VITAMIN AND SELENIUM CONTENT OF RIBEYE CUTS FROM GRASS- AND GRAIN-FINISHED BISON OF THE SAME HERD

JUDY A. DRISKELL[1,3], MARTIN J. MARCHELLO[2], DAVID W. GIRAUD[1] and AHMAD SULAEMAN[1,4]

[1]*Department of Nutrition and Health Sciences*
University of Nebraska
Lincoln, NE 68583-0806

[2]*Department of Animal and Range Sciences*
North Dakota State University
Fargo, ND 58105-5727

Accepted for Publication March 2, 2004

ABSTRACT

Individual ribeye cuts from 10 grass- and 8 grain-finished bulls of the same herd were analyzed for vitamin and selenium content. Vitamin A, vitamin E, thiamin, vitamin B_6, vitamin B_{12} and selenium concentrations of ribeye cuts from grass- and grain-finished bulls were similar. Vitamin C and folic acid levels were not detectable in ribeyes from both groups. Ribeyes from grass-finished bulls contained significantly higher quantities of β-carotene ($P < 0.0005$) and niacin ($P < 0.01$) and significantly lower ($P < 0.0001$) quantities of riboflavin than those from grain-finished bulls. Bison ribeyes from both groups were rich sources (>20% Daily Values) of vitamin B_{12} and selenium and good sources (10–19% Daily Values) of thiamin, niacin and vitamin B_6.

INTRODUCTION

Many consumers eat bison (*Bison bison*), also known as North American buffalo, an alternative meat source. Over 350,000 bison are currently being raised for meat in North America (National Bison Association 2004). Bison meat is low in fat and food energy and high in protein (Marchello *et al*. 1989, 1998; Koch *et al*. 1995). Bison meat also contains appreciable amounts of minerals, with the exceptions of calcium and sodium (Marchello *et al*. 1998).

[3] Contact author. TEL: 402-472-8975; FAX: 402-472-1587; EMAIL: jdriskell@unl.edu
[4] Current address: Jurusan Gizi Masyarakat dan Sumberdaya Keluarge, Fakultas Pertanian, Institut Pertanian Bogor, Kampus Darmaga, Bogor, Indonesia.

Journal of Food Quality **27** (2004) 388–398.

Published data on raw lean cuts (ribeye, top round, shoulder clod and top sirloin) indicate that bison meat contains substantial amounts of vitamin B_6, vitamin B_{12}, selenium and niacin as well as some thiamin and riboflavin, but is low to nil in vitamin E, vitamin A and vitamin C (Driskell *et al.* 1997, 2000; Marchello and Driskell 2001). Little differences in vitamin and selenium content were observed among these four cuts. These cuts were from 24 bulls, slaughtered at 21–27 months of age, representative of bison bulls raised for meat production in the United States and Canada. All of these bulls had been grain-finished for at least 180 days, with the exception of two, which were grass-finished. Similar to that among beef cattle producers, some controversy among bison producers on whether the meat from grass-finished bulls contains greater amounts of certain vitamins and selenium than that from grain-finished bulls exists. The purpose of this study was to determine the differences in the vitamin and selenium composition of the ribeye cuts from grass- and grain-finished bulls of the same herd.

MATERIALS AND METHODS

Individual ribeye cuts (longissimus muscle) were obtained from bison bulls born on the Niobrara Valley Preserve in Nebraska; these animals were of the same age group in the same herd. Ten animals were grass-fed with natural prairie grasses (60% cool season C_4:40% warm season C_3) and hay free-choice (during winter) following weaning. Eight animals were sold to individual producers and grain-finished. The grain-finished animals received wheat middlings, grain mix, wheat, cane molasses, alfalfa meal and cracked corn plus hay free-choice. The grass-finished bulls were not given vitamin supplements. The grain-finished bulls had 44,000 IU of vitamin A, 400 IU of vitamin D and 35.2 IU of vitamin E added to each kg of their ration. The protein content of the ration fed free-choice to the grain-finished animals was 120 g/kg feed. Although information was not available on the protein content of the grasses consumed by the grass-finished bulls, the protein content of prairie hay is listed as being 64 g/kg in the composition data of feeds commonly used in beef cattle diets (Subcommittee on Beef Animal Nutrition 2002). The grain-finished bulls were slaughtered at 21–24 months of age and the grass-finished at 30–32 months; bulls finished with grass and with grain are typically brought to market at these ages. These differences in age at slaughter are in line with the findings of Bidner *et al.* (1981) that forage-fed beef steers required an additional 160 days to reach the same weights as the grain-fed ones. The ribeye samples were flash-frozen approximately 24 h after slaughter and shipped to North Dakota State University where they were lyophilized, homogenized and stored at −20C. Portions of the lyophilized samples were shipped to the University of Nebraska for analysis of vitamin and selenium content.

The vitamin and selenium content of the samples were determined as well as moisture, crude fat and crude protein. Moisture was determined by oven-drying at 105C, crude fat content by the Foss-let procedure (AOAC 2002) and crude protein by the Kjeldahl method (AOAC 2002). The thiamin content was determined using fluorometry (AOAC 2002). The vitamin B_6, vitamin B_{12} and folic acid compositions of the samples were determined with microbiological assays using *Saccharomyces uvarum*, ATCC 9080 (Sauberlich 1967), *Lactobacillus leichmannii*, ATCC 7830 (AOAC 2002) and *Lactobacillus casei*, ATCC 7469 (Rader *et al.* 1998), respectively. Samples were saponified (Lederman *et al.* 1998) prior to high-performance liquid-chromography analysis for *a*-tocopherol, *β*-carotene and vitamin A, actually measured as retinol (Neirenberg and Nann 1992). HPLC techniques were utilized for determining the riboflavin (Dawson *et al.* 1988), niacin (Vidal-Valverde and Reche 1991) and vitamin C (Dodsen *et al.* 1992) concentrations of the samples. A fluorometric method was used for the determination of selenium content (Koh and Benson 1983). All nutrient analyses were conducted in duplicate. Recoveries were determined by standard addition to sample aliquots of bison meat with the appropriate nutrient at the beginning of each chemical method; all percentage recoveries were above 90%. All content values are expressed on a wet weight (w/w) basis.

Significant differences between nutrient content values for ribeyes from grass- and grain-finished bulls were determined by general linear measurements using computer software from SAS Institute (Cary, NC). Differences were considered significant at $P < 0.05$. Data were summarized as $\overline{x} \pm SD$.

RESULTS

The carcass weights of the grass-finished bulls (198.2 ± 15.8 kg, $\overline{x} \pm SD$) were significantly lower ($P < 0.05$) than those that were grain-finished (210.9 ± 76.1 kg). The moisture, crude fat and crude protein contents of the ribeye cuts from the grain-finished bulls (75.00 ± 1.15 g, 1.90 ± 1.60 g and 21.54 ± 0.94 g per 100 g, respectively) were similar ($P \geq 0.05$) to those of the grass-finished bulls (75.90 ± 0.50 g, 0.97 ± 0.47 g and 21.28 ± 0.58 per 100 g).

The concentrations of vitamins and selenium in ribeye cuts from the grass- and grain-finished bulls are given in Table 1. The riboflavin concentrations of the ribeye cuts of the bulls that were grain-finished were significantly higher ($P < 0.0001$) than those that were grass-finished, but the niacin and *β*-carotene contents of the ribeye cuts of these grain-finished bison were

TABLE 1.
VITAMIN AND SELENIUM CONCENTRATIONS OF RIBEYE CUTS FROM GRASS- AND GRAIN-FINISHED BISON BULLS OF THE SAME HERD

Nutrient	Grass-finished ($n = 10$) (per 100 g wet weight)	Grain-finished ($n = 8$) (per 100 g wet weight)
β-Carotene (μg)	14.930 ± 8.633*	0.063 ± 0.177
Retinol† (μg)	1.420 ± 0.834	1.250 ± 0.644
α-Tocopherol (mg)	0.137 ± 0.045	0.161 ± 0.038
Vitamin C (mg)	nd‡	nd
Thiamin (mg)	0.162 ± 0.052	0.195 ± 0.088
Riboflavin (mg)	0.073 ± 0.022§	0.118 ± 0.013
Niacin (mg)	3.040 ± 0.826¶	1.913 ± 0.745
Vitamin B_6 (mg)	0.197 ± 0.115	0.255 ± 0.116
Folic Acid (μg)	nd	nd
Vitamin B_{12} (μg)	2.157 ± 0.609	2.099 ± 0.258
Selenium (μg)	16.120 ± 6.204	20.263 ± 6.549

* Significantly higher ($P < 0.0005$) than that of grain-finished bulls.
† Preformed vitamin A measured as retinol.
‡ Not detectable.
§ Significantly lower ($P < 0.0001$) than that of grain-finished bulls.
¶ Significantly higher ($P < 0.01$) than that of grain-finished bulls.

significantly lower ($P < 0.01$ and <0.0005, respectively) than those of the grass-finished bulls. The thiamin, vitamin B_6, vitamin B_{12}, vitamin A, α-tocopherol and selenium contents of the ribeye cuts from the grass- and grain-finished bulls were similar ($P \geq 0.05$). Ribeyes from both groups had undetectable levels of vitamin C and folic acid.

DISCUSSION

The retinol (preformed vitamin A) concentrations of ribeye cuts from grass- and grain-finished bulls in the present study were similar, despite the grain-finished animals having received supplemental vitamin A. β-carotene concentrations of ribeyes from the grass-finished bulls were significantly higher ($P < 0.05$) than of those from the grain-finished bulls in the present study. Forages contain provitamin A carotenoids in large amounts, with the amount varying on a seasonal basis. Grains, with the exception of yellow corn, do not contain appreciable amounts of the provitamin A carotenoids (Subcommittee on Beef Cattle Nutrition 2002). Therefore, the β-carotene content of meat from grass-finished animals would be expected to be higher than the β-

carotene content of meat from grain-finished. To our knowledge, no prior reports of β-carotene content of meat from bison exist.

Two research groups have reported β-carotene content values for ribeyes of beef steers. The β-carotene content of ribeyes from the grass-finished bison bulls in the current study ($\overline{x} = 15$ μg per 100 g) is similar to that ($\overline{x} = 16$ μg per 100 g) reported for pasture-fed all Hereford cross steers raised in New Zealand (Yang *et al.* 2002); these researchers also reported a β-carotene content value ($\overline{x} = 1$ μg per 100 g) for ribeyes from grain-fed steers which was higher than that ($\overline{x} = 0.063$ μg per 100 g) observed in the current study. Simmonne *et al.* (1996) reported that the β-carotene content of ribeye steaks from pasture- and feedlot-finished Angus × Hereford steers were 64 and 36 μg per 100 g, respectively; these steers were finished on annual ryegrass pasture or a feedlot diet consisting of a grain and cotton seed meal. The steers in both of these studies were fed different grasses and grains from those fed to bison bulls.

β-carotene can be converted to vitamin A in the human body, hence, is a provitamin A carotenoid. Considerable observational epidemiological evidence suggests an association between high blood concentrations of β-carotene and other carotenoids found in foods and lower risk of several chronic diseases (Institute of Medicine 2000). Consumption of several carotenoids, especially β-carotene, appears to be associated with lower risk of some chronic diseases (Kritchevsky 1999). Evidence exists that β-carotene is an antioxidant *in vitro*, but it has not been conclusively shown to be important to health (Institute of Medicine 2000). According to the Institute of Medicine in the Dietary Reference Intakes publication relating to carotenoids (2000), the only clear function of β-carotene that is firmly linked to a health outcome is that it can be converted by the body to vitamin A, and thus prevent vitamin A deficiency. A recently published review of the role of carotenoids in human health is in agreement with the above statements (Johnson 2002).

According to the Institute of Medicine (2000), α-tocopherol is the only form of vitamin E that has vitamin E activity in humans. The α-tocopherol concentrations of ribeye cuts from grass- and grain-finished animals in the present study were similar, even though the grain-finished bulls received supplemental vitamin E in their rations. These findings are in line with those reported by Yang *et al.* (2002) that beef cattle raised on good pasture can achieve concentrations of α-tocopherol in muscles and other tissues at least as high as those obtained by grain-fed cattle given supra-nutritional supplements containing vitamin E.

The riboflavin content of ribeye cuts from the grain-finished bulls was significantly higher than those from grass-finished bulls in the present study. There is microbial synthesis of riboflavin in the rumen, and increased ruminal synthesis has been reported with diets containing more protein (Buziassy and Tribe 1960). It is likely that the difference in protein content of the diets consumed by the grass- and grain-finished bulls explains the difference in the riboflavin content of ribeyes.

The niacin concentrations of ribeye cuts from the grass-finished bulls were significantly higher than those from the grain-finished bulls in the current study. Ruminants obtain niacin from dietary niacin, conversion of tryptophan to niacin and ruminal synthesis (Subcommittee on Beef Cattle Nutrition 2002). Pasture grass is a "fair" source of niacin, whereas the niacin that is present in many grains is in a bound form that has limited bioavailability (McDowell 1989). This may be why the ribeye cuts from the grain-finished bison bulls contained less niacin than those from the grass-finished bulls.

The selenium content of the ribeyes from both groups of animals were similar. The selenium content of grasses, grains and seeds is known to be dependent on the selenium content of the soil where they are grown (World Health Organization 1987). The selenium content of the soil is higher in the Great Plains area, which includes Nebraska, than in the rest of the United States; forages and grains grown in the Great Plains area contain >0.1 p.p.m. of selenium (Pond *et al.* 1995). It is likely that these ribeye selenium content values are in line with the selenium content of the soil, and the selenium content of ribeyes from bison raised in the Great Plains area would be higher than the selenium content of ribeyes from bison raised in other parts of the country.

As is evident in Table 1, the content values for retinol (actually retinoids measured as retinol; also referred to as preformed vitamin A), α-tocopherol (the biologically active form of vitamin E), vitamin C, thiamin, riboflavin, niacin, vitamin B_6, vitamin B_{12} and selenium are generally comparable with those given in the USDA National Nutrient Database (2004) for game meat, bison, ribeye, separable lean only, trimmed to 0″ fat, raw, NDB no. 17268. The values given in the USDA database were from research of Driskell *et al.* (1997, 2000) and Marchello *et al.* (1998). Because of the sampling design of these studies, the nutrient content of the ribeye as well as the shoulder clod, top round and top sirloin cuts is representative of meat from grain-finished bison in the United States and Canada. Much animal-to-animal variation in vitamin and selenium concentrations of these four lean cuts was noted in previous studies (Driskell *et al.* 1997, 2000). The same was true with regard to animal-to-animal variation in vitamin and selenium concentrations of the ribeye cuts in the present study.

Not enough vitamin C, folic acid, vitamin A (from preformed vitamin A and provitamin A carotenoids) and vitamin E was present in the ribeye cuts of grass- or grain-finished bulls in the current study to be of any importance from a nutritional point of view. Not enough β-carotene was present in the ribeye cuts of the two groups of bulls in the present study to be of any nutritional importance with regard to conversion to vitamin A or other hypothesized, although unproven, functions of β-carotene.

The FDA (1992a) indicates that the terms "high," "rich in" or "major source of" should be used when a serving of food (in the case of meats, 100 g) contains 20% or more of the Daily Value for that nutrient, and the terms "source," "good source of" or "important source of" should be used when a serving of the food contains 10–19% of the Daily Value for that nutrient. The Daily Value (FDA 1992b) is used in nutrient labeling of processed foods and may also be used for meats and other unprocessed foods for which nutrient labeling is optional. Daily Values for vitamins and minerals for adults and children 4 years of age and over are available online (FDA 2004). The consumption of 100 g of bison ribeye cuts (raw) from grass- and grain-finished bison bulls in the present study would provide the following mean percentages of the Daily Values of the following nutrients: (per 100 g) thiamin, 11 and 13%; riboflavin, 4 and 7%; niacin, 15 and 10%; vitamin B_6, 10 and 13%; vitamin B_{12}, 36 and 35%; and selenium, 25 and 29%, respectively. If the nutrient content of a certain kind of food is <2% of the Daily Value for that nutrient, it is listed as such on the Nutrition Facts label; hence, the listing for ribeye cuts from both grass- and grain-finished bulls would be <2% for vitamin A (includes that from preformed vitamin A and the provitamin A carotenoids including β-carotene), vitamin E, vitamin C and folic acid. These bison ribeye cuts from both grass- and grain-finished bulls were excellent sources (>20% Daily Values) of vitamin B_{12} and selenium and good sources (10–19% Daily Values) of thiamin niacin, and vitamin B_6.

The nutrient content data in the present study were for raw (uncooked) bison ribeye cuts. Substantial quantities of vitamins are known to be lost during the cooking of foods; thus, the percentages of the Daily Values provided by 100 g (a serving) of a bison ribeye cut would be lower. Research conducted in our laboratory (Yuan *et al.* 1999) indicated that the mean retention of selected vitamins in cooked bison patties were 68.9% for thiamin, 67.5% for vitamin B_6, 67.0% for vitamin B_{12} and 76.1% for α-tocopherol (vitamin E). If these retention values are utilized in estimating the effect of cooking on the vitamin content of ribeye cuts from grain- and grass-finished bison in the current study, the cuts would still be an excellent source of vitamin B_{12} and selenium, those from grass-finished bulls would still be a good source of niacin, and those from grain-finished bulls would still be a good source of thiamin and vitamin B_6.

The USDA nutrient database (2004) does have a listing for game meat, bison, ribeye, separable lean only, 1 in. steak, cooked, broiled (NDB no. 17335). This database listing is based on a sample count of three ribeyes from grain-finished bulls. This listing indicates that 100 g of broiled ribeye steak contained 0.0 mg vitamin C, 0.137 mg thiamin, 0.307 mg riboflavin, 6.687 mg niacin, 0.475 mg vitamin B_6, 18 μg folate, 1.29 μg vitamin B_{12}, 0.21 mg α-tocopherol and 42.1 μg selenium; 0 was given as the sample count for vitamin C, folate, α-tocopherol and selenium, so it is likely that the content was imputed from another listing. The researcher (Buege 2003) providing these data to USDA indicated that the imputed values were for the broiled bison chuck round cut. If we used the retention values detailed in the previous paragraph (Yuan *et al*. 1999) in estimating the effect of cooking on the vitamin content of ribeye cuts from grain-finished bison in the current study, the estimated thiamin, vitamin B_{12} and vitamin E content values would be similar and the estimated riboflavin, niacin and vitamin B_6 would be lower than the NDB no. 17335 listing. Other than the USDA using imputed values and a sample size of only three, the differences may be explained by the considerable animal-to-animal variation that has been reported to exist in the vitamin and selenium content of lean meat cuts from bison bulls (Driskell *et al*. 1997, 2000).

CONCLUSION

The findings of the present study indicate that some differences in the vitamin and selenium content of ribeyes from grass- and grain-finished bison bulls exist, even though the animals were born into the same herd. However, these differences are of little importance nutritionally in terms of human consumption. Ribeyes from both grass- and grain-finished bison bulls were found to be excellent sources of vitamin B_{12} and selenium and good sources of thiamin, niacin and vitamin B_6.

ACKNOWLEDGMENT

This study was supported in part by the Nebraska and North Dakota Agricultural Experiment Stations and is Journal Series No. 14023 of the Nebraska Agricultural Research Division.

REFERENCES

AOAC. 2002. *Official Methods of Analysis*, 17th Ed., Assoc. of Official Analytical Chemists, Arlington, VA.

BIDNER, T.D., SCHUPP, A.R., MONTGOMERY, R.E. and CARPENTER, J.C., Jr. 1981. Acceptability of beef finished on all-forage, forage-plus-grain or high energy diets. J. Anim. Sci. *53*, 1181–1187.

BUEGE, D.R. 2003. Private communication, January 24.

BUZIASSY, C. and TRIBE, D.E. 1960. The synthesis of vitamins in the rumen of sheep: I. The effect of diet on the synthesis of thiamine, riboflavin, and nicotinic acid. Aust. J. Agric. Res. *11*, 989–1001.

DAWSON, K.R., UNKLESBAY, N.F. and HEDRICK, H.B. 1988. HPLC determination of riboflavin, niacin, and thiamin in beef, pork, and lamb after alternate heat-processing methods. J. Agric. Food Chem. *36*, 1176–1179.

DODSEN, K.Y., YOUNG, E.R. and SOLIMAN, A.G.M. 1992. Determination of total vitamin C in various food matrices by liquid chromatography and fluorescence detection. J. AOAC Int. *75*, 887–891.

DRISKELL, J.A., MARCHELLO, M.J. and GIRAUD, D.W. 2000. Riboflavin and niacin concentrations of bison cuts. J. Anim. Sci. *78*, 1267–1271.

DRISKELL, J.A., YUAN, X., GIRAUD, D.W., HADLEY, M. and MARCHELLO, M.J. 1997. Concentrations of selected vitamins and selenium in bison cuts. J. Anim. Sci. *75*, 2950–2954.

FDA. 1992a. Food Labeling: Nutrient Content Claims, General Principles, Petitions, Definitions of Terms; Nutrient Content Claims for the Fat, Fatty Acid, and Cholesterol Content of Food. Fed. Reg. December 17 (58 FR 2302).

FDA. 1992b. Food Labeling: Reference Daily Intakes and Daily Reference Values. Fed. Reg. October 29 (58 FR 2206).

FDA. 2004. *A Food Labeling Guide: Reference Values for Nutrition Labeling*. Retrieved February 5, 2004 from the World Wide Web: http://www.cfsan.fda.gov/~dms/flg-7a.html.

INSTITUTE OF MEDICINE, NATIONAL ACADEMY OF SCIENCES. 2000. *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids*, 506 p., National Academy Press, Washington, DC.

INSTITUTE OF MEDICINE, NATIONAL ACADEMY OF SCIENCES. 2001. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*, 773 p., National Academy Press, Washington, DC.

JOHNSON, E.J. 2002. The role of carotenoids in human health. Nutr. Clin. Care *5*, 56–65.

KOCH, R.M., JUNG, H.G., CROUSE, J.D., VAREL, V.H. and CUNDIFF, L.V. 1995. Growth, digestive capability, carcass, and meat characteristics of *Bison bison*, *Bos taurus*, and *Bos x Bison*. J. Anim. Sci. *73*, 1271–1281.

KOH, T.S. and BENSON, T.H. 1983. Critical re-appraisal of fluorometric method for determination of selenium in biological materials. J. AOAC Int. *66*, 918–926.

KRITCHEVSKY, S.B. 1999. β-carotene, carotenoids and the prevention of coronary heart diseases. J. Nutr. *129*, 5–8.

LEDERMAN, J.D., OVERTON, K.M., HOFMANN, N.E., MOORE, B.J., THORNTON, J. and ERDMAN, J.W., Jr. 1998. Ferrets (*Mustela putious furo*) inefficiently convert β-carotene to vitamin A. J. Nutr. *128*, 271–279.

MARCHELLO, M.J. and DRISKELL, J.A. 2001. Nutrient composition of grass- and grain-finished bison. Great Plains Res. *11*, 65–82.

MARCHELLO, M.J., SLANGER, W.D., HADLEY, M., MILNE, D.B. and DRISKELL, J.A. 1998. Nutrient composition of bison fed concentrate diets. J. Food Comp. Anal. *11*, 231–239.

MARCHELLO, M.J., SLANGER, W.D., MILNE, D.B., FISCHER, A.G. and BERG, P.T. 1989. Nutrient composition of raw and cooked Bison bison. J. Food Comp. Anal. *2*, 177–185.

MCDOWELL, L.R. 1989. *Vitamins in Animal Nutrition*, 486 p., Academic Press, Inc, San Diego, CA.

NATIONAL BISON ASSOCIATION. 2004. *Bison History*. Retrieved February 5, 2004 from the World Wide Web: (Bisoncentral Home Page): http://www.bisoncentral.com.

NEIRENBERG, D.W. and NANN, S.L. 1992. A method for determining concentrations of retinol, tocopherol, and five carotenoids in human plasma and tissue. Am. J. Clin. Nutr. *56*, 417–426.

POND, W.G., CHURCH, D.C. and POND, K.R. 1995. *Basic Animal Nutrition and Feeding*, 4th Ed., p. 186, John Wiley & Sons, New York.

RADER, J.J., WEAVER, C.M. and ANGYAL, G. 1998. Use of a microbiological assay with tri-enzyme extraction for measurement of pre-fortification levels of folates in enriched cereal-grain products. J. Food Chem. *62*, 451–465.

SAUBERLICH, H.E. 1967. Vitamin B_6. In *The Vitamins: Chemistry, Physiology, Pathology, Methods*, 2nd Ed., (P. György and W.N. Pearson, eds.) pp. 169–177, Academic Press, New York.

SIMMONNE, A.H., GREEN, N.R. and BRANSBY, D.I. 1996. Consumer acceptability and β-carotene content of beef as related to cattle finishing diets. J. Food Sci. *61*, 1254–1256, 1280.

SUBCOMMITTEE ON BEEF CATTLE NUTRITION, NATIONAL RESEARCH COUNCIL, NATIONAL ACADEMY OF SCIENCES. 2002. *Nutrient Requirements of Beef Cattle: Update 2000*, 7th Rev. Ed., p. 232, National Academy Press, Washington, DC.

USDA. 2004. *USDA National Nutrient Database for Standard Reference, Release 16*. Retrieved February 4, 2004 from the World Wide Web: (Nutrient Data Laboratory Home Page): http://www.nal.usda.gov/fnic/foodcomp.

VIDAL-VALVERDE, C. and RECHE, A. 1991. Determination of available niacin in legumes and meat by high-performance liquid chromatography. J. Agric. Food Chem. *39*, 116–121.

WORLD HEALTH ORGANIZATION. 1987. *Selenium. Environmental Health Criteria 58: A Report of the International Programme on Chemical Safety*, p. 306, World Health Organization, Geneva, Switzerland.

YANG, A., BREWSTER, M.J., LANARI, M.C. and TUME, R.K. 2002. Effect of vitamin E supplementation on α-tocopherol and β-carotene concentrations in tissues from pasture- and grain-fed cattle. Meat Sci. *60*, 35–40.

YUAN, X., MARCHELLO, M.J. and DRISKELL, J.A. 1999. Contents and retentions of selected vitamins in bison patties. J. Food Sci. *64*, 462–464.