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Effects of Finishing Diet and Length of Time on Feed on the Quality of Beef

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Abstract: The aim of the present study was evaluate the effect of finishing diets and the length of feeding on the quality of Chilean beef. A group of 75 steers were fed one of 5 finishing diets (n = 15 per diet): pasture for 90 days (P), oat grain plus pasture silage for 35 days (SO), oat grain plus pasture silage for 75 days (LO), wheat grain plus pasture silage for 35 days (SW) and wheat grain plus pasture silage for 75 days (LW). Physicochemical and sensory attributes and fatty acid composition of beef were determined. Beef from pasture-fed animals was more tener, darker, less red and with yellower fat than beef from grain-fed steers. The length of feeding with grain did not alter beef quality, except for the percentage of intramuscular fat which was higher and tenderness which was lower for the longer feeding period with wheat. Beef from pasture-fed steers had a more favourable fatty acid profile with higher levels of CLA and n-3 fatty acids and a lower n-6:n-3 fatty acid ratio than beef from grain-fed steers. Longer grain feeding decreased n-3 fatty acids and increased the n-6:n-3 ratio compared to the effect of shorter feeding, especially with the wheat diet.

Key words: Beef, physicochemical, grain, acid, ratio

INTRODUCTION

Both producers and consumers are interested in the nutritional quality of beef, producers because of the added value they can obtain for their product and consumers because of their concern about eating healthier food. Research has been focused on improving the nutritional quality of beef by modifying the animal diet. Beef production systems based on pasture have less environmental impact and cause less animal stress than other production systems (IICA, 2004). 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. 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 (Steen and Porter, 2003; Elgersma *et al*., 2003). Conjugated Linoleic Acid (CLA) naturally found in food products from ruminants, refers to a mixture of positional and geometric isomers of linoleic acid (C18:2 c-9, c-12) with two conjugated double bonds at various carbon positions in the fatty acid chain. Conjugated linoleic acid is deposited in beef by direct (ruminalbiohydrogenation and isomerisation) 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, among other effects. It has also been shown that CLA exhibits antioxidant properties, inhibiting the discolouration of meat during storage (Du *et al*., 2000).

In recent years, consumers are demanding healthier food (Realini *et al*., 2014; Kallas *et al*., 2014). A recent study has shown that consumers are willing to pay a premium for products enriched with n-3 and/or CLA fatty acids (Realini *et al*., 2014). In addition, Chilean consumers positively value animals fed on pasture and raised outdoors (Schnettler *et al*., 2008; Morales *et al*., 2013). The majority of the beef production system in the Southern regions relies on grazing of temperate pastures. Pasture production varies amply throughout the year with low growth rates in Winter and dry Summers resulting in growth rates as low as 20 g MS ha d-1 in Winter months (Teuber, 2009). To satisfy national and international beef markets, supplements are used with grain to finish steers in Winter. As well, better prices can be obtained in the cattle market in Winter than Spring and Summer when pasture production is higher and the majority of the animals in the Southern region of Chile are slaughtered.

The concentration of healthy fatty acids is higher in beef from animals finished on pasture than on grain-based diets. A recent study evaluated the nutritional quality (intramuscular fat and cholesterol content and fatty acid

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composition) of beef produced in Chile under different production systems classified according to the type of finishing diet (Morales *et al*., 2012). Nevertheless, beef finished on Winter diets including grains and with different feeding periods was not considered in the cited study. In Addition, limited information about the length of time on grain fed was found. The aim of the present study was to compare the quality of grain-fed and pasture-fed beef as well as to assess the impact of two feeding periods.

MATERIALS AND METHODS

Animals and diets: A group of 75 Holstein-Friesian steers of similar age (Autumn birth-14 months old) were selected fromthe animal production unit of Instituto de Investigaciones Agropecuarias (INIA) Remehue Centre for the present study. The animals were maintained under a common feeding system until reaching a target live weight of around 300-450 kg (Pre-experimental phase (Fig. 1). The animals were then divided into five groups of 15 steers each to be finished under different systems (Experimental phase): finishing for 35 days with oatgrain plus pasture silage (SO); finishing for 75 days with oat grain plus pasture silage (LO); finishing for 35 days with wheat plus pasture silage (SW); finishing for 75 days with wheat plus pasture silage (LW) and finishing on pasture for 90 days (P group) to achieve a target slaughter weight of ~500 kg. All grain treatments were formulated approximately isoprotein and isocaloric and the grain (wheat or oat) was provided at 1% of the live animal weight while grass silage was provided at 2% of live weight. Diets were adjusted weekly according to live animal weight. The five treatments were supplemented with a mineral mix. Initial and final live weights, average daily weight gain and diet characteristics are shown in Fig. 1. The pasture was permanent grassland composed mainly of perennial ryegrass (Loliumperenne), Brome grasses (*Bromus* sp.), Yorkshire fog (Holcuslanatus) and white clover (Trifoliumrepens).

Chemical and fatty acid composition of feed used in the pre-experimental and experimental phases are shown in Table 1. The chemical content of feed samples was analysed at the INIA Remehue Animal Nutrition and Environment Laboratory in Osorno, Chile. Dry matter, ether extract and ash were measured by the methods described by the AOAC (2005, 1984). Crude protein was determined according to the AOAC (1984) and metabolizable energy and neutral detergent fibre according to Sadzawka *et al*. (2007).

Slaughter and sampling procedure: Steers were slaughtered at a commercial meat plant licensed for export when they reached an average live weight between 460-500 kg. Slaughter followed standard procedures and average cold carcass weights were 242.8, 231.7, 247.2, 248.1 and 268.1 kg for the SO, LO, SW, LW and P groups, respectively.

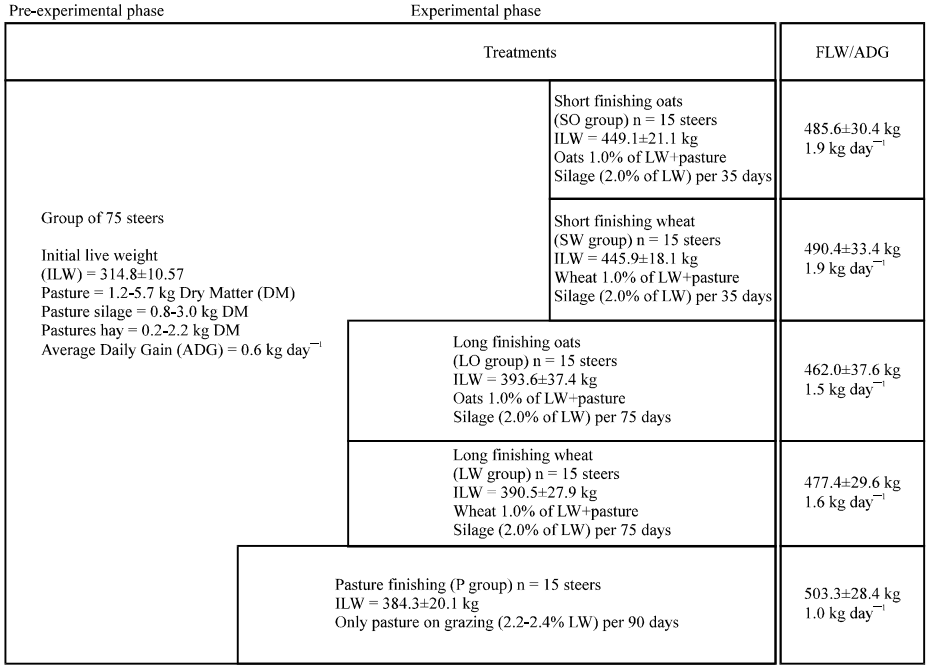

Fig. 1: Initial (ILW) and Final Live Weight (FLW), Average Daily Gain (ADG) and the pre-experimental and experimental phase diets for all treatments

Table 1: Average chemical compositions of the diets in the pre-experimental and experimental phases (n = 3)

	Pre-experimental feed			Experimental feed			
Parameteres	Pasture	Pasture silage	Pasture hay	Pasture	Pasture silage	Wheat	Oats
Dry mater (%)	12.80	19.40	82.50	19.80	40.8	85.1	84.7
Crude protein (%)	26.50	9.40	7.40	18.80	13.6	13.7	13.1
Metabolizable energy (Mcal kg^{-1})	2.75	2.54	2.04	2.84	2.5	3.2	2.7
Ash (%)	10.90	8.20	7.30	9.80	11.6	1.5	2.6
Ether extract (%)	2.80	3.40	1.30	4.00	2.6	1.3	2.8
Neutral detergent fibre (%)	44.50	58.30	67.00	43.10	52.2	12.0	32.0
C14:0	0.00	1.00	0.70	0.20	0.0	0.0	0.0
C15:1	4.30	4.30	5.30	5.00	3.5	0.0	0.0
C16	16.50	20.60	28.40	13.10	21.1	18.9	15.1
C16:1	2.10	1.50	1.50	2.30	1.5	0.0	0.0
C18	1.50	1.80	4.00	1.50	1.2	1.2	2.6
C18:1 n-9	1.60	3.90	11.20	1.40	1.7	15.1	40.3
C18:2 n-6	12.10	21.40	23.60	8.20	13.8	60.9	40.2
C18:3 n-3	61.90	45.30	23.70	68.40	56.9	4.0	1.2
C20:0	0.00	0.10	1.60	0.00	0.0	0.0	0.0
C20:1	0.00	0.00	0.00	0.10	0.0	0.0	0.7

Cold carcass weight and pH were measured at 24 h post-mortem in the abattoir. Three pH measurements were taken per carcass with a pH penetration electrode (Hanna FC232) of a portable pH-meter (Hanna 99163, Hanna Instruments, Woonsocket, Rhode Island, USA). A Longuissimus lumborum (LL) section was removed from each carcass and cut into three equal parts that were vacuum packaged and stored frozen at -18±2°C until analysis. The cranial part was used for sensory analysis, the middle section for colour and texture analysis and the caudal part for chemical composition and fatty acid analysis.

Sensory analysis: An eleven-member trained panel participated in the sensory analysis. The training and testing sessions were conducted at the sensory laboratory of the Remehue Centre of the INIA (Osorno, Chile). Panellists were selected from a group of 30 persons without previous experience in sensory evaluation that were trained following ASTM (1981) and ISO standards. The sensory laboratory was designed according to ISO standards with separate booths and the samples were evaluated in a sequence established to avoid the effect of sample order presentation, first-order or carry-over effects (MacFie *et al*., 1989).

Assessors evaluated beef colour intensity, fat colour intensity and the level of marbling in five raw steaks per session and beef flavour, tenderness and juiciness in cooked samples. Panellists evaluated the cooked samples in duplicate and five samples were analysed per session.

Immediately after visual evaluation, the steaks were covered with aluminium foil and cooked in a pre-heated oven (EKA®, KF 620, Famava, Santiago, Chile) at 170°C until reaching an internal temperature of 71°C which was determined with individual thermocouples inserted into the geometric centre of each steak.

Cooked steaks were diced into pieces of 20×20×25 mm (length x width x height), placed in coded trays and served to assessors. The descriptors were quantified using a hybrid scale ranging from 0 (absence) to 10 (maximum intensity) (Villanueva *et al*., 2005).

Colour and texture: Steaks were allowed to bloom for 30 min at room temperature prior to analysis. Instrumental colour measurements were recorded for L* (lightness; 0: black, 100: white) a* (redness/greenness; positive values: red, negative values: green) and b* (yellowness/blueness; positive values: yellow, negative values: blue) using a Minolta chromameter (CR-400, Minolta Inc., Osaka, Japan) with illuminat D_{65} and 2° viewing angle. Readings were taken from three locations of the upper surface of each steakrandomly selected to obtain a representative reading of the surface colour. The instrumental colour of the external fat surface was also measured.

After measuring colour, two steaks were used to determine shear force. The cooking procedure was the same as for sensory evaluation. After cooking, steaks were wrapped with film and stored for 24 h at 4±2°C. Subsequently, at least six cores 13 mm in diameter were obtained from each steak for Warner-Bratzler Shear Force (WBSF) analysis following the methodology described by Wheeler *et al*. (1997). The test was performed using a Warner-Bratzler shear blade with a triangular slot cutting edge and recording of the maximum shear force.

Intramuscular Fat (IMF) was measured by the Soxhlet Extraction Method (AOAC, 1990) after removing all external fat from the steaks.

Fatty acid composition: Samples of 10 and 35 g were used for fatty acid analysis of meat and fresh pasture, respectively. Fat was extracted according to Bligh and Dyer (1959) as modified by Lumley and Colwell (1991). Meat samples were methylated according to

Ichihara *et al.* (1996) and pasture samples according to Hartman and Lago (1973). Samples were analysed with gas chromatography (GC-2010 Plus, Shimadzu®, Kyoto, Japan) equipped with an FID detector. A capillary column SP-2560™ (Sigma-Aldrich Co., Bellefonte, Pennsylvania, USA) of 100×0.25 mm×0.25 μm film was used with helium as the carrier gas at 1.0 mL min^{-1} and an inlet pressure of 15 psi and the method of injection was split (100:1). The injector temperature was fixed at 250°C and the detector temperature at 260°C. The injected sample volume was 1.0 μL and the oven temperature was programmed to increase from 140°C (held for 5 min) to 240°C (held for 15 min) at 4°C min^{-1}. Fatty acids were identified by comparing the retention times of the chromatograph peaks to those of the methyl esters from a mixture prepared with a FAME standard of 37 components (Standard: 47885-U, Sigma-Aldrich Co., St. Louis, USA), C18:1 t-11 methyl ester standard (Standard: 46905-U, Sigma-Aldrich Co., St. Louis, USA), c-9, t-11 octadecadienoic conjugated methyl acid (Standard: 10-1823-7, Larodan AB, Malmo, Sweden) and PUFA-2 (Supelco Analytical, USA). C23 was used as an internal standard (NU-CheckPrep, INC, Elysian, USA) (Table 1).

Statistical analysis: Data were analysed by an ANOVA using the General Lineal Model (GLM) procedure by SAS (2001) with the type of finishing diet (SO, LO, SW, LW and P) as a fixed effect in the model. Least-square means were separated by Tukey's studentized range test.

The Principal Components were Analysed (PCA) for physico chemical parameters, sensory attributes and fatty acid profile using the XLSTAT statistical package (Addinsoft, France) to illustrate and better understand relationships among the variables.

RESULTS AND DISCUSSION

Physicochemical and sensory evaluations: Table 2 shows the physicochemical and sensory results of the treatments. There were no differences ($p>0.05$) in pH values among treatments with an average pH of 5.64 which is within the normal range for beef. Significant differences in meat redness (a*) were detected instrumentally among treatments. Beef from SW, SO and LW was redder than beef from pasture cattle. Similarly, SW was higher than P for red colour intensity as evaluated by a trained panel. Instrumental colour lightness (L*) and yellowness (b*) also differed ($p<0.05$) among treatments. SW was higher than P for L* and P was lower for b* than the other treatments with the exception of LO. Beef from treatment P was darker than beef from grain-finished animals. Others researcher have also found that muscles in pasture-fed beef are darker than in grain-fed beef (Schroeder *et al.*, 1980; Bidner *et al.*, 1986; McCaughey and Cliplef, 1996; Realini *et al.*, 2004).

Table 2: Physicochemical and sensory attributes of beef by dietary treatment (n = 15 per treatment)

Parameters	SO	LO	SW	LW	P	RMSE
Physicochemical variables						
pH	5.63	5.63	5.63	5.64	5.64	0.057
Shear force (kgf)	3.47^{a}	3.33^{a}	3.35^{a}	3.16^{ab}	2.85^{b}	0.655
Lean colour						
L*	33.69^{ab}	33.73^{ab}	34.43^{a}	34.23^{ab}	32.55^{b}	2.556
a*	21.35^{a}	20.49^{ab}	22.16^{a}	21.14^{a}	18.84^{b}	2.812
b*	11.23^{ab}	10.24^{bc}	11.76^{a}	10.78^{ab}	9.20^{c}	1.804
Fat colour						
L*	69.35^{a}	65.18^{bc}	68.77^{a}	66.16^{ab}	62.18^{c}	4.382
a*	5.86	5.47	6.49	6.80	6.13	2.155
b*	14.29^{a}	11.87^{b}	14.21^{a}	13.60^{ab}	14.64^{a}	2.694
Intramuscular fat (%)	3.17^{ab}	2.67^{b}	2.81^{b}	3.90^{a}	2.42^{b}	1.113
Sensory attributes						
Marbling	3.70^{ab}	3.30^{b}	3.50^{ab}	3.80^{ab}	3.90^{a}	1.204
Red colour intensity	4.80^{ab}	4.90^{ab}	5.00^{a}	4.70^{ab}	4.60^{b}	1.240
External fat colour	3.20^{b}	3.00^{b}	3.50^{ab}	3.10^{b}	3.60^{a}	1.207
Juiciness	4.20^{a}	3.50^{b}	4.00^{ab}	3.80^{ab}	3.80^{ab}	1.763
Tenderness	4.80^{ab}	4.30^{bc}	4.40^{ab}	3.90^{c}	5.00^{a}	1.888
Flavour	4.80^{b}	5.20^{ab}	4.90^{ab}	5.00^{ab}	5.30^{a}	1.285

$^{a-d}$The same letters in a row indicate there are no significant differences ($p>0.05$). RMSE: Root Mean Square Error; SO = Steers finished with oats (1.0% of live weight) grain and pasture silage (2.0% of live weight) for 35 days; LO = Steers finished with oats (1.0% of live weight) grain and pasture silage (2.0% of live weight) for 75 days; SW = Steers finished with wheat (1.0% of live weight) grain and pasture silage (2.0% of live weight) for 35 days; LW = Steers finished with wheat (1.0% of live weight) grain and pasture silage (2.0% of live weight) for 75 days; P = Steers finished on pasture for 90 days

The L* values for external fat colour were higher for all grain treatments than for the P treatment. Similarly, the external fat colour of beef of pasture-fed animals was more intense ($p<0.05$) than that of other treatments with the exception of SW. Pasture-fed beef often contains yellow fat due to the high carotenoid content of pastures while fat in feedlot beef tends to be white (Yang *et al.*, 2002).

The LW treatment had a higher percentage of Intramuscular Fat (IMF) than the LO, SW and P treatments. However, marbling values assigned by the trained panellists were higher for P than LO with no statistical differences among other treatments. A correlation was observed between marbling assessed by trained panellists and an IMF percentage of 0.46. The correlation between marbling and IMF is highly variable and previous studies reported ranges from 0.32-0.79 (Taylor and Johnson, 1992; Kruk *et al.*, 2002). This wide range could be due to many factors such as the range of IMF content, the range of marbling scores, the method of intramuscular fat extraction etc. (Kruk *et al.*, 2002).

Warner-Bratzler shear force was higher in beef from the SO, LO and SW treatments than beef from the pasture treatment. These results are in agreement with those reported by Realini *et al.* (2004, 2009)

and Del Campo *et al.* (2008) who also showed that beef from pasture-fed animals had lower shear force values than beef from grain-finished cattle. Similarly, the trained panellists assigned higher tenderness scores for beef from the pasture treatments than from LW and LO.

Beef flavour scores were higher ($p<0.05$) for P than SO with no differences ($p>0.05$) among the other treatments. In addition, the trained panel found that SO was higher than LO for juiciness.

Intramuscular fatty acid composition: Beef intramuscular fatty acid composition is shown in Table 3 for all the dietary treatments. Intramuscular fat from steers fed the P diet had lower ($p<0.05$) levels of C14:0 and C16:0 than corresponding fat from the LW treatment while LW was lower than LO, SW and P in C18:0. No differences were observed among treatments in C15:0, C17:0, C20:0 and C22:0 fatty acids. Intramuscular fat from the LO and SW treatments had higher values of all Saturated Fatty Acids (SFA) than pasture-fed beef.

Table 3: Intramuscular fatty acid composition of beef by dietary treatment (n = 15 per treatment)

Fatty acid	SO	LO	SW	LW	P	RMSE
C14:0	2.14^{ab}	2.17^{ab}	2.17^{ab}	2.34^{a}	1.94^{b}	0.403
C15:0	0.31	0.32	0.35	0.32	0.33	0.087
C16:0	26.00^{ab}	25.60^{bc}	26.0^{ab}	26.9^{a}	24.50^{c}	1.499
C17:0	0.83	0.79	0.88	0.82	0.81	0.128
C18:0	14.20^{ab}	14.90^{a}	14.7^{a}	12.9^{b}	14.50^{a}	1.826
C20:0	0.10	0.09	0.09	0.08	0.06	0.048
C22:0	0.07	0.10	0.06	0.06	0.10	0.062
SFA	43.70^{ab}	44.00^{a}	44.3^{a}	43.5^{ab}	42.20^{b}	2.114
C14:1	0.61^{ab}	0.59^{ab}	0.58^{ab}	0.73^{a}	0.52^{b}	0.238
C16:1	4.05^{ab}	3.92^{ab}	3.82^{ab}	4.50^{a}	3.81^{b}	0.876
C17:1	0.65^{b}	0.63^{b}	0.69^{ab}	0.80^{a}	0.69^{ab}	0.150
C18:1 t-11	1.05^{b}	1.10^{b}	1.27^{b}	1.05^{b}	1.62^{a}	0.480
C18:1 c-9	41.50	40.50	39.9	41.8	41.80	2.692
C18:1 c-7	1.29	1.15	1.31	1.41	1.21	0.361
C20:1	0.14	0.11	0.12	0.13	0.12	0.126
MUFA	49.40	48.00	47.8	50.4	48.40	2.877
C18:2 n-6	3.09	3.62	3.36	2.84	3.02	1.246
C18:2 n-6 trans	0.14^{b}	0.14^{b}	0.15^{b}	0.16^{b}	0.26^{a}	0.077
CLA C18:2 c-9 t-11	0.37^{bc}	0.36^{bc}	0.44^{b}	0.34^{c}	0.55^{a}	0.123
C18:3 n-6	0.06^{a}	0.06^{a}	0.04^{ab}	0.04^{ab}	0.01^{b}	0.044
C18:3 n-3	0.90^{bc}	0.78^{bc}	1.03^{b}	0.64^{c}	1.52^{a}	0.424
C20:2 c-11 c-14	0.01	0.02	0.01	0.01	0.01	0.013
C20:3 n-6	0.36^{ab}	0.39^{a}	0.41^{a}	0.32^{ab}	0.22^{b}	0.194
C20:4 n-6	1.41	1.70	1.44	1.24	1.50	0.719
C20:5 n-3, EPA	0.10^{bc}	0.04^{bc}	0.14^{b}	0.03^{d}	0.29^{a}	0.084
C22:5 n-3, DPA	0.64^{bc}	0.65^{bc}	0.75^{b}	0.44^{c}	1.03^{a}	0.385
C22:6 n-3, DHA	0.16	0.14	0.16	0.12	0.14	0.097
PUFA	7.30^{ab}	8.01^{ab}	8.01^{ab}	6.23^{b}	8.64^{a}	2.948
P:S	0.17^{ab}	0.18^{ab}	0.18^{ab}	0.15^{b}	0.21^{a}	0.073
n-6	5.43	6.28	5.85	4.94	5.56	2.116
n-3	1.79^{bc}	1.61^{bc}	2.09^{b}	1.22^{c}	2.98^{a}	0.909
n-6:n-3	3.10^{b}	4.01^{a}	2.87^{b}	4.09^{a}	2.11^{c}	0.720

$^{a-d}$The same letters in a row indicate there are no significant differences ($p>0.05$); RMSE: Root-Mean-Square 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+C16:1+C17:1+C18:1 c-9+C18:1 c-7+C18:1 t-11+C20:1; PUFA: polyunsaturated fatty acids: C18:2 n-6+C18:2 n-6 trans+C18:3 n-3+C18:3 n-6+C20:3 n-6+C20:3 n-3+C20:5 n-3; C22:6 n-3+CLA c-9 t-11. P:S: polyunsaturated:saturated fatty acid ratio; n-6:n-3: fatty acid ratio. SO = Steers finished with oats (1.0% of live weight) grain and pasture silage (2.0% Live weight) per 35 days; LO = Steers finished with oats (1.0% Live weight) grain and pasture silage (2.0% of live weight) for 75 days; SW = Steers finished with wheat (1.0% of live weight) grain and pasture silage (2.0% of live weight) for 35 days; LW = Steers finished with wheat (1.0% of live weight) grain and pasture silage (2.0% of live weight) for 75 days; P = Steers finished on pasture for 90 days

Intramuscular fat of the longissimus thoracis muscle from the LW treatment had higher percentages of C14:1 and C16:1 than corresponding fat from the pasture treatment and higher C17:1 than fat from the oat treatments. There were no differences among treatments in the percentages of total Monounsaturated Fatty Acids (MUFA), oleic acid (C18:1 c-9), C18:1 c-7 and C20:1.

Intramuscular fat from animals fed on pasture had a higher percentage of C18:1 t-11 (vaccenic acid) than those from the other finishing treatments ($p<0.05$) which is consistent with other studies (Descalzo *et al.*, 2005; Leheska *et al.*, 2008; Garcia *et al.*, 2008). C18:1 t-11 is an intermediate of the biohydrogenation of linoleic and linolenic acids. Some studies reported that the C18:1 t-11 hashypolipidemic (Jacome-Sosa *et al.*, 2010) and anticarcinogenic effects (Miller *et al.*, 2003). These researchers indicated that it is to due to the conversion of C18:1 t-11 to CLA c-9, t-11 in non-ruminants (Corl *et al.*, 2001; Miller *et al.*, 2003). Turpeinen *et al.* (2002) estimated the rate of conversion of C18:1 t-11 to CLA c-9, t-11 in the range from 5-12% in rodents and 19-30% in humans.

Beef from treatment P had a higher percentage of all PUFA than LW. In addition, beef from treatment P had higher percentages of C18:2 t-6, C18:3 n-3, Conjugated Linoleic Acid (CLA) c-9, t-11 C20:5 n-3 EPA and C22:5 n-3 DPA fatty acids. In contrast, beef from the oat treatments were higher than P in C18:3 n-6 fatty acid while beef from the LO and SW treatments were higher than P in C20:3 n-6. The percentages of all PUFAs were higher than those reported in other studies using different animal feed sources (Schor *et al.*, 2008; Morales *et al.*, 2012) but similar to those found by Padre *et al.* (2006) and Garcia *et al.* (2008) for Brazilian and Argentine beef, respectively.

Conjugated linoleic acid c-9, t-11 was higher ($p<0.05$) for steers finished on pasture than on the other treatments. Conjugated linoleic acid c-9, t-11 is produced as a result of biohydrogenation in the rumen where unsaturated fatty acids (mainly C18:2 n-6 and C18:3 n-3) from the diet are isomerised and then partially saturated (Christie, 1981). Biohydrogenationis affected as the concentrate content in the diet increases (Sauvant and Bas, 2001). CLA c-9, t-11 concentration in adipose tissue is higher when animals are fed on pasture than on stored forage 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 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; Morales *et al*., 2012). On the other hand, CLA c-9, t-11 is also synthesised by endogenous conversion of C18:1 t-11 by the enzyme Δ-9-desaturase in adipose tissue and mammary glands (Griinari and Bauman, 1999). Up to 90% of the CLA c-9, t-11 in meat and milk is from endogenous synthesis (Santora *et al*., 2000; Piperova *et al*., 2002) originating from the action of the Stearoyl Co-A Desaturase (SCD) enzyme (Corl *et al*., 2001) via C18:1 t-11 desaturation.

The percentages of CLA c-9, t-11, C18:3 n-3, C20:5 n-3 and C22:5 n-3 were higher for SW than LW, while there were no differences between the oat treatments. CLA c-9, t-11 was also lower in milk when wheat concentrate content was increased to induce subacuteruminal acidosis (Colman *et al*., 2010). Grain seeds are not usually regarded as a source of oil but oats (*Avena sativa* var. nuda) contain 90-100 g oil kg^{-1} almost twice as much as barley or wheat and 40-50 g oil kg^{-1} of the oil is in the form of PUFA (Abeysekara, 2003). In the present study, oats has twice of ether extract compared to wheat (Table 1). Studies have investigated the effect of naked oats in feed on the fatty acid composition of milk (Fearon *et al*., 1996; Woods and Fearon, 2009). Milk fat from early lactation cows fed on a naked oat diet (plus *ad libitum* grass silage) had higher levels of unsaturated fats and lower levels of saturated fatty acids than milk animals fed on a barley diet (Fearon *et al*., 1996). On the other hand, diets with oats favour the main rumen PUFA-biohydrogenation pathway (associated with modification of ruminal bacterial populations) inducing more complete hydrogenation of unsaturated fatty acids in the diet (Gomez-Cortes *et al*., 2009). Moreover, microorganisms in the rumen adapt to an increase in the unsaturated oil content of the diet so the biohydrogenation capacity increases with a higher number of competent bacteria and/or their activity (Zened *et al*., 2012). Further, studies are needed to evaluate the effect of including naked oats on the content and composition of intramuscular fat in steers.

The P:S ratio was higher in P than LW but none of the treatments had higher values than the recommended ratio of 0.4 or higher (British 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 effects on human health of monounsaturated fatty acids, such as C18:1 c-9 (Lee *et al*., 1998) are 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 while HDL-cholesterol reduces the risk of cardiovascular diseases (Kwiterovich, 1997).

Considerable attention has been given to the ratio between n-6 and n-3 fatty acids, a high n-6:n-3 ratio is considered a risk factor for certain cancers and coronary heart diseases (Hibbeln *et al*., 2006). A n-6:n-3 ratio of 4.0 or less is recommended (British Department of Health, 1994). The pasture, SO and SW treatments (35 days) had n-6:n-3 ratios >4.0 with the lowest ratio being from the pasture treatment which is in agreement with other studies (Enser *et al*., 1998; Nuernberg *et al*., 2002; Schor *et al*., 2008; De la Fuente *et al*., 2009; Morales *et al*., 2012). These results highlight the importance of the concentrate: forage ratio of the diet which indicates that feeding grass silage plus grain for 35 days but not 75 days is a suitable alternative to pasture to produce beef with a good n-6:n-3 ratio. Eriksson and Pickova (2007) also found an increase in the n-6:n-3 ratio and a decrease in the total PUFA content of muscle tissueof steers fed silage plus grain (wheat and oats) for the final 4 months compared to that of steers finished on pasture. Aldai *et al*. (2011) reported similar n-6:n-3 ratios in beef from steers finished on pasture and intensive concentrates for 1 month. Other studies have shown that diets high in concentrates negatively affect the n-6:n-3 ratio (Realini *et al*., 2004; Cifuni *et al*., 2004; De La Fuente *et al*., 2009; Aldai *et al*., 2011). Aldai *et al*. (2011) reported that beef of steers finished for 2 months on concentrates had a higher n-6:n-3 ratio, a lower C18:1 trans and CLA isomers and higher undesirable 18:1, 18:2 and CLA isomers than beef from animals fed on pasture.

CONCLUSION

Beef from pasture-fed animals was more tender, darker, less red and with yellower fat than beef from grain-fed steers. The length of time on feed with grain did not alter beef quality except for the percentage of intramuscular fat which was higher and tenderness which was lower for the longer grain-feeding period. Beef from pasture-fed steers had a more favourable fatty acid profile with higher levels of CLA and n-3 fatty acids and a lower n-6:n-3 fatty acid ratio than beef from grain-fed steers. The length of time on feed had a significant effect on the fatty acid profile. Beef from the longer feeding period had a lower n-3 fatty acid level and higher n-6:n-3 ratio than beef from the shorter feeding period, the difference being more pronounced with wheat than with oats.

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