RESEARCH

NUTRITIONAL QUALITY OF BEEF PRODUCED IN CHILE FROM DIFFERENT PRODUCTION SYSTEMS

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In recent years, beef industry has improved production processes to ensure quality and certification for overseas meat markets. However, there is limited scientific information about the nutritional quality of beef from Chile. The aim of the present study was to evaluate the nutritional quality of beef produced in Chile from different production systems classified according to the type of finishing diet. Two-hundred and five animals from 13 livestock farms were used, 80 steers were finished on grazing pasture, 79 on pasture supplemented with grain or concentrate and 46 steers were finished on a typical feedlot system in the central zone of Chile. *Longissimus thoracis* intramuscular fat, fatty acid composition and cholesterol content were determined. Beef from pasture-fed animals showed higher content of vaccenic acid (C18:1 *trans*-11) rumenic acid (CLA *cis*-9 *trans*-11) and *n*-3 fatty acids, and lower *n*-6:*n*-3 ratio than beef from feedlot animals. However, Chilean beef from the three production systems showed similar intramuscular fat percentages and a *n*-6:*n*-3 ratio lower than 4.0. Results indicate that the *Longissimus* muscle from Chilean beef could be recommended as a source of red meat for a healthy diet.

Key words: Fatty acids, pasture, feedlot, Chilean beef quality.

Producers and consumers are both interested in the nutritional quality of beef, due to the added value producers could obtain for their product and for consumers' willingness to eat healthier food.

It is well documented that the animal finishing diet affects the fat content and fatty acid composition of beef (Scollan *et al*., 2001; Latimori *et al*., 2008). Latimori *et al*. (2008) showed that beef from animals raised on pasture has lower fat and cholesterol concentrations, and more polyunsaturated fatty acids (PUFA) than beef from feedlot animals. Other authors have shown that beef from animals fed on pasture contains more *n*-3 fatty acids and conjugated linoleic acid (CLA) than beef from feedlot animals, due to the high content of linolenic acid (*n*-3) in pasture lipids (Christie, 1981; Steen and Porter, 2003; Elgersma *et al*., 2003). Conjugated linoleic acid is an isomer of linoleic acid and is deposited in beef by direct (ruminal biohydrogenation and isomerization) or indirect (endogenous synthesis) pathways (Ip *et al*., 1994). Whetsell *et al*. (2003) reported that CLA C18:2 *cis-9 trans-11* (rumenic acid) possess anticarcinogenic and immunostimulant properties. It has also been shown that CLA exhibits antioxidant properties, inhibiting the discoloration of meat during storage (Du *et al*., 2000).

In most developed countries and in Chile, heart disease, diabetes and some types of cancer are the principal causes of death, which are associated with high consumption of saturated and *trans* fatty acids, and refined carbohydrates, stress and a sedentary lifestyle (DEIS, 2007). Thus, there is consumer interest in increasing healthy and natural food and reducing processed foods in the diet to decrease the damaging impact of saturated fatty acids on health. Therefore, consumers are demanding healthier food, including beef (Ip *et al*., 1994; Whetsell *et al*., 2003; Wood *et al*., 2003; Grunert *et al*., 2004).

In Chile, there are different beef production systems according to the finishing diet. In the central part of Chile (32° to 38° S), animals are fed in feedlots using rations produced in the farms, such as corn silage, alfalfa hay and grain soiling. Waste by-products from different agro-industries, such as poultry feces as well as fruit and vegetable by-products, are normally used as feed in Chilean feedlots (Claro and González, 2005). Grain usually represents between 20 and 40% of the total diet in Chilean feedlots. In contrast, beef production in the southern regions of Chile (38° to 41° S) relies on direct grazing, where there is a temperate rainy climate and pasture is the main feeding source. In these regions, over 50% of beef and over 70% of milk are produced nationally (INE, 2007). The dairy industry is an important source of animals for beef production because only 20% of the

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animals produced in Chile are from beef cattle breeds, whereas the rest come from dairy systems (Goic, 2001). There is another type of semi-intensive production system in Chile that combines pasture grazing with supplement.

The beef production system based on pasture has a lower environmental impact and causes lower animal stress than other systems (IICA, 2004). Additionally, consumers positively value beef from animals fed on pasture and raised outdoors (Schnettler *et al*., 2008). The beef industry plays an important role in the economy of the southern regions of Chile where more than one million hectares of pastures are available for animal production and the country relies on an exceptional sanitary status. In recent years, the beef industry has improved production processes to ensure quality and certification for overseas meat markets. However, there is limited scientific information about the nutritional quality of beef from Chile. In addition, limited research has been focused on the influence of diet from different Chilean production systems on beef fatty acid profile and cholesterol content. The aim of this study was to evaluate the nutritional quality (intramuscular fat and cholesterol content and fatty acid composition) of beef produced in Chile under different production systems classified according to the type of finishing diet.

MATERIALS AND METHODS

Animals and diets

Two-hundred and five steers from 13 livestock farms were evaluated. Animals were classified into three production systems according to the type of finishing diet (the last 30 d before slaughter). The predominant animal breed was Friesian and Friesian-crosses from dairy farms whereas the rest were British breeds. The individual animal breed information was not available at the abattoir and some farmers had different breeds in the same slaughter group.

Eighty steers were finished on pasture (P), which consisted of typical native and improved pastures from Los Ríos and Los Lagos Regions in Southern Chile (39°50' to 41°30' S). The predominant species in these grasslands were *Lolium perenne* L., *Trifolium repens* L., *Bromus* spp. and *Holcus lanatus* L. (Siebald, 2005). Seventy nine steers were finished on pastures and supplemented with grain (wheat or corn) or concentrate (PG). Forty six steers were finished on a typical feedlot system (F) in the central zone of Chile (32º to 38º S). The number of farms and animals, and feed components of the finishing diets from the three production systems are shown in Table 1, and the chemical and fatty acid composition of the finishing diets in Table 2.

Table 1. Number of farms and animals, and feed components of the finishing diets from the three production systems.

Production system	Farms (n)	Animals (n)	Feed type
Pasture (P)	6	80	Pasture (predominantly *Lolium perenne* L., *Trifolium repens* L., *Bromus* spp., and *Holcus lanatus* L.)
Pasture plus supplement (PG)	1	10	Pasture + 3.0 kg corn
	1	8	Pasture + 1.5 kg wheat
	2	35	Pasture + 1.5 kg concentrate
	2	26	Pasture + 3.5 kg concentrate
Feedlot (F)	1	46	Ration composition (kg): 1 crushed oat 0.5 corn 3 sifted oat 6 chicken feces 5 chopped hay 3 broad bean pod

In the diet from Chilean feedlots, a low grain percentage is normally used between 20 and 40% DM (in the present study the grain level was approximately 24%, Table 2), in contrast to that of other countries such as USA (Lawrence *et al*., 2007). In addition, different sources of fiber are used, such as alfalfa silage and hay, and many different by-products from the fruit and vegetable agro-industries (Claro and González, 2005). The type of by-product used in the feedlot depends on the price, season, and localization of the source. In the present study a typical Chilean feedlot was selected that was representative of the beef produced in central Chile under this system.

Sampling procedures

Animals between 18 and 24-mo of age and with hot carcass weight ranging from 250 to 300 kg were slaughtered. At 24 h post-mortem, 200 g of *Longissimus thoracis* were removed from the 8th to the 9th vertebra and transported to the Meat Science Laboratory of the Remehue Regional Research Centre at the Instituto de Investigaciones Agropecuarias (INIA) in Osorno, Chile. Muscle samples were vacuum packed and stored at -18 ± 2 ºC until analysis.

Chemical analysis was performed on 100 g of the feedstuff and meat samples. Samples of feedstuff were collected days previous to slaughter. Grass samples were taken from pasture on the animals were grazing whereas grain and concentrate samples were obtained from storage silo. In order to quantify intramuscular fat (IMF) from meat samples, all external fat was removed.

Table 2. Average chemical composition of the finishing diets (last 30 d).

	Pasture plus supplement (PG)				
	Pasture (P) (n = 39)	Corn grain (n = 3)	Wheat grain (n = 3)	Concen-trate (n = 15)	Feedlot (F) (n = 3)
Dry mater, %	15.9	71.5	88.2	88.8	74.8
Crude protein, %	22.6	5.3	16.1	17.6	18.1
Metabolizable energy, Mcal kg^{-1}	2.8	3.5	2.9	2.6	2.2
Ash, %	9.5	1.2	1.7	6.4	15.9
Ether extract, %	2.7	2.5	1.7	4.3	2.3
C18:1 *n*-9, %	2.14	25.27	25.31	18.54	29.28
C18:2 *n*-6, %	12.01	58.00	57.30	57.21	31.70
C18:3 *n*-3, %	66.18	1.20	1.15	3.40	7.46
SFA, %	19.31	14.51	15.53	18.4	25.86
MUFA, %	2.29	26.15	26.02	20.56	30.46
PUFA, %	78.43	59.34	58.45	61.01	43.68
P:S	4.22	4.09	2.86	3.42	1.72
n-6:*n*-3	0.19	48.40	49.82	17.65	4.26

SFA: Saturated fatty acids (C14:0 + C16:0 + C18:0); MUFA: monounsaturated fatty acids (C18:1 *c*-9); PUFA: polyunsaturated fatty acids (C18:2 *n*-6; C18:3 *n*-3); P:S: Polyunsaturated: saturated fatty acid ratio; *n*-6:*n*-3 fatty acid ratio.

Samples were dried at 60 ± 2 ºC by 48 h and ground before analysis. Sample moisture was determined by drying at 105 ± 2 ºC until constant weight (Harris, 1970) and total fat and IMF was measured by Soxhlet extraction 920.39 method (AOAC, 1990). Total N was measured by the Kjeldahl 984.13 method (AOAC, 1990) and ash following the 942.05 method (AOAC, 1990).

Fatty acid composition

Fat extraction was performed according to that by Bligh and Dyer (1959) and Lumley and Colwell (1991). Previous to analysis 20 g of fresh sample were thawed and grounded and posteriorly extracted using methanol, chloroform and water (80:50:32 mL). After, the samples were homogenized for 30 min. Afterwards, the samples were filtrated through filter paper in a glass funnel and was added water until to observe a biphasic separation. The fat was concentrated in the chloroform layer. The chloroform phase was collected and removed by evaporation and 2.0 mL of n-hexane were added to the extract, which was then stored at -18 ± 2 °C until analysis. Approximately 0.5 g fat was obtained with this extraction. Before the fatty acid C23:0 (Nu-Chek Prep, Elysian, Minnesota, USA) was added to the samples as an internal standard. Transmethylation was carried out according to the method described by Ichihara *et al*. (1996). One hundred μL of KOH in 2 N methanol were added and the mixture (sample + 2.0 mL) was agitated for 3 min at room temperature. After phase separation, the supernatant was collected and analyzed by gas chromatography. The fatty acid profile was determined in a gas chromatograph (Clarus 600 Perkin Elmer®, Waltham, Massachusetts, USA) equipped with a flame ionization detector (FID). A capillary column SP-2560™ (Sigma-Aldrich Co., Bellefonte, Pennsylvania, USA) of 100 m × 0.25 mm × 0.25 μm film was used. Helium was used as the carrier gas at 1.0 mL min^{-1} and inlet pressure of 15 psi, and the method of injection was split (100:1). The injector temperature was fixed at 250 ºC and the detector temperature at 260 ºC. The injected sample volume was 1.0 μL and the oven temperature was programmed to increase from 140 ºC (held for 5 min) to 240 ºC (held for 15 min) at 4 ºC min^{-1}. Fatty acids were identified by comparing the retention times of the chromatograph peaks with those of the methyl esters from a mixture prepared with a FAME Mix standard of 37 components (Standard: 47885-U, SigmaAldrich Co, St. Louis, Missouri, USA), C18:1 *t*-11 methyl ester standard (Standard: 46905-U, SigmaAldrich) and octadecadienoic conjugated methyl acid (Standard: O5632, Sigma Aldrich).

Cholesterol content

Cholesterol extraction was performed in 2 g of sample by direct saponification of 2% KOH in 50 mL of absolute ethanol (Mazalli *et al*., 2003) with subsequent chromatographic analysis using the following conditions: the injector temperature was fixed at 270 ºC and the detector temperature at 300 ºC. The sample volume injected was 1.0 μL. The oven temperature was programmed to increase from 160 ºC (held for 1 min) to 300 ºC (held for 7 min) at 10 ºC min^{-1}. A capillary column Elite-1 (Perkin Elmer®, USA) of 30 m × 0.25 mm × 0.25 μm film was used. Cholesterol was quantified by the standard internal method using 5-alpha-cholestane (Supelco Analytical, Bellefonte, Pennsylvania, USA) as reference.

Statistical analysis

Data were analyzed by ANOVA using the General Lineal Model (GLM) procedure of SAS (SAS Institute, 2001) with the type of finishing diet (pasture, pasture plus supplement, and feedlot) as a fixed effect in the model. Least-square means were separated by Tukey's Studentized range test.

RESULTS AND DISCUSSION

Carcass weight, intramuscular fat percentage and cholesterol content of *Longissimus thoracis*

Hot carcass weight was higher (P < 0.05) for steers finished on the feedlot diet than those from animals finished on pasture or pasture plus supplement (Table 3). Animals from P and PG production systems in Chile are usually slaughtered, between 470 and 550 kg live weight depending on the breed, whereas steers from the Chilean feedlots are slaughtered at above 550 kg live weight (Goic and Rojas, 2004; Claro and González, 2005).

No differences (P > 0.05) were found among groups for IMF percentage despite differences found in carcass weight between the F and the other two P and PG groups. Intramuscular fat values from this study (2.3%, 2.1% and 2.3% for P, PG, and F, respectively) were similar to those reported by Contreras (2006) for Chilean steers (1.9%).

De la Fuente *et al*. (2009) found similar IMF values to those from the present study in beef from European and Uruguayan animals finished on pasture (1.76% to 2.36%), but higher values in beef from animals fed on pasture with supplement (2.92% to 2.95%). Other authors have reported higher IMF content of Argentinean (Garcia *et al*., 2008; Schor *et al*., 2008) and Brazilian (Padre *et al*., 2006)

Table 3. Least-squares means for carcass weight, intramuscular fat and cholesterol content of *Longissimus thoracis* from steers finished on pasture, pasture plus supplement and feedlot diet.

	Finishing diet			
	Pasture (P) (n = 80)	Pasture plus supplement (PG) (n = 79)	Feedlot (F) (n = 46)	RMSE
Hot carcass weight, kg	260.57 ± 30.53b	269.07 ± 58.57b	292.39 ± 35.65a	43.304
Intramuscular fat, %	2.33 ± 1.06	2.09 ± 0.79	2.29 ± 1.11	0.959
Cholesterol 100 mg g^{-1}	73.14 ± 15.61ab	66.89 ± 18.64b	79.87 ± 15.16a	16.834

RMSE: Root mean squared error.
Common letter within a row indicates no significant difference ($P > 0.05$).

beef than those reported here. These authors reported IMF values from 2.86% to 3.38% for beef from animals fed on pasture and 3.5% to 4.2% for those from feedlot animals. Besides diet, animal breed, age and weight at slaughter can influence fat deposition among other factors (Lawrence and Fowler, 1997), and it is difficult to draw conclusions regarding the main factor determining differences in IMF deposition among studies.

Beef from animals fed on pasture-based systems showed lower cholesterol values (Table 3) compared to that from feedlot animals (PG: 66.9 vs. F: 79.9 mg 100 g^{-1}, $P < 0.05$; and P: 73.1 vs. F: 79.9 mg 100 g^{-1}, $P > 0.05$, numerical difference). Similar cholesterol values have been observed by other authors (Schor *et al*., 2008; Orellana *et al*., 2009), whereas lower cholesterol values (45.6 to 52.3 mg 100 g^{-1}) have been reported for beef from steers fed on pasture by Padre *et al*. (2006) and feedlot by Rule *et al*. (2002). However, some authors have indicated that the cholesterol content of muscle does not differ significantly between the feeding regimes of cattle (Wheeler *et al*., 1987; Taylor and Smith, 1990; Rule *et al*., 1997).

Longissimus thoracis intramuscular fatty acid composition

Intramuscular fat from steers fed P and PG diets had higher ($P < 0.05$) proportions of C20:0 and C24:0 compared to beef from feedlot animals, with no differences between treatments in myristic (C14:0) fatty acid (Table 4). Intramuscular fat from feedlot animals showed higher values of all saturated fatty acid (SFA), C15:0, C16:0 (except for PG), C17:0 and C18:0 compared to beef from pasture-based systems. The sum of all monounsaturated fatty acid (MUFA), and particularly oleic acid (C18:1 *c*-9), was higher in intramuscular fat from animals fed P and PG diets compared with those fed the feedlot diet (43.3% and 42.5% vs. 39.8% MUFA, and 36.1% and 37.2% vs. 34.2% C18:1 *c*-9, respectively).

Longissimus thoracis muscle from P- and PG-fed animals showed lower percentages of C14:1, C15:1, C17:1, C20:1 (except for PG) and C24:1 and a higher percentage of C16:1 compared with F ($P < 0.05$). There were no differences ($P > 0.05$) among treatments in the percentage of all PUFA. However, beef from P and PG showed lower percentages of C18:2 *n*-6, and C20:3 *n*-3, and higher percentages of C18:3 *n*-3 and C20:3 *n*-6 (except for P which did not differ from F) than beef from the F production system ($P < 0.05$). The percentage of all PUFAs was higher than those reported in other studies using different animal feed sources (Schor *et al*., 2008), but similar to those found by Padre *et al*. (2006) and Garcia *et al*. (2008) for Brazilian and Argentinean beef, respectively.

Intramuscular fat from animals fed on pasture only showed a higher percentage of C18:1 *t*-11 (vaccenic acid) than the two other finishing diets ($P < 0.05$). In this sense, other studies have also found that steers fed on grass had higher C18:1 *t*-11 than those fed on grain-based diets (Leheska *et al*., 2008; Garcia *et al*., 2008). Moreover, some studies suggest a linear increase in CLA *c*-9, *t*-11 synthesis as the C18:1 *t*-11 content of the diet increased in human subjects (Salminen *et al*., 1998; Turpeinen *et al*., 2002a), whereas, the rate of conversion of C18:1 *t*-11 to CLA *c*-9, *t*-11 was estimated to range from 5 to 12% in rodents to 19 to 30% in humans (Turpeinen *et al*., 2002b).

CLA *c*-9, *t*-11 was higher ($P < 0.05$) for steers fed pasture only (1.32% and 0.88%) than for steers fed pasture plus supplement (1.08% and 0.70%) or a feedlot diet (0.94% and 0.61%). CLA *c*-9, *t*-11 is produced as a result of the biohydrogenation process occurring in the rumen, where unsaturated fatty acids (mainly C18:3 *n*-3 and C18:2 *n*-6) from the diet are first isomerized and partially saturated later (Christie, 1981). As was

Table 4. Least-squares means for fatty acid composition (%) of *Longissimus thoracis* from steers finished on pasture, pasture plus supplement and feedlot diet.

	Finishing diet			
Fatty acid	Pasture (P) (n = 80)	Pasture plus supplement (PG) (n = 79)	Feedlot (F) (n = 46)	RMSE
SFA				
C14:0	2.21 ± 0.63	2.19 ± 0.59	2.30 ± 0.40	0.569
C15:0	0.49 ± 0.11b	0.42 ± 0.09c	0.56 ± 0.10a	0.103
C16:0	23.49 ± 2.22b	24.13 ± 2.36ab	24.78a ± 1.34	2.115
C17:0	2.52 ± 0.65b	2.49 ± 0.86b	2.80 ± 0.42a	0.698
C18:0	20.47 ± 2.27b	20.23 ± 2.30b	21.80 ± 2.20a	2.267
C20:0	0.08 ± 0.05a	0.06 ± 0.06a	0.02 ± 0.03b	0.050
C24:0	0.09 ± 0.07a	0.09 ± 0.07a	0.04 ± 0.04b	0.063
MUFA				
C14:1	0.31 ± 0.12b	0.33 ± 0.12b	0.42 ± 0.12a	0.119
C15:1	0.19 ± 0.06b	0.17 ± 0.05b	0.35 ± 0.08a	0.061
C16:1	0.76 ± 0.53a	0.72 ± 0.65a	0.48 ± 0.08b	0.520
C17:1	1.08 ± 0.23a	0.96 ± 0.26b	1.17 ± 0.10a	0.223
C18:1 *t*-11	4.46 ± 3.27a	2.90 ± 2.73b	2.75 ± 1.85b	2.806
C18:1 *c*-9	36.10 ± 4.09a	37.21 ± 4.23a	34.18 ± 3.77b	4.075
C20:1	0.06 ± 0.05b	0.08 ± 0.04ab	0.09 ± 0.02a	0.042
C24:1	0.32 ± 0.28b	0.16 ± 0.29b	0.34 ± 0.24a	0.029
PUFA				
C18:2 *n*-6	2.02 ± 0.98c	2.61 ± 1.82b	3.24 ± 1.05a	1.368
CLA C18:2 *c*-9 *t*-11	0.88 ± 0.25a	0.70 ± 0.29b	0.61 ± 0.16b	0.246
C18:3 *n*-3	1.03 ± 0.38a	1.02 ± 0.32a	0.71 ± 0.36b	0.354
C20:2 *c*-11 *c*-14	0.08 ± 0.13	0.07 ± 0.13	0.06 ± 0.03	0.113
C20:3 *n*-6	0.18 ± 0.09ab	0.19 ± 0.01a	0.15 ± 0.05b	0.090
C20:3 *n*-3	0.16 ± 0.12b	0.15 ± 0.13b	0.32 ± 0.15a	0.127
C20:4 *n*-6	0.04 ± 0.05	0.03 ± 0.04	0.04 ± 0.02	0.041
C20:5 *n*-3, EPA	0.09 ± 0.25	0.22 ± 0.24	0.03 ± 0.05	0.048
C22:5 *n*-3, DPA	0.64 ± 0.43	0.68 ± 0.40	0.57 ± 0.30	0.393
Unidentified	2.24 ± 0.39	2.18 ± 0.51	2.21 ± 0.37	0.432
SFA	49.34 ± 2.74b	49.61 ± 3.15b	52.30 ± 1.81a	2.731
MUFA	43.29 ± 2.34a	42.53 ± 3.40a	39.78 ± 2.21b	2.756
PUFA	5.13 ± 1.93	5.65 ± 2.36	5.71 ± 1.64	2.040
P:S	0.11 ± 0.04	0.11 ± 0.05	0.11 ± 0.03	0.044
n-6	3.13 ± 1.02b	3.54 ± 1.79b	4.03 ± 1.06a	1.379
n-3	1.92 ± 0.96ab	2.08 ± 0.87a	1.63 ± 0.72b	0.879
n-6:*n*-3	1.75 ± 0.36b	1.84 ± 0.89b	2.79 ± 1.08a	0.789

RMSE: Root mean squared error; CLA: conjugated linoleic acid; EPA: Eicosapentaenoic acid; DPA: Docosapentaenoic acid; SFA: saturated fatty acids: C14:0 + C16:0 + C17:0 + C18:0 + C20:0 + C24:0; MUFA: monounsaturated fatty acids: C14:1 + C15:1 + C16:1 + C18:1 *c*-9 + C18:1 *t*-11 + C20:1 + C24:1; PUFA: polyunsaturated fatty acids: C18:2 *n*-6 + C18:3 *n*-3 + C20:2 *c*-11 *c*-14 + C20:3 *n*-6 + C20:3 *n*-3 + C20:4 *n*-6 + C20:5 *n*-3 + C22:5 *n*-3 + CLA C18:2 *c*-9 *t*-11. P:S: polyunsaturated:saturated fatty acid ratio; *n*-6:*n*-3: fatty acid ratio.
Common letter within a row indicates no significant difference ($P > 0.05$).

mentioned, CLA *c*-9, *t*-11 is also synthesized by endogenous conversion of C18:1 *t*-11 (*trans*-vaccenic acid) by the enzyme Δ-9-desaturase in the adipose tissue and the mammary gland (Griinari and Bauman, 1999). Biohydrogenation efficiency decreases as the concentrate in the animal diet increases (Sauvant and Bas, 2001) and the CLA *c*-9, *t*-11 concentration in the adipose tissue is higher when animals are fed on pasture than those fed on stored forages or grain (French *et al*., 2000). Other studies have also shown that steers finished on pasture had higher CLA *c*-9, *t*-11 than those fed on grain-based diets (French *et al*., 2000; Realini *et al*., 2004; Nuernberg *et al*., 2005; Garcia *et al*., 2008; Leheska *et al*., 2008; De la Fuente *et al*., 2009).

There were no differences among treatments in the P:S ratio of the intramuscular fat ($P > 0.05$). A value of 0.4 or higher is recommended for the P:S ratio (Department of Health, 1994). However, De la Fuente *et al*. (2009) indicated that the P:S ratio is of limited significance because not all saturated fatty acids increase cholesterol. Moreover, the positive effect of monounsaturated fatty acids such as C18:1 *c*-9 (Lee *et al*., 1998) for human health is not considered when this ratio is used. C18:1 *c*-9 increases human HDL-cholesterol and decreases LDL-cholesterol concentrations (Katan *et al*., 1994), and there is a positive relationship between LDL-cholesterol levels and human cardiovascular diseases. In contrast, HDL-cholesterol reduces the risk of cardiovascular diseases (Kwiterovich, 1997). Beef from P- and PG-fed animals showed higher values of C18:1 *c*-9 than that from F-fed animals (Table 4). Considerable attention has been paid to the relative proportion of *n*-6 and *n*-3 fatty acids, as diets with high *n*-6:*n*-3 ratios have been highlighted as risk factors in certain cancers and coronary heart diseases (Hibbeln *et al*., 2006). A value of 4.0 or less for a diet is recommended for the *n*-6:*n*-3 ratio (Department of Health, 1994).

Beef from all production systems evaluated showed *n*-6:*n*-3 ratios lower than 4.0. However, beef from steers fed P and PG showed ratio values lower than 2.0 (Table 4), whereas beef from feedlot steers showed a mean ratio value of 2.79 ($P < 0.05$). Similar results have been reported by other authors (Enser *et al*., 1998; Nuernberg *et al*., 2002; Schor *et al*., 2008; De la Fuente *et al*., 2009) who have also found that the *n*-6:*n*-3 ratio increases as the grain or concentrate content in the diet increases.

The quantitative fatty acid composition in mg of fatty acids per 100 g of muscle is shown in Table 5. Although seafood is the major dietary source of *n*-3 fatty acids, red meat also constitutes a significant source of *n*-3 fatty acids for some populations with reduced intake of seafood products (Sinclair *et al*., 1994). Beef from animals fed on pasture showed higher levels of *n*-3 fatty acids than that from feedlot animals. Two hundred and fifty grams of beef from pasture-fed animals provided 112.5 mg of *n*-3 fatty acids, roughly 5.6% of the dietary reference intake for *n*-3 fatty acids (FAO/WHO, 2008), whereas beef from feedlot animals supplied 80.5 mg of *n*-3 fatty acids, which would correspond to 4.1% of the recommended value.

Table 5. Least-squares means for fatty acid composition (mg 100 g^{-1}) of *Longissimus thoracis* from steers finished on pasture, pasture plus supplement and feedlot diet.

Selected fatty acids	Finishing diet: Pasture (P) (n = 80)	Pasture plus supplement (PG) (n = 79)	Feedlot (F) (n = 46)	RMSE
C18:2 *n*-6	47.4 ± 34.9b	49.3 ± 32.6b	68.6 ± 26.2a	32.23
C18:3 *n*-3	24.2 ± 16.7a	20.5 ± 9.6a	14.3 ± 5.9b	12.43
CLA C18:2 *c*-9, *t*-11	20.0 ± 10.4a	14.9 ± 9.0b	14.0 ± 7.7b	9.33
SFA	1148.2 ± 514.0	1020.9 ± 409.3	1202.4 ± 583.9	495.44
MUFA	1011.2 ± 469.7	886.3 ± 358.2	928.6 ± 497.8	438.59
PUFA	119.3 ± 77.1	111.3 ± 55.0	119.7 ± 36.0	61.73
n-6	72.7 ± 43.3ab	68.6 ± 36.3b	86.4 ± 32.2a	38.44
n-3	45.0 ± 34.7a	41.3 ± 22.7ab	32.2 ± 8.4b	26.34

RMSE: Root mean squared error; CLA: conjugated linoleic acid; SFA: saturated fatty acids: C14:0 + C16:0 + C17:0 + C18:0 + C20:0 + C24:0; MUFA: monounsaturated fatty acids: C14:1 + C15:1 + C16:1 + C18:1 *c*-9 + C18:1 *t*-11 + C20:1 + C24:1; PUFA: polyunsaturated fatty acids: C18:2 *n*-6 + C18:3 *n*-3 + C20:2 *c*-11 *c*-14 + C20:3 *n*-6 + C20:3 *n*-3 + C20:4 *n*-6 + C20:5 *n*-3 + C22:5 *n*-3 + CLA C18:2 *c*-9 *t*-11.
Common letter within a row indicates no significant difference ($P > 0.05$).

Based on the amount of CLA *c*-9, *t*-11 needed to reduce cancer in experimental animal studies (Ritzenthaler *et al*., 2001), humans would need to consume around 620 mg CLA *c*-9, *t*-11 d^{-1} for men and 441 mg CLA *c*-9, *t*-11 d^{-1} for women to have a cancer protective effect (Ritzenthaler *et al*., 2001). Results from the present study show that 250 g of Chilean beef from pasture-fed animals would provide 50 mg (8.1% to 11.3%) of the CLA *c*-9, *t*-11 requirements, whereas PG and F would contribute 37.8 mg (6.1% to 8.6%) and 35 mg (5.6% to 7.9%), respectively. Thus, Chilean beef from pasture-fed animals, coupled with the consumption of grass-fed dairy products, would provide a higher concentration of CLA *c*-9, *t*-11 than beef from feedlot cattle to achieve dietary CLA *c*-9, *t*-11 levels closer to the recommended values.

There is limited nutritional information available characterizing the nutritional quality of Chilean beef. Results from the present study provide quantitative information for human nutritionists to provide more accurate consumer recommendations with values from local beef, rather than using data from international nutritional tables. In addition, objective information on the nutritional quality of Chilean beef from different production systems will be valuable for promoting beef consumption in local and international trade.

CONCLUSIONS

Beef from pasture-fed animals showed higher contents of C18:1 *t*-11, CLA *c*-9, *t*-11 and *n*-3 fatty acids, and a lower *n*-6:*n*-3 ratio than beef from feedlot animals. Beef from animals fed on pasture supplemented with grain showed a similar composition to that from pasture-fed animals, and intermediate values for some fatty acids between pasture and feedlot diets. However, Chilean beef from

the three production systems evaluated showed similar levels of intramuscular fat and a *n*-6:*n*-3 ratio lower than 4.0. Results indicate that the *Longissimus* muscle from Chilean beef could be recommended as a source of red meat for a healthy diet.

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Calidad nutricional de carne obtenida de diferentes sistemas productivos. En los últimos años, el sector de carne bovina en Chile ha desarrollado un notable avance a nivel de mejoramiento de procesos de producción, aseguramiento de calidad, y certificación exportadora. Sin embargo, existe poca información disponible sobre la calidad nutricional de la carne producida en Chile. En el presente estudio se evaluó la calidad nutricional de la carne producida en Chile en diferentes sistemas de producción clasificados de acuerdo con el tipo de acabado. Se evaluó la carne de 205 animales de 13 predios: 80 novillos se finalizaron a pastoreo, 79 fueron finalizados a pastoreo más suplementación, mientras que 46 se terminaron en un típico feedlot de la zona central de Chile. En el músculo *Longuissimus thoracis* se determinó la cantidad de grasa intramuscular, el perfil de ácidos grasos, y el colesterol. La carne de los animales finalizados a pradera muestra altos niveles de ácido vaccénico (C18:1 *trans*-11), ácido ruménico (CLA *cis*-9 *trans*-11) y ácidos grasos *n*-3, además de un bajo nivel de la relación *n*-6:*n*-3 en comparación con los animales de feedlot. Sin embargo, la carne de los tres sistemas de producción muestra similares niveles de grasa intramuscular y una relación *n*-6:*n*-3 bajo 4.0. Los resultados indican que la carne chilena podría ser recomendada como fuente alimenticia para una dieta saludable.

Palabras clave: ácidos grasos, praderas, calidad de carne chilena.

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