Fatty Acid Profiles of Western Canadian Bison (*Bison bison*) Meat

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Abstract

Western Canadian bison meat is renowned for its natural healthfulness; however, studies on the dietary effects on the fatty acid (FA) profile are limited. Herein, we evaluated the FA profiles of retail bison (*longissimus dorsi*) representing grain-fed (Grain), grass-fed (Grass) and grass-fed plus oat and pea screening supplement from early (Early-con) or late (Late-con) season harvested finishing regimes. Bison meat contained less than 30 mg fat/g meat, and was lowest for Early-con bison. Proportions of polyunsaturated FA (PUFA) were greatest in Early-con and lowest for Late-con bison. Early-con bison had the greatest proportion of omega-6 (n-6) FA and Late-con bison the lowest, yet as mg/g meat, total n-6 content did not differ. In contrast, Grass and Early-con bison had greater proportions of 18:3n-3, 20:5n-3, 22:5n-3, 22:6n-3 and total omega-3 (n-3) FA. The n-3 content for Grain, Grass, Early-con and Late-con bison were 38, 90, 69 and 69 mg/100 g meat, respectively. The 3:1 n-6/n-3 ratios of Grass, Early-con and Late-con bison were superior to the 7:1 ratio of Grain bison. Proportions of potentially beneficial biohydrogenation intermediates (BI), including *t*11-18:1 and *c*9, *t*11-conjugated linoleic acid, were greater for Early-con and Late-con bison. Proportions of *cis*-monounsaturated FA were similar for both Grain and Grass bison; however, Late-con was greater than Early-con bison. Cumulatively, Grass, Early-con and Late-con bison were more desirable compared to Grain on account of greater proportions of n-3 FA and a lower n-6/n-3 ratio. Furthermore, seasonal supplementation enhanced the BI proportions with potential beneficial bioactivity in Early-con and Late-con bison.

Keywords: biohydrogenation intermediates, forage-fed, grain-fed, health effects, pea screenings, polyunsaturated fatty acid, *trans*-monounsaturated fatty acid

1. Introduction

The North American bison (*Bison bison*), once on the brink of extinction, now represents a thriving alternative livestock niche market for bison meat, owing in part to its reputation as a lean alternative to beef, with similar protein, vitamin and mineral content (Galbraith et al., 2006; Marchello et al., 1989). With increased consumer awareness of the links between diet and health, specifically in relation to fatty acids (FA), more information is being sought. Increased polyunsaturated FA (PUFA) intake, specifically omega-3 (n-3) PUFA, is currently recommended in an effort to correct the n-6/n-3 imbalance and pro-inflammatory state associated with Western diets (Smit, Mozaffarian, & Willett, 2009; Wijendran & Hayes, 2004). The nutrient value of meat, specifically the FA composition, can be affected by a number of factors, diet being the most predominant, however, age, sex and season are also factors (Raes, De Smet, & Demeyer, 2004; Wood et al., 2008). Data relevant to the healthfulness and meat quality of Canadian bison is limited, as most bison nutritional studies are based on U.S. herds where finishing practices can differ substantially.

The Canadian bison herds are concentrated in the Western provinces, which are prone to seasonal weather patterns, requiring producers to adopt feeding practices to mitigate these challenges. The majority of Canadian bison meat is marketed as grain-fed, however, limited U.S. studies suggest high grain diets can negatively affect the healthfulness of the FA profile (Marchello & Driskell, 2001; Rule, Broughton, Shellito, & Maiorano, 2002). In contrast, healthwise, grass-fed bison has a more desirable FA profile, with greater n-3 PUFA and a lower n-6/n-3 ratio (Marchello & Driskell, 2001; Rule et al., 2002). Environmental factors that shorten the grazing season and fodder availability can pose a problem for Canadian grass-fed bison producers. Alternative methods such as grazing while providing low level seasonal supplementation may mitigate seasonal challenges while

retaining the more desirable FA profile of grass-fed meat. Our objectives were to evaluate the FA profiles of Canadian retail bison meat under grain- and grass-fed conditions compared to the suitability of pasture supplemented with an oat and pulse-crop based protein concentrate during early and late season grazing.

2. Materials and Methods

2.1 Retail Bison Samples

Bison ribeye steaks (*longissumus dorsi*) from grain- and grass-fed feeding programs were purchased at retail under various farm labels. Multiple steaks sold under a single label were purchased over a period of months to be representative of the supply available to consumers. Efforts to determine the bison diets used during the finishing stage were made by contacting producers directly. In general, grain-fed bison (Grain, n = 19) were fed whole oats in drylot pens with access to conserved hay, whereas grass-fed bison (Grass, n = 19) were grazed on fresh pasture and wintered with either mixed brome or alfalfa hay. The sex and age of the animals were not available. The effects of seasonal pasture supplementation prior to slaughter were also investigated. These samples were collected from a single large producer and divided into two groups: Early-con (n = 59) bison were supplemented with 3.7 kg/head/day oats plus 0.5 kg commercial pea screening pellet containing 15% dry matter crude protein, from May until July, while on fresh native pasture; Late-con (n = 53) bison grazing native pasture beginning in May were supplemented with 3.7 kg/head/day oats plus 0.5 kg commercial pea screening pellet from July until slaughter. All collected samples were immediately stored at -20 °C until lipid extraction.

2.2 Fatty Acid Analysis

Bison steaks were trimmed of subcutaneous fat and homogenised using a food processor (Hobart Food Equipment Group, North York, ON, Canada) and lipids were extracted from 1 g tissue using a modified Folch extraction (Aldai, Dugan, Rolland, & Kramer, 2009). Extracted lipids were methylated using base (sodium methoxide) and acid (methanolic HCl) reagents in a two-stage process as described by McNiven et al. (2004), with the addition of 1 mg methyl tridecanoate (13:0ME, Nu-Chek Prep Inc., Waterville, MN, USA) as a reference peak for quantification of individual peaks. Fatty acid methyl esters were analysed using a CP-3800 gas chromatograph (Varian Inc., Walnut Creek, USA) equipped with an SP-2560 column (100 m, 25 μm ID, 0.2 μm film thickness). Helium was used as the carrier gas under constant flow (1 mL/min), with injector and flame ionization detectors temperatures held at 250 °C. The initial temperature, 45 °C, was held for 4 min, increased to 175 °C at 13 °C/min and held for 27 min, then increased to 215 °C at 4 °C/min and held for 35 min. Individual fatty acids were reported as a proportion of total fatty acid methyl esters. Quantification of n-6 and n-3 FA were determined based on peak area in relation to area of internal reference peak, 13:0ME, and gravimetrically determined fat content of extracted sample. Commercial reference standards (Nu-Chek Prep Inc., Waterville, MN, USA) were used to identify fatty acids by retention time as well as peak order and retention times reported in literature (Cruz-Hernandez et al., 2004; Kramer et al., 2008).

2.3 Statistical Analysis

The FA data was analysed as a one-way analysis of variance to determine differences between feeding programs using the mixed model procedure of Statistical Analysis System software v9.1 (SAS, Cary, NC, USA). Farm label was used as a random factor. Sex and age of bison were not known and excluded from the model. Difference of least square means are reported at a significance level of $P < 0.05$ along with the standard error of the means.

3. Results

3.1 Total Lipids and Fatty Acid Groups

Intramuscular fat content of bison meat was similar among the different bison feeding programs, with the exception of the Early-con bison, which was lower than the other bison meat samples ($P < 0.05$, Figure 1). The proportion of PUFA was greatest for Early-con bison, decreasing slightly for Grass then Grain bison, and was lowest for Late-con bison ($P < 0.01$, Figure 1). In contrast, the proportion of *cis*-monounsaturated FA (*c*-MUFA) was greater for Late-con than Early-con bison, while Grain and Grass bison were both intermediate ($P < 0.05$, Figure 1). The saturated FA (SFA) proportion did not differ between bison groups (Figure 1). In addition, the PUFA/SFA ratio was highest for the Early-con bison, followed by the Grass and Grain bison, with the Late-con bison having the lowest ratio, 0.5, 0.4, 0.3 and 0.2, respectively ($P < 0.01$).

3.2 Polyunsaturated Fatty Acid Content

Feeding program influenced the proportion of individual PUFA in bison meat, including those obtained from diet and long-chain PUFA (LC-PUFA, ≥20 carbon) derived from dietary precursors and are presented in Table 1. The

proportion of 18:2n-6 was greatest for the Early-con, slightly lower for Grain and Grass bison, and lowest for the Late-con bison ($P < 0.01$). The Early-con bison also had the greatest proportion of 18:3n-6, whereas the other bison feeding programs were similar ($P < 0.01$). Likewise, the proportion of 20:3n-6 was greater for Grass and Early-con bison than the Late-con bison, whereas the Grain bison were intermediate ($P < 0.05$). In contrast to its precursors, concentration of 20:4n-6, the predominant n-6 LC-PUFA, did not differ between bison groups. Cumulatively, n-6 FA accounted for the majority of PUFA present in bison meat, with the Early-con bison having a greater content than the Late-con bison, while the Grain and Grass bison were both intermediate ($P < 0.05$). However, total n-6 FA content, mg/100 g muscle, did not differ between groups ($P > 0.05$, *data not shown*).
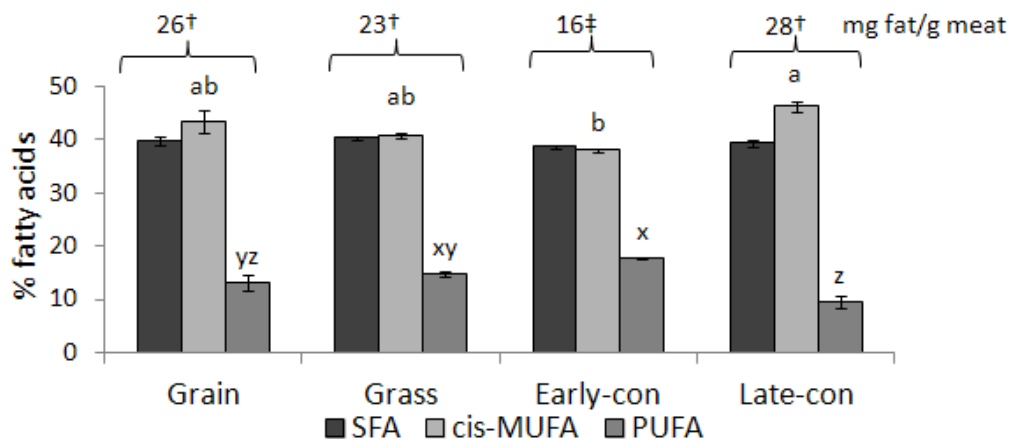

Figure 1. Effect of finishing program on total fat content (mg/g meat) and the proportion of total SFA, *cis*-MUFA and PUFA in bison meat. Significant difference ($P < 0.05$, ± s.e.m.) of fat content indicated by symbols ([†-‡]) and differences within specific fatty acid group letters [(a-b; x-z)]

Table 1. Influence of bison feeding program on the proportion of individual PUFA (% FAME) in meat

	Grain	Grass	Early-con	Late-con	s.e.m.	P value
18:2n-6	7.85[ab]	7.16[bc]	9.34[a]	4.83[c]	0.82	<0.01
18:3n-6	0.05[b]	0.05[b]	0.08[a]	0.04[b]	0.01	<0.01
20:3n-6	0.29[ab]	0.32[a]	0.36[a]	0.17[b]	0.04	<0.05
20:4n-6	2.69	2.91	3.23	1.76	0.43	
n-6	11.09[ab]	10.60[ab]	13.21[a]	6.92[b]	1.28	<0.05
18:3n-3	0.68[b]	1.67[a]	1.69[a]	1.10[b]	0.13	<0.01
20:5n-3	0.31[b]	0.83[a]	0.90[a]	0.44[b]	0.08	<0.01
22:5n-3	0.59[b]	1.36[a]	1.48[a]	0.74[b]	0.12	<0.001
22:6n-3	0.17[b]	0.30[ab]	0.41[a]	0.24[b]	0.04	<0.05
n-3	1.57[b]	4.20[a]	4.49[a]	2.52[b]	0.30	<0.001
n-6/n-3	6.9[a]	2.5[b]	2.9[b]	2.7[b]	0.22	<0.001

[a-c] Means with a different superscript for an individual fatty acid are statistically different ($P<0.05$); s.e.m., standard error of the mean; n-6 = ∑ 18:2n-6 + 18:3n-6 + 20:3n-6 + 20:4n-6; n-3 = ∑18:3n-3 + 20:5n-3 + 22:5n-3 + 22:6n-3.

Feeding program also affected the proportion of 18:3n-3, which was greater for Grass and Early-con bison than the Late-con and Grain bison ($P < 0.01$, Table 1). The n-3 LC-PUFA derivatives were also affected by diet, with proportions of 20:5n-3 and 22:5n-3 greater for the Grass and Early-con bison than either the Grain or Late-con bison ($P < 0.01$). Similarly, the proportion of 22:6n-3 was greater for the Early-con than the Grain and Late-con bison, while Grass bison were intermediate ($P < 0.01$). Overall, n-3 FA proportions were greater for the Grass

and Early-con bison than the Late-con and Grain bison ($P < 0.001$). On an absolute basis, content of n-3 FA were greatest for Grass bison, intermediate for Early-con and Late-con bison, while Grain bison was lowest, at 90, 69, 69 and 38 mg/100 g muscle, respectively ($P < 0.05$). As a result of the dietary influence on PUFA content, the n-6/n-3 ratio was 3:1 for the Grass, Early-con and Late-con bison, whereas the Grain bison had a 7:1 ratio ($P < 0.001$, Table 1).

3.3 Microbial Derived Fatty Acid Formation

Microbial hydrogenation of dietary unsaturated fatty acids produce a number of biohydrogenation intermediates (BI) represented predominantly as *trans*-MUFA (*t*-MUFA) and to a lesser extent, atypical dienes and those containing a conjugated double bond. Across bison feeding programs, *t*-MUFA accounted for less than 3% of total fats, with the Early-con and Late-con bison having a greater proportion than that observed in the Grain and Grass bison ($P < 0.001$, Table 2). The *t*11-18:1 isomer accounted for roughly 50% of total *t*-MUFA, with Early-con and Late-con bison having a greater proportion than the Grain and Grass bison ($P < 0.01$). Early-con bison had a greater proportion of combined *t*13/*t*14-18:1 than other bison ($P < 0.01$). The proportion of *t*9-18:1 and *t*12-18:1 were both greater for Early-con and Late-con than Grain or Grass bison ($P < 0.01$). The proportion of *t*10-18:1 was greatest for the Early-con bison, slightly lower for the Late-con and Grain bison, and lowest for the Grass bison ($P < 0.01$). The *t*11-/*t*10-18:1 ratio was highest for Grass bison, intermediate for Early-con and Late-con bison and lowest for Grain bison ($P < 0.01$).

Table 2. Influence of bison feeding program on the proportion of individual biohydrogenation intermediates (% FAME) in meat

	Grain	Grass	Early-con	Late-con	s.e.m.	*P* value
∑*trans*-MUFA	1.62[b]	1.79[b]	2.84[a]	2.63[a]	0.21	<0.01
*t*9-18:1	0.19[b]	0.17[b]	0.25[a]	0.25[a]	0.01	<0.001
*t*10-18:1	0.18[bc]	0.14[c]	0.23[a]	0.23[ab]	0.02	<0.01
*t*11-18:1	0.74[b]	1.00[b]	1.57[a]	1.51[a]	0.16	<0.01
*t*12-18:1	0.10[b]	0.08[b]	0.15[a]	0.13[a]	0.01	<0.05
*t*13/14-18:1	0.29[b]	0.29[b]	0.46[a]	0.36[b]	0.03	<0.01
*t*16-18:1	0.15	0.15	0.19	0.18	0.02	
*t*11-/*t*10-18:1	4.93[c]	9.19[a]	6.76[b]	7.13[b]	0.03	<0.001
∑atypical dienes	0.36	0.45	0.56	0.53	0.05	
*c*9,*t*13/*t*9,*c*12-18:2	0.11[b]	0.12[b]	0.16[a]	0.17[a]	0.01	<0.05
*t*8,*c*13/*c*9,*t*14-18:2	0.05[b]	0.06[b]	0.08[a]	0.08[a]	0.004	<0.01
*c*9,*t*12-18:2	0.05[b]	0.06[b]	0.07[a]	0.07[a]	0.003	<0.01
*t*11,*c*15-18:2	0.11[b]	0.17[ab]	0.25[a]	0.23[a]	0.03	<0.05
conjugated-FA						
*c*9,*t*11-CLA[z]	0.19[b]	0.25[b]	0.36[a]	0.40[a]	0.04	<0.01
*c*9,*t*11,*c*15-18:3	0.11[b]	0.13[b]	0.20[a]	0.10[b]	0.02	<0.05

[a-c] Means with a different superscript for an individual fatty acid are statistically different ($P<0.05$); s.e.m., standard error of the mean; trans-MUFA = ∑ *t*6/*t*8- + *t*9- + *t*10- *t*11- + *t*12- +*t*13/t14- + *t*16-18:1; atypical dienes = ∑ *c*9,*t*13/*t*9,*c*12-18:2 + *t*8,*c*13/*c*9,*t*14-18:2 + *c*9,*t*12-18:2 + *t*9,*c*12-18:2 + *t*11,*c*15-18:2.

[z] *c*9,*t*11-CLA represents coeluting *t*7,*c*9-/*c*9,*t*11-/*t*8,*c*10-CLA peaks.

The proportion of individual atypical dienes were influenced by bison feeding programs; however, total atypical dienes did not differ between bison feeding programs ($P = 0.07$, Table 2). The proportion of the main atypical diene, *t*11,*c*15-18:2, was greater for the Early-con and Late-con bison, slightly lower for the Grass bison and lowest for the Grain bison ($P < 0.05$). Likewise, proportions of *c*9, *t*12-18:2/*t*9, *c*12-18:2, *t*8, *c*13-18:2/*c*9, *t*14-18:2 and *c*9, *t*12-18:2 were greater for the Early-con and Late-con bison than the Grain and Grass bison ($P<0.01$).

Bison feeding program also affected the proportion of conjugated linoleic acid (CLA), with Early-con and Late-con bison having a greater proportion of $c9,t11$-CLA than Grass or Grain bison ($P < 0.01$). Similarly, the $c9$, $t11$, $c15$-18:3 proportion was greater for the Late-con bison than the other bison feeding programs ($P < 0.05$).

3.4 Saturated and Cis-Monounsaturated Fatty Acids

Among individual SFA, 16:0 and 18:0 were present in roughly equal proportions, accounting for 90% of the total SFA (Table 3). Although diet did not affect 18:0, the proportion of 16:0 was greater for Late-con bison than the Early-con bison, while Grain and Grass groups were intermediate ($P < 0.05$). Similarly, the 14:0 level was greatest for the Late-con and Grass bison, followed by Grain bison whereas the Early-con bison had the lowest level ($P < 0.01$). Microbial derived branched-chain fatty acids accounted for slightly more than 1% of total fatty acids; however, content did not differ between bison. Likewise, proportions of odd chain FA, i.e. 15:0 and 17:0, were not affected by the different bison feeding program.

The proportion of $c9$-18:1 accounted for nearly 90% of the total c-MUFA, and was greater for Late-con than Grass and Early-con bison, whereas Grain bison were intermediate ($P < 0.05$, Table 3). Having a similar pattern, but at a much lower level, $c11$-20:1 content was greatest for the Late-con bison, intermediate for the Grain bison and lowest for the Early-con and Grass bison ($P < 0.05$). The proportion of other minor c-MUFA isomers did not differ between the different bison feeding programs.

Table 3. Influence of bison finishing program on the saturated and *cis*-monounsaturated fatty acid profile (% FAME) in meat

	Grain	Grass	Early-con	Late-con	s.e.m.	*P*-value
14:0	1.11[ab]	1.27[a]	0.94[b]	1.24[a]	0.06	<0.01
15:0	0.36	0.38	0.32	0.31	0.03	
16:0	18.7[ab]	19.1[ab]	17.9[b]	20.0[a]	0.45	<0.05
17:0	1.29	1.38	0.97	1.21	0.12	
18:0	18.1	18.2	18.3	16.4	1.06	
∑BCFA	1.27	1.37	1.18	1.10	0.15	
$c9$-16:1	1.71	1.62	1.44	1.76	0.15	
$c9$-17:0	0.67	0.66	0.48	0.62	0.07	
$c9$-18:1	38.6[ab]	36.1[b]	33.7[b]	41.6[a]	1.75	<0.05
$c11$-18:1	1.68	1.60	1.59	1.46	0.09	
$c11$-20:1	0.18[ab]	0.16[b]	0.15[b]	0.20[a]	0.01	<0.05

Branched-chain fatty acids (BCFA) = ∑ iso-15:0 + anteiso-15:0 + iso-16:0 + iso-17:0 + anteiso-17:0 + iso-18:0.

4. Discussion

Bison samples obtained in Western Canada contained less than 3% fat, with little variation observed that did not appear to be affected by grain- or grass-based diets (Figure 1). This is consistent with previous reports in scientific literature, which indicate that bison meat is generally lean, with only slight differences in fat content related to feeding program and muscle (Galbraith et al., 2006; Marchello & Driskell, 2001; Rule et al., 2002). The relative leanness of bison meat contributes to its perceived healthfulness compared to beef or pork (Marchello et al., 1989). The slightly lower lipid content of the Early-con bison compared to other bison is likely related to rapid lean growth in spring and summer in combination with supplementation duration. In support of this, bison seasonal metabolism studies have shown bison tend to reduce intake during winter and undergo compensatory gain in the spring as well as building body reserves in the fall (Anderson & Miller, 1997; Rutley, Jahn, & Hudson, 1997). As an index of cardiovascular disease risk, the preferred higher PUFA/SFA ratio of the Early-con bison also reflect lower endogenous FA synthesis and total fat content. Typically, beef has a PUFA/SFA ratio less than 0.1, whereas Grass and Early-con bison achieved the ≥ 0.4 PUFA/SFA considered desirable for human health (Wood et al., 2008). In correlation, health benefits from the regular consumption of bison meat, having half the fat content of beef, was demonstrated to lower atherogenic risk by reducing inflammation and oxidative stress markers over a prolonged period (McDaniel et al., 2013).

Differences in fat content between bison relates to endogenous FA synthesis, which affected the proportions of PUFA and *c*-MUFA (Figure 1). Comparing Early-con and Late-con bison, lower lipid content corresponded to an elevated proportion of PUFA; however, with increased fat content, the proportion of *c*-MUFA increased at the expense of PUFA (Figure 1). This is expected as for ruminants, PUFA are mainly associated with tissue membranes, whereas endogenous fat synthesis increases neutral lipid deposition, i.e. intramuscular fat (Duckett et al., 1993; Wood et al., 2008). Accumulating intramuscular fat corresponds to increased *c*-MUFA synthesis, on account of increased stearoyl-CoA desaturase (SCD) activity, which may also indirectly govern the SFA proportion, as it remains relatively stable (Duckett et al., 1993; Smith et al., 2012). Bison studies from the U.S.A. indicate that feedlot-fed bison tend to be fatter and have a lower SFA and greater *c*-MUFA proportion compared to their grass-fed counter parts (Marchello & Driskell, 2001; Rule et al., 2002). The absence of dietary induced differences in SFA content of meat from the present bison study may be attributed to the general leanness of the bison or lower intensity grain-feeding in comparison to U.S.A. studies.

Differences in fat content largely accounted for the proportional differences in 18:2n-6, 18:3n-6, 20:3n-6 and total n-6 FA between bison (Table 1). However, total n-6 FA content, mg/100 g muscle, did not differ between bison (*data not shown*). In contrast, forage feeding, as well as relative leanness contributed to the greater proportions of 18:3n-3, 20:5n-3, 22:5n-3 and 22:6n-3 in Grass and Early-con bison, respectively (Table 1). In absolute amounts, n-3 FA content was 38, 70 and 90 mg/100 g meat for Grain, Early-con/Late-con and Grass, respectively. These differences exemplify the effects of high forage-to-concentrate diets on meat n-3 FA content and related contribution to daily intakes. Lean red meat is increasingly recognised as substantially contributing to daily n-3 LC-PUFA, particularly in regions with traditionally low consumption of marine foods (Givens, Kliem & Gibbs, 2006; Meyer, 2011). As a result of dietary effects on n-3 FA, the n-6/n-3 ratios (Table 1) of Grass, Early-con, Late-con were roughly 3:1, whereas the Grain bison had a ratio of 7:1. Meat with a lower n-6/n-3 ratio would contribute towards achieving a dietary 4:1 n-6/n-3 ratio, which is considered desirable for human health (Daley et al., 2010). Presently, wide use of vegetable oils in cooking have increased our intake of n-6 FA, leading to n-6/n-3 ratios exceeding 10:1, which has been associated with the rise in a number of metabolic inflammatory disorders including obesity, diabetes, cardiovascular disease and some cancers (Ailhaud et al., 2006). Increasing n-3 FA intake, thereby lowering the dietary n-6/n-3 ratio, contributes to the formation of anti-inflammatory eicosanoids and reducing the risks of metabolic disorders (Burdge & Calder, 2006; Smit et al., 2009; Wijendran & Hayes, 2004). This is facilitated through a preference for n-3 FA by desaturases, contributing to the greater formation and content of n-3 LC-PUFA (Williams & Burdge, 2006). As a result, lean red meat having a low n-6/n-3 ratio can provide some of the much desired n-3 LC-PUFA, thereby contributing to a healthier lifestyle. For example, circulating levels of n-3 LC-PUFA can be increased through regular consumption of grass-fed vs. conventional beef, having n-6/n-3 ratios of 2.3 and 8.4 respectively, (McAfee et al., 2011). Similar effects would be expected from the low n-6/n-3 ratio of Grass, Early-con and Late-con bison, in addition to the beneficial effects of a leaner product.

The greater proportions of BI, particularly *t*-MUFA of Early-con and Late-con bison suggests a synergetic effect between pasture grazing and the oat-pea supplement (Table 2). In the rumen, dietary unsaturated FA undergo extensive hydrogenation to yield 18:0; however, incomplete biohydrogenation produces a wide range of intermediates, predominantly as *t*-MUFA, and to a lesser extent atypical or conjugated dienes and trienes. The composition of BI leaving the rumen is largely dependent on the unsaturated precursor and dietary factors that influence the microbial population (Shingfield, Bernard, Leroux, & Chilliard, 2010). In regards to the Early-con and Late-con bison, a number of factors may have contributed to the increased proportions of *t*-MUFA isomers. Compared to strictly grass, the greater degradability of the oat-pea screening supplement could have contributed to increased rumen passage rate, while the additional unsaturated FA may enhance the outflow of BI. Diets having low dietary forage-to-concentrate ratios have been shown to increased rumen passage rate and an association between PUFA intake and increased BI outflow (Bartocci et al., 1997; Noci, French, Monahan, & Moloney, 2007). Regardless of feeding program, *t*11-18:1 accounted for the majority of *t*-MUFA in the bison, accompanied by lesser proportions of *t*9-, *t*10-, *t*12- and *t*13/*t*14-18:1 (Table 2). When provided with an adequate forage-to-concentrate ratio, microbial populations favour *t*11-18:1 formation during 18:2n-6 and 18:3n-3 biohydrogenation (Lourenço, Ramos-Morales, & Wallace, 2010; Shingfield et al., 2010). However, when fed a high concentrate diet, rumen pH decreases, microbial populations are affected and biohydrogenation pathways shift whereby *t*10-18:1 becomes the predominant *t*-MUFA (Bessa, Portugal, Mendes, & Santos-Silva, 2005; Dugan et al., 2011; Leheska et al., 2008). Although the present bison did not indicate such an extreme shift, the *t*11-/*t*10-18:1 ratio did decrease in relation to increasing proportion of concentrate in the diet. This may have undesirable consequences for human nutrition as *t*10-18:1 has been associated with increased atherogenesis in animal models (Bauchart et al., 2007). In contrast, *t*11-18:1 has been associated with a number of health benefits

such as reducing the risk of coronary heart disease, possibly in connection with its better known conjugated desaturate, c9,t11-CLA (Field, Blewett, Proctor, & Vine, 2009; Gebauer et al., 2011). Feeding programs which promote t11-18:1 deposition are also advantageous as c9,t11-CLA is predominantly formed endogenously by SCD similar to c-MUFA (Griinari et al., 2000). As such, enhancing t11-18:1 and c9,t11-CLA content may present a marketing opportunity as a number of positive effects have been attributed to c9,t11-CLA, including anticancerogenic, antiatherogenic and anti-inflammatory effects (Dilzer & Park, 2012; Schmid, Collomb, Sieber, & Bee, 2006). Further studies will be necessary to explore optimal oat-pea screening supplementation while on pasture to enhance the content of bioactive biohydrogenation intermediates.

Incomplete biohydrogenation can also produce a number of atypical dienes with currently unknown biofunctional attributes, with t11,c15-18:2 as the predominant isomer in Early-con and Late-con bison feeding programs (Table 2). Similar to t-MUFA, dietary factors affecting biohydrogenation pathways can yield a variety of atypical dienes with some only formed in the rumen, i.e. t11,c15-18:2, originating from 18:3n-3 (Shingfield et al., 2010). However, those with c9-bonds may also be formed endogenously via SCD from t-MUFA precursors such as c9,t13-18:2. Again, the oat-pea screening supplement likely aided rumen passage rates, increasing the outflow of t11,c15-18:2, with both peas and forage contributing to dietary 18:3n-3 intake. Supplementing finishing lambs with peas was also reported to increase 18:3n-3 in meat, and would likely have also enhanced t11,c15-18:2 content, had atypical dienes been quantified (Scerra et al., 2011). Slightly greater proportions of t11,c15-18:2 were found for Grass vs. Grain bison; however, longer rumen retention times likely resulted in more extensive biohydrogenation compared to the supplemented bison groups. The relative importance of t11,c15-18:2 relates to its potential to be desaturated *in situ* to form c9,t11,c15-18:3. Initial studies indicate that human health effects of conjugated trienes, i.e. c9,t11,c15-18:3 may be equivalent or even more potent than those of c9,t11-CLA (Hennessy, Ross, Devery, & Stanton, 2011).

Proportions of individual SFA were equivalent between Grain or Grass bison; however, differences between Early-con and Late-con 14:0 and 16:0 proportions seem more related to fat content than a direct diet effect. Due to extensive biohydrogenation of dietary unsaturated FA, 18:0 accounts for the majority of SFA leaving the rumen; in contrast, 14:0 and 16:0 are largely derived via *de novo* synthesis (Shingfield, Bonnet, & Scollan, 2013). Presumably, lower endogenous fat synthesis associated with rapid spring growth would account for the lower 14:0 and 16:0 proportions of the Early-con bison. Alternatively, longer supplementation period and slowing growth in fall may also have contributed to increased fat deposition and slightly greater 16:0 proportion of the Late-con bison. For humans, a lower 14:0 and 16:0 content may have desirable health consequences, as both have been correlated with undesirable increases in serum cholesterol (Mensink, Zock, Kester, & Katan, 2003). In contrast, 18:0 is reported to have neutral or even positive effects on serum cholesterol in comparison to 14:0 or 16:0 (Hunter, Zhang, & Kris-Etherton, 2010).

Lower proportions of c9-18:1 for Grass and Early-con bison may relate to dietary 18:3n-3 reducing SCD expression in combination with general lower fat content (Smith, Gill, Lunt, & Brooks, 2009). In beef, grain-based diets increase intramuscular fat deposits and concomitantly c-MUFA, whereas forage-based diets tend to suppress SCD activity and c-MUFA formation, resulting in a more saturated FA profile (Smith et al., 2009). Comparison of grass-fed and feedlot-fed bison c-MUFA and SFA proportions would suggest a mechanism parallel to that of beef (Marchello & Driskell, 2001; Rule et al., 2002). There were no other differences among bison groups of other direct SCD products, though as an elongase product, c11-20:1 reflected the c9-18:1 differences between the bison groups.

5. Conclusion

In general, Canadian retail bison ribeye steaks contained less than 3% fat. Grass bison had the greatest n-3 FA content; however, the equivalent 3:1 n-6/n-3 ratios of Grass, Early-con and Late-con bison would likely impart similar beneficial health effects and was considered to be more desirable than that of Grain bison. Additionally, Early-con and Late-con bison had greater proportions of potentially healthful BI, including t11-18:1 and c9,t11-CLA, as well as other BI with potential bioactive properties. Seasonal pasture supplementation may be a management option to enhance the healthfulness of bison during short Canadian grazing periods, without having to resort to intensive grain-based diets. Further studies will be necessary to determine optimal seasonal supplementation rates and composition, without reducing the proportion of desirable fatty acids in bison meat.

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