Carcass and quality characteristics of bison heifers compared to bison bulls

A final report to the Peace Country Bison Association

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Abstract

Gender differences in carcass and meat quality are known to exist in cattle and other domestic livestock, however no information is presently available regarding potential gender differences in bison. To determine if differences exist which may impact the bison industry, twenty head of bison (10 bulls and 10 heifers) from the Millennium Bison Ranch (High Level, AB) were finished to market weight on the same ration at the Long-Term Grazing Facility at the Agriculture and Agri-Food Canada Dominion Research Farm in Fort Vermilion, AB. Following slaughter at the Lacombe Research Centre, official grades, Blue Tag colour, marbling and backfat assessments, commercial lean yield dissections, meat quality, proximate analyses, sensory analyses and retail display characteristics were determined. At slaughter bison heifers had significantly lighter live weights, a higher dressing percentage, smaller rib-eye areas and greater backfat depth compared to bison bulls. Both bison bulls and heifers had very little visible marbling fat at the grade site. Bison bulls had significantly higher total saleable yields than bison heifers. On a weight basis, bison bulls yielded 10 kg more saleable yield in the forequarter and approximately 7 kg more saleable yield in the hindquarter, with bison bulls yielding a higher proportion of hump, shoulder and brisket than heifers. In the hindquarter, bison heifers yielded a higher proportion of tenderloin than bison bulls. There were no significant differences in objective meat colour, shear force or sensory characteristics between bison bulls and bison heifers. However, heifers had significantly greater amounts of intramuscular fat and significantly lower moisture content than bulls. Meat from both bison bulls and heifers had a limited shelf life with only 10% of retail steaks from bulls, and 0% of retail steaks from heifers rated as acceptable after 3 d of retail display due to the rapid development of a brown colour. This has been observed previously in retail display and does not appear to be related to microbial spoilage. Further work should be conducted to determine the reason for the rapid loss in fresh meat colour stability in bison meat and to develop means of prevention.

Although not a gender difference, meat colour of bison tended to be darker than normal beef at time of grading which is typical of a “dark cutting” condition in cattle which develops from extended pre-slaughter stress. Although the quality characteristics of drip loss and objective colour were indicative of “dark cutting”, the pH and glucidic metabolites were not typical of dark cutting. Both extending the time post-mortem before grading and allowing a longer bloom time prior to colour assessment has been shown to improve bison meat colour. Since the bison grading system was originally developed without consideration of potential species differences in colour development, perhaps both time of grading and bloom time for bison meat should be reconsidered to improve the ability to discriminate true dark cutters from animals which have a slow development of a normal bright red colour.

Introduction

Bison herds in the Peace Country (British Columbia and Alberta) and Canada continue to grow exponentially while meat markets are currently growing linearly or at a reduced exponential rate at best. While overall meat sales continue to increase this temporary imbalance has impacted the industry. There has been a major reduction in breeding stock prices as well as red meat prices. Two options remain for the bison industry; 1) increase meat sales, and or 2) reduce the size of the breeding herd by marketing lower quality breeding or non-breeding females as meat. This current market condition is also indicative of what awaits the bison industry once the demand for red meat product plateaus. Therefore, maintaining a balance between the size of the breeding herd (thus animals for market) and red meat demands is essential for long-term stability in the bison industry.

Known gender effects exist in all domestic species (Berg and Butterfield 1976; Lawrie 1998). Baseline research has recently been conducted on the meat quality characteristics of bison males (Janz et al. 2001) but not for finished bison females. Anecdotal data indicates that bison females tend to distribute fat differently than bison males, and the effects of this on carcass grade, yield and meat quality are unknown.

Hence the purpose of the present study is to compare the carcass and meat quality characteristics of bison males with bison females, to determine if differences exist which may impact the bison industry.

Objectives

1. To determine if bison heifers can achieve similar carcass grades as bison bulls.

2. To determine if carcass cut-out and meat quality characteristics of bison heifers are similar to bison bulls.

Methods

Slaughter

Twenty head of bison (10 bulls and 10 heifers) from the Millennium Bison Ranch (High Level, AB) were finished to market weight on the same ration at the Long-Term Grazing Facility at the Agriculture and Agri-Food Canada Dominion Farm in Fort Vermilion, AB. Animals were slaughtered (alternating between sexes) at the Lacombe Research Centre abattoir over two slaughter dates in accordance with the principles and guidelines established by the Canadian Council on Animal Care (1993). Animals were stunned, exsanguinated and dressed in a simulated commercial manner. Final live weights were recorded just prior to slaughter. Following splitting of the carcass, hot side weights were recorded (trimmed and untrimmed) and a muscle core sample (37 mm) was removed from the left *longissimus lumborum* (LL). The cores were flash frozen in liquid nitrogen, placed in pre-labeled whirlpak bags and stored at -80°C for later analysis of glucidic metabolites. At the same time, a 1-hour pH and temperature were recorded on the LL (Visor Palm Pilot and a Fisher Scientific Accumet Module using handspring software equipped with an Orion Ingold electrode [Udorf, Switzerland]). Temperature and pH values were also recorded at 3 and 24 hours and at the same time core samples were removed and flash frozen for glucidic metabolites.

Meat Quality

At 24 hours, carcass sides were weighed to determine cooler shrink loss. The right carcass sides were ribbed at the Canadian grade site (between the 11^{th} and 12^{th} ribs) and allowed a 20-minute period of exposure to atmospheric oxygen. Blue Tag data including colour assessment, marbling assessment and backfat depth were collected. Rib-eye areas were determined from tracings (COHU solid state camera and Jandel Scientific Video Analysis Program V1.31, Jandel Scientific 1989). Three colour measurements (CIE L*[brightness], a*[red-green axis], b*[yellow-blue axis] values; [Commission Internationale de l'Eclairage, 1978]) were collected at the grade site using a Minolta CR-300 with Spectra QC-300 Software (Minolta Canada Inc., Mississauga, ON). These values were converted to hue (H_{ab}=arctan[b*/a*]) and chroma ($C_{ab}=[a^{*2}+b^{*2}]^{0.5}$). The left side of the carcass was officially graded and then broken down into sub-primals specific to bison (Pimm & Robertson 2003). The left *longissimus thoracis* (LT) was removed from the carcass at time of

dissection and vacuum packaged (Multivac AGW, Multivac Inc., Kansas City, MO) and stored in a cooler at 2° with wind speeds of 0.5m/sec until 8 d post mortem.

The left LT was removed from the cooler and 8-day pH and temperature readings were taken. Five steaks (25 mm thick) were removed from the left LT muscle. The first steak was pre-weighed into a polystyrene tray with a dri-loc pad, over-wrapped with oxygen permeable film (8000 ml m^{-2} 24 h^{-1} vitafilm choice wrap, Goodyear Canada Inc.) and stored for 4 days at 1°C to determine drip loss. The second and third steaks were vacuum-packaged and frozen for sensory panel analysis. Following objective determinations of colour with a Minolta CR-300 as described previously, spear point temperature probes (10 cm) were inserted into the mid-point of the fourth steak. These steaks were grilled (Garland Grill ED30B, Condon Barr Food Equipment Ltd., Edmonton, AB) to an internal temperature of 40 °C, turned and cooked to a final temperature of 72°C (Hewlett Packard HP34970A Data Logger, Hewlett Packard Co., Boise ID). Upon removal from the grill, steaks were placed into polyethylene bags, sealed and immediately immersed in an ice/water bath to prevent further cooking. Steaks were held for 24 h at 2°C prior to shearing. Six cores, 19mm in diameter, were removed parallel to the muscle fiber grain and peak shear force determined on each core perpendicular to the fiber grain (Instron 4301 Material Testing System equipped with a Warner-Bratzler cell and Series 9 Software, Instron Canada, Burlington ON). The fifth steak was placed on a polystyrene tray, over-wrapped with oxygen permeable film (8000 ml m^{-2} 24 h^{-1} vitafilm choice wrap, Goodyear Canada Inc.) and stored in a retail display case at 1°C for 0, 1, 2, and 3 d to simulate commercial retail practices. On each day steaks were subjectively evaluated for colour, discolouration and retail acceptability by 5 trained raters using a 9-point descriptive (1=white and 9=extremely dark red), 7-point descriptive (1=0% and 7=100% discolouration) and 7-point hedonic (1=extremely undesirable and 7=extremely desirable) scale, respectively.

The remaining portion of the rib-eye was ground three times (Butcher Boy Meat Grinder Model TCA22 with a 1/8-inch grind plate, Lasar Manufacturing Co., Los Angeles, CA). One hundred g of the ground meat were weighed into stainless steel beakers and placed in a mechanical convection-drying oven at 102 °C for a 24-h period (VWR Scientific Model 1370FM, Mississauga, ON). Beakers were removed from the oven and final weights recorded for moisture loss determination. The dried sample was pulverized to a fine grind and analyzed for crude fat content by petroleum ether extraction (Tecator Soxtec System HT-1043, Tecator Ltd., Hoganas, Sweden). Nitrogen content was determined from fat-free grind (Nitrogen/Protein Determinator CNS2000, Leco Corp., St. Joseph, MI) to complete proximate analysis.

Glucidic Analysis

Glucidic metabolites were extracted from frozen muscle samples by pulverizing the sample with a mortar and pestle in liquid nitrogen. One g of the crushed sample was weighed into 5 ml of 0.6N perchloric acid. The sample was homogenized for 30 seconds (Polytron Homogenizer PT1200 with a 12 mm generator, Brinkmann Instruments Inc., Mississauga, ON) and a 0.20 ml aliquot removed (Dalrymple & Hamm 1973). Potassium carbonate (3 M) and amyloglucosidase were added to the aliquot and it was placed in a 40°C waterbath for extraction of glycogen. Following incubation the glycogen samples were centrifuged (Beckmann Floor Model J2-MC and JA-14 rotor, Beckmann Instruments Ltd., Mississauga ON) and the supernatant neutralized with 3M potassium carbonate. Neutralized supernatant was analyzed for glycogen determinations. The remainder of the crushed homogenate was centrifuged and neutralized with potassium carbonate, to be used for glucose and lactate analysis (Yambayamba et al. 1996). All glucidic metabolites were measured within the range of a standard curve utilizing a YSI 2300 StatPlus (YSI Incorporated, Dayton OH) and were reported as µmol/g of tissue.

Sensory Evaluation

Steaks for sensory evaluation were removed from the freezer, weighed and placed in a refrigerator at 4°C to thaw for 24 h. Fifteen min prior to grilling, the steaks were removed from the refrigerator and weighed to determine thaw losses and raw muscle weights. Type T thermocouple temperature probes were inserted horizontally to the mid-point along the long axis of the steak. Steaks were grilled (Garland electric grill ED-30B set to 210°C) to an internal temperature of 35°C, turned and cooked to a final temperature of 70°C. After cooling for 3 minutes, cooking losses were determined by weight difference. Each steak was cut into 1.9 cm cubes, avoiding connective tissue and large areas of fat. Seven cubes from each sample were randomly assigned to a seven-member semi-trained lab panel. Samples were placed in glass jars in a circulating water bath at 70°C and allowed to equilibrate for 7 minutes to prior to evaluation. Panelists rated samples under white lighting, 56x10Lux, in well ventilated, partitioned booths. Distilled water (room temperature) and unsalted soda crackers were provided for removal of residual flavours between each sample evaluation (Larmond, 1977). Rating was done using nine-point descriptive scales for initial and overall tenderness (9 = extremely tender; 1 = extremely tough), juiciness (9 = extremely juicy; 1 = extremely dry), flavour and flavour intensity (9 = extremely intense flavour; 1 = extremely bland flavour), amount of connective tissue (9=none; 1=abundant). Overall palatability was rated on a nine point hedonic scale, (9=extremely desirable; 1=extremely undesirable). Initial tenderness was rated on the 1st bite through the cut center surface with the incisors, initial juiciness was rated after 10 chews with the molars, flavour and flavour intensity between 10-20 chews, and after 25 chews

connective tissue and overall tenderness were rated. Overall palatability was rated prior to expelling. Results were recorded on the computer terminals and means determined from six of the semi-trained panelists.

Statistical Analysis

All data were analyzed using the multiple linear regression subset of the General Linear Model computer algorithm of the SAS Insititute, Inc. (2001) using the following models:

$\gamma = \mu$ + Gender (meat quality, carcass and grade data)

$\gamma = \mu$ + Blue Tag Backfat Depth & Colour Assessment (meat quality data)

$\gamma = \mu$ + Gender + Time + Gender*Time (glucidic metabolites, pH and temperature, and retail ratings)

where Gender = bull or heifer; Blue Tag Backfat Depth & Colour Assessment = bright red with 1-6 mm backfat, bright red with 7-12 mm backfat, bright red with >12 mm backfat, medium to dark red with unclassified backfat; Time = post mortem collection times (1, 3 and 24 hours for glucidic metabolites and pH and temperature) or days of aging (0, 1, 2, and 3 days for retail ratings).

Results and discussion

Effect of gender on carcass weights and grades

At slaughter bison heifers had significantly lighter live weights and a higher dressing percentage compared to bison bulls (Table 1). Despite large differences in carcass weight (219 vs. 180 kg), weight losses in the cooler were similar between bison bulls and heifers. Reflecting the larger carcass, rib-eye areas were 15% larger in the bison bulls than heifers. Bison heifers had greater backfat depth than bison bulls (17 vs. 9 mm, respectively). All these differences between bison heifers and bulls are similar gender effects to those observed in cattle, where females are earlier maturing than intact males (Berg and Butterfield 1976). As a result of the differences in backfat depth, bison heifers were officially graded as 60% A2 and 40% A3. In contrast, 70% of bison bulls fell into the A1 grade, and 30% into the A2 grade (Table 2).

Despite all carcasses officially being graded as A-grade carcasses, there were notable differences in rib-eye colour at grading (Table 3). Sixty percent of the bull carcasses and 30% of the heifer carcasses had medium dark to dark muscle colour. Dark cutting in beef carcasses is generally associated with a muscle pH at grading of greater than 5.9, muscle colour brightness values (L*) of <30 (which appear dark and undesirable to consumers), a lower drip loss and a greater susceptibility to bacterial spoilage (Hood and Tarrant 1981). Dark cutting generally occurs when animals experience prolonged stress prior to slaughter, thereby depleting their muscle energy stores (glycogen and intramuscular fat) and resulting in an abnormal post-mortem metabolism. In comparison to normal slaughter cattle, both bison bulls and heifers have very little visible marbling fat at the grade site, with only one carcass attaining a traces level of marbling (Table 3), suggesting they may have a limited physiological capacity for withstanding the prolonged rigours of shipping/mixing/holding prior to slaughter.

Effect of gender on carcass cutability

As a percentage of side weight, bison bulls had significantly higher total saleable yields than bison heifers (76.0 vs. 74.3; Table 4), which in cattle has been demonstrated to be due to a higher proportion of fat trim on heifers (Berg et al. 1979). On a weight basis, bison bulls yielded 10 kg more saleable yield in the forequarter and approximately 7 kg more saleable yield in the hindquarter. Despite the overall increase in saleable yield, the actual distribution of the yield was quite similar. Predicatably, bison bulls yielded a higher proportion of hump, shoulder and brisket

than heifers, reflecting normal sex hormone induced differences in the forequarter (Berg & Butterfield 1976). In the hindquarter, bison heifers yielded a higher proportion of tenderloin than bison bulls (1.82 vs. 1.65%; P=0.03). Although unexpected, historical data on gender differences in cattle have noted that females may finish with a higher proportion of their muscle weight in muscles surrounding the spinal column (Berg and Butterfield 1976).

Effect of gender on meat quality, sensory panel evaluation and retail display

There were no significant differences in objective meat colour, nor shear force between bison bulls and bison heifers (Table 5). However, there was a tendency for slightly lower driploss in bison bulls than bison heifers, which likely reflects the slightly higher proportion of bull carcasses that were rated as medium to dark in colour by Blue Tag assessment. Bison heifers were fatter than bison bulls, having significantly greater amount of intramuscular fat as determined by proximate analyses. The higher fat content corresponded with a significantly lower moisture content. There was a slight, but non-significant, tendency for increased crude protein in the bison heifers. These changes to proximate analyses are reflective of earlier maturity (earlier fattening) in bison heifers (Berg & Butterfield 1976).

There were no significant differences in sensory scores for tenderness, flavour, juiciness, or overall palatability between bison heifers and bison bulls (Table 6). In some species, particularly swine, an objectionable sex-taint can be detectable between genders, however similar extreme sex-related sensory issues have not been observed in cattle (Field 1971). Sex-related sensory differences in cattle, when they occur, tend to result from differences in rates of fattening, and are not a direct result of gender differences *per se*. Nevertheless for most domesticated meat animals, entire males are castrated. While this may control the development of sex-taint in some species and reduce handling and management difficulties with entire males, there is a significant cost in terms of lean meat yield. Since castration of farm animals is under pressure as a routine husbandry practice in other industries, it is important to note there do not appear to be any quality-based reasons for implementing castration in the bison industry.

Despite having no difference in sensory characteristics between bison heifers and bison bulls, meat from heifers required significantly longer cook times time to reach an internal temperature of 72 ºC than the bulls (Table 6). While this may appear to be a gender effect, it is actually related to the differences in fat and water content in the muscle between heifers and bulls. Although some reports indicate that cooking time is longest for steaks with the lowest fat content (Cross et al. 1977), in general fat retards the rate of heat penetration in meat thus higher fat content results in a slower rate of heating (Oroszvari et al. 2003). Since

most meat is cooked to specific endpoint temperatures (either measured objectively with a meat thermometer or subjectively judged “degree of doneness”) this difference in cook time is unlikely to be of commercial significance.

Meat from both bison bulls and heifers has a limited shelf life in retail display (Table 7). Beef can normally be displayed in retail cases for 3 d (industry standard) without an appreciable loss in retail acceptance. In the present study, after 3 d of retail display, only 10% of retail steaks from bulls, and 0% of retail steaks from heifers were rated as acceptable due to the rapid development of a brown colour. This has been observed previously in retail display and does not appear to be related to microbial spoilage. Hence, it would appear that the oxidative stability of the myoglobin is lower in bison meat, resulting in a more rapid conversion of oxymyoglobin to metmyoglobin in oxygen permeable packaging (Aalhus & Dugan, in press). A number of inherent factors, including the type of fatty acids in the membrane (e.g. polyunsaturated fatty acids), the activity of metmyoglobin reductase, the presence or absence of antioxidants (e.g. Vitamin E), the muscle pH etc., can affect the stability of colour formation. Further work should be conducted to determine the reason for the rapid loss in fresh meat colour stability in bison meat and to develop means of prevention.

Effect of Blue Tag colour and backfat assessment on meat quality and glucidic metabolites

To determine if carcasses assessed as medium to dark in colour exhibited quality attributes typical of dark cutting in cattle, the data were analysed by Blue Tag colour & backfat assessments, irrespective of gender. Bison carcasses assessed as medium to dark red in colour had significantly lower drip loss, in addition to having lower L* and hue values than observed in A grade carcasses (Table 8). These quality differences are typical of classic “dark cutting” in beef cattle. Carcasses assessed as medium to dark red in meat colour also had significantly lower marbling fat in compared to carcasses assessed with bright red meat colour, which would further support the theory that these animals may have had a lowered ability to respond to stressful circumstances during shipping to slaughter. However, true dark cutting meat generally has a pH of >5.9 following the completion of post-mortem metabolism. The carcasses which were visually assessed as being medium to dark red in colour at 24 h, were in fact, not dark cutters. This is particularly evident, when the glucidic metabolites, glycogen and lactate were examined in relation to normal cattle (shipped 6 h to slaughter) over 24 h post-mortem (Figure 1). All bison carcasses, regardless of their colour or backfat assessment had significantly higher glycogen stores than cattle initially, and after 3 and 24 h post-mortem. Similarly, the accumulation of lactate over 24 h was more extensive in bison than in cattle. Since there is no evidence that glycogen was lacking, nor that pH was

failing to drop in a normal manner post-mortem, it is clear that the dark coloured meat observed at grading was not due to classic dark cutting.

Species differences in meat colour are known to occur, with non-domestic species tending to have a darker colour due to higher myoglobin levels in the muscle associated with a higher frequency of aerobic, red muscle fibres (Forrest et al. 1975). However, in previous work conducted at Lacombe (Janz et al. 2002) no differences were observed between bison and cattle in the frequency of aerobic, red muscle fibres, although there was a slightly higher frequency of fast, oxidative, glycolytic (FOG) or intermediate fibres. It is also possible that bison meat requires a longer time post-mortem to allow glycolysis to proceed to completion before grading, or longer than the current 20 mins for meat to "bloom" prior to colour assessment. In unpublished data, Robertson (pers. comm.) has shown significant improvements in the brightness (L*) and intensity (chroma) of muscle colour when bison carcasses are graded at 72 h rather than 24 h. In addition, in the present study the effect of bloom time (increasing from 20 to 120 mins) was investigated, and there was a clear indication that subjective colour could be improved by allowing a longer bloom time (Figure 2). Especially for carcasses originally assessed as "medium dark" initially, the longer bloom time resulted in slight improvements to brightness (L* - see Figure 2a) and intensity (chroma – see Figure 2c) of the colour, and to a large improvement in hue angle (actual colour – see Figure 2b). The bison grading system was originally developed using the beef grading system as a template, hence species differences in colour development were not considered at the time. The bison grade standards currently indicate that the meat should be "bright red" in colour in order to receive an A grade. In practice, these colour standards are not stringently applied by graders due to their contextual knowledge of meat colour in bison. Adjusting both the time of grading and the length of bloom time would enhance the development of a "bright red" colour to meet the grade standard. More importantly, adjusting these parameters may improve the ability to distinguish true dark cutters from animals which have a slow development of a normal bright red colour. Conversely, the grade standards could be adjusted to discriminate less stringently on the basis of colour and a measure of ultimate pH could be implemented to distinguish true dark cutters.

Conclusions

The observed differences between bison heifers and bison bulls are typical of gender effects seen in cattle, where heifers are earlier maturing and thus begin to fatten at a lighter weight than bulls. Hence bison heifers had lighter weights at slaughter, yet had higher dressing percents. Bison bulls had greater saleable yield than heifers, and had a greater proportion of their yield in the hump, shoulder and brisket. Bison heifers and bulls yielded similar meat quality, with a higher intramuscular fat content in the heifers. There were no discernable gender differences in eating quality. Bison meat, regardless of gender tended to brown more quickly under aerobic conditions in retail than normally observed in cattle. Further work should be conducted to determine the reason for the rapid loss in fresh meat colour stability in bison meat and to develop means of prevention. Although bison meat appears darker at grading than normal beef, the darker colour does not appear to be indicative of typical dark cutting. It may be that bison should be graded after further chilling (greater than 24h) and after a longer bloom time (greater than 20 min) to improve the ability to discriminate true dark cutters from animals which have a slow development of a normal bright red colour.

References

Aalhus, J. L. and Dugan, M. E. R. 2003. Spoilage, factors affecting (b) Oxidative and enzymatic. In Encyclopedia of Meat Sciences, Elsevier, Oxford, U.K. (in press).

Berg, R. T. and Butterfield, R. M. 1976. New Concepts of Cattle Growth. Sydney University Press, Sydney.

Berg, R. T., Jones, S. D. M., Price, M. A., Fukuhara, R., Butterfield, R. M. and Hardin, R. T. 1979. Patterns of carcass fat deposition in heifers, steers and bulls. Can. J. Anim. Sci. **59:**359-366.

Canadian Council on Animal Care. 1993. Guide to the care and use of experimental animals, Vol. 1**.** E. D. Olfert, B. M. Cross and A. A. McWilliam, eds. Ottawa, ON.

Commission Internationale de l'Eclairage. 1976. 18th Session, London, England. Sept. 1975. CIE Publication 36.

Cross, H. R. 1977. Effects of amount, distribution and texture of marbling on cooking properties of beef longissimus. J. Food Sci. **42**:182-185.

Dalrymple R.H. and Hamm R. 1973. A method for the extraction of glycogen and metabolites from a single muscle sample. J. Food Technol. **8**:439-444.

Field, R. A. 1971. Effect of castration on meat quality and quantity. J. Anim. Sci. **32**:849-858.

Forrest, J. C., Aberle, E. D., Hedrick, H. B., Judge, M. D. and Merkel, R. A. 1975. Principles of Meat Science. W. H. Freeman and Company, San Francisco.

Hood, D. E. and Tarrant, P. V. 1981. The Problem of Dark Cutting in Beef. Martinus Nijhoff, The Netherlands.

Janz, J.A.M., Aalhus, J.L. and Price, M.A. 2001. Blast chilling and low voltage electrical stimulation influences on bison (*Bison bison bison*) meat quality. Meat Sci. **57**: 403-411.

Janz, J. A. M., Aalhus, J. L. and Price, M. A. 2002. Fibre type characteristics and postmortem glycolysis of bison (Bison bison bison). Can. J. Anim. Sci. **82(2**):259-262.

Larmond, E. 1977. Laboratory methods for sensory evaluation of foods. Agriculture Canada Publication Number 1637, Ottawa, Ont.

Oroszvari, B. K. , Sjoholm, I. and Tornberg, E. 2003. Measurement of thermal properties of beef burgers during frying for prediction of heat transfer. Internet Resource. http://www.foodfactory.sik.se/Posters%20i%20PDF/B%20KOVACSNE%20OROSZVARI%20poster.pdf

Pimm, C. and Robertson, W. M. 2003. Illustrated guide to Lacombe Research Centre standardized bison carcass cut-out. Agriculture and Agri-Food Canada, Lacombe Research Centre, Lacombe, AB.

SAS Institute Inc. 2001. SAS User's Guide: Statistics. SAS for Windows, Version 8.2. SAS Institute, Inc., Cary, NC.

Yambayamba, E. S. K., Aalhus, J. L., Price, M. A. and Jones, S. D. M. 1996. Glycogen metabolites and meat quality in feed-restricted re-fed beef heifers. Can. J. Anim. Sci. **76**:517-522.

Table 1: The effect of bison gender on carcass traits

	Male	Female	Probability
Live Weight, kg	373	297	<.0001
Hot Weight, kg	223	183	<.0001
Cold Weight, kg	219	180	<.0001
Dressing Percentage	60.0	61.2	0.0021
Cooler Loss, $g.kg^{-1}$	19.0	19.4	0.1621
Fat Depth, mm	9	17	0.0007
Rib-eye Area, cm^2	52.8	45.7	0.0014

Table 2: Distribution (% of total) of official bison grades amongst gender

Official Grade	Male	Female
A1	70	-
A2	30	60
A3	-	40

Table 3: Distribution of Blue Tag meat colour, backfat depth and marbling assessment in bison

Blue Tag Meat Color	Male	Female
Bright	10	30
Good	30	40
Medium Dark	20	10
Dark	40	20

Blue Tag Backfat Depth	Male	Female
1-6 mm	40	10
7-12 mm	0	40
>12 mm	0	20
Unclassified*	60	30

* Carcasses were medium dark to dark in colour hence fat depth was not assessed.

Blue Tag Marbling Scores	Male	Female
Devoid	60	80
Practically Devoid	40	10
Traces	0	10

Table 4: Bison gender effects on carcass cutability

	Male	Female	Probability
Total Saleable Yield %	76.0	74.3	0.02
Forequarter, %			
Blade eye (hump)	6.27	5.39	<0.01
Short cut clod	3.86	3.77	0.22
Chuck tender	1.15	1.12	0.53
Flat iron	1.26	1.22	0.40
Rib fingers	1.12	1.21	0.26
Neck	2.87	2.52	0.09
Shoulder	1.66	1.40	<0.01
Brisket point	2.44	2.12	<0.01
Short ribs	0.88	0.87	0.71
Inside skirt	0.69	0.70	0.57
Outside skirt	0.59	0.58	0.72
Foreshank	2.31	2.20	0.25
Ribeye	4.01	4.26	0.25
Blade meat	2.27	2.25	0.89
Navel	2.71	2.60	0.29
Forequarter Saleable Yield, kg	45.08	35.08	<.0001
Hindquarter, %			
Inside round	6.68	6.72	0.81
Outside round	4.07	4.13	0.45
Eye of round	1.77	1.74	0.62
Sirloin tip (peeled)	3.89	3.92	0.66
Shank meat	1.59	1.54	0.29
Striploin	3.76	3.84	0.54
Top butt	3.20	3.24	0.75
Tenderloin	1.65	1.82	0.03
Inside shank	1.41	1.48	0.42
Flank steak	0.52	0.50	0.51
Hindquarter Saleable Yield, kg	38.40	31.62	<.0001

Table 5: Bison gender effects on quality

	Male	Female	Probability
24 h Minolta Colour			
L*	30.0	30.8	0.3376
Hue	21.2	21.8	0.2260
Chroma	19.9	21.3	0.1718
24 h pH	5.63	5.57	0.3273
Temperature	1.7	1.7	1.0000
Driploss, $mg.g^{-1}$	28.5	33.2	0.0764
Shear, kg	5.08	4.94	0.8414
Shear Variance	1.11	0.83	0.3570
Proximate Analysis, $mg.g^{-1}$			
Moisture	758.8	749.2	0.0001
Fat	11.7	18.0	0.0028
Crude Protein	215.9	219.0	0.0828

Table 6: Sensory evaluation characteristics of bison by gender

	Male	Female	Probability
Cooking Loss, $mg.g^{-1}$	283.5	280.6	0.8029
Cooking Time, $sec.g^{-1}$	5.1	7.2	0.0003
Initial Tenderness	7.2	7.2	0.9354
Juiciness	6.4	6.2	0.6421
Flavour	5.9	6.0	0.5680
Flavour Intensity	6.1	6.1	0.4032
Amount of Connective Tissue	7.8	7.8	0.7717
Overall Tenderness	7.3	7.3	0.9630
Overall Palatability	6.2	6.4	0.4625

Table 7: Proportion of bison retail steaks rated as acceptable after 1 to 4 d of retail display

Retail Appearance	Male	Female
Day 0	100	100
Day 1	100	80
Day 2	30	30
Day 3	10	0

Table 8. Quality characteristics of bison carcasses from different Blue Tag colour assessments and backfat depths

Blue Tag colour	Bright Red			Medium to dark red	
Blue Tag backfat depth	**1-6 mm**	**7-12 mm**	**>12 mm**	**Unclassified**	**Probability**
24 h Minolta Colour					
L*	30.1	31.8	32.3	29.5	0.0872
Hue	21.5	22.2	22.5	20.9	0.0934
Chroma	20.5	22.0	22.7	19.6	0.1802
24 h pH	5.58	5.59	5.64	5.61	0.9297
Temperature	1.5	1.8	2.0	1.7	0.6328
Driploss, $mg.g^{-1}$	31.8^{a}	36.3^{a}	37.4^{a}	26.5^{b}	0.0029
Shear, kg	4.81	5.57	4.82	4.91	0.8866
Shear Variance	0.81	0.87	0.95	1.10	0.8938
Proximate Analysis, $mg.g^{-1}$					
Moisture	758.5	748.5	748.2	755.2	0.0539
Fat	10.9^{a}	18.6^{b}	23.6^{b}	13.3^{a}	0.0013
Crude Protein	216.2	220.8	215.7	217.0	0.2773

a,b Means in the same row followed by different superscripts are significantly different ($P<0.05$).

Figure 1. Postmortem metabolites in bison carcasses based on Blue Tag colour assessments (med. dark to dark red vs. bright red), compared to average beef animals

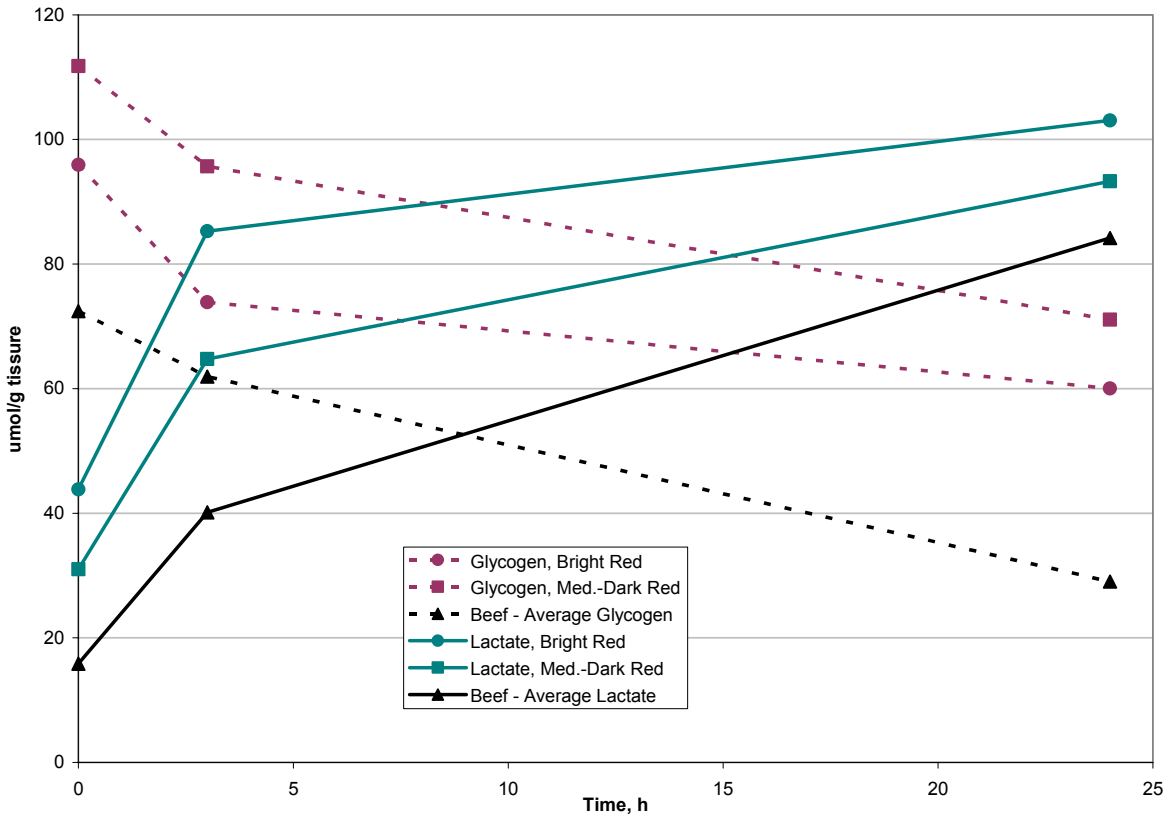

Figure 2. The effect of increased bloom time in carcasses originally assessed as “bright”, “medium dark” and “dark” on a) colour brightness (L*), b) hue angle (actual colour) and c) intensity of colour (chroma)