FATTY ACID NUTRITIVE VALUE OF RETAIL BISON (*BOS BISON*) MEAT FROM WESTERN CANADA

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Abstract – Canadian bison (*Bos bison*) is perceived as a leaner, healthier alternative to conventional beef. Information on the influence of diet on fatty acid (FA) content is limited. Herein, bison steaks representing grain-fed (Grain), grass-fed (Grass), and early and late season pasture-supplemented (Early-Con and Late-Con, respectively) feeding programs were assessed for effects on the FA profile. Fat content was below 3% for all groups, with Early-Con bison lower than other groups (P<0.05). Seasonal growth patterns affecting intramuscular fat content made assessing dietary effects difficult. Polyunsaturated FA (PUFA) content was greatest for Early-Con and lowest for Late-Con bison (P<0.05). Diet, in addition to total fat, affected omega-6 (n-6) content, with Early-Con highest and Late-Con lowest; Grain was slightly greater than Grass (P<0.01). In contrast, the omega-3 (n-3) content of the Grass and Early-Con bison was greater than the Grain and Late-Con bison (P<0.01). Omega-3 content (mg/g tissue) was greater for Grass, followed by Early-Con and Late-Con, and lowest for Grain (P<0.01). The n-6/n-3 ratio was 3:1 for the Grass, Early-Con, and Late-Con bison, whereas Grain had a ratio over 7:1 (P<0.001). This study confirms that retail bison from grass-fed and pasture-supplemented programs is low in fat and provides a desirable n-6/n-3 ratio.

I. INTRODUCTION

North American bison (*Bos bison*), once on the brink of extinction, now represent a vibrant, growing alternative livestock industry in Canada. Part of the popularity stems from the perceived wholesomeness of bison meat, free from feed additives, providing a leaner, healthier alternative to conventional feedlot beef whilst having a similar protein, vitamin, and mineral content (1,2). Currently, there is little information regarding the content of beneficial fatty acids in bison produced under Canadian conditions. With today's consumers more conscientious of dietary fats and fatty acids, seeking to lower total fat while increasing polyunsaturated fatty acid (PUFA) intake, bison can be an attractive option. For many cultures, lean red meat contributes significantly to daily omega-3 (n-3) long-chain PUFA (LC-PUFA, ≥20 carbon) intake (3). Ruminant products are also a source of other potentially bioactive fatty acids, such as *t*11-18:1 and *c*9,*t*11-conjugated linoleic acid (CLA) (4). The fatty acid profile of bison, similar to other species, is largely related to diet, although sex, season, and age can also be contributing factors (4). American studies comparing feedlot and forage-fed bison suggest high grain diets increased total fat and lowered PUFA, specifically 18:3n-3 content, resulting in an elevated n-6/n-3 ratio compared to grass-fed bison (5,6). The challenge for Canadian bison producers is to find the optimal forage-to-grain ratio to promote higher content of beneficial fatty acids, as the long winter season limits grazing. Bison fatty acid profiles of *longissumus dorsi*, representing grain-fed and grass-fed production systems, were compared to pasture + concentrate systems with early and late seasonal harvest periods.

II. MATERIALS AND METHODS

Retail samples

Bison ribeye steaks (*longissumus dorsi*) from grass and grain finishing programs were purchased at retail, sold under various farm labels. Determination of bison diets was attempted by contacting producers directly. In general, grain-fed bison (Grain, n = 19) were fed oats in drylot pens with access to conserved hay, whereas grass-fed bison (Grass, n = 19) were fed on fresh native pasture. Age and sex of the animals were not available. Targeted seasonal feeding effects using a combination of fresh forage and concentrate prior to slaughter were also investigated as means of enhancing the bioactive fatty acid content. Samples were collected from a single producer representing two groups. Early-Con (n = 59) were bison bulls on pasture supplemented with 3.7 kg/head/day oats plus 0.5 kg of a commercial pea screening pellet containing 15% dry matter crude protein from May until slaughter in summer. Late-Con (n = 53) were bison heifers on pasture from May until slaughter in early winter, fed the same supplement from July until slaughter. Collected samples were stored at -80 °C until lipid extraction.

Fatty acid analysis
Total lipids were extracted from bison samples using a modified Folch extraction as described by Prema *et al.* (7) and methylated using sodium methoxide and methanolic HCl. Analysis of fatty acid methyl esters by gas chromatography was performed using conditions described by Prema *et al*. (7). Peak identification was determined from commercial reference standards (Nu-Chek Prep. Inc. MN, USA).

Statistical analysis
The data was analyzed as a one-way ANOVA using the PROC MIXED of SAS v9.2 (Statistical Analysis System, NC, USA). Farm was used as a random factor. Sex and slaughter date were not known for all animals and subsequently excluded from the model. Significance was set at $P<0.05$, with means and standard error of the means reported.

III. RESULTS AND DISCUSSION

Total fat content of bison *longissumus dorsi* was below 3.0% for all groups, with Early-Con lower than the other groups ($P<0.05$, Table 1). The fat content of bison finished under presently described feeding programs are within the range of grass- and grain-finished bison reported earlier from Canadian and US studies (1,5,6). The lower lipid content of the Early-Con bison was likely a consequence of compensatory gain in spring and reduced intramuscular fat deposition. Bison, like other wild species, tend to reduce their metabolic rate in winter, undergoing rapid growth in spring and summer corresponding to more plentiful vegetation, and building body reserves in fall for winter survival (8).

The fatty acid profile indicated that the total saturated fatty acid (SFA) content did not differ between bison programs in spite of differences in total fat content (Table 1). Previous US studies have reported greater SFA for grass-fed vs. feedlot-fed bison, which likely reflects more intense concentrate feeding (5,6). Among individual SFA, 16:0 and 18:0 were present in roughly equal proportions, accounting for 90% of the SFA. Late-Con bison had a greater 16:0 content than the Early-Con bison; Grain and Grass bison were similar to both groups ($P<0.05$). Content of 18:0 did not differ between bison groups. Factors relating to seasonal growth patterns likely account for observed effects, yet limited available data indicates that heifers tend to deposit more fat than intact bulls on similar diets (1), possibly contributing to the differences between Early-Con and Late-Con bison. Although present in low amounts, greater 14:0 content for Grass and Late-Con bison compared to Early-Con bison ($P<0.01$) may also be related to the proportion and maturity of forage in the diet.

The *cis*-monounsaturated fatty acid (*c*-MUFA) content was greater for Late-Con than Early-Con bison, which were both similar to the Grain and Grass bison ($P<0.05$). Similarly, *c*9-18:1 content, accounting for nearly 90% of *c*-MUFA, was greater for the Late-Con than Early-Con and Grass bison, while Grain bison was intermediate ($P<0.05$). In beef, as intramuscular fat deposition increases, so does stearoyl-CoA desaturase (SCD) mediated conversion of SFA to MUFA, being more pronounced for grain-based diets. Similar effects are expected for bison, with relative fat content and forage feeding contributing to the low *c*-MUFA content of Early-Con and Grass bison, respectively. It is unclear if the greater *c*9-18:1/MUFA content of the Late-Con bison was related to total fat content or if heifers had greater SCD expression.

Ruminal microbial biohydrogenation of dietary unsaturated fatty acids produce a number of intermediates, primarily as *trans*-MUFA (*t*-MUFA). Interestingly, *t*-MUFA content was greater for the Early-Con and Late-Con bison than the Grain or Grass bison ($P<0.01$, Table

Table 1 Influence of bison finishing program on the fatty acid profile (% FAME) of m. *longissumus dorsi.*

	Grain	Early-Con	Late-Con	Grass	s.e.m.	*P* value
Lipid (mg/g tissue)	25.6[a]	15.7[b]	28.0[a]	23.0[a]	2.55	<0.05
SFA	39.9	38.7	39.3	40.4	0.93	
16:0	18.7[ab]	17.9[b]	20.0[a]	19.1[ab]	0.45	<0.05
18:0	18.1	18.3	16.4	18.2	1.06	
cis-MUFA	43.4[ab]	38.1[b]	46.3[a]	40.7[ab]	1.94	<0.05
*c*9-18:1	38.6[ab]	33.7[b]	41.6[a]	36.1[b]	1.75	<0.05
trans-MUFA	1.58[b]	2.84[a]	2.63[a]	1.77[b]	0.21	<0.01
*t*11-18:1	0.74[b]	1.57[a]	1.51[a]	1.00[b]	0.16	<0.01
*t*11-/*t*10-18:1	4.9[c]	6.8[b]	7.1[b]	9.2[a]	0.03	<0.01
*c*9,*t*11-CLA	0.19[b]	0.36[a]	0.40[a]	0.25[b]	0.04	<0.01
PUFA	13.1[bc]	17.7[a]	9.5[c]	14.7[ab]	1.5	<0.01
PUFA/SFA	0.3[bc]	0.5[a]	0.2[c]	0.4[b]	0.03	<0.01
18:2n-6	7.8[ab]	9.3[a]	4.8[c]	7.2[bc]	0.8	<0.01
20:4n-6	2.69	3.23	1.76	2.91	0.43	
18:3n-3	0.68[b]	1.69[a]	1.10[b]	1.67[a]	0.13	<0.01
20:5n-3	0.31[b]	0.90[a]	0.44[b]	0.83[a]	0.08	<0.01
22:5n-3	0.59[b]	1.48[a]	0.74[b]	1.36[a]	0.12	<0.001
22:6n-3	0.17[b]	0.41[a]	0.24[b]	0.30[ab]	0.04	<0.05
n-6/n-3	7.4[a]	3.1[b]	2.8[b]	2.7[b]	0.2	<0.001

s.e.m., standard error of the mean; significance (P<0.05) indicated by letters a-c.
SFA = 14:0 + 16:0 + 18:0 + 20:0; *cis*-MUFA = *c*9-14:1 + *c*9-16:1 + *c*9-18:1 + *c*11-18:1 + *c*13-18:1 + *c*9-20:1; *trans*-MUFA = *t*9-18:1 + *t*10-18:1 + *t*11-18:1 + *t*12-18:1 + *t*13/*t*14-18:1 + *t*16-18:1; *c*9,*t*11-CLA = *t*7,*c*9- + *c*9,*t*11- + *t*8,*c*12-CLA; PUFA = n-6 + n-3; n-6 = 18:2n-6 + 18:3n-6 + 20:3n-6 + 20:4n-6; n-3 = 18:3n-3 + 20:3n-3 + 20:5n-3 + 22:5n-3 + 22:6n-3.

1). This suggests that providing the pea screening supplement while grazing increased dietary PUFA intake, possibly in conjunction with greater rumen passage rate, resulting in increased tissue *t*-MUFA deposition. For all bison groups, *t*11-18:1 was the predominant *t*-MUFA, being greater for the Early-Con and Late-Con bison (*P*<0.01). High concentrate diets can affect biohydrogenation pathways leading to increased *t*10-18:1 formation. The *t*11-/*t*10-18:1 ratio illustrates this shift, being lowest for the Grain bison, higher for the Early-Con and Late-Con bison and highest for the Grass bison (*P*<0.01). Greater *t*11-18:1 content is desirable as the majority of *c*9,*t*11-CLA is derived from it via SCD in muscle. Early-Con and Late-Con bison had greater contents of *c*9,*t*11-CLA than Grain or Grass bison (*P*<0.01).

The majority of PUFAs are associated with membrane lipids, hence content proportionally decreased in relation to endogenous lipid synthesis (i.e. marbling). PUFA content was greatest for Early-Con and lowest for Late-Con bison. Grass bison PUFA content was more similar to Early-Con, whereas Grain bison was more similar to Late-Con bison (*P*<0.01, Table 1). The differences in PUFA content were reflected in the PUFA/SFA ratio, with Early-Con greater than Grass and Late-Con having the lowest ratio (*P*<0.01). As an indirect indicator of cardiovascular disease risk, the desired ≥0.4 ratio was achieved by the Early-Con and Grass bison. In conjunction, compared to conventional beef, regular consumption of leaner bison has been demonstrated to have more positive effects on blood triglyceride and inflammatory marker levels, reducing atherogenic risk (9). The proportion of 18:2n-6, the most abundant PUFA, was affected mainly by total fat and, to a lesser extent, diet. As such, 18:2n-6 content was greatest for the Early-Con bison, followed by grain, then Grass and Late-Con (*P*<0.05). Content of 20:4n-6, the major n-6 metabolite, was not affected by feeding program. In mg/100 g muscle, the n-6 content did not differ between bison programs. Diet was more influential on the 18:3n-3 content, which was greater for the Grass and Early-Con bison than the Grain and Late-Con bison (*P*<0.01). This was also reflected in the metabolites, with 20:5n-3, 22:5n-3, and 22:6n-3 content greater for Grass and Early-Con bison than Grain and Late-Con bison (*P*<0.01). In absolute amounts, Grass bison had the greatest n-3 content, intermediate for Early-Con and Late-Con, and lowest for Grain, at 90, 69, and 38 mg/100 g tissue, respectively (*P*<0.01). This highlights the impact feeding programs can have towards increasing daily intake of n-3 PUFA. As a consequence, the n-6/n-3 ratio of Grass, Early-Con, and Late-Con bison were all near the recommended 3:1, whereas Grain bison exceeded 7:1. Recent studies have shown that regular human consumption of red meat with an n-6/n-3 ratio below 4:1 increases circulating n-3 LC-PUFA, a factor which may contribute towards reducing the risk of cardiovascular disease and pro-inflammatory responses (10). Similar results would be anticipated from habitual bison consumption with a similar n-6/n-3 ratio.

IV. CONCLUSION

Retail bison from all feeding programs was lean, containing less than 3% fat, with SFA and MUFA content similar between Grain and Grass bison. Circannual growth patterns seemed to affect endogenous fatty acid synthesis of the Early-Con and Late-Con groups, accounting for the differences in *cis*-MUFA content. Factors such as season and sex need to be considered when planning feeding programs. Moderate supplementing on pasture enhanced the *t*11-18:1 and *c*9,*t*11-CLA content, whereas high grain diets had negative implications by lowering the *t*11-/*t*10-18:1 ratio. In general, grass and pasture + supplement programs resulted in the greatest content of desirable bioactive lipids, and a more desirable n-6/n-3 ratio compared to grain-based finishing.

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REFERENCES

1. Galbraith, J. K., Hauer, G., Helbig, L., Wang, Z., Marchello, M. J., & Goonewardene, L. A. (2006). Nutrient profiles in retail cuts of bison meat. Meat Science 74: 648-654.
2. Marchello, M. J., Slanger, W. D., Milne, D. B., Fischer, A. G., & Berg, P. T. (1989). Nutrient composition of raw and cooked *Bison bison*. Journal of Food Composition and Analysis 2: 177-185.
3. Meyer, B. J. (2011). Are we consuming enough long chain omega-3 polyunsaturated fatty acids for optimal health? Prostaglandins Leukotrienes and Essential Fatty Acids 85: 275-280.
4. Raes, K., De Smet, S., & Demeyer, D. (2004). Effect of dietary fatty acids on incorporation of long chain polyunsaturated fatty acids and conjugated linoleic acid in lamb, beef and pork meat: a review. Animal Feed Science and Technology 113: 199-221.
5. Rule, D. C., Broughton, K. S., Shellito, S. M., & Maiorano, G. (2002). Comparison of muscle fatty acid profiles and cholesterol concentrations of bison, beef cattle, elk, and chicken. Journal of Animal Science 80: 1202-1211.
6. Marchello, M. J., & Driskell, J. A. (2001). Nutrient composition of grass and grain finished bison. Great Plains Research 11: 65-82.
7. Prema, D., Pilfold, J. L., Krauchi, J., Church, J. S., Donkor, K. K., & Cinel, B. (2013). Rapid determination of total conjugated linoleic acid content in select canadian cheeses by ^{1}H NMR Spectroscopy. Journal of Agricultural and Food Chemistry 61: 9915-9921.
8. Rutley, B. D., Jahn, C. M., & Hudson, R. J. (1997). Management, gain and productivity of Peace Country bison (*Bison bison*). Canadian Journal of Animal Science 77: 347-353.
9. McDaniel, J., Askew, W., Bennett, D., Mihalopoulos, J., Anantharaman, S., Fjeldstad, A. S., Rule, D. C., Nanjee, N. M., Harris, R. A., & Richardson, R. S. (2013). Bison meat has a lower atherogenic risk than beef in healthy men. Nutrition Research 33: 293-302.
10. McAfee, A. J., McSorley, E. M., Cuskelly, G. J., Fearon, A. M., Moss, B. W., Beattie, J. A. M., Wallace, J. M. W., Bonham, M. P., & Strain, J. J. (2011). Red meat from animals offered a grass diet increases plasma and platelet n-3 PUFA in healthy consumers. British Journal of Nutrition 105: 80-89.