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Nutrient profiles in retail cuts of bison meat

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Abstract

The objectives were to determine the nutrient composition and variation in eight cuts of bison meat in bulls and heifers and identify nutrient relationships in the clod and sirloin by principal component analysis. The nutrients analyzed were: energy, protein, total fat, saturated fat, monounsaturated fat, polyunsaturated fat, transfat, cholesterol, vitamin A, Ca, Fe, Na and moisture. Differences were observed in fat components between cuts and bulls had higher ($P < 0.05$) amounts of total, saturated, monounsaturated and polyunsaturated fat in the blade compared to the other cuts. The sirloins had less ($P < 0.05$) cholesterol than all the other cuts in bulls and the clod in heifers. Fat varied more than protein and moisture in all cuts. Four principal components (PC) accounted for 63.9% of the total variation of the nutrient composition. Total, monounsaturated and saturated fats were in PC1 and cholesterol in PC2 showing that cholesterol is independent of other fats. If dietary alterations elicit changes in bison meat fatty acid profiles, it may be possible to reduce cholesterol independent of total, monounsaturated or saturated fat.

Keywords: Bison; Nutrient; Fat; Cholesterol; Principal component analysis; Cut

1. Introduction

The farmed bison (*Bison bison*) population in Alberta, Canada is estimated at 90,000 head and there are approximately 800 bison farms in the province (Alberta Agriculture, Food and Rural Development, 2005 unpublished). In 2001, Statistics Canada estimated 950 farms and 79,731 bison in Alberta, and the total for Canada was 1887 farms and 145,094 bison (Census of Agriculture, 2001).

It is generally accepted the North American population is more diet conscious today, especially of the types of fat and fatty acids, and the cholesterol content of meats. As such the composition of nutrients, especially fats in meats, has become important. There also appears to be a move to try alternate sources of meat to the more traditional beef, pork, lamb and poultry in North America. Bison meat is deemed to have less energy contents and fat compared to beef (McClenahan & Driskell, 2002), and there is a perception that consumption of bison meat is healthier than beef (Rule, Broughton, Shellito, & Maiorano, 2002). However, the nutrient composition of bison and other meats are dependent on a number of factors such as age, type of feed, maturity, gender, type of cut, genetics and season (Berg & Butterfield, 1976; De Smet, Raes, & Demeyer, 2004; Huerta-Leidenz et al., 1996; Marchello & Driskell, 2001). There are a few studies reporting on the nutrient content of bison muscle (retail) cuts (Koch, Jung, Crouse, Varel, & Cundiff, 1995; Marchello & Driskell, 2001; Marchello, Slanger, Hadley, Milne, & Driskell, 1998; Rule et al., 2002) but these studies report data primarily from the USA. This study was undertaken as little published information is available in Canada. The study will also enable the Canadian consumers make informed decisions about alternate meats that are available for consumption such as bison.

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The objective of the study was to report the nutrient content and variation in nutrient content in retail cuts of bison meat in bulls and heifers and regroup the nutrients across the clod and sirloin cuts by a principal component analysis (PCA) and identify possible interrelationships among nutrients.

2. Materials and methods

Bison meat samples were collected at a federally inspected, commercial slaughter plant in Edmonton, Alberta (Northwest Foods Inc.) during March 2004. The meat samples came from bison raised by two producers in large bison operations and are representative of what is standard in the industry. Bulls and heifers were between 20 and 22 months of age. Bulls and heifers were started on pasture and the heifers were finished for 100 days on a 80% barley silage, 15% barley grain, 5% hay diet free choice and the bulls were finished for 100 days on 70–80% rolled barley 20–30% straw diet provided free choice. Typically Alberta grown barley silage contains 64.4% moisture, 11.4% protein, 0.62% Ca, 0.28% P, 32.8% ADF and 48.2% NDF, barley grain contains 11.8% moisture, 12.6% protein, 0.07% Ca, 0.35% P and 12.97 MJ/kg ME, Brome hay contains 13.1% moisture, 9.8% protein, 0.57% Ca, 0.16% P, 34.8% ADF and 37.2% NDF and cereal straw contains 9.1% moisture, 5.7% protein, 0.33% Ca, 0.14% P and 41.2% ADF (NRC, 2000; Suleiman, 1995). The practice in the industry is to feed bulls and heifers differently hence bulls were fed diets higher in energy. The cuts blade ($n = 10$), bottom roll ($n = 10$), shoulder clod ($n = 15$), eye of the round ($n = 10$), rib eye ($n = 15$), sirloin tip ($n = 9$), sirloin ($n = 15$) and tenderloin ($n = 15$) were sampled from bulls. Samples from the shoulder clod ($n = 15$) and sirloin ($n = 13$) were obtained from heifers. The samples were placed in a cooler containing ice and taken to a commercial laboratory (Enviro-Test Lab, Edmonton) for analysis. Whole cuts were trimmed of any visible fat such that the results would represent the lean meat only. The 13 nutrients measured were: energy (Ener), protein (Prot), total fat (Tofat), saturated fat (Sfat) which was the sum of $C_{4:0}$, $C_{6:0}$, $C_{8:0}$ etc., monounsaturated fat (Mufat) which was the sum of $C_{16:1}$, $C_{17:1}$, $C_{18:1}$ etc. only of the *cis* form, polyunsaturated fat (Pufat) which was the sum of $C_{18:2n5t}$, $C_{18:2n6c}$, $C_{18:3n6}$, $C_{18:3n3}$, $C_{20:2}$, $C_{20:3n6}$, $C_{20:2n3}$, $C_{20:4n6}$, $C_{22:2}$, $C_{20:5n3}$ and $C_{22:6n3}$, transfat (Trfat) which included $C_{18:1-\mathrm{trans}}$ and $C_{18:2-\mathrm{trans}}$, Cholesterol (Chol), Vitamin A (VitA), Calcium (Ca), iron (Fe), sodium (Na) and moisture (Moist). Association of Official Analytical Chemists (AOAC, 2000) and US Environmental Protection Agency (EPA-2005) methods were used to analyze the following: Ener (Atwater method), Prot (AOAC-984.13 TKN), Tofat (AOAC-960.39), Sfat, Mufat, Pufat and Trfat (AOAC-996.06), Chol (AOAC-994.10), VitA (AOAC-992.04), Ca, Fe and Na (EPA 6020) and Moist (AOAC-925.09). All animals were managed according to the recommended code of practice for the care and handling of farmed bison.

The data were analyzed in two ways: (a) an analysis of variance was done to determine differences in nutrients with respect to the cuts (fixed effect) within gender (bulls and heifers) using the general linear model (GLM) of SAS (Statistical Analysis System, 1989). Least square means and standard errors are reported. (b) a total of 13 nutrient composition variables (Ener, Prot, Tofat, Sfat, Mufat, Pufat, Trfat, Chol, VitA, Ca, Fe, Na, Moist) from the clod and sirloin were analyzed by PRINCOMP and CORR procedures of the Statistical Analysis System (SAS, 1989). The PRINCOMP procedure standardizes the variables to a mean of zero and a standard deviation of one. The correlation matrix was used to generate principal component eigen values and associated eigen vectors. The loadings (eigen vectors) in each principal component were retained when the loadings were greater than the absolute average eigen value for that component (SAS, 1989). The PCA procedures described by Goonewardene et al. (2004) and Destefanis et al. (2000) were followed.

3. Results

The nutrient content of the different bison meat cuts within sex, along with the SEM is shown in Table 1. in bulls, the blade appeared to have the highest energy content and the sirloin tip the lowest. The high-energy content was associated with the high levels of total fat in the tissues. Protein and moisture content among the cuts was very similar and consistent and was uniform across cuts as the coefficients of variation (not shown) were 1.64 for moisture and 5.08 for protein. There was also considerable overlap in protein content across the different cuts. The fat profiles varied much across cuts and the CV's ranged from 29.39% to 348.99%. Only traces of transfat were detected in all cuts. The cholesterol content in the sirloin of bulls was low ($P < 0.05$) compared to all of the other cuts and in heifers the cholesterol content of the sirloin was lower ($P < 0.05$) than in the clod. The vitamin A content was similar ($P < 0.05$) for all cuts in bulls and for the clod and sirloin in heifers.

Pearson correlation coefficients between nutrients are shown in Table 2 for the sirloin and clod cuts in bulls and heifers. The energy content in the clod and sirloin was positively correlated ($r = 0.57$) with total fat but negatively correlated with moisture. Total fat was positively correlated with saturated and monounsaturated fat but not cholesterol ($P > 0.05$). Polyunsaturated fat content was positively correlated with cholesterol ($r = 0.5$). The saturated fat content was positively correlated with monounsaturated ($r = 0.89$) and polyunsaturated fats ($r = 0.38$) in the clod and sirloin.

Principal components and eigen values for the first four components are shown in Table 3. The four PC's accounted for 63.9% of the total variation of the nutrient composition in the sirloin and clod with gender pooled. The coefficients of the loadings or eigen vectors for PC1–PC4 are shown in Table 4. The first PC contained the nutri-

Table 1
Nutrient composition of bison cuts within bulls (B) and heifers (H)-least squares means, standard errors of the mean (SEM) and coefficients of variation (CV) combined for B and H

Cut [n][B]	Nutrients[A]												
	Ener (KJ/100 g)	Prot (g/100 g)	Tofat (g/100 g)	Sfat (g/100 g)	Mufat (g/100 g)	Pufat (g/100 g)	Trfat (g/100 g)	Chol (mg/100 g)	VitA (μg/100 g)[C]	Ca (mg/100 g)	Fe (mg/100 g)	Na (mg/100 g)	Moist (%)
Bulls													
Blade [10]	527.52a	21.08c	4.58a	1.34a	1.45a	0.22a	0.03	46.52ab	2.39	8.01b	2.89abc	53.62b	72.18c
Bot. roll [10]	428.74c	22.29abc	1.46c	0.31c	0.45c	0.17b	0	43.27ab	1.94	5.31bc	2.61c	60.09a	73.61ab
Clod [15]	433.47c	22.43ab	1.67c	0.44c	0.55c	0.16b	0	45.35ab	2.34	5.21bc	3.08ab	44.31cde	74.06ab
Eye round [10]	437.77c	22.56ab	1.87c	0.31c	0.47c	0.10c	0	40.19b	1.74	5.30bc	2.69bc	49.88bc	73.79ab
Ribeye [15]	479.57b	21.29bc	3.31b	1.08b	1.15b	0.17b	0.01	48.27a	2.46	10.90a	2.94abc	46.85cd	73.67ab
Sirloin Tip [9]	413.40c	21.83abc	1.62c	0.50c	0.62c	0.17b	0	39.73b	1.69	4.23c	2.63c	42.79de	75.11a
Sirloin [15]	443.92c	22.72a	1.53c	0.40c	0.48c	0.11c	0	25.70c	1.79	4.06c	3.15a	40.55de	72.87ab
Tenderloin [15]	441.78c	22.22abc	2.14c	0.65c	0.62c	0.13bc	0.02	45.61ab	2.08	4.43c	2.93abc	39.00e	74.02ab
SEM (bulls)	10.66	0.33	0.31	0.09	0.10	0.01	0.00	1.85	0.23	0.89	0.10	1.74	0.35
Heifers													
Clod [15]	437.73	22.32	1.97	0.49	0.59	0.18	0	51.46a	1.95	5.64a	3.10a	44.41a	73.59
Sirloin [13]	457.12	21.98	2.05	0.48	0.57	0.18	0.01	43.07b	2.18	3.23b	2.56b	34.67b	72.69
SEM (heifers)	6.81	0.29	0.16	0.04	0.05	0.01	0.00	1.27	0.17	0.76	0.09	1.43	0.29
CV% (B + H)	7.61	5.08	43.77	50.59	46.38	29.39	348.00	14.03	37.19	53.67	12.40	12.97	1.64

a,b,c... Least squares means with different letters are significant ($P < 0.05$) and compare cuts within each nutrient separately for bulls and heifers.

[A] Nutrients: Ener = energy, Prot = protein, Tofat = total fat, Sfat = saturated fat, Mufat = monounsaturated fat, Pufat = polyunsaturated fat, Trfat = transfat, Chol = cholesterol, VitA = vitaminA, Ca = calcium, Fe = iron, Na = sodium, Moist = moisture.

[B] [n] = number of observations.

[C] Expressed as μg retinol equivalents/100 g.

Table 2
Pearson correlations among nutrients in bison meat

Nutrient[a]	Ener	Prot	Tofat	Sfat	Mufat	Pufat	Trfat	Chol	Vit A	Ca	Fe	Na	Moist
Ener	1.0	0.11	0.57**	0.26	0.22	−0.02	0.06	−0.09	−0.05	−0.13	−0.12	−0.29*	−0.86**
Prot		1.0	−0.26	−0.05	−0.10	−0.01	0.02	−0.08	−0.09	0.06	0.08	0.03	−0.27*
Tofat			1.0	0.44**	0.43**	0.24	0.14	0.18	0.23	−0.33*	−0.29*	−0.26	−0.12
Sfat				1.0	0.89**	0.38**	0.22	0.08	0.13	−0.09	−0.27*	−0.04	−0.05
Mufat					1.0	0.36**	0.12	0.13	−0.02	−0.21	−0.25	−0.11	−0.02
Pufat						1.0	0.12	0.50**	0.13	−0.09	−0.27**	−0.04	−0.05
Trfat							1.0	−0.05	0.32*	−0.06	−0.16	−0.18	−0.04
Chol								1.0	0.06	0.09	−0.08	0.09	0.23
Vit A									1.0	−0.12	−0.25	−0.10	0.20
Ca										1.0	0.24	0.37**	−0.13
Fe											1.0	0.61**	0.01
Na												1.0	0.27*
Moist													1.0

**$P < 0.01$, *$P < 0.05$.

[a] Nutrients: Ener = energy, Prot = protein, Tofat = total fat, Sfat = saturated fat, Mufat = monounsaturated fat, Pufat = polyunsaturated fat, Trfat = transfat, Chol = cholesterol, VitA = vitaminA, Ca = calcium, Fe = iron, Na = sodium, Moist = moisture.

Table 3
Principal component (PC) eigen values for the first four components

Principal component	Eigen value	Proportion of total variance (%)	Cumulative variance proportion (%)
PC1	3.23	25.3	25.3
PC2	2.20	17.0	42.3
PC3	1.59	12.2	54.5
PC4	1.22	9.4	63.9
ΣPC5-PC13	5.13	36.1	100

ent energy, total fat saturated fat, monounsaturated fat and polyunsaturated fat as these loadings were higher than the mean absolute loading value in PC1. The second PC contained cholesterol, vitamin A (fat related) and moisture. The loading for polyunsaturated fat was 0.30 in PC2 and 0.31 in PC1, which indicates that this nutrient could be considered in either PC1 or PC2. The minerals Ca, Fe and Na were identified in PC3 as being a linear combination while protein was identified alone in PC4.

4. Discussion

In general the energy, protein, Fe, Na and moisture values reported in our study are similar to other data (Aalhus, Larsen, Robertson, Gibson, & Rutley, 2003; Marchello & Driskell, 2001). However, some of the fat profiles for bison in our study are different to the US studies. For example, Marchello and Driskell (2001) studied the nutrient composition of bison in the clod, ribeye, top round and top sirloin. In our study we included the clod and ribeye which were the same muscle groups studied by Marchello and Driskell (2001). In addition, our study included the eye of the round and sirloin that is anatomically comparable muscle groups to the top round and top sirloin of McClenahan and Driskell (2002). Averaging the total fat between these four cuts, the Canadian bison showed total fat values of 2.1 g/100 g, which is similar to the total fat reported for grain fed bison in the US (Marchello & Driskell, 2001). The proportion of saturated, monounsaturated and poly-

Table 4
Coefficients of the loadings (eigen vectors) for the first four principal components (PC)

Response variables	PC1 (%)	PC2 (%)	PC3 (%)	PC4 (%)
Energy	0.27[a] (8)	−0.52	0.13	0.04
Protein	−0.08	−0.22	0.07	0.47[a] (18)
Total fat	0.41[a] (13)	−0.06	0.04	−0.23
Saturated fat	0.41[a] (13)	0.06	0.37	−0.18
Monounsaturated fat	0.40[a] (12)	0.07	0.36	−0.23
Polyunsaturated fat	0.31[a] (9)	0.30	0.12	0.30
Transfat	0.18	0.02	−0.19	0.02
Cholesterol	0.11	0.33[a] (13)	0.25	0.32
Vitamin A	0.15	0.20[a] (8)	−0.31	−0.03
Calcium	−0.21	−0.06	0.36[a] (12)	0.31
Iron	−0.35	−0.08	0.33[a] (11)	−0.29
Sodium	−0.28	0.17	0.48[a] (15)	−0.16
Moisture	−0.10	0.61[a] (23)	−0.09	−0.02
Total loadings	3.27 = 100	2.65 = 100	3.11 = 100	2.60 = 100

[a] Variables with loadings greater than the mean of the absolute loading value in each PC.

unsaturated fats differ slightly from those reported for US bison (Marchello & Driskell, 2001; McClenahan & Driskell, 2002; Medeiros et al., 2005). Lower cholesterol levels (25.7–51.5 mg/100 g) in the cuts were observed in our study compared to values of (43.8–66 mg/100 g) from bison in the US (Koch et al., 1995; Marchello & Driskell, 2001; Rule et al., 2002). The cholesterol content of lean bison meat in our study was also lower compared to chicken breast (59.3 mg/100 g; Rule et al., 2002), thigh (81 mg/100 g; Buege, Kreul, & Howe, 2001) and the longissimus (58.3 mg/100 g), semitendinosus (63.9 mg/100 g) and triceps brachii (63.7 mg/100 g) in crossbred beef bulls and steers (Eichhorn, Wakayama, Blomquist, & Bailey, 1986). The amounts of cholesterol reported in different studies are dependent on the analytical methods employed (McClenahan & Driskell, 2002) and should be interpreted with caution. The average Ca content in meat cuts in our study was 5.9 mg/100 g which is higher than the average of 4.9 mg/100 g reported for grain fed bison (Marchello et al., 1998) and closer to the value of 5.5 mg/100 g for grass fed bison (Marchello & Driskell, 2001). The Fe content in bison meat in our study was 2.9 mg/100 g compared to 2.6 mg/100 for beef, 1.2 mg/100 g for chicken and 1.0 mg/100 g for pork (Buege et al., 2001). The vitamin A content in all bison cuts in this study ranged from 1.74 to 2.46μg/100 g (Table 1), which was 2–3 times higher than the average value of 0.848μg/100 g reported by Driskell, Yuan, Giraud, Hadley, and Marchello (1997) for the clod, ribeye, top round and top sirloin combined.

Bison bulls were found to contain less Tofat, Sfat, Mufat, Pufat and Chol in the clod and sirloin compared to heifers (Table 1). There is evidence from the literature to show that at the same slaughter age or weight, intact males have less fat than castrates and females, and this is attributed to the hormone testosterone in intact males (Aalhus et al., 2003; Berg & Butterfield, 1976; Butterfield, 1988; Campbell, Johnson, King, & Taverner, 1990; Crews, Shannon, Crews, & Kemp, 2002; Knight, Cosgrove, Death, & Anderson, 1999). Intact male goats were reported to have less cholesterol in the *longissimus dorsi* muscle compared to castrates (Murray & Pratiwi, 2003) and the cholesterol levels in the same muscle were similar in beef steers and heifers (Wheeler, Davis, Stoecker, & Harmon, 1987). Interestingly, although the energy content in the finishing diets for bulls was higher than for heifers, the heifers had higher levels of fat in the meat.

The PCA gives a global representation of the data in a two dimensional plane defined by two or more components in a multivariate type of analysis which the conventional univariate analysis will not reveal (Goonewardene et al., 2004). As each component is both independent and orthogonal, and the correlated traits within each component are identified, it is also more effective than the typical correlation analysis where pairs of variables are compared without taking into account other correlated variables and partial correlations. In a conventional univariate analysis of variance, these data would be analyzed by declaring cuts as independent (fixed) and each trait (Ener, Prot, Tofat, Sfat, Mufat, Pufat, Trfat, Chol, VitA, Ca, Fe, Na, Moist) measured being dependent variables. Such an analysis would identify differences between cuts or gender for each dependent variable separately. In the PC analysis, traits that are associated will be expressed as one group based on their loadings as a single component and the traits included in the second and subsequent components are orthogonal to each other. The PCA is therefore a good choice for grouping and data reduction, and as seen from our results, where a number of possibly similar and/or dissimilar variables are analyzed simultaneously. In our results, the nutrients associated with energy contribution (Ener, Tofat, Sfat, Mufat, Pufat) were described in one component and orthogonal to that were the fat derived or fat soluble nutrients (Vit A and cholesterol), and orthogonal to both previous groups were the minerals (Ca, Fe and Na) and orthogonal to the three previous groups was protein. However, there are times when the PCA approach is used that certain traits will not fit into any of the primary components.

The PCA analysis points out that the association of cholesterol and the total fat and other fat components (Sfat, Mufat,Trfat) is weak. In fact, the only significant ($P < 0.01$) correlation with cholesterol was polyunsaturated fat ($r = 0.50$) (Table 2) but this correlation is not considered high as Pufat accounted for only 25% ($r^2 = 0.50$) of the variation in cholesterol. Although there is literature to support that polyunsaturated fatty acids are associated with lower levels of serum cholesterol (Sabaté et al., 1993), this was not so in bison muscle tissue and the reasons for this are unclear. Also the Pufat had a 0.31 loading in PC1 and a 0.30 loading in PC2 and PC3 (Table 4), which indicated that Pufat could have been included in PC1, PC2 or PC3. The plots of the loadings of PC1 vs. PC2 and PC1 vs. PC3 are shown in Figs. 1 and 2. While PC1 differentiated the fat variables Pufat, Mufat, Sfat, Tofat and Ener, PC2 differentiated Chol and VitA (Fig. 1). In Fig. 2, PC1 differentiated the same fat variables and Ener while PC3 differentiated the minerals Ca, Na and Fe. The score plots (not shown) showed that the variation among heifers with respect to the transformed values of the nutrient variables was greater than in bulls.

As animals grow, develop and mature, changes in the primary tissues muscle, fat and bone occur. The ratios of muscle to fat and bone also change over time (Berg & Butterfield, 1976; Butterfield, 1988). Among the primary tissues muscle, fat and bone, the most variation occurs in fat especially as animals fatten or approach maturity. The composition and amount of fat in bison meat cuts is affected by diet (Marchello & Driskell, 2001; Marchello, Hadely, Slanger, Milne, & Driskell, 1996; Marchello et al., 1998). The fatty acid composition and levels of cholesterol in meat animals has received much interest today due to its implications on human health. Many studies have been undertaken to increase the beneficial fatty acids such as the conjugated linoleic and omega 3 fatty acids by altering animal diets thus adding value to meats (De Smet

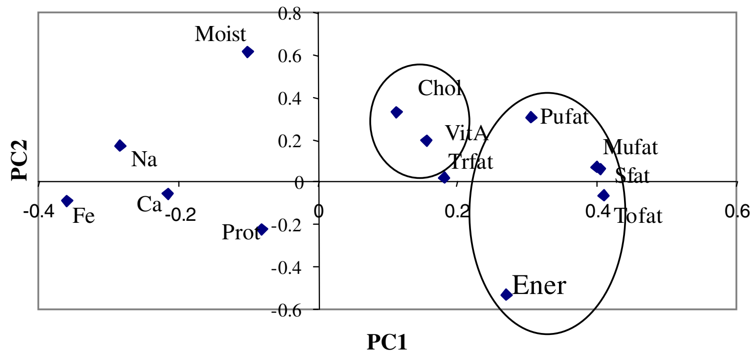

Fig. 1. Score plot PC1 vs. PC2. Ener = energy, Prot = protein, Tofat = total fat, Sfat = saturated fat, Mufat = monounsaturated fat, Pufat = polyunsaturated fat, Trfat = transfat, Chol = cholesterol, VitA = vitaminA, Ca = calcium, Fe = iron, Na = sodium, and Moist = moisture.

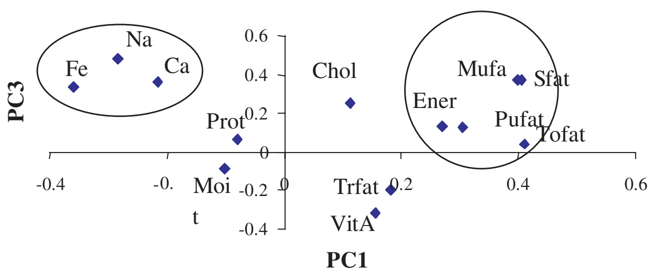

Fig. 2. Loading plot PC1 vs. PC3. Ener = energy, Prot = protein, Tofat = total fat, Sfat = saturated fat, Mufat = monounsaturated fat, Pufat = polyunsaturated fat, Trfat = transfat, Chol = cholesterol, VitA = vitaminA, Ca = calcium, Fe = iron, Na = sodium, and Moist = moisture.

et al., 2004; Mir et al., 2003; Ponnampalam, Sinclair, Hosking, & Egan, 2002). Also, the levels of cholesterol in cows milk, liver, serum and muscle have been altered by dietary manipulation (Muci et al., 1992; Shah & Mir, 2004). Our study shows that as cholesterol in bison meat is not closely associated with total fat, monounsaturated or saturated fat, it is possible to decrease cholesterol by dietary alteration with little change in total, monounsaturated and saturated fat.

5. Conclusions

This research supports the work of others in the US and recognises bison meat to be lean. Bison bulls had higher amounts of total, saturated, monounsaturated and polyunsaturated fat in the blade compared to the other cuts. The sirloins had less cholesterol than all the other cuts in bulls and the clod in heifers. The fat levels varied more across all cuts compared to the levels of protein and moisture. The vitamin A content was similar in all cuts and was between 2 and 2.9 times greater than the reported values for bison meat in the literature. If dietary alterations are made so as to elicit changes in meat fatty acid profiles, it may be possible to reduce cholesterol in bison meat independent of the changes in total, monounsaturated or saturated fat.

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