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RESEARCH PAPER

Finishing strategies for steers based on pasture or silage plus grain and time on feed and their effects on beef quality

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Abstract

R. Morales, J. Parga, I. Subiabre, and C.E. Realini. 2015. Finishing strategies for steers based on pasture or silage plus grain and time on feed and their effects on beef quality. **Cien. Inv. Agr. 42(1): 5-18.** The aims of the present study were to compare the quality of grain-fed and pasture-fed beef and to assess the effects of two feeding periods on grain for finishing steers. A group of 75 steers were fed one of 5 finishing diets (n = 15 per diet): pasture for 90 d (P), oat grain plus pasture silage for 35 d (SO), oat grain plus pasture silage for 75 d (LO), wheat grain plus pasture silage for 35 d (SW), and wheat grain plus pasture silage for 75 d (LW). The physicochemical and sensory attributes and the fatty acid composition of the *longissimus lumborum* muscle were determined. The beef from pasture-fed animals tended to be tenderer, darker, less red, and with yellower fat than the beef from grain-fed steers. The beef from steers fed wheat plus silage for 75 d had lower tenderness scores than beef from steers fed for 35 d on grain plus silage. The beef from pasture-fed steers had higher levels of conjugated linoleic acid *c*-9 *t*-11 and *n*-3 fatty acids and a lower *n*-6:*n*-3 fatty acid ratio than the beef from grain-fed steers. The time fed on grain plus silage had a significant effect on the fatty acid composition of the beef from steers fed wheat, but no similar effect was observed in beef from steers fed oats. However, the *n*-6:*n*-3 ratio of beef was more favorable when steers were fed grain (wheat or oats) plus silage for 35 d than for 75 d.

Key words: Beef quality, CLA, fatty acids, Holstein Friesian steers.

Introduction

Producers and consumers are both interested in the nutritional quality of beef, because of the added value the producers obtain for their product and because of the desire of consumers to eat healthier food. Research has focused on improving the nutritional quality of beef with modifications of the animal diet. The beef from animals raised on pasture has lower concentrations of fat and cholesterol and more polyunsaturated fatty acids (PUFAs) than beef from animals raised on feedlots (Schor *et al*., 2008). Additionally, the beef from animals fed on pasture contains more *n*-3 fatty acids and conjugated linoleic acid (CLA) than beef from feedlot animals because of the high content of linolenic acid (*n*-3) in

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lipids from pastures (Elgersma *et al.,* 2006). Conjugated linoleic acid (CLA), naturally found in food products from ruminants, is a mixture of positional and geometric isomers of linoleic acid (C18:2 *n*-6 *c*-9, *c*-12), with two conjugated double bonds at various carbon positions in the fatty acid chain. Dilzer and Park (2012) reported that CLA C18:2 *cis-9 trans-11* (rumenic acid) possessed anticarcinogenic and immunostimulant properties, among others.

In recent years, consumers have demanded healthier foods and are willing to pay a premium for products enriched with *n*-3 and/or CLA fatty acids (Realini *et al*., 2014). Additionally, Chilean consumers have a positive view of animals fed on pasture and raised outdoors (Morales *et al*., 2013). The majority of the beef production system in the southern regions relies on grazing in temperate pastures. However, pasture production varies considerably throughout the year and growth rates are low in winter and dry summers, with growth rates as low as 20 g of dry matter ha d^{-1} in winter months (Teuber, 2009). Thus, grains are used as supplements during the winter to finish steers for the national and international beef markets. In general, the finishing of beef cattle in the southern regions of Chile relies on conserved forage (silage or hay) and supplementation with grains during the winter. Oats and wheat, among other grains, are traditionally used for cattle finishing (Rojas *et al*., 2011). Additionally, better cattle prices are obtained on the markets in winter than in summer, when pasture production is high and the majority of the animals in the southern regions of Chile are slaughtered.

The concentration of healthy fatty acids is higher in the beef from animals finished on pasture than in the beef from steers finished on grain-based diets. A recent study evaluated the nutritional quality (intramuscular fat, cholesterol content and fatty acid composition) of beef produced in Chile under different production systems that were classified according to the type of finishing diet (Morales *et al.,* 2012). Information on the use of diets of grain plus pasture on beef fatty acid profiles is also available (Klee *et al.,* 2011). Nevertheless, in the cited studies, the quality of beef finished on winter diets, including grains, and using different feeding periods was not considered. Additionally, limited information is available on the length of time to feed cattle on grain for finishing. The aims of the present study were to compare the quality of grain-fed and pasture-fed beef and to assess the effects of two different feeding periods on grain on the finishing of steers.

Materials and methods

Animals and diets

A group of 75 Holstein-Friesian steers of similar age (autumn birth, 14 months old) were selected from the animal production unit of the Instituto de Investigaciones Agropecuarias (INIA) Remehue (40°31'S; 73°3'O; altitude 73 m; annual rainfall 1,300 mm) for the present study. The average initial live weight of an animal in the group was 355.9 ± 55.2 kg, and the steers were maintained with a common feeding system until they reached a target live weight (390-450 kg). The preexperimental phase was conducted for 90 days in the winter months (Preexperimental phase, Figure 1). The animals were then divided according to live weights into five groups of 15 steers each to be finished under the different systems (Experimental phase). The steers were blocked according to live weight within the treatments. The steers with live weights of 450 kg were assigned to finishing for 35 d with oat grain (SO) or with wheat grain (SW) plus pasture silage, whereas the rest of the steers were finished for 75 d with oat grain (LO) or wheat grain (LW) plus pasture silage or only pasture for 90 d (P). The target live weight at slaughter was approximately 500 kg. All grain treatments were formulated to be approximately protein equivalent and isocaloric, and the grain (wheat or oat) was provided at 1% of the animal live weight, whereas the pasture

silage was provided at 2% of live weight. The diets were adjusted weekly according to the animal live weight. The five treatments were supplemented with a mineral mix. The initial and final live weights, the average daily weight gain and the characteristics of the diet are shown in Figure 1. The pasture was improved grassland with an approximate production of 10 ton dry matter ha^{-1} $year^{-1}$, which was composed primarily of perennial ryegrass (*Lolium perenne*), brome grasses (Bromus spp.), Yorkshire fog (*Holcus lanatus*), and white clover (*Trifolium repens*). The grazing system used for the P-group was strip grazing, which was used during the spring (September-December).

The chemical and fatty acid composition of the feed used in the preexperimental and experimental phases are shown in Table 1. The simulated grazed pasture samples were collected in plastics bags from the allowance pasture strips. All the feed samples were transported refrigerated to the laboratory and were dried for 48 h at 60 °C for chemical analyses. The chemical content of the feed samples was analyzed at the INIA Remehue Animal Nutrition and Environment Laboratory in Osorno, Chile. The dry matter, crude protein, ether extract and ash were measured with the methods described by the AOAC (2005). The metabolizable energy and the neutral detergent fiber were determined according to Sadzawka *et al*. (2007).

Pre-experimental phase	Experimental phase	
	Treatments	FLW /ADG
Group of 75 steers Initial Live Weight (ILW)= 355.8 ± 55.2 kg Pasture=1.2 -5.7 kg Dry Matter (DM) Pasture Silage= 0.8 – 3.0 kg DM Pasture Hay= 0.2 -2.2 kg DM Average daily gain (ADG)= 0.6 kg d^{-1} Period = 90 d	Short finishing Oats (SO group) *n* = 15 steers ILW = 449.1 kg ± 21.1 kg Oats 1.0 % of LW + pasture silage (2.0 % of LW) per 35 d	485.6 kg ± 30.4 kg 1.9 kg d^{-1}
	Short finishing Wheat (SW group) *n* = 15 steers ILW = 445.9 kg ± 18.1 kg Wheat 1.0 % of LW + pasture silage (2.0 % of LW) per 35 d	490.4 kg ± 33.4 kg 1.9 kg d^{-1}
	Long finishing Oats (LO group) *n* = 15 steers ILW = 393.6 kg ± 37.4 kg Oats 1.0 % of LW + pasture silage (2.0 % of LW) per 75 d	462.0 kg ± 37.6 kg 1.5 kg d^{-1}
	Long finishing wheat (LW group) *n* = 15 steers ILW = 390.5 kg ± 27.9 kg Wheat 1.0 % of LW + pasture silage (2.0 % of LW) per 75 d	477.4 kg ± 29.6 kg 1.6 kg d^{-1}
	Pasture finishing (P group) *n* = 15 steers ILW = 384.3 kg ± 20.1 kg Only Pasture on grazing (2.2-2.4 % of LW) per 90 d	503.3 kg ± 28.4 kg 1.0 kg d^{-1}

Figure 1. Initial (ILW) and final live weights (FLW), average daily gain (ADG) and the preexperimental and experimental phase diets for all treatments.

Slaughter and sample procedure

The steers were slaughtered at a commercial meat plant that was licensed for export when the treatment was completed. The average live weight of the steers slaughtered was between 460 and 500 kg. The animals were slaughtered following standard procedures, and the 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.

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

	Pre-experimental feed			Experimental feed			
	Pasture	Pasture silage	Pasture hay	Pasture	Pasture silage	Wheat	Oats
Dry mater (%)	12.8	19.4	82.5	19.8	40.8	85.1	84.7
Crude protein (%)	26.5	9.4	7.4	18.8	13.6	13.7	13.1
Metabolizable energy (Mcal kg^{-1})	2.75	2.54	2.04	2.84	2.50	3.20	2.70
Ash (%)	10.9	8.2	7.3	9.8	11.6	1.5	2.6
Ether extract (%)	2.8	3.4	1.3	4.0	2.6	1.3	2.8
Neutral Detergent Fibre (%)	44.5	58.3	67.0	43.1	52.2	12.0	32.0
Fatty acids (g 100 g-1 of total fatty acids)							
C14:0	0.0	1.0	0.7	0.2	0.0	0.0	0.0
C15:1	4.3	4.3	5.3	5.0	3.5	0.0	0.0
C16	16.5	20.6	28.4	13.1	21.1	18.9	15.1
C16:1	2.1	1.5	1.5	2.3	1.5	0.0	0.0
C18	1.5	1.8	4.0	1.5	1.2	1.2	2.6
C18:1 *n*-9	1.6	3.9	11.2	1.4	1.7	15.1	40.3
C18:2 *n*-6	12.1	21.4	23.6	8.2	13.8	60.9	40.2
C18:3 *n*-3	61.9	45.3	23.7	68.4	56.9	4.0	1.2
C20:0	0.0	0.1	1.6	0.0	0.0	0.0	0.0
C20:1	0.0	0.0	0.0	0.1	0.0	0.0	0.7

The cold carcass weights and the pH values were measured 24 h postmortem at 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, RI, USA). A section of the *longissimus lumborum* (LL) was removed from each carcass and was cut into three equal parts that were vacuum packaged and stored frozen at -18 ± 2 °C until analysis. The cranial part was used for the sensory analysis, the middle part for the color and texture analyses and the caudal part for the intramuscular fat and fatty acid analyses.

Sensory analysis

An eleven-member trained panel participated in the sensory analysis. The training and testing sessions were conducted at the sensory laboratory of INIA Remehue (Osorno, Chile). The panelists were selected from a group of 30 people without previous experience in sensory evaluation; the panelists were trained following the standards of ASTM and ISO. 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 and the first-order or carry-over effects.

The assessors evaluated the beef color intensity, fat color intensity and level of marbling in five raw steaks per session and the beef flavor, tenderness and juiciness in cooked samples. The panelists evaluated the cooked samples in duplicate and analyzed five samples per session.

Immediately after the visual evaluations, the steaks were covered with aluminum foil and cooked in a preheated oven (EKA®, KF 620; Famava, Santiago, Chile) at 170 °C until an internal temperature of

71 °C was reached, which was determined with individual thermocouples inserted into the geometric center of each steak. The cooked steaks were diced into pieces of 20 mm ´ 20 mm ´ 25 mm (length × width × height), placed in coded trays and served to the assessors. The descriptors were quantified using a hybrid scale that ranged from 0 (absence) to 10 (maximum intensity).

Color and texture

The steaks were allowed to bloom for 30 min at room temperature before the analysis. The instrument color measurements were recorded for *L** (lightness: 0 = black to 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 a 2° viewing angle. The readings were taken from three randomly selected locations of the upper surface of each steak to obtain a representative reading of the surface color. The instrument color of the external fat surface was also measured.

After measuring the color, two steaks were used to determine shear force. The cooking procedure was the same as for the sensory evaluation. After cooking, the 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 the Warner–Bratzler shear force (WBSF) analysis, which followed the USDA methodology. The test was performed using a Warner–Bratzler shear blade with a triangular slot cutting edge to record the maximum shear force.

Intramuscular fat

The intramuscular fat (IMF) was measured with extraction using the Soxhlet equipment with petroleum ether (AOAC, 2005), after removing all external fat from the steaks.

Fatty acid composition

Samples of 10 g and 35 g were used for the fatty acid analyses of meats and fresh pastures, respectively. The fat was extracted according to Bligh and Dyer (1959), as modified by Lumley and Colwell (1991). Briefly, the samples were thawed and ground and then were extracted using methanol, chloroform and water (80:50:32 mL). Subsequently, the samples were homogenized for 30 min. and then filtrated through filter paper using a glass funnel. Water was added until biphasic separation was observed and the fat was concentrated in the chloroform layer. The chloroform phase was collected and removed by evaporation, and 2.0 mL of n-hexane was added to the extract, which was then stored at -18 ± 2 °C until the analysis. Approximately 0.5 g of fat was obtained with this extraction. Before the fatty acid extraction, C23:0 (Nu-Chek Prep Inc. Elysian, MN, USA) was added to the samples as an internal standard. The meat samples were methylated according to Ichihara *et al.* (1996) and the pasture samples according to Hartman and Lago (1973). The samples were analyzed with a gas chromatograph (GC-2010 Plus; Shimadzu®, Kyoto, Japan) equipped with an FID detector. A capillary column SP-2560™ (Sigma-Aldrich Co., Bellefonte, PA, USA) of 100 m × 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 (maintained for 5 min) to 240 °C (maintained for 15 min) at 4 °C min^{-1}. The fatty acids were identified by comparison of the retention times of the chromatograph peaks with those of the methyl esters from a mixture prepared with a FAME standard of 37 components (Standard: 47885-U; Sigma-Aldrich Co., St. Louis, MO, USA), a C18:1 *t*-11 methyl ester standard (Standard: 46905-U; Sigma-Aldrich Co., St. Louis, MO, USA), a conjugated linoleic acid (CLA) *c*-9 *t*-11 methyl acid (Standard: 10-1823-7;

Larodan AB, Malmo, Sweden), and a PUFA-2 (Supelco Analytical, USA). The C23:0 was used as an internal standard (NU-CheckPrep, Inc., Elysian, USA).

Statistical analyses

The physicochemical and sensory data were analyzed with ANOVA using the General Linear Model (GLM) procedure of the SAS statistical software package (SAS Institute Inc., Cary, NC, USA), with the type of finishing diet (SO, LO, SW, LW and P) as a fixed effect in the model. For the sensory data, the session effect was also included in the model as a fixed effect. Least-square means were separated with Tukey's studentized range tests.

The CORR procedure of SAS was used to calculate the linear correlations between marbling and IMF.

Results and discussion

Physicochemical and sensory evaluations

The physicochemical and sensory attributes of beef from the different dietary treatments are shown in Table 2. There were no differences ($P>0.05$) in pH values among the treatments, with an average pH of 5.64, which was within the normal range for beef. Significant differences in instrument meat redness (a^*) were detected among the treatments. The beef from SW, SO and LW was redder than beef from pasture-finished cattle. Similarly, the beef from the SW treatment was higher than beef from the P-treatment for red color intensity, as evaluated by a trained panel. The instrument color lightness (L^*) and yellowness (b^*) also differed significantly ($P\leq0.05$) among the treatments. The SW beef was higher than P beef for L^*, and the P beef was lower for b^* than the other treatments, with the exception of the LO beef. The beef from the P-treatment was darker than the beef from grain-finished animals. Other authors also found that the muscles from pasture-fed animals were darker than the muscles from grain-fed cattle (Realini *et al.,* 2004).

The L^* values for external fat color were higher for the beef from all grain treatments than for the beef of the P-treatment. Similarly, the external fat color of beef that was assessed by panelists from pasture-fed animals was more intense ($P\leq0.05$) than that from the other treatments, with the exception of the SW beef. Pasture-fed beef often contains yellow fat because of the high carotenoid content of pastures, whereas the fat from feedlot beef tends to be white (Yang *et al.,* 2002).

The beef from the LW treatment had a higher percentage of intramuscular fat (IMF) than the beef from the LO, SW and P treatments. However, marbling scores assigned by the trained panelists were higher for P than for LO beef, with no significant differences among the other treatments. A correlation of 0.46 was observed between the marbling assessed by the trained panelists and the percentage of IMF. Correlations between marbling and IMF are highly variable, and previous studies reported a range from 0.32 to 0.79 (Kruk *et al.,* 2002). This wide range could be caused by many factors, such as the range of IMF content, the range of marbling scores, the method to extract intramuscular fat, and the visual contrast of the fat color with the background color of the meat, among others (Kruk *et al.,* 2002). The visual assessment of fat against a darker lean background might have overestimated the marbling score in beef from the P-treatment, compared with beef from the other diets.

The Warner-Bratzler shear force was higher in beef from the SO, LO and SW treatments than beef from the pasture treatment. These results are consistent with those reported by Realini *et al.* (2004) and Del Campo *et al.* (2008), who also found that beef from pasture-fed animals had lower shear force values than beef from grain-finished cattle. Similarly, the trained panelists assigned higher tenderness scores to the beef from the pasture treatment than to the beef from LW and LO diets.

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

	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[1]	3.33 a	3.35 a	3.16 ab	2.85 b	0.655
Lean color						
*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 color						
*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 (Scale from 0 to 10)						
Marbling	3.7 ab[1]	3.3 b	3.5 ab	3.8 ab	3.9 a	1.204
Red color intensity	4.8 ab	4.9 ab	5.0 a	4.7 ab	4.6 b	1.240
External fat color	3.2 b	3.0 b	3.5 ab	3.1 b	3.6 a	1.207
Juiciness	4.2 a	3.5 b	4.0 ab	3.8 ab	3.8 ab	1.763
Tenderness	4.8 ab	4.3 bc	4.4 ab	3.9 c	5.0 a	1.888
Flavor	4.8 b	5.2 ab	4.9 ab	5.0 ab	5.3 a	1.285

[1]The same letters in a row indicate there are no significant differences (P>0.05).
RMSE: Root-mean-square error.
SO = Steers finished with oat grain (1.0% of live weight) and pasture silage (2.0% of live weight) for 35 d.
LO = Steers finished with oat grain (1.0% of live weight) and pasture silage (2.0% of live weight) for 75 d.
SW = Steers finished with wheat grain (1.0% of live weight) and pasture silage (2.0% of live weight) for 35 d.
LW = Steers finished with wheat grain (1.0% of live weight) and pasture silage (2.0% of live weight) for 75 d.
P = Steers finished on pasture for 90 d.
L*: lightness: 0 = black, 100 = white.
a*: redness/greenness: positive values, red; negative values, green.
b*: yellowness/blueness: positive values, yellow; negative values, blue.

The beef flavor scores were higher (P≤0.05) for the P than the SO treatment, with no differences (P>0.05) among the other treatments. Additionally, the trained panel found that the beef from the SO treatment was higher than the LO beef for juiciness.

Intramuscular fatty acid composition

The intramuscular fatty acid composition is shown in Table 3 for the beef of all dietary treatments. The intramuscular fat from steers fed the P-diet had lower (P≤0.05) levels of C14:0 and C16:0 than the fat from the LW treatment, whereas the beef from the LW diet was lower than the LO, SW and P beef in C18:0 content. No differences were observed among the treatments for C15:0, C17:0, C20:0 and C22:0 fatty acids. The intramuscular fat of beef from the LO and SW treatments had higher values of all saturated fatty acids (SFA) than the pasture-fed beef (P≤0.05).

Table 3. Intramuscular fatty acid composition (g 100 g^{-1} of total fatty acids) of beef affected by dietary treatment (n = 15 per treatment).

Fatty acid	SO	LO	SW	LW	P	RMSE
C14:0	2.14 ab[1]	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	26.0 ab	25.6 bc	26.0 ab	26.9 a	24.5 c	1.499
C17:0	0.83	0.79	0.88	0.82	0.81	0.128
C18:0	14.2 ab	14.9 a	14.7 a	12.9 b	14.5 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	43.7 ab	44.0 a	44.3 a	43.5 ab	42.2 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	41.5	40.5	39.9	41.8	41.8	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	49.4	48.0	47.8	50.4	48.4	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

[1]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 oat grain (1.0% of live weight) and pasture silage (2.0% live weight) per 35 d.
LO = Steers finished with oat grain (1.0% live weight) and pasture silage (2.0% of live weight) for 75 d.
SW = Steers finished with wheat grain (1.0% of live weight) and pasture silage (2.0% of live weight) for 35 d.
LW = Steers finished with wheat grain (1.0% of live weight) and pasture silage (2.0% of live weight) for 75 d.
P = Steers finished on pasture for 90 d.

The intramuscular fat of the *longissimus lumborum* muscle from the LW treatment had higher percentages of C14:1 and C16:1 than the corresponding fat from the pasture treatment and a higher percentage of C17:1 than the fat from the oat treatments (P≤0.05). There were no differences among the treatments in the percentages of total monounsaturated fatty acids (MUFA), oleic acid (C18:1 *c*-9), C18:1 c-7 and C20:1 (P>0.05).

The intramuscular fat from animals fed on pasture had a higher percentage of C18:1 *t*-11 (vaccenic acid) than that from the other finishing treatments (P≤0.05), which was consistent with other studies (Leheska *et al.,* 2008; García *et al.,* 2008). The C18:1 *t*-11 is an intermediate in the biohydrogenation of linoleic (C18:2 *n*-6) and linolenic (C18:3 *n*-3) acids and was higher in beef from pasture-fed cattle. This particular fatty acid is of great interest because it is converted to conjugated linoleic acid (CLA) *c*-9 *t*-11 through endogenous desaturation in the host animal tissue (Kalač and Samková, 2010; Dilzer and Park, 2012).

The beef from the P-treatment had a higher percentage of all PUFAs than the LW beef (P≤0.05). Additionally, the beef from the P-treatment had higher percentages of C18:2 *t*-6, C18:3 *n*-3, CLA *c*-9 *t*-11, C20:5 *n*-3 EPA, and C22:5 *n*-3 DPA fatty acids (P≤0.05) than the other dietary treatments. By contrast, the beef from the oat treatments was higher in C18:3 *n*-6 fatty acid content than that from the P-treatment (P≤0.05), whereas the beef from the LO and SW treatments had higher contents of C20:3 *n*-6 than the beef from the P-treatment (P≤0.05). The percentages of all PUFAs were similar to those reported in other studies that used different sources of feed (Garcia *et al*., 2008; Morales *et al.,* 2012).

The content of conjugated linoleic acid *c*-9 *t*-11 was higher (P≤0.05) in beef from steers finished on pasture than in beef from the other treatments. Conjugated linoleic acid *c*-9 *t*-11 is produced as an intermediate of the biohydrogenation process that occurs in the rumen in which dietary unsaturated fatty acids (primarily C18:2 *n*-6 and C18:3 *n*-3) undergo successive steps of isomerization and reduction (Kalač and Samková, 2010). The concentration of conjugated linoleic acid *c*-9 *t*-11 in adipose tissue is higher when animals are fed on pasture than when fed on stored forage or grain (Schor *et al*., 2008). Other studies also showed that steers finished on pasture had higher beef contents of CLA *c*-9 *t*-11 than those finished on grain-based diets (Realini *et al*., 2004; Garcia *et al*., 2008; Leheska *et al*., 2008; De la Fuente *et al*., 2009).

The time of feeding with wheat had a significant effect on the fatty acid profile of beef. The percentages of C18:0, CLA *c*-9 *t*-11, C18:3 *n*-3, C20:5 *n*-3, and C22:5 *n*-3 were higher for beef from the SW than from the LW treatment (P≤0.05), whereas there were no differences between the oat treatments. Aldai *et al.* (2011) reported that beef from steers finished for two months on grains (primarily barley) had similar levels of CLA *c*-9 *t*-11, C20:5 *n*-3, and C22:5 *n*-3 but a lower level of C18:3 *n*-3 than beef finished for one month on grains. Aldai *et al.* (2012) highlighted that the concentrations of fiber and starch in the rumen affected the fatty acid metabolism. In this respect, wheat had a lower proportion of NDF (Table 1), and it is well documented that wheat has higher starch content than oats (Shewry, 2009). However, the pH of the rumen is primarily influenced by the fermentable carbohydrate in the diet, and the amount and source of starch and/or the rate of ruminal degradation of starch affects biohydrogenation in the rumen (Mohammed *et al*., 2010). Wheat grain reduces the ruminal pH and is used to induce subacute ruminal acidosis (SARA); subacute ruminal acidosis results in changes of the fermentation pattern in the rumen, with possible changes in the production of fatty acids (Enjalbert *et al*., 2008). These authors reported that diets with 20 and 34% wheat induced a marginal or a severe SARA, respectively. In the present study, although approximately 30% of the diet was wheat grain, the steers fed wheat did not show symptoms of SARA. However, the proportion used could have

affected the ruminal pH, which then affected the IMF fatty acid profile. Enjalbert *et al*. (2008) reported lower contents of C18:0 and CLA *c*-9 *t*-11 in milk fat when wheat grain was added to the diet to induce SARA. Colman *et al*. (2010) also found that the concentrations of C18:0 and CLA *c*-9 *t*-11 in milk fat were lower in the third week postinduction of mild SARA with wheat grain in the diet.

For the diets with oats, the quantity of oil in the oats could have influenced the results. In the present study, the ether extract was twofold greater in oats than that in wheat (Table 1). Previous studies investigated the effect of naked oats in feed on the fatty acid composition of milk (Woods and Fearon, 2009), and the milk fat from early and mid-lactation cows fed a naked oat diet (plus *ad libitum* grass silage) had higher levels of unsaturated fats (primarily C18:1) and lower levels of saturated fatty acids (C12:0, C14:0 and C16:0) than milk fat from animals fed a barley diet (Fearon *et al.,* 1996). However, diets with oats favor the primary rumen PUFA-biohydrogenation pathway (associated with modification of ruminal bacterial populations), which induces more complete hydrogenation of unsaturated fatty acids in the diet (Gómez-Cortés *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 and/or activity of competent bacteria (Zened *et al*., 2012). Further studies are needed to evaluate the effects of including naked oats in the diet on the content and composition of intramuscular fat in steers.

The attention focused on the ratio between *n*-6 and *n*-3 fatty acids is considerable. A high *n*-6:*n*-3 ratio is considered a risk factor for certain cancers and coronary heart diseases (Hibbeln *et al*., 2006), and an *n*-6:*n*-3 ratio for beef of 4.0 or less is recommended. The P, SO and SW treatments (35 d) had beef with *n*-6:*n*-3 ratios lower than 4.0, with the lowest ratio in beef from the pasture treatment, which was consistent with other studies (Schor *et al*., 2008; De la Fuente *et al.*, 2009; Morales *et al.,* 2012). These results highlighted the importance of the concentrate:forage ratio of the diet; to produce beef with a favorable *n*-6:*n*-3 ratio, feeding grass silage plus grain for 35 d, but not for 75 d, is a suitable alternative to pasture. Fredriksson, 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 tissue of steers fed silage plus grain (wheat and oats) for the final four months compared with steers that finished on pasture. Similarly, Klee *et al.* (2011) found higher *n*-6:*n*-3 ratios in tenderloin and round cuts from steers fed on pasture plus oat grain than in those cuts from steers fed only on pasture. Aldai *et al*. (2011) reported lower *n*-6:*n*-3 ratios in beef from steers finished on pasture than from those fed on intensive grains (primarily barley). Additionally, the highest *n*-6:*n*-3 ratio was found in beef from steers fed grain for two months compared with one month. Other studies also showed that diets high in concentrates negatively affected the *n*-6:*n*-3 fatty acid ratio (Realini *et al.,* 2004; De la Fuente *et al.,* 2009).

In the present study, animals were maintained in similar preexperimental conditions (Table 1). Although the time on feed in the preexperimental phase could have affected the results of the experiment, previous studies indicated that feeding during the background phase marginally affected the quality of beef. Moreover, Duckett *et al.* (2009) found no effect of the level of supplementation during the winter background on beef quality of pasture- or concentrate-finished steers. Similarly, Chicatún *et al.* (2006) evaluated the beef quality of steers not supplemented or supplemented with two levels of corn silage during the growing phase and three levels of corn grain during the finishing phase, and the authors found no significant effect of the background feeding on the quality of beef. Finally, Pordomingo *et al.* (2012) evaluated four background strategies, *i.e*., 100% pasture and three different levels of alfalfa hay (40, 70 and 100%) with concentrate, before finishing on pasture. The authors found residual effects of the background strategies on the intramuscular fat of pasture-

finished animals; the pasture and 100% alfalfa hay treatments had beef with higher concentrations of CLA *c*-9 *t*-11 and 18:3 *n*-3 and a lower *n*-6:*n*-3 ratio, although the differences among the treatments were marginal.

The beef from pasture-fed steers tended to be tenderer, darker, less red and with yellower fat than the beef from grain-fed steers. The beef from steers fed silage plus wheat for 75 d had lower tenderness scores than the beef from short-term feeding on grain. The beef from pasture-fed steers had a more favorable fatty acid profile, with higher levels of CLA *c*-9 *t*-11 and *n*-3 fatty acids and a lower *n*-6:*n*-3 fatty acid ratio than the beef from grain-fed steers. The time feeding on silage plus grain had a significant effect on the fatty acid composition of beef when feeding the steers wheat but not oats. Moreover, the *n*-6:*n*-3 ratio of beef was more favorable when steers were fed silage plus wheat or oats for a shorter time compared with a longer finishing time (35 vs. 75 d).

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Resumen

R. Morales, J. Parga, I. Subiabre y C.E. Realini. 2015. Estrategias para novillos en engorda a base de pradera o ensilaje más grano y el tiempo de alimentación y sus efectos sobre la calidad de la carne. Cien. Inv. Agr. 42(1): 5-18. El objetivo del presente estudio fue comparar la calidad de carne de novillos finalizados con pradera y grano, como también, evaluar el impacto de dos periodos de finalización con grano. Un grupo de 75 novillos se alimentó en cinco diferentes dietas: (*n*= 15 por dieta): pradera por 90 días (P), avena más ensilaje de pradera por 35 días (SO), avena más ensilaje de pradera por 75 días (LO), trigo más ensilaje de pradera por 35 días (SW) y trigo más ensilaje de pradera por 75 días. En el músculo *longissimus lumborum*, se determinaron análisis fisicoquímicos, sensoriales y de ácidos grasos. La carne de los animales alimentados en pradera tiende a ser más tierna, oscura, menos roja y con una grasa más amarilla que la obtenida a partir de granos. La carne de novillos alimentados con trigo más ensilaje por 75 días tiene menor terneza que la obtenida en la engorda con grano más ensilaje por 35 días. La carne de novillos finalizados a pradera tiene mayores niveles de ácido linoleico conjugado *c*-9 *t*-11, ácidos grasos *n*-3 y un baja relación de los ácidos grasos *n*-6:*n*-3 en comparación de la carne obtenida de novillos alimentados con granos más ensilaje. El tiempo en grano más ensilaje tiene un efecto significativo en la composición de ácidos grasos de la carne cuando se utiliza el grano de trigo pero no la avena. Sin embargo, la relación de los ácidos grasos *n*-6:*n*-3 de la carne fue más favorable cuando los novillos fueron alimentados con grano (trigo o avena) más ensilaje por 35 días en comparación a los engordados por 75 días.

Palabras clave: Ácidos grasos, ALC, calidad de carnes, novillos Holstein Friesian.

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