Comparison of muscle fatty acid profiles and cholesterol concentrations of bison, beef cattle, elk, and chicken[1]

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ABSTRACT: The objective of this study was to compare fatty acid weight percentages and cholesterol concentrations of longissimus dorsi (LD), semitendinosus (ST), and supraspinatus (SS) muscles (n = 10 for each) of range bison (31 mo of age), feedlot-finished bison (18 mo of age), range beef cows (4 to 7 yr of age), feedlot steers (18 mo of age), free-ranging cow elk (3 to 5 yr of age), and chicken breast. Lipids were analyzed by capillary GLC. Total saturated fatty acids (SFA) were greater ($P < 0.01$) in range bison than in feedlot bison and were greater ($P < 0.01$) in SS of range beef cattle than in feedlot steers. Muscles of elk and range bison were similar ($P > 0.05$) in SAT. In LD, polyunsaturated fatty acids (PUFA) were highest ($P < 0.01$) for elk and range bison and lowest ($P < 0.01$) for feedlot steers within each muscle. Range bison and range beef cows had greater ($P < 0.01$) PUFA in LD and ST than feedlot bison or steers, respectively. Range-fed animals had higher ($P < 0.01$) *n*–3 fatty acids than feedlot-fed animals or chicken breast. Chicken breast *n*–6 fatty acids were greater ($P < 0.01$) than for muscles from bison, beef, or elk. Elk had higher ($P < 0.01$) *n*–6 fatty acids than bison or beef cattle; however, range-fed animals had higher ($P < 0.01$) *n*–6 fatty acids than feedlot-fed animals in ST. Conjugated linoleic acid (CLA, 18:2*cis*-9, *trans*-11) in LD was greatest ($P < 0.01$) for range beef cows (0.4%), and lowest for chicken breast and elk (mean = 0.1%). In ST, CLA was greatest ($P < 0.01$) for range and feedlot bison and range beef cows (mean = 0.4%) and lowest for elk and chicken breast (mean = 0.1%). Also, SS CLA was greatest ($P < 0.01$) for range beef cows (0.5%) and lowest for chicken breast (0.1%). Mean total fatty acid concentration (g/100 g tissue) for all muscles was highest ($P < 0.01$) for feedlot bison and feedlot cattle and lowest ($P < 0.01$) for range bison, range beef cows, elk, and chicken. Chicken breast cholesterol (mg/100 g tissue) was higher ($P < 0.01$) than LD and ST cholesterol, which were lowest ($P < 0.01$; 43.8) for range bison and intermediate for the other species. Cholesterol in SS was highest ($P < 0.01$) for feedlot bison and steers, which were similar to chicken breast (mean = 61.2 vs 52.8 for the mean of the other species). We conclude that lipid composition of bison muscle varies with feeding regimen, and range-fed bison had muscle lipid composition similar to that of forage-fed beef cows and wild elk.

Key Words: Feedlots, Lipids, Rangelands

 J. Anim. Sci. 2002. 80:1202–1211

Introduction

Many consumers are interested in alternatives to conventional meat products. Bison (*Bison bison*) consumption in the United States has increased in popularity; currently, there are about 250,000 bison in the United States (National Bison Association, 1998). In addition to cultural interest, bison meat is leaner than beef when both species are reared similarly (Koch et al., 1995), potentially enhancing the perception that consuming bison meat may be more healthful than consuming beef. Towle et al. (1994) reported a 5.6% increase ($P < 0.02$) in serum low-density lipoprotein (**LDL**) cholesterol in 12 human subjects who consumed 227 g/d of 12 to 13% fat ground beef; however, no increase in LDL-cholesterol was observed when subjects consumed ground meat from a beef × bison cross that contained the same total fat concentration. Several studies have reported the nutrient composition of bison meat (Marchello et al., 1989; Driskell et al., 1997; Driskell et al., 2000), as well as its fatty acid profile.

[1]Research was funded under project # WYO 319-98, Wyoming Agric. Exp. Sta. Authors thank Eldon Handrich of the Prairie Monarch Bison Ranch, Bob Dineen of Rocky Mountain Natural Foods, and the Wyoming Game and Fish Department, Pinedale, WY for providing muscles from bison and elk. We also thank James Kaltenbach for expert technical assistance.

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Received August 14, 2001.

Accepted December 10, 2001.

In addition to the leanness of bison meat, which may be its most salient feature, the presence of *n*–3 and *n*–6 fatty acids, as well as conjugated linoleic acid (**CLA**), may contribute to the nutritional quality of bison meat. Consumption of CLA by laboratory animals is associated with several health benefits (Pariza, 1999), and *n*–3 fatty acids reduce serum triacylglycerols in humans (Harris, 1997). Presently, however, data for *n*–3 PUFA and CLA in bison meat are lacking. Furthermore, comparisons of bison meat from animals finished in a feedlot with those raised on range are lacking. Thus, comparison of bison meat with meat of other species known to be lean, such as elk, chicken breast, and range cows, is warranted. Therefore, our objective was to compare fatty acid profiles and cholesterol concentrations of longissimus dorsi (**LD**), semitendinosus (**ST**), and supraspinatus (**SS**) muscles of range bison, feedlot-finished bison, range beef cows, feedlot steers, free-ranging cow elk, and chicken breast.

Materials and Methods

Animals and Tissues

Samples of LD (12th rib), ST, and SS were obtained from 10 animals of each of the following species: range-raised bison bulls (31 mo of age), feedlot-finished bison bulls (18 mo of age), range/pasture-fed beef cows (4 to 7 yr old), feedlot-fed crossbred steers (18 mo of age), and free-ranging cow elk (3 to 5 yr old). Poultry samples were obtained from chicken breasts (skin-off) of commercially produced animals, purchased from a local grocery store. Free-ranging elk were harvested in northwest Wyoming by Wyoming Game and Fish Department representatives. The range-raised bison were obtained from a local bison producer (Prairie Monarch Bison Ranch, Laramie, WY) that raises bison exclusively on forage. Range-fed bison were stunned and exsanguinated on location then transported (20 min) to the University of Wyoming abattoir for the remainder of processing. Muscle samples from the feedlot-finished bison were harvested from a commercial bison processing facility (Rocky Mountain Natural Foods, Denver, CO). Feedlot-finished bison are typically placed into the feedlot at 12 mo of age and fed high-grain diets for 6 mo prior to harvest. The feedlot steers were fed a corn-based, high-energy diet for 6 mo and harvested at the University of Wyoming abattoir. The range-fed beef cows were crossbreds obtained from a local rancher, and harvested at the University of Wyoming abattoir as part of a separate project. All muscle samples, except those obtained from the commercial facility, were dissected 48 h postmortem. Feedlot-finished bison muscle samples were obtained when those carcasses were fabricated.

Fatty Acid and Cholesterol Analysis

Muscle samples were freeze-dried and then ground and homogenized using a home-style coffee grinder. One hundred milligrams was then subjected to direct saponification at 90°C with 4.0 mL of 1.18 *M* KOH in ethanol in 16- × 125-mm screw-cap culture tubes. Stigmasterol (Matreya, Pleasant Gap, PA), 0.2 mg, was used as internal standard for cholesterol assay. Nonsaponifiable materials were extracted in hexane and transferred to vials and sealed for analysis of cholesterol by GLC.

The original tubes were acidified with 1.0 mL of concentrated HCl and fatty acids extracted with hexane and transferred to clean tubes. Hexane was evaporated under N_2 and fatty acid methyl esters were prepared with 4.0 mL of 0.545 *M* HCl in methanol for 1 h at 80°C. Fatty acid methyl esters were extracted with 3.0 mL of hexane and transferred into vials and sealed for GLC analysis. Tridecanoic acid (13:0, 1.0 mg) was used as fatty acid internal standard.

Cholesterol was quantified by GLC as described by Rule et al. (1997). Fatty acids were determined by GLC using a 100-m capillary column (SP 2560, Supelco, Bellefonte, PA) with a split ratio of 100:1 and He as carrier gas for a column flow rate of 1.0 mL/min. Injector and detector temperatures were 250°C and column temperature was ramped from 140° to 240°C at 3.5°C/min.

Statistical Analysis

Inherent to the study, species varied in age and dietary regimen. However, within each species, these parameters are used for normal production. The present study was predicated on the hypothesis that each type of product was different in fatty acid composition and cholesterol content. Therefore, within a muscle type, each species was compared to the other by one-way ANOVA. For significant *F*-statistics, Duncan's New Multiple Range Test (Steele and Torrie, 1980) was used to determine species/regimen differences. Poultry was included in each muscle comparison, even though chicken breast was the only poultry muscle type used. Statistical analysis was conducted using SAS software for all computations (SAS Inst. Inc., Cary, NC).

Results and Discussion

C14 and C15 Fatty Acids

Weight percentages of all fatty acids are shown in Tables 1, 2, and 3 for LD, ST, and SS, respectively. Elk had the highest ($P < 0.01$) weight percentage of 14:0 for each muscle, although in ST 14:0 was not different ($P > 0.05$) from that in feedlot steers. For feedlot steers, 14:0 was greater ($P < 0.01$) than that for range beef cows in LD and SS, but not in ST ($P > 0.05$). Bison had lower numerical values for 14:0 than the other species, but generally values were not different ($P > 0.05$) from those of range beef cows for any of the muscles tested. No 14:1*cis*-9 was detected in LD

or ST of range bison, elk, or chicken breast; however, for elk, 14:1*cis*-9 was detected only in SS. When detected, 14:1*cis*-9 was generally similar ($P > 0.05$) among species.

Weight percentages of 15:0 were highest ($P < 0.01$) in elk for each muscle. Within bison, 15:0 was higher ($P < 0.01$) for range compared with feedlot animals in LD and ST, but not in SS. Within beef animals, a pattern similar to that of bison was observed for 15:0, but this fatty acid was greater ($P < 0.01$) in LD of range beef cows than in feedlot steers. Of the 15:0 branched fatty acids identified, iso-15:0 was highest ($P < 0.01$) for range bison within each muscle tested and range beef cows had higher ($P < 0.01$) iso-15:0 than feedlot

Table 1. Weight percentage of fatty acids[a] and concentrations of cholesterol and total fatty acids in longissmus dorsi muscle of bison, beef cattle, and elk and in chicken breast

	Bison		Beef cattle				
Fatty acid[b]	Range	Feedlot	Range	Feedlot	Elk	Chicken breast	SEM (n = 10)
14:0	1.58^{e}	1.47^{e}	2.03^{e}	2.66^{d}	3.84^{c}	0.48^{f}	0.20
14:1*cis*-9	0.00^{f}	0.18^{e}	0.60^{c}	0.39^{d}	0.00^{f}	0.00^{f}	0.05
$_{i}$15:0	0.27^{c}	0.01^{f}	0.19^{d}	0.04^{f}	0.03^{f}	0.09^{e}	0.02
$_{a}$15:0	0.00^{d}	0.00^{d}	0.12^{d}	0.03^{d}	0.31^{c}	0.00^{d}	0.06
15:0	3.61^{c}	2.25^{d}	1.54^{d}	0.42^{e}	4.05^{c}	2.48^{d}	0.36
$_{i}$16:0	0.02^{de}	0.14^{c}	0.16^{c}	0.10^{cd}	0.18^{c}	0.00^{e}	0.03
16:0	17.2^{e}	18.0^{e}	22.2^{cd}	25.8^{c}	23.8^{cd}	21.8^{d}	0.97
16:1*cis*-9	2.58^{e}	3.08^{de}	2.67^{e}	3.75^{de}	10.9^{c}	5.30^{d}	0.71
$_{i}$17:0	0.70^{c}	0.30^{d}	0.56^{c}	0.26^{d}	0.23^{d}	0.21^{d}	0.07
17:0	1.31^{d}	2.19^{c}	1.32^{d}	1.20^{d}	0.50^{e}	0.04^{f}	0.09
17:1*cis*-9	1.22^{d}	2.26^{c}	1.26^{d}	1.05^{d}	0.42^{f}	0.74^{e}	0.09
18:0	16.8^{c}	12.6^{d}	13.4^{d}	13.5^{d}	8.75^{e}	8.83^{e}	0.53
18:1*trans*	0.16^{d}	0.01^{e}	0.14^{d}	0.01^{e}	0.29^{c}	0.36^{c}	0.05
18:1*cis*-9	30.7^{e}	43.3^{c}	37.5^{d}	40.4^{cd}	12.9^{f}	28.1^{e}	1.52
18:1*cis*-11	0.47^{e}	0.00^{e}	0.37^{e}	0.00^{e}	5.72^{c}	2.55^{d}	0.20
18:2*cis*-9,12	7.81^{de}	6.75^{e}	4.10^{f}	3.11^{f}	10.1^{d}	17.0^{c}	0.83
18:2*cis*-9, *trans*-11	0.34^{d}	0.28^{e}	0.41^{c}	0.26^{e}	0.10^{f}	0.07^{f}	0.02
18:2*trans*-10, *cis*-12	0.02^{d}	0.01^{f}	0.12^{c}	0.01^{de}	0.03^{de}	0.00^{f}	0.01
18:2*cis*-10,12	0.07^{cde}	0.04^{e}	0.10^{c}	0.04^{e}	0.06^{de}	0.09^{cd}	0.01
18:3*cis*-6,9,12	0.00^{e}	0.00^{e}	0.18^{c}	0.00^{e}	0.02^{d}	0.00^{e}	0.003
18:3*cis*-9,12,15	2.81^{c}	0.41^{f}	1.48^{e}	0.22^{f}	2.13^{d}	0.45^{f}	0.17
18:4*cis*-6,9,12,15	0.18^{c}	0.08^{d}	0.10^{d}	0.05^{e}	0.10^{d}	0.16^{c}	0.01
20:1*cis*-11	0.00^{d}	0.00^{d}	0.14^{c}	0.00^{d}	0.00^{d}	0.00^{d}	0.01
20:2*cis*-11,14	0.14^{d}	0.06^{e}	0.07^{e}	0.05^{e}	0.07^{e}	0.36^{c}	0.01
20:3*cis*-8,11,14	0.07^{e}	0.05^{e}	0.09^{de}	0.02^{f}	0.11^{d}	0.16^{c}	0.01
20:4*cis*-5,8,11,14	2.46^{d}	1.86^{de}	1.47^{ef}	0.79^{f}	3.82^{c}	4.69^{c}	0.29
20:5*cis*-5,8,11,14,17	1.07^{d}	0.40^{ef}	0.62^{e}	0.13^{f}	1.44^{c}	0.18^{f}	0.12
22:0	0.24^{d}	0.10^{e}	0.19^{d}	0.08^{e}	0.20^{d}	0.56^{c}	0.03
22:1*cis*-13	0.34^{e}	0.22^{e}	0.39^{de}	0.24^{e}	0.57^{d}	1.19^{c}	0.06
22:2*cis*-13,16	0.10^{d}	0.00^{e}	0.20^{c}	0.02^{e}	0.10^{d}	0.00^{e}	0.01
22:4*cis*-7,10,13,16	0.12^{d}	0.11^{d}	0.07^{d}	0.10^{d}	0.09^{d}	1.05^{c}	0.03
22:5*cis*-7,10,13,16,19	1.25^{c}	0.53^{de}	0.71^{d}	0.26^{e}	1.31^{c}	0.31^{e}	0.10
22:6*cis*-4,7,10,13,16,19	0.23^{c}	0.18^{d}	0.09^{e}	0.04^{f}	0.11^{e}	0.26^{c}	0.01
24:0	0.04^{d}	0.01^{e}	0.01^{e}	0.01^{e}	0.01^{e}	0.15^{c}	0.01
Unknown-<C16	1.94^{d}	0.53^{e}	0.74^{de}	0.33^{e}	3.75^{c}	0.05^{e}	0.40
Unknown-C16-18	2.26^{d}	1.16^{e}	3.17^{c}	0.41^{f}	2.39^{d}	1.00^{e}	0.17
Unknown->C18	1.97	1.44	1.52	4.25	1.70	1.24	1.24
SFA	41.7^{c}	37.0^{d}	41.7^{c}	44.0^{c}	41.9^{c}	34.7^{d}	1.00
PUFA	16.5^{d}	10.7^{e}	9.53^{ef}	5.04^{f}	19.4^{d}	24.6^{c}	1.43
P/S	0.40^{de}	0.29^{ef}	0.23^{fg}	0.12^{g}	0.49^{d}	0.71^{c}	0.05
$n - 3$	5.35^{c}	1.51^{e}	2.90^{d}	0.64^{e}	5.00^{c}	1.19^{e}	0.38
$n - 6$	10.3^{e}	8.66^{ef}	5.66^{fg}	3.92^{g}	14.0^{d}	21.9^{c}	1.08
$n - 6/n - 3$	1.94^{e}	5.73^{d}	1.95^{e}	6.38^{d}	2.84^{e}	18.5^{c}	0.35
Total fatty acids, mg/100 g	11.1^{e}	20.7^{d}	10.7^{e}	28.8^{c}	8.05^{e}	7.94^{e}	1.90
Cholesterol, mg/100 g	43.8^{e}	54.1^{d}	52.3^{d}	52.7^{d}	50.2^{d}	59.3^{c}	1.23

[a]Weight percentage values are relative proportions of all peaks observed by GLC.

[b]Fatty acids are represented as number of carbon atoms:number of carbon–carbon double bonds. Unknowns were peaks presumed to be fatty acids of the carbon lengths indicated based on retention times relative to known fatty acids. P/S ratio is the ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA). $n - 3$ fatty acids included 18:3*cis*-9,12,15, 20:5*cis*-5,8,11,14,17, 22:5*cis*-7,10,13,16,19, and 22:6*cis*-4,7,10,13,16,19, and $n - 6$ fatty acids included 18:2*cis*-9,12, 20:3*cis*-8,11,14, and 20:4*cis*-5,8,11,14.

[c,d,e,f,g]Means in a row with different superscripts are different ($P < 0.01$).

steers in LD and SS, but not in ST. Anti-iso-15:0 was detected or not detected in each muscle of each species except the LD of elk and range beef cows.

Weight percentages of 14:0 and 14:1*cis*-9 in the feedlot bison muscles were comparable to values reported for the LD of bison, primarily from feedlot-fed animals (Larick et al., 1989; Marchello et al., 1989). For beef samples, 14:0 weight percentages were similar to values reported previously in feedlot-fed cattle (Rule et al., 1997) and to weight percentages calculated from data reported for grass-fed cattle (Larick and Turner, 1989). In elk, 14:0 values were comparable to those reported by Cordain et al. (2001); however, we detected little, or no, 14:1*cis*-9, whereas Cordain et al. (2001) reported 1.2 wt% of this fatty acid in biceps femoris of free-ranging elk.

Table 2. Weight percentage of fatty acids[a] and concentrations of cholesterol and total fatty acids in semitendinosus muscle of bison, beef cattle, and elk and in chicken breast

	Bison		Beef cattle				
Fatty acid[b]	Range	Feedlot	Range	Feedlot	Elk	Chicken breast	SEM (n = 10)
14:0	1.44^{e}	1.48^{e}	1.97^{de}	2.52^{cd}	3.06^{c}	0.48^{f}	0.19
14:1*cis*-9	0.00^{e}	0.51^{d}	0.66^{c}	0.44^{d}	0.00^{e}	0.00^{e}	0.06
$_{i}$15:0	0.22^{c}	0.03^{d}	0.06^{d}	0.05^{d}	0.02^{d}	0.09^{d}	0.02
$_{a}$15:0	0.00^{d}	0.02^{d}	0.02^{d}	0.06^{d}	0.49^{c}	0.00^{d}	0.05
15:0	3.71^{d}	1.71^{ef}	1.50^{ef}	0.69^{f}	5.87^{c}	2.48^{e}	0.29
$_{i}$16:0	0.08^{de}	0.10^{d}	0.03^{de}	0.09^{de}	0.21^{c}	0.00^{e}	0.02
16:0	16.3^{f}	18.1^{ef}	21.9^{d}	25.0^{c}	19.8^{de}	21.8^{d}	0.68
16:1*cis*-9	2.91^{d}	4.39^{d}	5.39^{d}	3.99^{d}	11.5^{c}	5.30^{d}	0.75
$_{i}$17:0	0.70^{c}	0.39^{d}	0.26^{e}	0.32^{de}	0.22^{e}	0.21^{e}	0.03
17:0	1.17^{d}	1.97^{c}	1.18^{d}	1.30^{d}	0.46^{e}	0.04^{f}	0.06
17:1*cis*-9	1.20^{d}	2.59^{c}	2.63^{c}	1.23^{d}	0.46^{e}	0.74^{e}	0.10
18:0	14.2^{c}	9.74^{e}	12.8^{cd}	11.9^{d}	8.94^{e}	8.83^{e}	0.49
18:1*trans*	0.52^{c}	0.01^{d}	0.36^{c}	0.01^{d}	0.45^{c}	0.36^{c}	0.09
18:1*cis*-9	29.0^{d}	45.6^{c}	28.5^{d}	43.3^{c}	12.6^{e}	28.1^{d}	1.02
18:1*cis*-11	0.93^{e}	0.00^{e}	0.73^{e}	0.00^{e}	6.86^{c}	2.55^{d}	0.31
18:2*cis*-9,12	8.32^{de}	5.57^{ef}	6.07^{e}	3.52^{f}	10.8^{d}	17.0^{c}	0.65
18:2*cis*-9, *trans*-11	0.39^{c}	0.37^{cd}	0.32^{cd}	0.28^{d}	0.10^{e}	0.07^{e}	0.02
18:2*trans*-10 *cis*-12	0.03^{c}	0.03^{cd}	0.03^{cd}	0.01^{cd}	0.03^{c}	0.00^{d}	0.01
18:2*cis*-10,12	0.07^{cd}	0.05^{cd}	0.07^{cd}	0.04^{d}	0.06^{cd}	0.09^{c}	0.01
18:3*cis*-6,9,12	0.00^{d}	0.01^{d}	0.10^{c}	0.00^{d}	0.01^{d}	0.00^{d}	0.00
18:3*cis*-9,12,15	3.01^{c}	0.39^{e}	1.72^{d}	0.30^{e}	3.31^{c}	0.45^{e}	0.17
18:4*cis*-6,9,12,15	0.18^{c}	0.08^{e}	0.12^{d}	0.05^{e}	0.12^{d}	0.16^{c}	0.01
20:1*cis*-11	0.00^{d}	0.00^{d}	0.11^{c}	0.00^{d}	0.00^{d}	0.00^{d}	0.00
20:2*cis*-11,14	0.17^{d}	0.07^{e}	0.09^{e}	0.06^{e}	0.06^{e}	0.36^{c}	0.01
20:3*cis*-8,11,14	0.10^{de}	0.06^{ef}	0.06^{ef}	0.02^{f}	0.12^{d}	0.16^{c}	0.01
20:4*cis*-5,8,11,14	3.57^{de}	1.97^{e}	3.04^{e}	1.08^{f}	4.59^{cd}	4.69^{c}	0.26
20:5*cis*-5,8,11,14,17	1.68^{c}	0.50^{e}	1.22^{d}	0.22^{e}	1.50^{cd}	0.18^{e}	0.09
22:0	0.27^{d}	0.10^{e}	0.20^{d}	0.10^{e}	0.22^{d}	0.56^{c}	0.02
22:1*cis*-13	0.53^{d}	0.23^{c}	0.66^{d}	0.31^{e}	0.59^{d}	1.20^{c}	0.05
22:2*cis*-13,16	0.15^{d}	0.01^{f}	0.27^{c}	0.03^{f}	0.11^{e}	0.00^{f}	0.01
22:4*cis*-7,10,13,16	0.17^{d}	0.11^{d}	0.11^{d}	0.12^{d}	0.10^{d}	1.05^{c}	0.03
22:5*cis*-7,10,13,16,19	1.96^{c}	0.59^{e}	1.23^{d}	0.37^{e}	1.42^{d}	0.31^{e}	0.07
22:6*cis*-4,7,10,13,16,19	0.27^{c}	0.22^{c}	0.14^{d}	0.06^{e}	0.13^{d}	0.26^{c}	0.02
24:0	0.04^{d}	0.02^{e}	0.02^{e}	0.00^{e}	0.00^{e}	0.15^{c}	0.00
Unknown-<C16	2.20^{c}	0.45^{cd}	1.94^{d}	0.37^{de}	2.60^{c}	0.05^{e}	0.21
Unknown-C16-18	2.41^{d}	0.82^{e}	3.38^{c}	0.54^{e}	2.51^{d}	1.00^{e}	0.18
Unknown->C18	2.03^{c}	1.76^{c}	1.07^{d}	1.67^{c}	1.72^{c}	1.24^{d}	0.10
SFA	38.1^{d}	33.6^{e}	39.9^{cd}	42.0^{c}	39.3^{d}	34.7^{e}	0.64
PUFA	19.9^{c}	9.96^{de}	14.4^{d}	6.11^{e}	21.3^{c}	24.6^{c}	1.32
P/S	0.52^{d}	0.30^{e}	0.36^{e}	0.15^{f}	0.54^{d}	0.71^{c}	0.03
n – 3	6.92^{c}	1.70^{e}	4.31^{d}	0.95^{e}	5.35^{d}	1.19^{e}	0.35
n – 6	12.0^{e}	7.62^{fg}	9.17^{ef}	4.62^{g}	15.5^{d}	21.9^{c}	1.00
n – 6/n – 3	1.73^{f}	4.43^{d}	2.22^{ef}	4.89^{d}	2.93^{e}	18.5^{c}	0.28
Total fatty acids, mg/100 g	9.64^{d}	25.2^{c}	8.21^{d}	22.9^{c}	7.35^{d}	7.94^{d}	1.80
Cholesterol, mg/100 g	45.8^{f}	51.0^{de}	48.7^{ef}	53.4^{d}	52.1^{de}	59.3^{c}	1.02

[a]Weight percentage values are relative proportions of all peaks observed by GLC.

[b]Fatty acids are represented as number of carbon atoms:number of carbon–carbon double bonds. Unknowns were peaks presumed to be fatty acids of the carbon lengths indicated based on retention times relative to known fatty acids. P/S ratio is the ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA). n – 3 fatty acids included 18:3*cis*-9,12,15, 20:5*cis*-5,8,11,14,17, 22:5*cis*-7,10,13,16,19, and 22:6*cis*-4,7,10,13,16,19, and n – 6 fatty acids included 18:2*cis*-9,12, 20:3*cis*-8,11,14, and 20:4*cis*-5,8,11,14.

[c,d,e,f,g]Means in a row with different superscripts are different ($P < 0.01$).

C16 and C17 Fatty Acids

Iso-16:0 was observed in all muscles analyzed of each species except for chicken breast, and iso-17:0 was observed in all samples tested. In LD, 16:0 was higher ($P < 0.01$) for feedlot steers than for bison or chicken breast but was similar to that in range beef cows and elk. In ST 16:0 was highest ($P < 0.01$) for feedlot steers, whereas the LD of range beef cows, elk, and chicken breast had similar weight percentages of this fatty acid. In SS, 16:0 was lower ($P < 0.01$) for bison and range beef cows than for feedlot steers, elk, or chicken breast. The desaturation product of 16:0, 16:1*cis*-9, was highest ($P < 0.01$) for elk in each muscle tested as well as compared with chicken breast, which was generally higher than 16:1*cis*-9 in LD of the other non-elk species. In ST 16:1*cis*-9 was numerically lower for range bison compared with the other species and

Table 3. Weight percentage of fatty acids[a] and concentrations of cholesterol and total fatty acids in supraspinatus muscle of bison, beef cattle, and elk and in chicken breast

	Bison		Beef cattle				
Fatty acid[b]	Range	Feedlot	Range	Feedlot	Elk	Chicken breast	SEM (n = 10)
14:0	1.56^{ef}	1.28^{f}	1.84^{e}	2.33^{d}	3.34^{c}	0.48^{g}	0.15
14:1*cis*-9	0.00^{d}	0.43^{d}	0.41^{c}	0.42^{d}	0.24^{d}	0.00^{d}	0.13
$_{i}$15:0	0.32^{c}	0.04^{e}	0.18^{d}	0.05^{e}	0.11^{de}	0.09^{de}	0.03
$_{a}$15:0	0.09^{d}	0.00^{d}	0.00^{d}	0.08^{d}	0.43^{c}	0.00^{d}	0.05
15:0	2.45^{d}	2.20^{d}	0.41^{e}	1.06^{e}	4.77^{c}	2.48^{d}	0.29
$_{i}$16:0	0.11^{d}	0.09^{de}	0.31^{c}	0.18^{d}	0.14^{d}	0.00^{e}	0.03
16:0	16.8^{d}	15.7^{d}	17.6^{d}	22.4^{c}	20.9^{c}	21.8^{c}	0.72
16:1*cis*-9	2.81^{e}	2.95^{e}	2.78^{e}	3.34^{de}	9.77^{c}	5.30^{d}	0.63
$_{i}$17:0	0.87^{c}	0.33^{d}	0.13^{e}	0.32^{d}	0.33^{d}	0.21^{e}	0.03
17:0	1.39^{d}	1.94^{c}	1.45^{d}	1.35^{d}	0.64^{e}	0.41^{f}	0.15
17:1*cis*-9	1.33^{de}	2.53^{c}	1.57^{d}	1.22^{e}	0.52^{f}	0.74^{f}	0.08
18:0	18.8^{c}	13.0^{d}	13.4^{d}	13.1^{d}	11.2^{e}	8.83^{f}	0.58
18:1*trans*	0.00^{d}	0.00^{d}	0.02^{d}	1.14^{c}	0.36^{cd}	0.36^{cd}	0.41
18:1*cis*-9	31.7^{e}	44.1^{c}	35.8^{d}	41.8^{c}	16.6^{g}	28.1^{f}	1.11
18:1*cis*-11	0.00^{e}	0.00^{e}	0.76^{e}	0.00^{e}	4.58^{c}	2.55^{d}	0.23
18:2*cis*-9,12	7.81^{de}	7.78^{de}	5.59^{ef}	4.44^{f}	9.63^{d}	17.0^{c}	0.68
18:2*cis*-9, *trans*-11	0.42^{d}	0.31^{e}	0.52^{c}	0.31^{e}	0.19^{f}	0.07^{g}	0.02
18:2*trans*-10, *cis*-10	0.06^{c}	0.01^{e}	0.04^{cd}	0.01^{e}	0.03^{d}	0.00^{e}	0.01
18:2*cis*-10,12	0.03	0.04	0.11	0.02	1.86	0.09	0.86
18:3*cis*-6,9,12	0.00^{d}	0.00^{d}	0.11^{c}	0.00^{d}	0.22^{d}	0.00^{d}	0.01
18:3*cis*-9,12,15	2.80^{c}	0.43^{e}	1.94^{d}	0.33^{e}	2.32^{cd}	0.45^{e}	0.16
18:4*cis*-6,9,12,15	0.16^{c}	0.08^{de}	0.10^{d}	0.05^{e}	0.09^{d}	0.16^{c}	0.01
20:1*cis*-11	0.00^{d}	0.00^{d}	0.15^{c}	0.00^{d}	0.00^{d}	0.00^{d}	0.004
20:2*cis*-11,14	0.09^{d}	0.07^{d}	0.08^{d}	0.07^{d}	0.07^{d}	0.36^{c}	0.01
20:3*cis*-8,11,14	0.06^{e}	0.06^{e}	0.03^{e}	0.03^{e}	0.09^{d}	0.16^{c}	0.01
20:4*cis*-5,8,11,14	2.10^{e}	2.09^{e}	1.85^{e}	1.22^{e}	3.40^{d}	4.69^{c}	0.28
20:5*cis*-5,8,11,14,17	0.77^{c}	0.28^{d}	0.72^{c}	0.16^{d}	0.71^{c}	0.18^{d}	0.07
22.0	0.19^{de}	0.11^{e}	0.20^{d}	0.11^{e}	0.22^{b}	0.56^{a}	0.03
22:1*cis*-13	0.26^{e}	0.21^{e}	0.51^{d}	0.37^{de}	0.39^{de}	1.19^{c}	0.06
22:2*cis*-13,16	0.08^{d}	0.00^{e}	0.26^{c}	0.03^{e}	0.09^{d}	0.00^{e}	0.01
22:4*cis*-7,10,13,16	0.93^{d}	0.11^{d}	0.08^{d}	0.19^{d}	0.09^{d}	1.05^{c}	0.04
22:5*cis*-7,10,13,16,19	1.10^{de}	0.47^{e}	0.88^{d}	0.39^{e}	1.16^{c}	0.31^{e}	0.08
22:6*cis*-4,7,10,13,16,19	0.19^{d}	0.20^{d}	0.10^{e}	0.05^{e}	0.09^{e}	0.26^{c}	0.02
24:0	0.04^{d}	0.01^{e}	0.02^{de}	0.01^{e}	0.02^{de}	0.15^{c}	0.01
Unknown-<C16	1.96^{c}	0.31^{e}	1.39^{d}	0.32^{e}	1.76^{cd}	0.05^{e}	0.15
Unknown-C16-18	1.03^{d}	1.42^{d}	7.24^{c}	1.43^{d}	2.11^{d}	1.00^{d}	0.33
Unknown->C18	2.05^{c}	1.46^{de}	1.48^{de}	1.70^{cd}	1.85^{cd}	1.24^{e}	0.13
SFA	42.6^{c}	34.7^{d}	35.5^{d}	41.0^{c}	42.0^{c}	34.7^{d}	0.86
PUFA	15.5^{e}	11.8^{e}	12.2^{e}	7.24^{f}	19.7^{d}	24.6^{c}	1.19
P/S	0.37^{e}	0.34^{e}	0.35^{e}	0.18^{f}	0.49^{d}	0.71^{c}	0.04
n – 3	4.77^{c}	1.37^{e}	3.63^{d}	0.93^{e}	4.27^{cd}	1.19^{e}	0.30
n – 6	9.97^{e}	9.93^{e}	7.47^{ef}	5.69^{f}	13.11^{d}	21.87^{c}	0.91
n – 6/*n* – 3	2.09^{e}	7.22^{d}	2.13^{e}	6.28^{d}	3.14^{e}	18.5^{c}	0.36
Total fatty acids, mg/100 g	21.2^{de}	29.2^{c}	13.8^{ef}	26.6^{cd}	10.4^{f}	7.94^{f}	2.10
Cholesterol, mg/100 g	54.6^{d}	62.8^{c}	52.7^{d}	61.4^{c}	51.2^{d}	59.3^{c}	1.28

[a]Weight percentage values are relative proportions of all peaks observed by GLC.

[b]Fatty acids are represented as number of carbon atoms:number of carbon–carbon double bonds. Unknowns were peaks presumed to be fatty acids of the carbon lengths indicated based on retention times relative to known fatty acids. P/S ratio is the ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA). *n* – 3 fatty acids included 18:3*cis*-9,12,15, 20:5*cis*-5,8,11,14,17, 22:5*cis*-7,10,13,16,19, and 22:6*cis*-4,7,10,13,16,19, and *n* – 6 fatty acids included 18:2*cis*-9,12, 20:3*cis*-8,11,14, and 20:4*cis*-5,8,11,14.

chicken breast, but differences were not significant ($P > 0.05$). In SS, 16:1*cis*-9 was generally lowest for bison and beef. In each muscle 17:0 and 17:1*cis*-9 were lower ($P < 0.01$) for chicken breast and elk than for the other species.

Results of the present study in which 16:0 in bison was lower ($P < 0.01$) than 16:0 in beef cattle LD were consistent with results reported by Marchello et al. (1989). However, 16:0 in elk muscle was higher in the present study compared with values reported by Cordain et al. (2001), in which 16:0 was 16.4% in biceps femoris muscle. Marchello et al. (1989) reported lower 16:1*cis*-9 in bison LD than in beef cattle LD, whereas we did not observe a difference in 16:1*cis*-9 in LD of beef cattle and bison in the present study. Values for 17:0 reported by Cordain et al. (2001) were similar to those observed in the present study.

C18 Saturated and Monoenoic Fatty Acids

In LD and SS, 18:0 was highest ($P < 0.01$) for range bison, intermediate ($P < 0.01$) for feedlot bison and beef cattle, and lowest ($P < 0.01$) for elk and chicken breast. In ST, 18:0 was also greater ($P < 0.01$) for range bison than for feedlot bison, feedlot steers, elk, and chicken breast but was similar ($P > 0.05$) in 18:0 for range beef cows. In ST, elk and feedlot bison had a similar ($P > 0.05$) weight percentage of 18:0. Elk LD and ST weight percentages of 18:0 were similar ($P > 0.05$) to that of chicken breast, but 18:0 in elk SS was greater ($P < 0.01$) than that in chicken breast. Differences in 16:0 and 18:0 between bison and cattle were consistent with previous observations (Larick et al., 1989; Marchello et al., 1989).

Weight percentages of 18:1*trans* isomers in LD were similar ($P > 0.05$) for range bison and range beef cows, both of which were higher ($P < 0.01$) than 18:1*trans* for feedlot bison and steers. Elk LD had higher ($P < 0.01$) 18:1*trans* than LD of the other species but was similar ($P > 0.05$) to 18:1*trans* in chicken breast.

Feedlot steers and feedlot bison had the highest ($P < 0.01$) 18:1*cis*-9 (oleic acid) in LD, ST, and SS, whereas elk had the lowest ($P < 0.01$) 18:1*cis*-9 in each muscle. For 18:1*cis*-11, however, weight percentages ranged from 0.00 for feedlot bison and steers to 0.93 for range bison in all muscles, whereas elk had 5.72, 6.86, and 4.58% of this fatty acid in LD, ST, and SS, respectively. Cordain et al. (2001) reported 6.06% 18:1*cis*-11 in biceps femoris of elk, as well as lower ($P < 0.05$) 18:0 and 18:1*cis*-9 for elk than for deer or pronghorn antelope in biceps femoris; however, 18:1*cis*-11 was two- to fivefold lower for the latter two species compared with elk. In the present study, chicken breast had about half ($P < 0.01$) the weight percentage of 18:1*cis*-11 that was observed for elk.

In each muscle, elk had the highest ($P < 0.01$) weight percentage of 16:1*cis*-9 and 18:1*cis*-11 but the lowest ($P < 0.01$) weight percentage of 18:1*cis*-9. Both 16:1*cis*-9 and 18:1*cis*-9 are desaturation products of 16:0 and 18:0, respectively, and occur through activity of stearoyl-CoA (Δ^9) desaturase (Kim and Ntambi, 1999). The greater weight percentage of 16:1*cis*-9 of elk compared with the other species studied suggests that stearoyl-CoA desaturase may prefer 16:0 over 18:0 as substrate in elk. Biohydrogenation of dietary 18:2*cis*-9,12 and 18:2*cis*-9,12,15 by R 7/5 Gram-negative rod bacteria produces 18:1*cis*-11 (Hazelwood et al., 1976). The greater weight percentage of 18:1*cis*-11 in the elk muscles of the present study suggests that the ruminal ecology of this species may be markedly different from that of bison or beef cattle.

C18 Diunsaturated, Conjugated Linoleic Acid, and Polyunsaturated Fatty Acids

Weight percentages of 18:2*cis*-9,12 (linoleic acid) were lower ($P < 0.01$) for range and feedlot cattle than for bison in LD. In ST, 18:2*cis*-9,12 was greater ($P < 0.01$) for range beef cows than for feedlot steers but was similar ($P > 0.05$) for range bison, feedlot bison, and range beef cows; a similar trend was observed for 18:2*cis*-9,12 in SS, except range and feedlot cattle were not different ($P > 0.05$). Except for range bison SS, elk generally had higher 18:2*cis*-9,12 in each muscle. In contrast, chicken breast 18:2*cis*-9,12 was higher ($P < 0.01$) than that of the ruminant species because of the lack of ruminal biohydrogenation of dietary 18:2*cis*-9,12; poultry diets commonly contain corn, the oil of which is high in 18:2*cis*-9,12.

Of the isomers of CLA detected, 18:2*cis*-9,*trans*-11 was the most abundant; however, weight percentages were less than 1%. Conjugated linoleic acid is an intermediate in the biohydrogenation pathway of 18:2*cis*-9,12 (Harfoot, 1981). In LD, range beef cows had the highest ($P < 0.01$) weight percentage of 18:2*cis*-9,*trans*-11; however, in the same muscle, range bison had higher ($P < 0.01$) 18:2*cis*-9,*trans*-11 than feedlot bison or feedlot steers. Elk had the lowest ($P < 0.01$) 18:2*cis*-9,*trans*-11 in LD but was similar ($P > 0.05$) to that observed in chicken breast. Very low values for 18:2*cis*-9,*trans*-11 in biceps femoris of elk were reported by Cordain et al. (2001); however, the observation of this fatty acid in chicken breast was unexpected. The chicken breasts were purchased from a grocery store; thus, we can only assume that the chickens were fed animal fat of ruminant origin. In each muscle 18:2*trans*-10,*cis*-12 and 18:2*cis*-10,12 were very low but were generally highest for range bison and range beef cows. Species differences in CLA were likely indicative of differences in the diet and(or) ruminal microflora.

In ST and SS, 18:2*cis*-9,*trans*-11 was lowest ($P < 0.01$) for elk and chicken breast. In ST, weight percentages of this fatty acid were similar for bison and beef cattle except that range bison had a greater ($P < 0.01$) value than feedlot beef steers. In SS, range beef cows had the highest ($P < 0.01$) 18:2*cis*-9,*trans*-11, whereas

range bison had greater ($P < 0.01$) 18:2*cis*-9,*trans*-11 than either feedlot bison or feedlot steers.

Weight percentages of 18:3*cis*-6,9,12 (λ-linolenic acid) were detected in each muscle of range beef cows and the SS of elk. Substantial weight percentages of 18:3*cis*-9,12,15 (α-linolenic acid) were observed for range bison, range beef cows, and elk in each muscle. In each muscle, the feedlot-fed counterparts of the bison and beef cattle had the lowest ($P < 0.01$) 18:3*cis*-9,12,15. In LD, elk and range bison had the highest ($P < 0.01$) 18:3*cis*-9,12,15; range beef cows had lower ($P < 0.01$) proportions of this fatty acid than range bison. In ST, 18:3*cis*-9,12,15 was similar ($P > 0.05$) for elk and range bison, both of which had greater ($P < 0.01$) values for this fatty acid than range beef cows. In SS, a similar pattern was observed for 18:3cis-9,12,15, except that elk and range beef cows had similar ($P > 0.05$) values, with range bison still retaining higher weight percentages than those observed in range beef cows. Weight percentages of 18:3cis-9,12,15 in the present study were of a magnitude similar to those reported for elk, deer, and pronghorn antelope (Cordain et al., 2001). Ruminants fed high-forage diets tend to have greater tissues levels of 18:3*cis*-9,12,15 than when fed high-concentrate diets. For example, Field et al. (1992) reported greater 18:3*cis*-9,12,15 in adipose tissue of lambs fed alfalfa pellets than in those fed a high-corn diet. Additionally, high-forage diets commonly contain lipids with higher proportions of 18:3*cis*-9,12,15 (Whitney et al., 1999). Differences in weight percentages of 18:4*cis*-6,9,12,15 in each muscle followed a similar pattern of comparison between species as did 18:3*cis*-9,12,15, likely because it is the desaturation product of 18:3*cis*-9,12,15 (Cook, 1985).

C20, 22, and 24 Saturated and Unsaturated Fatty Acids

Muscles of only range beef cows contained 20:1*cis*-11, but at low weight percentages. For the most part, 20:2*cis*-11,14 and 20:3*cis*-8,11,14 were observed at only trace levels in each muscle. Weight percentages of 20:4*cis*-5,8,11,14 (arachidonic acid) varied with and within species similarly to that observed for 18:2*cis*-9,12; this was expected because 20:4*cis*-5,8,11,14 is synthesized by elongation and desaturation of 18:2*cis*-9,12 (Cook, 1985). Elk LD and chicken breast were higher ($P < 0.01$) in weight percentage of 20:4*cis*-5,8,11,14, whereas feedlot steer LD was lowest ($P < 0.01$). In ST, 20:4*cis*-5,8,11,14 was similar ($P > 0.05$) for elk and range bison, lowest ($P < 0.01$) for feedlot steers, but similar ($P > 0.05$) between bison and range beef cows. In SS, 20:4*cis*-5,8,11,14 was similar ($P > 0.05$) for bison and beef cattle, each of which were lower ($P < 0.01$) in 20:4*cis*-5,8,11,14 than elk SS and chicken breast.

In LD, 20:5*cis*-5,8,11,14,17 (eicosapentanoic acid) was greatest ($P < 0.01$) for elk, second highest ($P < 0.01$) for range bison, and lowest ($P < 0.01$) for feedlot steer LD and chicken breast. In ST, this fatty acid was similar ($P > 0.05$) for range bison and elk and similar ($P > 0.05$) for feedlot bison and feedlot steers. In SS, weight percentages of 20:5*cis*-5,8,11,14,17 were generally lower than those observed for other muscles, but species comparisons were similar. Except for 22:4*cis*-7,10,13,16, weight percentages of C22 fatty acids in each muscle were generally greater for the range bison, range beef cows, and elk than for the feedlot fed bison and steers. This result would be expected because these fatty acids are synthesized from elongation and desaturation of 18:3*cis*-9,12,15 (Cook, 1985), and 18:3*cis*-9,12,15 was highest in forage-fed animals.

The only GLC peak consistently observed beyond that associated with 22:6*cis*-4,7,10,13,16,19 (docosahexanoic acid) was for 24:0. This fatty acid occurred in trace amounts within each muscle for the ruminant species.

Fatty Acid Totals and Selected Ratios

Total saturated fatty acids (**SFA**) in LD were higher ($P < 0.01$) for range bison, beef cattle, and elk than for feedlot bison and chicken breast. In ST, beef cattle had the highest ($P < 0.01$) SFA and feedlot bison and chicken breast had the lowest ($P < 0.01$). In SS, range bison, feedlot steers, and elk were highest ($P < 0.01$) in SFA. Total polyunsaturated fatty acids (**PUFA**) in LD were lowest ($P < 0.01$) for beef cattle; among the ruminant species' LD, PUFA were highest ($P < 0.01$) for range bison and elk. In ST, PUFA were greatest ($P < 0.01$) for range bison and elk, which were similar ($P > 0.05$) to PUFA in chicken breast. The feedlot-fed animals had lower ($P < 0.01$) PUFA in ST than their range counterparts. Bison and range beef cows had similar ($P > 0.05$) PUFA in SS, which were lower ($P < 0.01$) than that for elk SS and chicken breast. Feedlot steer SS had the lowest ($P < 0.01$) PUFA.

The ratio of PUFA to SFA (**P/S**) was highest ($P < 0.01$) for chicken breast because of the greater 18:2*cis*-9,12. Other than chicken breast, range bison and elk had the highest ($P < 0.01$) P/S ratio in LD and ST, whereas in SS, elk had the highest ($P < 0.01$) P/S ratio. Feedlot bison and range beef had similar ($P > 0.05$) P/S ratios and feedlot steers generally had the lowest P/S ratios in each muscle. Compared with muscles of the other species, chicken breast and elk muscle had higher 18:2*cis*-9,12 and 20:4*cis*-5,8,11,14 and lower 18:0, which were largely responsible for the higher P/S ratios observed for these species. However, elk muscles had greater 14:0 and 16:0 than bison muscles; therefore, nutritional implications of greater P/S ratios from these data may be somewhat deceiving because 14:0 and 16:0 are understood to be among the most atherogenic fatty acids (Spady et al., 1993). Additionally, 18:0 is thought to be neutral with respect to atherogenicity (Bonanome and Grundy, 1988), and 18:2*cis*-9,12 and 20:4*cis*-5,8,11,14, although not atherogenic, contribute to synthesis of prostaglandins

that are understood to exacerbate inflammatory responses (Broughton et al., 1991).

In the present study, *n*–6 fatty acids were composed of 18:2*cis*-9,12, 20:3*cis*-8,11,14, and 20:4*cis*-5,8,11,14, and the *n*–3 fatty acids were composed of 18:3*cis*-9,12,15, 20:5*cis*-5,8,11,14,17, 22:5*cis*-7,10,13,16,19, and 22:6*cis*-4,7,10,13,16,19. Chicken breast had higher ($P < 0.01$) *n*–6 than muscles of the other species, but within each muscle, elk had higher ($P < 0.01$) *n*–6 than bison or beef. In LD and ST, range bison and beef cows generally had higher *n*–6 than their feedlot-fed counterparts. In LD and SS, *n*–3 were highest ($P < 0.01$) for elk and range bison, which were similar ($P > 0.05$) to each other. Range beef cow LD was intermediate ($P < 0.01$) in *n*–3, whereas muscles of feedlot bison and feedlot steers were lowest ($P < 0.01$) in *n*–3 but similar ($P > 0.05$) to chicken breast. In ST, range bison had the highest ($P < 0.01$) *n*–3, and elk and range beef cows were intermediate ($P < 0.01$).

By calculating ratios of *n*–6 fatty acids to *n*–3 fatty acids, the fatty acid profile can be evaluated for both anti-atherogenicity and anti-inflammatory effects. Furthermore, *n*–6 and *n*–3 fatty acids are composed of PUFA. The ratio of *n*–6 to *n*–3 (*n*–6/*n*–3) was highest ($P < 0.01$) for chicken breast. Feedlot bison and feedlot steers had similar ($P > 0.05$) *n*–6/*n*–3 for each muscle, and each was higher ($P < 0.01$) than for range-fed animals and elk. The latter three types of animals generally had similar ($P > 0.05$) *n*–6/*n*–3, which were among the lowest ($P < 0.01$) values for *n*–6/*n*–3. Consumption of sufficient levels of *n*–3 fatty acids decreases serum triacylglycerols, slightly increases low-density and high-density lipoprotein cholesterol, and has essentially no effect on serum total cholesterol (Harris, 1997). Recommended intake by humans of *n*–6 fatty acids is suggested to be about 4% of dietary energy with a minimum of 1.5%, and intake of *n*–3 fatty acids should be about 0.75% of dietary energy (Innis, 1996) to avoid essential fatty acid deficiency. Thus, an *n*–6/*n*–3 ratio of between 2.5 to 5 would be considered optimal and is consistent with Lee et al. (1989), who concluded that an *n*–6/*n*–3 ratio of 5 simultaneous with a P/S of 2 produced maximal influence on lipid and eicosanoid levels in rats. In the present study, P/S ratios were less than one for each muscle and species. However, at the levels of fatty acids observed, results of the P/S and *n*–6/*n*–3 comparisons suggest that the fatty acids in LD, ST, and SS of range bison, range cows, and elk would have the most beneficial profile compared to either feedlot bison, feedlot steers, or chicken breast as it relates to cardioprotectiveness. Furthermore, 20:4*cis*-5,8,11,14 did not constitute a major fraction of the PUFA. In studies on mice, elevated levels of dietary 20:4*cis*-5,8,11,14 was detrimental because it led to overproduction of proinflammatory and proasthmatic eicosanoids (Whelan et al., 1992).

Muscle Fatty Acid Comparison with Species

Variation in fatty acid composition from muscle location was observed in the present study. Comparison of muscles for major fatty acids, fatty acid totals, and selected ratios are described below (data not shown).

Range Bison. Fatty acids 16:0 and 18:1*cis*-9 were similar ($P \geq 0.23$) for each muscle. Supraspinatus had the highest ($P < 0.01$) 18:0, which was lowest ($P < 0.01$) in ST and intermediate in LD. Total saturated fatty acids, PUFA, P/S, *n*–3, and *n*–6 were highest ($P < 0.01$) for ST and similar ($P > 0.05$) for LD and SS. The ratio of *n*–6: ST *n*–3 was highest ($P < 0.01$) for SS, lowest ($P < 0.01$) for ST, and intermediate for LD.

Feedlot Bison. In feedlot bison, LD and ST 16:0 was highest ($P < 0.01$) compared with SS, whereas 18:0 was lowest ($P < 0.01$) in ST. Total saturated fatty acids were highest ($P < 0.01$) in LD. The highest ($P = 0.04$) *n*–6 weight percentage observed was in SS and was lowest ($P = 0.04$) in ST. The ratio of *n*–6:*n*–3 was highest ($P < 0.01$) in SS, lowest ($P < 0.01$) in ST, and intermediate for LD.

Range Beef Cows. Longissimus dorsi tended ($P = 0.06$) to have the highest 16:0 in the range beef cows. Total saturated fatty acids were highest ($P < 0.01$) in SS and similar ($P > 0.05$) for LD and ST. No differences ($P \geq 0.29$) were observed for the other fatty acid groups or ratios between muscles of the range beef cows.

Feedlot Steers. The LD of the feedlot steers had the highest ($P < 0.01$) 16:0, whereas 18:0 tended ($P = 0.08$) to be highest in the LD. In SS, PUFA and *n*–6 tended ($P = 0.06$) to be highest in SS. The P/S and *n*–3 were highest ($P \leq 0.04$) for ST and SS.

Elk. For elk, the only muscle effect observed was for 18:1*cis*-9, which was highest ($P < 0.01$) in SS and similar ($P > 0.05$) in LD and ST.

In ovine muscle, 18:0 and 18:1*cis*-9 were greater in LD compared with ST (Bolte et al., 2001). In a summary of results on bovine muscle fatty acids (Rule et al., 1995), 16:0 was similar for LD, ST, triceps brachii, and biceps femoris and lowest in psoas major. Similar 18:0 was shown for LD, triceps brachii, and psoas major, whereas 18:0 was lowest in ST and highest for biceps femoris. Psoas major had the lowest 18:1*cis*-9, which was highest in triceps brachii and intermediate in LD, ST, and biceps femoris. For 18:2*cis*-9,12, triceps brachii was lowest, psoas major was highest, and LD, ST, and biceps femoris were intermediate. In beef bulls, LD had the highest weight percentage of 16:0 and 18:0, and 18:0 was lowest in ST and intermediate in triceps brachii (Eichhorn et al., 1985); PUFA were highest in ST in this study. Total saturated fatty acids were lowest and PUFA were highest in ST and similar in psoas major and LD of water buffalo (Sharma et al., 1986). Compared with the present study, previous studies have shown numerous similarities in fatty acid composition across muscle for the major fatty acids in beef cattle and bison. Elk, however, did not demonstrate as much muscle variation in fatty acid composi-

tion in the present study. Miller et al. (1986), however, reported greater 16:0 and 18:1*cis*-9 and less 18:2*cis*-9,12, 18:3*cis*-9,12,15, and 20:4*cis*-5,8,11,14 in LD than in biceps femoris of elk.

Cholesterol and Total Fatty Acid Concentrations

Cholesterol and total fatty acid concentrations in LD, ST, and SS are shown in Tables 1, 2, and 3, respectively. In LD, cholesterol was lowest ($P < 0.01$) for range bison but similar ($P > 0.05$) for the other species as well as chicken breast. Marchello et al. (1989) reported concentrations of cholesterol in LD for bison that were similar to beef LD or chicken breast. In ST, range-fed animals had less ($P < 0.01$) cholesterol than their feedlot-fed counterparts. However, for elk, ST cholesterol was similar ($P > 0.05$) to that observed for feedlot bison and feedlot steers. Chicken breast had a greater ($P < 0.01$) cholesterol concentration than ST of bison, beef, or elk. In SS, feedlot-fed animals had greater ($P < 0.01$) cholesterol than range-fed animals and elk. Chicken breast cholesterol concentration was similar ($P > 0.05$) to those in SS of feedlot bison and feedlot steers. In LD, the milligrams of total fatty acids/gram of fresh muscle was greatest ($P < 0.01$) for feedlot steers, intermediate ($P < 0.01$) for feedlot bison, and lowest ($P < 0.01$) for range-fed animals, elk, and chicken breast; the latter three types of animals had similar ($P > 0.05$) total fatty acid concentrations, and thus they were the leanest. In ST, both feedlot-fed bison and steers had the highest ($P < 0.01$) total fatty acid concentrations, whereas range-fed animals, elk, and chicken breast had the lowest ($P < 0.01$) total fatty acid concentrations. In SS, range bison had less ($P < 0.01$) total fatty acids than feedlot bison, but total fatty acid concentration in SS of range bison was not different ($P > 0.05$) from that of feedlot steers. Like the other muscles, total fatty acid concentrations were lowest ($P < 0.01$) for elk and chicken breast.

Overall, the present study compared lipid composition within and across species that varied in age, dietary regimen, and sex. Increased age affects fatty acid composition in cattle by increasing monounsaturated and decreasing SFA (Rule et al., 1995). Forage feeding has generally resulted in greater PUFA compared with feeding high-grain diets in ruminants (Rule et al., 1995). Pasture-fed steers had lower *n*–6/*n*–3 in muscle lipids than grain-fed steers (Cordain et al., 2001). Reduction in SFA and greater unsaturated fatty acids was shown to occur in ram lambs compared with wethers in several studies (Rule et al., 1995), and muscle of beef bulls contained greater weight percentages of PUFA and lower SFA than beef steers (Eichhorn et al., 1985). Thus, in addition to species differences, age, diet, and sex variation likely contributed to differences in lipid composition observed in the present study. However, production of meat from each of the species and regimens under investigation is currently in use. In summary, the three muscles examined from the range-fed bison had fatty acid compositions that were similar in magnitude to those of range beef cows and elk, especially with regard to *n*–6 and *n*–3 fatty acids. Likewise, feedlot-fed bison and steers had similar fatty acid profiles; however, total fatty acid concentration was lower for the feedlot bison. Although weight percentages of CLA varied with species and muscle, values were not unusually high for any one species; however, elk muscles were much lower in CLA compared with the other species. Elk muscle also exhibited unusual profiles of 16:1*cis*-9 and 18:1*cis*-11, suggesting potential species differences in tissue desaturase regulation as well as differences in ruminal bacterial ecology. We conclude that the lipid composition of bison skeletal muscle is dependent on feeding regimen, and that muscles of range-fed bison have many similarities to muscle lipid composition and concentration of forage-fed beef cows and free-ranging elk.

Implications

Range-fed bison and range-fed beef cows would provide consumers with very lean meat that is comparable to meat from free-ranging elk with respect to fatty acid profiles currently regarded as the most healthful. The feeding regimen for bison production affects the leanness and fatty acid profile of the meat. Range bison production should be emphasized to obtain the leanest bison meat with the lowest cholesterol concentration possible. Muscles of each species had fatty acids that could not be identified in the present study, and several of the unknown peaks observed in bison muscle were not observed in muscles of the other species, and vice versa. Identification of the unknown peaks and investigation into possible health benefits of these substances are needed to completely understand nutritional benefits of meat from each species and production method discussed in the present study.

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