PE4.25 Meat quality of bison slaughtered in a mobile or stationary abattoir 87.00

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***Abstract*—The present study compared carcass and meat quality of bison slaughtered on-farm in a mobile location abattoir in either a pre-slaughter penned (MLAPEN) or confined (MLACON) treatment, to a transported group processed at a stationary land-based plant (LAND). Even though higher pH and lactate 1h post mortem indicated a more rapid glycolysis in the MLACON group, they (and MLAPEN) displayed a lower shear force (7.47kg, 7.34kg, respectively) than the LAND group (9.52kg). Pre-slaughter management of bison impacted the tenderness of bison meat.**

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***Index Terms*—Bison, Meat Quality, Mobile Abattoir**

I. INTRODUCTION

Bison (*Bison bison*) are raised for their meat and other products in North America. In 2008 in the Canadian province of Alberta, there were over 19,000 bison slaughtered in inspected abattoirs [1]. As a result of limited slaughter facilities for bison, it is common for bison to be transported for several hours to get to an abattoir. Transport is often followed by lairage overnight in pens for slaughter the next morning. Assembly, loading, transport, unloading, regrouping, feed and water withdrawal, novel surroundings and temperature fluctuations are all factors that can create both physiological challenges and psychological disruptions which ultimately impact carcass yield and meat quality [2].

Branding and niche market opportunities are increasing for livestock producers [3,4] but in some cases slaughter facilities are unable or unwilling to separate and market these low volume niche products. Despite an improved willingness to pay for certain credence attributes such as animal welfare, natural, organic, and local production [5], they are difficult to retain through the current Canadian commodity systems. A mobile abattoir system could facilitate the development of low volume, high value livestock products for local markets.

The purpose of the present study was to compare carcass characteristics and meat quality attributes of bison slaughtered in a stationary land-based facility following a period of transport and pre-slaughter handling to animals slaughtered in a mobile-location abattoir (MLA) at their home farm locations. Two levels of on-farm pre-slaughter management were investigated prior to processing through the MLA, penned and confined prior to dispatching.

II. MATERIALS AND METHODS

A. Animals and Slaughter

Four bison farms were recruited for participation in the trial; one farm per week on four different weeks. On three farms a total of 15 bison were used in the trial. On one farm 10 bison were used. The bison ranged in age from 16-40 months. The finishing diets varied, ranging from grass to barley finishing diets. On each slaughter week five animals from a farm were shipped to the land based facility at the LRC (transport time 1.5-3 h) and held in lairage overnight with free access to water until time of slaughter (LAND). The following day 10 animals from the same farm were slaughtered on site through the MLA. Five animals were confined to a squeeze chute or single animal cell and dispatched (MLACON) while another five were placed in a pen (approximately 100 x 200 feet) and dispatched (MLAPEN). On the last week five animals were slaughtered on-farm, all of which were dispatched in a pen. All animals were stunned and exsanguinated in accordance with Canadian Council on Animal Care guidelines [6].

Following splitting of the carcass, hot side weights were recorded, and initial (1h) pH and temp were recorded posterior to the left 11th/12th thoracic vertebrae *Longissimus lumborum* (LL) [Fisher Scientific Accumet AP72 pH meter (Fisher Scientific, Mississauga ON) equipped with an Orion Ingold electrode (Udorf, Switzerland)]. A muscle sample (10g) was removed at the same time and location, flash

frozen in liquid nitrogen, placed in pre-labeled whirlpak bags and stored at -80°C for glucidic metabolite analysis. Upon entry into the cooler stainless steel thermocouples (10cm) were placed in both the loin (LL) and deep hip (*semimembranosus*) and temperatures recorded for 24h using data temperature loggers (Mark III, MC4000 Sumaq Wholesalers, Toronto, ON).

B. Carcass Treatment

At 24h, left carcass sides were ribbed at the Canadian grade site (between 11th and 12th ribs) and exposed to atmospheric oxygen for 20min prior to assessing carcass grade characteristics including grade fat, rib-eye area, carcass conformation, marbling, fat and lean colour [7]. The left *Longissimus thoracis* (LT) and LL were pulled from the carcass at 24h, labeled, and trimmed. Final pH (pH_{24}) and temperature values were recorded in the LL. A second muscle sample was collected, flash frozen, and stored at -80°C for glucidic analysis. Loins from animals slaughtered through the MLA were returned to the LRC to complete meat quality analysis.

C. Meat Quality

A five-inch portion of the LL was removed from the anterior end, labeled, vacuum packaged and aged in a cooler for 7d. The remaining portion of the LL was trimmed of all silver skin and ground three times through a 1/8-inch grind plate and 100g sub-sampled for gravimetric moisture determination following 24h of drying at 102°C. The dried sample was pulverized to a fine grind and analyzed for crude fat [8] and crude protein by nitrogen analyses [9].

A thin slice was removed from the posterior end of the LT and sarcomere lengths and diameters were determined [10].

Four steaks (25mm thick) were removed from all muscles. Following a 20-min period of exposure to atmospheric oxygen, objective color measurements (CIE L*[brightness], a*[red-green axis], b*[yellow-blue axis]; [11] were collected from three locations across the first steak and converted to hue and chroma, (Minolta CM2002 [Minolta Canada Inc., Mississauga, ON]).

The steak was pre-weighed onto a polystyrene tray with a dri-loc pad, over-wrapped with oxygen permeable film and stored for 4d at 2°C to determine steak driploss.

The second, third and fourth steak were labeled as 2d, 7d and 14d of ageing, respectively. Steaks were individually vacuum packaged and aged at 2°C. On each specific ageing day, steaks were removed from the cooler, taken out of packaging and raw steak weight recorded prior to cooking. Shear force and cook loss were determined as previously described [12] with the exception that the steaks were cooked to an internal temperature of 35°C, turned and cooked to a final temperature of 70°C.

Following the 7d-ageing period, the remaining LL piece was removed from cooler and fabricated into four steaks (25 mm thick). The first and second steaks were labeled, individually vacuum packaged and placed into a -35°C freezer until sensory evaluation. The third steak was placed into a polystyrene tray as previously described and put into a retail display case set to 1°C for retail evaluation after 0, 1, 2 and 3d. The fourth steak was cut in half and one half was immediately blixed (Robot Coupe Blixir BX3 USA, Ridgeland MS) and concentration of thiobarbituric acid reactive (TBAR) substances (0d in retail) determined [13]. The remaining half steak was held for 3d under described retail conditions before being processed for TBAR determinations. Glucidic metabolites were extracted from frozen muscle as previously described [14,15] with the exception that lactate content of samples were determined using a YSI 2300 Stat Plus glucose/lactate analyzer (YSI Incorporated, Yellow Springs, OH). Glucidic metabolites were reported as μmol/g.

D. Retail Evaluation

All samples were placed into the display case controlling for treatment location within the temperature gradients within the display case. On each ageing day three objective color measurements were made as previously described using a different Minolta meter (CM2002).

Subjective retail appearance, lean colour score, percent surface discolouration, colour of discolouration, amount of marbling and marbling colour was performed by five trained raters using an 8-point hedonic (1=extremely undesirable, 8=extremely desirable), 8-point descriptive (1=white, 8=extremely dark red), 7-point descriptive (1=0%, 7=100% discoloration), 7-point descriptive (1=no browning, 7=black), 6-point descriptive (1=devoid, 6=abundant) and 5-point descriptive (1=white, 5=red) scales respectively.

E. Sensory Analysis

Taste panel steaks were removed from the freezer and prepared as previously published [16] with the following exceptions. Steaks were grilled to an internal temperature of 35°C, turned and cooked to a final

temperature of 70°C. Eight cubes from each sample were randomly assigned to an eight-member trained taste panel to assess. Eight point descriptive and hedonic scales were used for initial and overall tenderness, initial and sustainable juiciness, beef flavour intensity, off flavour intensity, amount of connective tissue, flavour desirability and overall palatability (8= extremely tender, extremely juicy, extremely intense, no off flavour, none detected, extremely desirable; 1=extremely tough, extremely dry extremely bland. extremely intense off flavour, abundant, extremely undesirable).

F. Statistical Analysis

The PROC MIXED procedure of SAS Institute [17] was used to analyze all variables, with ante-mortem management treatment (MLACON, MLAPEN, LAND) as the main effect. Gender, live weight grouping, and farm were used as random variables. Shear force values were run with carcass temperatures at 5 and 10 h post mortem as a covariate. Least-square means were calculated for all main effects and means were separated (KR) when the *F*-test for the model was significant ($p \leq 0.05$). Frequency tables were generated along with Fisher's exact test for muscling, fat color and quality, muscle colour and degree of marbling.

	MLACON	MLAPEN	LAND	SEM	P
Carcass :					
Hot Commercial Weight, kg	227.67	225.44	221.74	28.28	0.65
Grade Fat, mm	7.57^{ab}	8.87^{a}	5.26^{b}	3.93	0.03
Rib-eye Area, cm^2	48.59	48.51	51.04	4.63	0.21
Quality:					
pH 1 h	6.43^{b}	6.66^{a}	6.65^{a}	0.12	0.00
pH 24 h	5.70	5.76	5.71	0.06	0.36
Musle Temp 5 h, ^{o}C	12.54^{a}	12.91^{a}	7.32^{b}	1.5	<0.01
Musle Temp 10 h, ^{o}C	4.94^{a}	5.02^{a}	3.72^{b}	2.00	0.02
Glycolytic Metabolites, µmole.g^{-1}					
Glycogen 1 h	62.05	73.36	72.57	12.34	0.19
24 h	39.2^{ab}	46.92^{a}	34.14^{b}	9.09	0.02
Lactate 1 h	56.10^{a}	42.24^{b}	32.02^{c}	7.63	<0.01
24 h	95.24	92.71	98.94	4.50	0.07
Glucidic Potential 1 h	93.19	96.32	90.01	10.42	0.52
24 h	91.96	97.34	88.25	8.24	0.20
Objective Colour Measurements, 24h					
L*	34.75	33.36	32.88	1.13	0.08
Chroma	20.65^{a}	18.57^{b}	19.02^{b}	1.58	0.03
Hue	20.81	20.30	20.44	0.80	0.56
Driploss, mg.g^{-1}	25.58^{a}	17.45^{b}	13.45^{b}	3.39	<0.01
Proximate Analysis, mg.g-1					
Moisture	760.4^{a}	753.7^{b}	755.1^{b}	7.10	0.04
Fat	16.3	17.9	16.9	5.74	0.66
Protein	213.4^{b}	217.6^{a}	219.1^{a}	2.00	<0.01
Fiber Measurements, µm					
Sarcomere Length	1.76^{a}	1.61^{b}	1.55^{b}	0.09	0.01
Diameter	76.37	78.07	75.22	4.89	0.82
Shear, kg	7.34^{b}	7.47^{b}	9.52^{a}	0.84	<0.01
Cookloss, mg.g-1	214.04^{a}	194.14^{b}	200.97^{b}	7.32	0.01
Sensory Evaluation:					
Initial Tenderness	4.95^{a}	4.55^{a}	3.93^{b}	0.39	0.01
Overall Tenderness	4.85	4.64	4.12	0.37	0.06
Overall Palatability	4.36	4.25	3.93	0.33	0.07
Retail Measurements:					
Objective Colour Measurements					
L*	36.73^{a}	36.37^{a}	35.53^{b}	0.77	<0.01
Chroma	17.81^{a}	16.97^{b}	16.80^{b}	0.60	0.02
Hue	37.98	37.62	36.88	1.37	0.11
Subjective Evaluation					
Retail Appearance	4.52^{b}	4.80^{b}	5.31^{a}	0.31	<0.01
Lean Colour Score	6.11^{c}	6.48^{b}	6.69^{a}	0.43	<0.01
Percent Surface Discolouration	3.72^{a}	3.33^{b}	3.22^{b}	0.43	0.02
Colour of Discolouration	2.43	2.37	2.18	0.15	0.05
Malonaldehyde, mg.kg^{-1} of meat					
0 d	0.08	0.09	0.10	0.01	0.17
3 d	1.16	0.76	0.83	0.32	0.09

III. RESULTS AND DISCUSSION

A. Animal and Slaughter

In total 55 bison were slaughtered for this project, 35 of which were processed through the MLA. The design of the MLA was sufficiently robust to process the 10 bison per d utilized in the present study.

There were no significant differences between treatments in hot commercial weight or rib-eye area (Table 1). There were significant differences amongst treatments ($P<0.01$) in the proportion of carcasses receiving downgraded colour scores (Table 2). Of note is the higher proportion (40%) of LAND carcasses that were identified as slightly dark to black in colour and the identification of 13% of MLACON carcasses as exhibiting a pale-wet colour.

Table 1: The effect of pre-slaughter treatment on meat quality traits in bison

$^{a, b}$ Values within same row bearing different letters are significantly different ($P \leq 0.05$)

Prolonged stress ante mortem can result in a pre-harvest depletion of glycogen, an abnormally high pH meat and dark meat colour. However, neither the average total glucidic potential, nor the average pH_{24} reflect the observed subjective differences in the frequency of colour scores at the time of grading. This is in agreement with a study comparing meat quality and stress between paddock-dispatched and commercially slaughtered red deer, where the ultimate pH level in the muscle tissue was not different based on pre-slaughter treatment [18]. The pH_{24} values found in the present study are similar to the mean value of 5.67 reported in a study of 5494 head of cattle in 2005 [19], and conventionally chilled bison carcasses (LL) of 5.77 [12].

Table 2: Percentage of carcasses in muscle colour groupings ($P<0.001$)

Colour	MLACON	MLAPEN	LAND
Good-Bright	73.3	65.0	60.0
Sl. Dark-Black	13.3	35.0	40.0
Pale Wet	13.3	0.0	0.0

However, in MLACON both the pH and lactate levels at 1h postmortem indicate a more rapid glycolysis early postmortem while carcass

temperatures are high. This may indicate that the stress experienced in this group was more acute, occurring immediately prior to exsanguination, compared to LAND and MLAPEN groups that appear to experience a more prolonged stress. In extreme cases accumulation of lactate and rapid pH drops while carcass temperatures are high can cause protein denaturation and can result in quality problems (pale, soft and exudative meat). In the present study the more rapid glycolysis in MLACON resulted in significantly higher drip losses ($P<0.01$) and a tendency towards a lighter meat colour (higher L*, $P=0.08$ and chroma, $P=0.03$). In addition MLACON had lower protein content compared to the other groups, which may result from an increased loss of sarcoplasmic proteins in the drip.

Despite these apparent deleterious effects on quality associated with a more rapid glycolysis in MLACON, this group had the lowest shear force overall, equivalent to MLAPEN and significantly lower than LAND ($P<0.01$). Not only did LAND have the highest shear force overall, this effect on tenderness persisted throughout 14d of ageing, and was evident after freezing/thawing and serving to panelists. Initial tenderness was significantly lower ($P<0.01$) and both overall tenderness ($P=0.06$) and overall palatability ($P=0.07$) tended to be lower in LAND than either MLA group.

The cooling regime 24h *post mortem* can greatly impact meat tenderness [20]. Muscle temperature at 5 and 10h were different between the MLA and LAND groups. While the carcass coolers were set to the same temperature, the MLA cooler did not maintain the setting as effectively on loading as the much larger LAND cooler. However, when carcass temperatures at 5 and 10h *post mortem* were included in the model as covariates, the MLA groups still had significantly lower shear values than LAND. This suggests the cooling rates of the carcasses in the two coolers, while different, were not solely responsible for the observed differences in LL tenderness. Associated with a more rapid temperature decline, LAND had the slowest accumulation of lactate at 1h and significantly shorter sarcomere lengths than MLACON. Janz et al. [12] found that comparatively longer sarcomere lengths in bison equated to lower shear force and indeed much work has been published in this area [21,22]. However, Smulders et al. indicated that the relationship between sarcomere length and shear force holds true only for slow glycolysing carcasses, and that in rapidly glycolysing carcasses the relationship between sarcomere length and shear force ceases to exist. This may explain why MLAPEN, despite having sarcomere lengths similar to LAND, had overall shear force values similar to MLACON. At the same time, their rate of lactate accumulation at 1h was significantly faster than the LAND group.

IV. Conclusion

This work provides novel information about meat quality of bison slaughtered on-farm compared to following transport. Improved meat tenderness and retail appearance was seen in bison slaughtered through a mobile abattoir compared to those slaughtered at a stationary plant. Pre-slaughter management of bison can affect the retail appearance and tenderness of bison meat.

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References

[1] Steenbergen, J. (2009). Alberta Agriculture and Rural Development Personal communication.

[2] Schaefer, A. L., Stanley, R. W., Tong, A. K. W., Dubeski, P., Robinson, B., Aalhus, J. L., & Robertson, W. M. (2006). The impact of antemortem nutrition in beef cattle on carcass yield and quality grade. Canadian Journal of Animal Science, 86, 317-323.

[3] Today's Retail Meat Case (2007). National Meat Case Study. http://www.beefretail.org/uDocs/nmcs_execsum11408.pdf

[4] Paganini, R. (2004). An alternative natural beef production system: A differentiation strategy for California producers and packers. Agricultural and Resource Economics Update, 8 (1), 9-11.

[5] Carlsson, F., Frykblom, P., & Lagerkvist, C. J. (2007). Consumer willingness to pay for farm animal welfare: mobile abattoirs versus transportation to slaughter. European Review of Agricultural Economics, 34 (3), 321-344

[6] Canadian Council on Animal Care. (1993). Guide to the care and use of experimental animals. Vol. 1, 2nd ed. E.D. Olfert, B.M. Cross, A.A. McWilliam, eds CCAC, Ottawa, ON.

[7] Canadian Food Inspection Agency 2007. Livestock and poultry carcass grading regulations, part VI section 48-54.1 Schedule I – IV. http://laws.justice.gc.ca/en/showdoc/cr/SOR-92-541/bo-ga:l_VI//en#anchorbo-ga:l_VI

[8] Association of Official Analytical Chemists. (1995). Method 960.39. Fat (Crude) or Ether Extract in Meat Final Action. OAOC. 39:2.

[9] Association of Official Analytical Chemists. (1995). Method 992.15 Crude Protein in Meat and Meat Products Including Pet Foods. Combustion Method. Final Action 1992. OAOC. 39:6-7.

[10] Aalhus, J. L., Best, D. R., Costello, F., & Jeremiah, L. E. (1999). A simple, on-line processing method for improving beef tenderness. Canadian Journal of Animal Science, 79, 27-34.

[11] Commission Internationale de l'Eclairage (1978). Recommendations on uniform color spaces-color difference equations – psychometric color terms, CIE Publication No. 15 (E-1.3.1) 1971/(TC-1.3), Supplement No.2, (pp. 8-12). Paris.

[12] Janz, J. A. M., Aalhus, J. L., & Price, M. A. (2002). Meat quality of bison (*Bison bison bison*) longissimus thoracis et lumborum following very fast chilling. Canadian Journal of Animal Science, 82, 327-337.

[13] Nielsen, J. H., Sorensen, B., Skibsted, L. H., & Bertelsen, G. (1997). Oxidation in pre-cooked minced pork as influenced by chill storage of raw muscle. Meat Science, 46(2), 191-197.

[14] Dalrymple, R. H., & Hamm, R. (1973). A method for the extraction of glycogen and metabolites from a single muscle sample. Journal of Food Technology, 8, 439-44.

[15] Yambayamba, E. S. K., Aalhus, J. L., Price, M. A., & Jones, S. D. M. (1996). Glycogen metabolites and meat quality in feed-restricted re-fed beef heifers. Canadian Journal of Animal Science, 9, 157-179.

[16] Aalhus, J. L., Jeremiah, L. E., Dugan, M. E. R., Larsen, I. L., & Gibson, L. L. (2004). Establishment of consumer thresholds for beef quality attributes. Canadian Journal of Animal Science, 84, 631-638.

[17] SAS Institute Inc. (1989) (4th ed.). SAS/Stat User's guide. Version 6 (Vol.2). Cary, NC: SAS Institute Inc.

[18] Pollard, J. C., Littlejohn, R., Asher, G. W., Pearse, A. J. T., Stevenson-Barry, J. M., McGregor, Manley, T. R., Duncan, S. J., Sutton, C. M., Pollock, K. L., & Prescott, J. (2002). A comparison of biochemical and meat quality variables in red deer (*Cervus elephus*) following either slaughter at pasture or killing at a deer slaughter plant. Meat Science, 60, 85-94.

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

[20] Savell, J. W., Mueller, S. L., & Baird, B. E. (2005). The chilling of carcasses. Meat Science, 70, 449-459.

[21] Bouton, P. E., Harris, P. V., Shorthose, W. R., and Baxter, R. I. (1973). A comparison of the effects of aging, conditioning and skeletal restraint on the tenderness of mutton. Journal of Food Science, 38. 932-937.

[22] Smulders, F. J. M., Marsh, B. B., Swartz, R. L., and Hoenecke, M. E. (1990). Beef tenderness and sarcomere length. Meat Science, 28, 349-363.