:3 cis11,14,17	21.84	17.62	1.767	0.0946
C20:4 cis5,8,11,14	211.46	179.78	6.399	0.0009
C20:5 cis5,8,11,14,17	50.39	77.74	4.473	<0.0001
C22:2 cis13,16	—	—	—	—
C22:4 cis7,10,13,16	3.59	2.01	0.627	0.0803
C22:5 cis7,10,13,16,19	57.25	83.39	5.247	0.0008
C22:6 cis4,7,10,13,16,19	19.05	20.31	2.601	0.7327

*Fatty acids present in minimal amounts that were undetected by gas chromatography analysis.

[1] Treatments: GRAIN = bison bulls (*n* = 30) backgrounded on pasture and finished for 130 days with ad libitum access to grass hay, alfalfa, and corn concentrate prior to slaughter. GRASS = bison bulls (*n* = 30) remained on pasture until slaughter.

[2] Standard error of the mean.

[3] Probability of difference among least square means.

Table 2-7. Least square means for the effect of finishing system on the fatty acid composition (µg/g wet sample basis) of raw tissue from bison *longissimus dorsi* of grain- or grass-finished bison bulls.

Fatty Acids	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]
Total Fatty Acids	13789.00	7735.95	337.930	<0.0001
SFA	5262.03	2954.98	150.580	<0.0001
MUFA	6739.89	3270.77	178.730	<0.0001
PUFA	1609.30	1327.79	36.502	<0.0001
BCFA	178.00	182.41	7.894	0.6940
LCPUFA	376.45	391.21	19.743	0.5991
n-3 PUFA	308.81	440.62	14.517	<0.0001
n-6 PUFA	1253.82	853.82	24.133	<0.0001
n-3 LCPUFA	308.15	440.37	14.432	<0.0001
n-6 LCPUFA	218.98	183.36	7.440	0.0013
P/S	0.31	0.46	0.015	<0.0001
n-6/n-3	4.40	1.96	0.203	<0.0001
LC n-3/n-3	0.74	0.42	0.019	<0.0001

*Fatty acids present in minimal amounts that were undetected by gas chromatography analysis.

[1] Treatments: GRAIN = bison bulls (*n* = 30) backgrounded on pasture and finished for 130 days with ad libitum access to grass hay, alfalfa, and corn concentrate prior to slaughter. GRASS = bison bulls (*n* = 30) remained on pasture until slaughter.

[2] Standard error of the mean.

[3] Probability of difference among least square means.

Table 2-8. Least square means for the effect of finishing system on the saturated fatty acid composition (%, g/100g total fatty acids) of raw tissue from bison *longissimus dorsi* of grain- or grass-finished bison bulls.

Fatty Acids	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]
C8:0	0.01	0.02	0.001	0.0933
C10:0	0.06	0.05	0.002	<0.0001
C11:0	0.00253	0.00187	0.000171	0.0078
C12:0	0.05	0.05	0.002	0.9170
C13:0	0.04	0.08	0.003	<0.0001
12methyl				
C14:0	2.68	1.37	0.105	<0.0001
C14:0	0.13	0.34	0.001	<0.0001
13methyl				
C14:0	0.21	0.42	0.012	<0.0001
12methyl				
C15:0	0.52	0.57	0.019	0.0396
C15:0	0.23	0.32	0.010	<0.0001
14methyl				
C16:0	8.59	8.91	0.093	0.0198
C16:0	0.47	0.87	0.012	<0.0001
15methyl				
C16:0	0.18	0.30	0.008	<0.0001
14methyl				
C16:0	—	—	—	—
3,7,11,15				
tetramethyl				
C17:0	1.84	1.50	0.052	<0.0001
C18:0	24.16	25.40	0.298	0.0046
C19:0	0.05	0.06	0.002	<0.0001
C20:0	0.06	0.09	0.005	0.0002
C21:0	0.00123	0.0011	0.000828	0.8387
C22:0	0.00090	0.00207	0.001136	0.4706
C23:0	0.0037	0.0014	0.000419	0.0418
C24:0	—	—	—	—

*Fatty acids present in minimal amounts that were undetected by gas chromatography analysis.

[1] Treatments: GRAIN = bison bulls (*n* = 30) backgrounded on pasture and finished for 130 days with ad libitum access to grass hay, alfalfa, and corn concentrate prior to slaughter. GRASS = bison bulls (*n* = 30) remained on pasture until slaughter.

[2] Standard error of the mean.

[3] Probability of difference among least square means.

Table 2-9. Least square means for the effect of finishing system on the monounsaturated fatty acid composition (%, g/100g total fatty acids) of raw tissue from bison *longissimus dorsi* of grain- or grass-finished bison bulls.

Fatty Acids	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]
C14:1 cis9	0.25	0.31	0.010	<0.0001
C15:1 UN	0.25	0.39	0.028	0.0008
C15:1 cis9	0.06	0.11	0.007	<0.0001
C16:1 cis6	0.43	0.67	0.011	<0.0001
C16:1 cis9	1.64	1.31	0.038	<0.0001
C16:1 cis7	0.36	0.47	0.011	<0.0001
C16:1 cis9 14methyl	0.01	0.02	0.004	0.7196
C17:1 cis10	0.89	0.76	0.029	0.0020
C18:1 trans11	1.04	1.91	0.125	<0.0001
C18:1 trans9	0.23	0.73	0.033	<0.0001
C18:1 cis9	40.98	33.32	0.481	<0.0001
C18:1 cis11	1.99	1.72	0.057	0.0018
C18:1 UN	—	—	—	—
C18:1 cis12	0.08	0.00	0.005	<0.0001
C18:1 cis13	0.15	0.10	0.007	<0.0001
C18:1 UN	0.14	0.13	0.006	0.2117
C19:1 cis10	0.05	0.08	0.004	<0.0001
C19:1 UN	0.06	0.00	0.003	<0.0001
C20:1 cis11	0.18	0.15	0.011	0.0576
C22:1 cis13	0.002000	0.009200	0.001245	0.0001
C24:1 cis15	—	—	—	—

*Fatty acids present in minimal amounts that were undetected by gas chromatography analysis.

[1] Treatments: GRAIN = bison bulls (*n* = 30) backgrounded on pasture and finished for 130 days with ad libitum access to grass hay, alfalfa, and corn concentrate prior to slaughter. GRASS = bison bulls (*n* = 30) remained on pasture until slaughter.

[2] Standard error of the mean.

[3] Probability of difference among least square means.

Table 2-10. Least square means for the effect of finishing system on the polyunsaturated fatty acid composition (%, g/100g total fatty acids) of raw tissue from bison *longissimus dorsi* of grain- or grass-finished bison bulls.

Fatty Acids	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]
C18:2 trans9,12	0.09	0.08	0.006	0.0573
C18:2 cis9,12	7.56	8.77	0.241	0.0008
C18:2 cis12,15	0.00423	0.00247	0.001757	0.4799
C18:3 cis6,9,12	0.07	0.05	0.006	0.0143
C18:3 cis9,12,15	1.18	3.17	0.114	<0.0001
C18:2 cis9 trans11	0.18	0.24	0.013	0.0014
C18:3 UN	—	—	—	—
C18:2 trans10,12	0.01	0.00	0.002	0.0129
C20:2 cis11,14	0.02	0.01	0.006	0.2136
C20:3 UN	0.06	0.11	0.010	0.0003
C20:2 cis9,12	0.008200	0.004533	0.003926	0.5116
C20:3 cis8,11,14	0.003800	0.006167	0.003549	0.6390
C20:3 cis11,14,17	0.16	0.23	0.018	0.0064
C20:4 cis5,8,11,14	1.57	2.37	0.078	<0.0001
C20:5 cis5,8,11,14,17	0.37	1.02	0.053	<0.0001
C22:2 cis13,16	—	—	—	—
C22:4 cis7,10,13,16	0.03	0.03	0.006	0.9804
C22:5 cis7,10,13,16,19	0.43	1.10	0.066	<0.0001
C22:6 cis4,7,10,13,16,19	0.14	0.27	0.026	0.0010

*Fatty acids present in minimal amounts that were undetected by gas chromatography analysis.

[1] Treatments: GRAIN = bison bulls (*n* = 30) backgrounded on pasture and finished for 130 days with ad libitum access to grass hay, alfalfa, and corn concentrate prior to slaughter. GRASS = bison bulls (*n* = 30) remained on pasture until slaughter.

[2] Standard error of the mean.

[3] Probability of difference among least square means.

Table 2-11. Least square means for the effect of finishing system on the fatty acid composition (%, g/100g total fatty acids) of raw tissue from bison *longissimus dorsi* of grain- or grass-finished bison bulls.

Fatty Acids	GRAIN[1]	GRASS[1]	SEM[2]	*P*-value[3]
SFA	38.03	38.03	0.365	0.9902
MUFA	48.79	42.16	0.420	<0.0001
PUFA	11.90	17.47	0.467	<0.0001
BCFA	1.29	2.34	0.047	<0.0001
LCPUFA	2.80	5.15	0.234	<0.0001
n-3 PUFA	2.29	5.80	0.179	<0.0001
n-6 PUFA	9.27	11.24	0.312	<0.0001
n-3 LCPUFA	2.29	5.79	0.179	<0.0001
n-6 LCPUFA	1.62	2.41	0.084	<0.0001
P/S	0.31	0.46	0.015	<0.0001
n-6/n-3	4.40	1.96	0.203	<0.0001
LC n-3/n-3	0.74	0.42	0.019	<0.0001

*Fatty acids present in minimal amounts that were undetected by gas chromatography analysis.

[1] Treatments: GRAIN = bison bulls (*n* = 30) backgrounded on pasture and finished for 130 days with ad libitum access to grass hay, alfalfa, and corn concentrate prior to slaughter. GRASS = bison bulls (*n* = 30) remained on pasture until slaughter.

[2] Standard error of the mean.

[3] Probability of difference among least square means.

CHAPTER 3: THE EFFECT OF ANIMAL AGE ON CARCACASS CHARACTERISTICS OF BISON BULLS

Introduction

The United States Department of Agriculture, Agricultural Marketing Service has provided a marketing report for bison (*Bison bison*) harvested in the United States since 2017 (USDA-AMS). On this report, bison are classified as either young (<30 months of age) or aged (>30 months of age) and carcass value varies based upon this age classification. Since USDA-AMS began reporting bison carcass prices, the average price per hundred weight for young bulls has ranged from $373.27-489.88 and the average price for aged bulls has ranged from $274.29-436.29; with average prices of young bulls always greater than the price for aged bison bulls, likely due to challenges with palatability of meat from older animals.

As an animal ages, cartilage ossifies into bone and the color of muscle tissue becomes darker and more red as the concentration of myoglobin in the muscle increases (Gerrard and Grant, 2003). In addition, the concentration of connective tissue in muscle increases, while the solubility of connective tissue decreases with increasing animal age (Cross et al., 1984; Gerrard and Grant, 2003). This increase in connective tissue content and decrease in solubility influences meat tenderness, resulting in tougher meat from older animals compared to meat from younger animals (Gerrard and Grant, 2003). An increased pH value is also associated with a darker lean color and potential palatability issues in meat. In beef, pH values over 6.0 have been correlated with darker lean color, decreased tenderness, and increased water holding capacity

(Bureš and Bartoň, 2012; Kopuzlu et al., 2018). The pH value is a concern in older animals and intact males as the pH value of meat tends to increase with animal age and bull meat has an increased pH value compared to meat from castrates (Bureš and Bartoň, 2012; Kopuzlu et al., 2018).

While chronological age of an animal can be known, after slaughter, physiological age is used as the final determination of maturity. For beef cattle, maturity can be determined by evaluating the degree of ossification of the thoracic buttons of the vertebrae and lean color of the exposed ribeye muscle when the carcass is ribbed between the 12^{th} and 13^{th} rib. Degree of ossification of the thoracic buttons is also evaluated to determine bison carcass maturity, however lean color is not included as a measure of animal age. Research investigating the influence of maturity on carcass and meat quality characteristics in bison is limited. Lopez-Campos et al. (2013) compared carcass and meat quality traits of bison bulls and heifers classified into youthful or intermediate physiological maturity groups according to the Canadian Bison Grading System and reported limited differences due to ossification group. However, the influence of more advanced animal age on carcass traits of bison raised in typical U.S. production systems has not been reported. Therefore, the objective of this study is to determine the influence of animal age (29 mo. vs. 36 mo.) on carcass traits of grass-finished bison bulls.

Materials and Methods

Animals, Carcass Evaluation, and Striploin Collection

Grass-finished bison bulls (*bison bison*) from a common herd were selected for harvest at two chronological endpoints: 1) Young bulls (n=98) were slaughtered at 29 mo of age; 2) Mature bulls (n=24) were slaughtered at 36 mo of age following use in the breeding herd. Both groups of bulls were allowed to graze native rangelands in the Sandhills Ecoregion of Nebraska until harvest. Mature bulls were transported approximately 370 km to a commercial harvest facility in Brush, CO when they were approximately 36 mo of age and slaughtered at over a one-day period in June of 2020. Young bulls were transported to the same commercial harvest facility when they were approximately 29 mo of age and slaughtered over a two-day period (49 head harvested each day) in November of 2020.

Live weight was recorded at the harvest facility. Hot carcass weight was recorded and kidney, pelvic, and heart fat percentage was determined as the difference in carcass weight before and after removal of the kidney knob. Following an approximately 20 hr chilling period, carcasses were ribbed between the 12th and 13th rib and ribeye area, backfat thickness, marbling score, skeletal maturity, subjective lean color, and subjective fat color were evaluated by United States Department of Agriculture (USDA) graders. Skeletal maturity was evaluated based on the ossification percentage of the thoracic cartilage buttons and assigned a score corresponding with the ossification percentages as follows: 0-24% (slight), 25-49% (moderate), 50-99% (hardbone) and 100+% (extreme hardbone). Subjective lean color was evaluated at the exposed ribeye and assigned a score based upon a color description as follows: bright red, moderately bright red, slightly bright red, red, pale red, and dark cutter. Fat color was scored based on the

external fat color of the subcutaneous fat color opposite the ribeye as follows: white, moderately white, slightly white, moderately yellow, and yellow. Instrumental color (L*, a*, and b*) of the exposed ribeye area at the 12th rib break and the subcutaneous fat of the carcass surface opposite the ribeye was also collected using a handheld Minolta colorimeter (Model CR-310, Minolta Corp., Ramsey, NJ; 50 mm diameter measuring space; D_{65} illuminant).

The striploin (*M. longissimus lumborum*) was collected from the left side of all mature bulls (n=24) and from a subsample of young bulls (n=30 carcasses closest to the treatment average hot carcass weight). Striploins were vacuum packaged and transported in a refrigerated trailer to the South Dakota State University Meat Laboratory. Striploin samples arrived at the South Dakota State University Meat Laboratory at 2- or 3-days postmortem depending upon kill date. Striploins were removed from vacuum packaging and ultimate pH was recorded at the posterior end using a handheld pH meter (Thermo-Scientific Orion Star, Beverly, MA, Model# A221 and Star A321 Portable pH probe). Striploins were trimmed and fabricated for analysis associated with other projects.

Statistical Analysis

Live body weight, dressing percent, carcass measurements, and objective color data were analyzed using the MIXED procedures of SAS (SAS Inst. Inc., Cary, NC). Yield grade, subjective skeletal maturity, subjective lean color, and subjective fat color were analyzed using the GLIMMIX procedures 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 was used as the experimental unit for all 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, yield grade, and marbling scores were calculated using the USDA beef grading standards. Bison bulls in the current study were harvested at approximately 29 and 36 months of age, which falls within the average age range of harvest (between 20 and 36 months) reported by previous 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 weights and carcass data are reported in Table 3-1. Mature bulls had increased live weight, hot carcass weight, dressing percentage, ribeye area, kidney, pelvic, and heart fat percentage, and marbling scores ($P < 0.01$) compared to Young bulls. However, Young bulls had increased backfat thickness ($P = 0.0003$) when compared to Mature bulls. The carcass weight of Mature bulls in this study is lower than the range reported by USDA-AMS for aged bulls (313 kg – 560kg) in the National Monthly Bison Report (USDA-AMS, 2021). Young bulls were also lighter than the USDA report for young bulls, however the USDA-AMS report is focused on grain-finished bulls, therefore it is not unexpected that grass-finished bulls in the current study are lighter. Dressing percentage of Young (55.9%) and Mature (57.8%) bulls is less than the dressing percentage reported by Peters (1958) for grain-finished bison bulls (60.1%). This could

be a response of grass-finishing resulting in a more developed rumen but less backfat and lighter muscling.

Ribeye area of Mature bulls was 64.4cm^2, which is similar the ribeye area of grain-finished heifers (64.6 cm^2) reported by Janssen et al. (2021) while Young bulls had a ribeye are of 59.8 cm^2, which is similar to the ribeye area of bison steers (60.5 cm^2) reported by Hawley (1986). Mature bison bulls had an increased ($P < 0.0001$) kidney, pelvic, heart fat percentage when compared to Young bulls (0.20% and 0.07%, respectively). While the difference in kidney, pelvic, heart fat percentage was statistically significant, the amount of kidney, pelvic, heart fat detected in both treatments was negligible. Young and Mature bulls had marbling scores of 105 and 191, respectively. Marbling scores for both age groups in this study would fall into the practically devoid category of the USDA beef quality grading system. To compare Yield Grades (YG) of bison bulls, measurements were recorded and evaluated according to the equation used to calculate beef yield grades. An increased proportion ($P = 0.0013$) of Young bison bulls were categorized as YG 1 compared to Mature bulls. An increased proportion ($P = 0.0013$) of Mature bulls were categorized as YG 2. There were no YG 3, 4, or 5 carcasses in the study.

Carcass Maturity and Subjective External Fat and Lean Color

Subjective skeletal maturity, lean color, and external fat color data are reported in Table 3-1. Age group did not influence ($P > 0.05$) the proportion of bulls in each ossification category. No bison bulls in the current study were classified in the extreme

hardbone (100+% ossification) or hardbone (50-99% ossification) categories for skeletal maturity.

There was no difference ($P > 0.05$) in the proportion of each treatment classified as dark cutter or moderately bright red. A greater proportion of ($P = 0.0003$) of Young bulls were classified as having slightly bright red lean color compared to Mature bulls. However, a greater percentage ($P < 0.05$) of Mature bulls had lean color classified as pale red, and red. Young bulls were more likely to be categorized as having slightly bright red lean color (75.51%) and least likely to be categorized as having pale red lean color (1.02%). Mature bulls were relatively evenly distributed between pale red, red, slightly bright red, and moderately bright red, indicating advancing age may result in less consistent lean color.

There was no difference ($P > 0.05$) in the proportion of bulls classified as slightly white, moderately white, or white for external fat color. A greater percentage ($P < 0.05$) of Mature bulls were classified as having yellow or moderately yellow external fat color compared to Young bison bulls. This increase in yellow fat for Mature bulls could be due to an increased concentration of β-carotene accumulated over time within adipose tissue, which is known to cause a yellow color in fat when cattle are finished on grass (Yang et al., 2002; Kerth et al., 2007). Regardless of treatment, bulls in this study were most likely to be categorized as having moderately yellow external fat (39.80% and 66.67% for Young and Mature bulls, respectively), which is not unexpected in a grass-finishing system. Additionally, no Mature bulls were classified as having moderately white, or white exterior fat color.

Objective Color and Ultimate pH

Objective color and ultimate pH are reported in Table 3-2. Age group did not influence ($P > 0.05$) L* or a* values of the lean tissue or subcutaneous backfat. The b* value of the exposed ribeye was increased for Mature bison bulls compared to Young bulls. The b* value of the subcutaneous backfat was also increased for Mature bulls, which aligns with the increased proportion of Mature bulls categorized as yellow or moderately yellow compared to Young bulls. Animal age at harvest did not influence ($P > 0.05$) the ultimate pH of bison striploins.

Conclusion

This study indicates that animal age at slaughter influences carcass characteristics of bison bulls. Mature bison bulls had increased live weight, carcass weight, dressing percentage, ribeye area, kidney, pelvic, and heart fat percentage, and marbling score when compared to Young bulls. Mature bulls were also more likely to have ribeye lean classified as pale red or red and fat classified as yellow or moderately yellow. However, Young bulls were more likely to have ribeye lean be classified as slightly bright red than Mature bulls. Bison producers should consider the influence of animal age on carcass outcomes when making marketing decisions.

Literature Cited

Bureš, D., and L. Bartoň. 2012. Growth performance, carcass traits and meat quality of bulls and heifers slaughtered at different ages. Czech J. Anim. Sci 57(1):34-43.

Cross, H. R., J. D. Crouse, and M. D. MacNeil. 1984. Influence of Breed, Sex, Age and Electrical Stimulation on Carcass and Palatability Traits of Three Bovine Muscles1. J. Anim. Sci. 58(6):1358-1365. doi: 10.2527/jas1984.5861358x

Galbraith, J. K., G. Hauer, L.Helbig, Z. Wang, M.J. Marchello, and L. A. Goonewardene. 2006. Nutrient profiles in retail cuts of bison meat. Meat Science74(4):648-654. doi: https://doi.org/10.1016/j.meatsci.2006.05.015

Gerrard, D. and A. Grant. Principles of Animal Growth and Development. Dubuque, IA. Kendall Hunt Publishing Company. 2003.

Hawley, A. W. L. 1986. Carcass characteristics of bison (Bison-bison) steers. Canadian Journal of Animal Science 66(1):293-295. doi: 10.4141/cjas86-030

Janssen, J., K. Cammack, J. Legako, R. Cox, J. K. Grubbs, K. Underwood, J. Hansen, C. Kruse, and A. Blair. 2021. Influence of grain- and grass-finishing systems on carcass characteristics, meat quality, nutritional composition, and consumer sensory attributes of bison. Foods 10(5):1060. doi: 10.3390/foods10051060

Kerth, C., K. Braden, R. Cox, L. Kerth, and D. Rankins Jr. 2007. Carcass, sensory, fat color, and consumer acceptance characteristics of Angus-cross steers finished on ryegrass (Lolium multiflorum) forage or on a high-concentrate diet. Meat Science 75(2)324-331.

Kopuzlu, S., N. Esenbuga, A. Onenc. M. Macit, M. Yanar, S. Yuksel, A. Ozluturk, and N. Unlu. 2018. Effects of slaughter age and muscle type on meat quality characteristics of Eastern Anatolian Red bulls. Archives Animal Breeding 61(4):497-504.

Lopez-Campos, O., J. L. Aalhus, J. Galbraith, I. L. Larsen, M. Juarez, B. Uttaro, and W. M. Robertson. 2013. The relationship of carcass physiological maturity to meat quality in the Canadian Bison Grading System. Canadian Journal of Animal Science 94(1):55-62. doi: 10.4141/cjas2013-047

Marchello, M. and J. Driskell. 2001. Nutrient composition of grass- and grain-finished bison. Great Plains Research 11:65-82.

Marchello, M., W. Slanger, M. Hadley, D. Milne, and J. Driskell. 1998. Nutrient composition of bison fed concentrate diets. Journal of Food Composition and Analysis 11(3):231-239.

Marchello, M., W. Slanger, D. Milne, A. Fischer, and P. Berg. 1989. Nutrient composition of raw and cooked *Bison bison*. Journal of Feed Composition and Analysis 2(2):177-185.

Peters, H. 1958. A feedlot study of bison, cattalo, and Hereford calves. Canadian Journal of Animal Science 38(1):87-90.

Rule, D. C., K. S. Broughton, S. M. Shellito, and G. Maiorano. 2002. Comparison of muscle fatty acid profiles and cholesterol concentration of bison, beef cattle, elk, and chicken. Journal of Animal Science 80(5):1202-1211.

USDA-AMS. 2021. USDA Monthly Bison Carcass and Cuts. https://mymarketnews.ams.usda.gov/viewReport/2827 (Accessed Dec 2 2021).

Yang, A., M. Brewster, M. Lanari, and R. Tume. 2002. Effect of vitamin E supplementation on alpha-tocopherol and beta-carotene concentrations in tissues from pasture- and grain-fed cattle. Meat Science 60(1):35-40.

Table 3-1. Least squares means for effect of animal age on live weight and carcass characteristics of Young or Mature bison bulls.

Variable	Young[1]	Mature[1]	SEM[2]	*P*-value[3]
Live weight, kg	414	510	5.4	<0.0001
Hot carcass weight, kg	232	295	3.6	<0.0001
Dressing percentage, %	55.9	557.8	0.33	<0.0001
Ribeye area, cm^2	59.8	64.4	1.27	0.0018
Backfat thickness, cm	0.25	0.20	0.012	0.0003
Kidney, pelvic, and heart fat, %	0.07	0.20	0.028	<0.0001
Marbling score[4]	105	191	6.1	<0.0001
Yield Grade[5]				
Yield Grade 1, %	77.55	41.67	10.060	0.0013
Yield Grade 2, %	22.45	58.33	10.060	0.0013
Subjective Skeletal Maturity[6]				
Moderate, %	0.00	16.67	7.607	0.9702
Slight, %	100.00	83.33	7.607	0.9702
Lean maturity[7]				
Dark Cutter, %	0.00	4.17	4.079	0.9732
Pale Red, %	1.02	16.67	7.607	0.0108
Red, %	11.22	29.17	9.278	0.0343
Slightly Bright Red, %	75.51	33.33	9.623	0.0003
Moderately Bright Red, %	12.24	16.67	7.607	0.5678
Subjective external fat color[8]				
Yellow, %	3.06	16.67	7.607	0.0232
Moderately Yellow, %	39.80	66.67	9.623	0.0227
Slightly White, %	8.16	16.67	7.607	0.2219
Moderately White, %	15.31	0.00	3.637	0.9775
White, %	33.67	0.00	4.774	0.9758

[1]Treatments: Young bison bulls (n=98) slaughtered at 29 months of age. Mature bison bulls (n=24) slaughtered at 36 months of age
[2]Standard error of the mean
[3]Probability of difference among least square means
[4]Marbling score: 100=Practically Devoid0, 200=Traces0
[5]Yield Grade calculated according to USDA beef grading system.
[6]Skeletal maturity assigned by USDA.
[7]Subjective lean maturity assigned by USDA.
[8]Subjective external fat color assigned by USDA.

Table 3-2. Least squares means for effect of animal age on objective color measurements and ultimate pH of Young and Mature bison bulls[1]

Variable	Young	Mature	SEM[2]	*P*-Value[3]
Objective Color: lean tissue at ribeye area [4]				
L*	35.93	35.56	0.393	0.4022
a*	20.93	21.16	0.329	0.5332
b*	6.72	7.28	0.229	0.0312
Objective Color: subcutaneous backfat [5]				
L*	76.01	75.99	0.562	0.9786
a*	2.52	2.92	0.404	0.3684
b*	18.62	24.25	0.675	<0.0001
Ultimate pH[6]	5.65	5.64	0.015	0.3658

[1]Treatments: Young bison bulls (n=98) slaughtered at 29 months of age. Mature bison bulls (n=24) slaughtered at 36 months of age

[2] Standard error of the mean.

[3] Probability of difference among least square means.

[4] Objective color measurement recorded on the exposed ribeye 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 ribeye 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-days postmortem from Young (n = 30) and Mature (n = 24) striploins.