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RESEARCH ARTICLE

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Influence of feeding system on growth performance, carcass characteristics and meat and fat quality of Avileña-Negra Ibérica calves' breed

Argimiro Daza[1], Ana Isabel Rey[2]*, Celia Lopez-Carrasco[3] and Clemente J. Lopez-Bote[2]

[1] Dpto. Producción Animal. ETSIA. Universidad Politécnica de Madrid. Ciudad Universitaria. 28040 Madrid, Spain. [2] Dpto. Producción Animal. Facultad de Veterinaria. Universidad Complutense. Ciudad Universitaria. 28040 Madrid, Spain. [3] CIA "Dehesón del Encinar". Junta de Comunidades de Castilla-La Mancha. Oropesa (Toledo), Spain

Abstract

The effect of feeding system (calves reared under free-range conditions supplemented with concentrate *vs.* calves fed on concentrate and cereal straw in confinement) during finishing period on growth performance, carcass traits and meat and fat quality was investigated. Fourteen entire males of Avileña-Negra Ibérica breed were used. The feeding system had no effect on growth performance, carcass characteristics, muscle colour, drip losses and intramuscular fat (IMF) percentage in *Longissimus thoracis*. Free-range calves had more content of vitamin E in omental fat and tended ($p < 0.1$) to have more vitamin E in IMF than calves finished in confinement. C16:0 and C16:1 n-9 proportions in omental fat were higher in calves finished in confinement, while C18:1 n-7, C18:3 n-3, Σn-3 proportions were lower. The ratio Σpolyunsaturated fatty acids (PUFA) to Σsaturated fatty acids (SFA) was significantly greater in omental fat from free-range calves. The C14:0, C16:0, C16:1, C17:0, C17:1, C18:1 n-9 and Σmonounsaturated fatty acids (MUFA) were higher and C18:3 n-3 and Σn-3 proportions lower in IMF from calves finished in confinement. The ratio C18:1 n-9 to C18:0 was higher in IMF from calves fed on concentrate and straw and the ratio ΣPUFA to ΣSFA tended ($p < 0.1$) to be greater in free-range calves. Intramuscular fat percentage affected to fatty acid composition of *Longissimus thoracis*. Feeding system based in finishing calves in confinement with straw and concentrate can be replaced by supplementation with concentrate in grazing without detrimental effect on quality.

Additional key words: grass-fed calves; carcass traits; fatty acids; intramuscular fat; meat colour.

Introduction

Meat from Avileña-Negra Ibérica breed is a quality product guaranteed by one Protected Geographical Indication since 2008. During their first stage of life, calves from this breed are fed by their mothers under free-range conditions in the Spanish wooded rangeland (*dehesa*) located in the middle and western region of Spain. After weaning, calves are generally fattened in confinement and fed with cereal straw and concentrates. Recently, calves fattening in grazing is becoming a common practice in order to reduce the production cost. Nevertheless calves fattened under extensive conditions impair growth performance (Keane & Allen, 1998) and decrease carcass yield, conformation and fatness score (Sami *et al*., 2004). In addition, meat of calves fattened on pasture is darker (Priolo *et al*., 2001; Mancini & Hunt, 2005) and have lower intramuscular fat (IMF) content (Leheska *et al*., 2008) than that from calves finished on concentrate. Since bright red colour is used by consumers as an indicator of freshness and wholesomeness (Mancini & Hunt, 2005) that influences on purchasing decision, beef produced on grazing is worse accepted by the Spanish industry and consumers

*Corresponding author: anarey@vet.ucm.es
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Abbreviations used: ADG (average daily gain); FS (feeding system); IMF (intramuscular fat); MUFA (monounsaturated fatty acids); PUFA (polyunsaturated fatty acids); SEM (standard error of the mean); SFA (saturated fatty acids).

than that produced in confinement with concentrates. Moreover, several studies have shown that pasture-fed calves have higher concentration of C18:0, Σpolyunsaturated fatty acids (PUFA), Σn-3 fatty acids (Realini *et al*., 2004; Pordomingo *et al*., 2012) and lower Σn-6 / Σn-3 ratio than calves fed on protein concentrates (Muchenje *et al*., 2009). The supplementation with concentrate increases the Σn-6 / Σn-3 and decreases ΣPUFA / Σsaturated fatty acids (SFA) ratios (Alfaia *et al*., 2009), which means a fat quality reduction due to its implications for human health (Wood *et al*., 2008). Grazing also enhances the content of other compounds like tocopherol, which may improve the shelf life of meat (Yang *et al*., 2002). There is not enough information of grazing supplementation effect (in the Spanish *dehesa*) with concentrates on carcass, meat and fat quality in Avileña-Negra Ibérica calves. We hypothesised that the feeding system based on calves finished in confinement with straw and concentrate can be replaced by concentrate supplementation in grazing without effect on performance and carcass quality.

Therefore, the objective of this experiment was to compare calves reared under free-range conditions supplemented with concentrate *vs.* calves in confinement finished on concentrate and cereal straw with regard to growth performance, carcass characteristic and meat and fat quality of young bulls of Avileña-Negra Ibérica breed.

Material and methods

All the experimental procedures used in this study were approved by the Animal Ethics Committee of the Universidad Politécnica de Madrid and were in compliance with the Spanish guidelines for the care and use of animals in research (BOE, 2005).

Experimental design and growth performance

Fourteen entire males of Avileña-Negra Ibérica breed from CIA "El Dehesón del Encinar" (Junta de Comunidades de Castilla-La Mancha, Oropesa, Toledo, Spain), that were weaned with 265.50 kg (SEM = 11.40 kg) were used. All calves were kept in a fence containing a commercial field that included the following grassland species: *Trifolium subterraneum* L, *Trifolium michelianum* Savi, *Trifolium incarnatum* L., *Trifolium resupinatum* L., *Ornithopus compressus* L., *Biserrula pelecinus* L. and *Lolium multiflorum* L. From July 2 (date of weaning) to November 30 of 2011 the calves received an average daily supplementation of 2.98 kg of a mixed diet per animal and the stocking rate was 1 calf ha^{-1}. The mixed diet composition was 60.0% barley, 9.7% wheat, 27.3% feld pea and 3.0% of minerals-premix. According to *Fundación Española para el Desarrollo de la Nutrición Animal* (FEDNA, 2010) the calculated composition of feed was 2,684.3 kcal ME kg^{-1}, 123.73 g crude protein kg^{-1} and 2.30, 0.10, 1.96, 6.33 and 0.80 g kg^{-1} of C16:0, C18:0, C18:1 n-9, C18:2 n-6 and C18:3 n-3, respectively. The prairie was fertilized in October, after the first rain, with 36 kg P ha^{-1}. From December 1 of 2011 to February 14 of 2012 seven calves, chosen at random, at 408.70 kg of live weight (SEM=5.89 kg), were finished on cereal straw offered *ad libitum* (intensive feeding system), whereas the other seven calves at 409.41 kg of live weight (SEM = 7.68 kg), remained in the meadow supplemented with the same mixed diet free-range feeding system) until February 21 of 2012. During such period, average daily consumption of feed and straw per calf in group fed in intensive conditions were 9.50 and 1.14 kg, respectively, while the calves reared under free-range feeding system received an average daily supplementation per calf of 4.75 kg of feed.

Slaughtering, sampling and carcass measurements

The calves were slaughtered at 519.25 (SEM = 18.61) kg of live in a commercial slaughterhouse (Carnicas Hermanos Alonso, Alcaudete de la Jara, Toledo, Spain). Carcass weight, carcass length, thoracic depth, leg length, leg perimeter and leg width were collected 24 h after slaughter, according to the procedures proposed by Sañudo & Campo (1998). The carcass conformation and degree of fatness were estimated according to the EEC carcasses classification (EEC, 1991), by means of a subjective scale that ranged from 1 to 15 points (1: the worst; 15: the best). The carcasses were divided into four large joints: leg, fore-quarter, loin (sirloin and high and low loin) and

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flank (flank and lower area of the ribs). The carcass joints were weighed. Omental fat samples were taken to determine the fatty acid profile and α-tocopherol content. One piece of *Longissimus thoracis* muscle was collected to analyze muscle colour and to determine the IMF percentage and fatty acids profile of IMF, α-tocopherol content and drip losses. Samples for muscle and fatty acid analysis were vacuum packed and stored at –20°C until analysis.

Laboratorial determinations for meat and fat samples

A 2-cm thick sample was displayed on trays and maintained at 4°C for colour measurements. Muscle colour was evaluated at day 7 after slaughter, by means of a chromameter (CM 2002, Minolta, Camera, Osaka, Japan) previously calibrated against a white tile, according to the manufacturer's recommendations (CIE, 1976). The average of three random readings was used to measure lightness (L^*), redness (a^*) and yellowness (b^*). Additionally, chroma and hue angle were calculated as chroma = $(a^{*2} + b^{*2})^{0.5}$ and hue = $57.29 \cdot \text{arctg}\ (b^* / a^*)$, respectively. Reflectance data at selected wavelengths were used for oxymyoglobin (630 nm and 525 nm) and metmyoglobin (570, 580 and 525 nm) calculations. Lipids from omental fat were extracted by the procedure proposed by Bligh & Dyer (1959). *Longissimus thoracis* IMF was obtained according to the method developed by Marmer & Maxwell (1981). Fat extracts were methylated in the presence of sulphuric acid and identified by gas chromatography as described elsewhere (López Bote *et al*., 1997) using a 6890 Hewlett Packard (Avondale, PA, USA) gas chromatograph equipped with an automatic injector, a flame ionisation detector and a capillary column (HP- Innowax, 30 m × 0.32 mm i.d. and 0.25 μm cross-linked polyethylene glycol; Agilent Technologies Gmbh, Germany). A temperature program of 170°C to 245°C was used. The injector and detector were maintained at 250°C. A split ratio of 1:50 was used. The carrier gas (helium) flow rate was 3 mL min^{-1}.

The content of α-tocopherol in *Longissimus thoracis* was quantified according to the method described by Rey & López Bote (2001). Muscle samples were homogenized in a 0.054 mol L^{-1} dibasic sodium phosphate buffer adjusted to pH 7.0 with HCl. After mixing with absolute ethanol and hexane, the upper layer containing α-tocopherol was evaporated and dissolved in ethanol prior analyses by reverse-phase HPLC (HP 1100, with a diode array detector) (Hewlett Packard, Waldbronn, Germany). The content of α-tocopherol in omental fat was analyzed using the method described by Rey *et al*. (2006). Samples (0.05 g) were saponified in the presence of KOH (50%), KCl (1.15%) and pyrogallol (3% in ethanol) at 70°C for 30 min. Vitamin was extracted in hexane, concentrated in ethanol and analyzed by HPLC (HP 1100, with a diode array detector; Hewlett Packard, Waldbronn, Germany).

Drip loss was estimated by a suspension method (Honikel *et al*., 1986). Approximately 15 g of fresh as well as thawed specimens were weighed and then placed in a saturated atmosphere at 4°C. The same samples were weighed after 72 h of refrigerated storage. Drip loss was calculated as the percentage of initial weight loss.

Statistical analysis

Data obtained for growth performance were studied by means of covariance analysis, considering feeding system (intensive *vs* free range) as fixed effect and calves initial weight as covariate. Carcass characteristics were studied by means of covariance analysis that considered feeding system as fixed effect and carcass weight as covariate. Colour variables, IMF percentage, vitamin E content in omental and IMF, drip loss and composition in fatty acid of omental and IMF were studied by means of variance analysis that included the feeding system as fixed effect. The covariates were considered significant when $p < 0.05$, removing them from statistical models when $p > 0.05$. Duncan test was used to compare means. Shaphiro-Wilh test was used to confirm the normal distribution of the data. Correlation analysis was carried out to study the relation between IMF percentage and fatty acid proportions in *Longissimus thoracis*. All analysis were carried out by means of the statistical package SAS (1999).

Results and discussion

Growth performance and carcass quality

The feeding system had not significant effect on growth performance and carcass characteristics

Table 1. Growth performance and carcass traits as affected by feeding system.

Feeding system	Intensive	Free-range	SEM[a]	*p* value	*p* value covariate[b]
Weaning weight (kg)	269.71	261.30	11.40	0.60	
Slaughter weight (kg)	523.90	514.61	18.61	0.71	0.09 [1]
Days of fattening	232	239			
ADG (kg)[c]	1.10	1.06	0.07	0.68	0.86 [1]
Carcass weight (kg)	274.74	274.83	8.95	0.96	
Carcass yield (%)	52.44	53.41	0.76	0.13	0.69 [2]
Carcass length (cm)	133.50	131.79	1.57	0.22	0.007 [3]
Leg length (cm)	75.10	74.90	1.01	0.84	0.0047 [3]
Leg perimeter (cm)	43.67	43.69	0.41	0.97	0.0001 [3]
Leg width (cm)	46.16	46.41	0.42	0.68	0.021 [3]
Thorax depth (cm)	45.28	46.29	0.59	0.27	0.72 [3]
Legs weight (kg)	87.39	87.35	0.82	0.97	0.0001 [3]
Fore-quarter weight (kg)	103.78	102.96	0.80	0.48	0.0001 [3]
Loins weight (kg)	44.37	44.56	0.53	0.81	0.0001 [3]
Flank weigth (kg)	38.86	39.54	1.00	0.64	0.0003 [3]
% Legs	31.84	31.92	0.30	0.86	0.041 [3]
% Fore-quarter	37.53	37.77	0.31	0.59	0.21 [3]
% Loins	16.24	16.16	0.19	0.76	0.96 [3]
% Flank	14.40	14.14	0.36	0.62	0.41 [3]
Conformation	5.71	5.72	0.20	0.95	0.027 [3]
Fatness degree	6.85	6.86	0.18	0.96	0.050 [3]

[a] SEM = standard error of the mean. [b] [1] covariate weaning weight. [2] covariate weight at slaughter. [3] covariate carcass weight. Variable values with *p* covariate < 0.05 are least square means. [c] ADG = average daily gain.

(Table 1). These results can be explained because the energy consumed by calves during growing and finishing periods was not different between intensive and free-range system to find differences in growth performance and carcass traits according to feeding system. As expected, carcass weight had influence ($p < 0.05$) on the most of carcass traits (Daza *et al*., 2012). Keane and Allen (1998) and Humada *et al*. (2012) found higher average daily gain (ADG) and carcass fatness degree in calves finished in confinement with forage and concentrate than in calves finished on pasture, although no difference in carcass conformation was observed. Also Sami *et al*. (2004) observed greater ADG, carcass yield and fatness degree in calves fed in intensive conditions compared to those fed extensively; however, in this study the daily energy intake was around 40% higher in intensive than in extensive calves. Cerdeño *et al*. (2006) found a positive relation between concentrate consumption and ADG, subcutaneous fat depth and fatness score in Spanish Brown Swiss × Limousine young bulls, but carcass weight, carcass yield, carcass length and conformation were not affected by concentrate intake. Also, Keane & Allen (1998) did not find difference in carcass yield and leg length between confinement and pasture-fed calves, and neither difference was observed for hind quarter, loin and ribs weights.

Meat quality

Feeding system had no effect on colour variables, IMF percentage in *Longissimus thoracis* muscle and drip loss. Nevertheless, calves finished under free-range conditions and supplemented with concentrate had more content of vitamin E in omental fat and tended ($p < 0.1$) to have more vitamin E in IMF than those finished in confinement with cereal straw and concentrate (Table 2). Free-range system theoretically implicates a higher physical activity and therefore higher myoglobine content and a^* value (Lawrie, 1977). On the other hand, the forage or grass consumption led to increase the colour intensity (Vestergaard *et al*., 2000; Raes *et al*., 2003) and according to Priolo *et al*. (2001) meat from animals finished on pasture was darker than meat from animals finished on concentrate. However, French *et al*. (2001) did not find any diet effect on *Longissimus* muscle colour when steers were finished on grass and/or concentrate. In the current experiment colour intensity at day 7 after slaughter

Table 2. Effect of feeding system on the variables of muscle instrumental colour (7 days after slaughter), intramuscular fat (IMF) of *Longissimus thoracis,* drip loss (DL), and vitamin E concentrations in omental fat and muscle

Feeding system	Intensive	Free-range	SEM[a]	*p* value
L*	36.55	35.09	0.91	0.28
a*	10.96	12.86	1.43	0.37
b*	11.40	12.23	1.10	0.60
chroma	15.90	17.02	1.72	0.49
hue	47.19	43.78	2.10	0.27
Oxymyoglobin	1.99	2.11	0.13	0.51
Metmyoglobin	0.87	0.90	0.02	0.38
Ox/Met[b]	2.32	2.36	0.17	0.85
IMF (%)	1.25	0.84	0.20	0.17
DL (%)	4.86	3.98	0.72	0.40
Vit E omental fat (μg g^{-1})	7.80	11.65	1.24	0.049
Vit E IMF (μg g^{-1})	3.16	4.19	0.40	0.09

[a] SEM = standard error of the mean. [b] Ox/Met = ratio oxymyoglobin/metmyoglobin.

was numerically higher in muscle from calves reared under free-range conditions than those finished by the intensive system, nevertheless colour variables were not statistically different. Other authors reported that the feeding system had little influence on colour instrumental variables in different Spanish cattle breeds (Albertí *et al*., 1991; Cerdeño *et al*., 2006; Zea & Díaz, 2008) and in Simmental bulls (Sami *et al*., 2004).

Concerning IMF content, some authors reported that it was positively related with consumption of concentrates (Sami *et al*., 2004; Leheska *et al*., 2008; Wood *et al*., 2008; Alfaia *et al*., 2009). Moreover, fat is lighter in colour than muscle and therefore its presence could be contributed to an increased L* value (Priolo *et al*., 2001). However, in the present experiment seems that feeding differences were not enough to affect colour instrumental variables and IMF percentage of *Longissimus thoracis* muscle. These results agree with those observed in Rubia Gallega calves (Zea & Díaz, 2008), and in Alentejano calves (raised in Portuguese *dehesa*) (Alfaia *et al*., 2009). Also, in the present study the correlation coefficient found between L* value and IMF percentage was $r = 0.54$ ($p < 0.05$).

On the other hand, the vitamin E increases the colour stability and this effect seems to be related with the antioxidant function of α-tocopherol (Faustman *et al*., 1998). Mancini & Hunt (2005) also reported that feeding effects on colour were attributed to the relationship between lipid and pigment oxidation. Therefore, an increase of α-tocopherol content in IMF would increase lipid stability, which, in turn, would reduce hue value and improve *longissimus* colour life. Nevertheless, in the current experiment the higher content of vitamin E in *Longissimus thoracis* IMF from calves finished under free-range conditions did not affect muscle colour at day 7 after slaughter. However, a*, oximyoglobin and oximyoglobin/metamyoglobin ratio were numerically higher, and hue angle lower in free-range than in intensive-fed calves, even though differences were not statistically significant. According to Faustman *et al*. (1998), a high consumption of grass allows high levels of α-tocopherol in muscle; however, it may not be an accurate indicator of colour stability.

The feeding system neither affected muscle drip loss (Table 3). This lack of effect by the feeding system has been reported by other authors (Albertí *et al*., 1988; Zea & Díaz, 2008). Cerdeño *et al*. (2006) did not find different drip loss in *Longissimus thoracis* between Spanish Brow Swis × Limousine calves that consumed barley straw and concentrate *ad libitum* or alfalfa hay *ad* libitum and 4 kg of concentrate per animal day^{-1} during 60 days of finishing. French *et al*. (2001) neither found any effect on drip loss in meat from steers by supplementing with concentrates or by increasing grass supply.

Fat quality

The fatty acid composition of omental and IMF are presented in Tables 3 and 4, respectively. The C15:0, C16:0 and C16:1 n-9 proportions in omental fat were

Table 3. Fatty acid profile of omental fat as affected by feeding system.

Fatty acid[a]	Feeding system		SEM[b]	*p* value
	Intensive	Free-range		
C10:0	0.04	0.04	0.005	0.99
C12:0	0.08	0.08	0.01	0.92
C14:0	3.09	2.60	0.20	0.10
C15:0	0.60	0.49	0.03	0.049
C16:0	25.41	22.20	0.72	0.0086
C16:1 n-9	0.19	0.07	0.04	0.05
C16:1 n-7	1.26	1.44	0.16	0.42
C17:0	1.58	1.42	0.07	0.14
C17:1	0.39	0.37	0.02	0.55
C18:0	32.83	33.51	1.13	0.67
C18:1 n-9	28.84	30.99	1.09	0.19
C18:1 n-7	1.05	1.72	0.18	0.02
C18:2 n-6	3.09	3.28	0.14	0.35
C18:3 n-3	0.38	0.62	0.05	0.006
C18:4 n-3	0.28	0.28	0.02	0.98
C20:0	0.41	0.37	0.02	0.22
C20:1	0.35	0.37	0.01	0.16
C20:3 n-9	0.07	0.07	0.005	0.48
C20:4 n-6	0.03	0.03	0.02	0.77
ΣSFA	64.04	60.72	1.31	0.098
ΣMUFA	32.11	35.01	1.20	0.10
ΣPUFA	3.85	4.27	0.16	0.089
Σn-6	3.13	3.81	0.14	0.38
Σn-3	0.66	0.90	0.06	0.01
C16:1 n-7/C16:0	0.05	0.06	0.006	0.13
C18:1 n-9/C18:0	0.88	0.94	0.06	0.54
ΣMUFA/ΣSFA	0.50	0.58	0.03	0.10
Σn-6/Σn-3	4.92	3.84	0.43	0.10
ΣPUFA/ΣSFA	0.06	0.07	0.003	0.05

[a] ΣSFA, ΣMUFA, ΣPUFA, Σn-6, Σn-3 = sum of all saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), n-6 and n-3 fatty acids, respectively. [b] SEM = standard error of the mean.

significantly higher, and ΣSFA proportion tended ($p < 0.1$) to be greater in calves finished in confinement fed with straw and concentrate, while C18:1 n-7, C18:3 n-3, and Σn-3 proportions were significantly lower. No difference in C18:0 and C18:1 n-9 was detected in omental fat according to finishing system (Table 3). In IMF from *Longissimus thoracis* C14:0, C16:0, C16:1, C17:0, C17:1, C18:1 n-9, ΣMUFA proportions and C18:1 n-9/C18:0 ratio were significantly higher and C18:0, C18:1 n-7, C18:2 n-6, ΣPUFA proportions and ΣPUFA/ΣSFA ratio tended ($p < 0.1$) to be lower in intensive than in free-range calves, whereas C18:3 n-3 and Σn-3 proportions were greater in free-range than in intensive-reared calves (Table 4).

There is little information on the feeding system effect on the fatty acid pattern of cattle omental fat. In the present experiment the ΣSFA proportion in omental fat was higher and ΣMUFA and ΣPUFA lower than those observed by Daza *et al*. (2012) in subcutaneous backfat from bulls of Avileña-Negra Ibérica breed. Several studies have found that ΣSFA and ΣMUFA proportions were lower and ΣPUFA higher in subcutaneous fat from grass-fed calves than in those concentrate-fed (Noci *et al*., 2005). Yang *et al*. (2002) also observed similar results in IMF. Realini *et al*. (2004) pointed out that pasture-fed animals had higher concentration of C18:0, C18:2 n-6, C20:4 n-6, C18:3 n-3 and ΣPUFA fatty acids in IMF than those animals fed protein concentrates. Dietary n-6 and n-3 PUFA can be incorporated into adipose tissue and muscle of ruminants despite the biohydrogenation of dietary fatty acid in the rumen (Wood *et al*., 2008). Furthermore,

Table 4. Fatty acid composition of intramuscular fat from *Longissimus thoracis* as affected by feeding system

Fatty acid[a]	Feeding system		SEM[b]	*p* value covariate[c]
	Intensive	Free-range		
C10:0	0.35	0.41	0.06	0.50
C12:0	0.05	0.03	0.01	0.21
C14:0	2.30	1.74	0.15	0.02
C16:0	23.67	20.24	0.76	0.008
C16:1	2.31	1.86	0.11	0.015
C17:0	1.36	1.11	0.06	0.021
C17:1	0.69	0.55	0.03	0.014
C18:0	22.23	24.08	0.62	0.056
C18:1 n-9	34.46	31.48	0.97	0.050
C18:1 n-7	0.67	0.91	0.08	0.063
C18:2 n-6	7.95	11.90	1.41	0.070
C18:3 n-3	0.66	1.28	0.18	0.036
C18:4 n-3	0.32	0.29	0.02	0.26
C20:0	0.22	0.22	0.01	0.99
C20:1	0.31	0.28	0.03	0.59
C20:3 n-9	0.11	0.11	0.02	0.99
C20:4 n-6	1.99	3.00	0.46	0.14
20:5 n-3	0.34	0.47	0.006	0.16
ΣSFA	50.18	47.84	1.14	0.17
ΣMUFA	38.45	35.10	1.06	0.046
ΣPUFA	11.37	17.05	2.05	0.073
Σn-6	9.94	14.90	1.85	0.082
Σn-3	1.32	2.04	0.22	0.044
C16:1/C16:0	0.10	0.09	0.003	0.26
C18:1 n-9/C18:0	1.56	1.31	0.05	0.0049
ΣMUFA/ΣSFA	0.77	0.73	0.015	0.12
Σn-6/Σn-3	7.55	7.43	0.69	0.90
ΣPUFA/ΣSFA	0.23	0.37	0.05	0.078

[a] ΣSFA, ΣMUFA, ΣPUFA, Σn-6, Σn-3 = sum of all saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), n-6 and n-3 fatty acids. [b] SEM = standard error of the mean. [c] Intramuscular fat percentage.

Leheska *et al*. (2008) observed greater C18:0, ΣSFA and Σn-3 and lower ΣMUFA proportions in ground beef and strip steaks from grass-fed than in concentrate-fed calves, but no significant differences in Σn-6 and ΣPUFA were detected. Moreover, Nürnberg *et al*. (1998) reported that the concentrate feeding in confinement increased C18:1 n-9 and reduced C18:3 n-3 and Σn-3 proportions in IMF from steers and lambs when permanent indoors, pasture indoors and permanent on pasture feeding systems were compared. Alfaia *et al*. (2009) also observed higher proportions of C14:0, C16:0 (hypercholesterolemic fatty acids), C16:1, C18:1 n-9 and ΣMUFA and lower C18:0, C18:3 n-3 and Σn-3 proportions in IMF from calves fattened with concentrates when compared with those fed on pasture and supplemented with concentrate. Similarly, Humada *et al*. (2012) found higher ΣSFA, ΣMUFA and lower ΣPUFA and Σn-3 proportions in IMF from *Longissimus thoracis* muscle of young bulls of Spanish Tudanca breed fattened under intensive conditions. The high levels of C18:1 n-9 observed in ruminants fed concentrates might be explained by an increase of delta-9 desaturase enzyme activity, likely mediated by an elevated production of insuline (Daniel *et al*., 2004; Sinclair, 2007). The C18:1 n-9 fatty acid has been reported to be an important parameter of beef tenderness and palatability (Malau-Aduli *et al*., 1998) and monounsatureted and n-3 fatty acids aid in reducing heart disease risk, while some saturated fatty acids increase serum cholesterol levels (Groff & Gropper, 1999).

The ΣPUFA/ΣSFA ratio was higher ($p = 0.05$) and Σn-6/Σn-3 ratio tended ($p < 0.1$) to be lower in omental

fat from calves finished under free-range conditions. Also, in IMF, ΣPUFA/ΣSFA ratio tended ($p < 0.1$) to be higher in free- range than in those calves fed in intensive conditions but no significant difference was found for Σn-6/Σn-3 ratio.

According to Wood & Enser (1997), these results may suggest that omental fat quality of calves reared in free-range is better from the health point of view, than that from animals finished under intensive conditions with straw and concentrate. Beef fed on grass can exhibit an improved Σn-6/Σn-3 fatty acid ratio that has positive cardiovascular impact (Muchenje *et al*., 2009). In the present work the lack of significant reduction of Σn-6/Σn-3 ratio in calves finished in pasture can be explained by the noticeable supplementation with concentrate of high C18:2 n-6 content.

The IMF percentage in *Longissimus thoracis* had significant influence on C10:0, C14:0, C16:0, C17:0, C18:1 n-9, C18:2 n-6, C18:3 n-3, C20:4 n-6, C20:5 n-3, ΣSFA, ΣMUFA, ΣPUFA, Σn-6 and Σn-3 proportions and ΣPUFA/ΣSFA ratio in IMF. Positive and significant correlation coefficients between IMF and C14:0, C16:0, C17:0, C18:1 n-9, ΣSFA and ΣMUFA proportions were obtained, while negative and significant correlation coefficients were detected for C18:2 n-6, C18:3 n-3, C20:2 n-6, C20:5 n-3, ΣPUFA proportions and ΣPUFA/ΣSFA ratio (Table 5). In general, variation in IMF content had a marked influence on its fatty acid composition (Alfaia *et al*., 2009). It was observed that, as the IMF content rises the proportion of ΣSFA and ΣMUFA also increases and ΣPUFA decreases (De Smet *et al*., 2001; Moreno *et al*., 2006). According to Warren *et al*. (2008) as total lipids increase in cattle muscle, C18:2 n-6 and C18:3 n-3 proportions decreased according to curvilinear pattern, while C18:1 n-9 proportion increased. These results are in accordance with the positive correlation coefficients obtained in the current experiment between SFA and MUFA proportions and IMF percentage as well as the negative correlation coefficients between PUFA proportion and percentage of IMF.

In conclusion, data reported in the current experiment indicate that when both grazing feeding systems are compared (calves raised under free-range conditions and afterwards finished in confinement with straw and concentrate during 2.5 months *vs.* free-range calves supplemented with moderate quantity of concentrate), no effects were observed on growth performance, carcass traits, muscle colour and IMF percentage in *Longissimus thoracis* muscle. However, omental fat quality is better in free-range than in intensive-fed calves. Therefore, the feeding system based on calves finished in confinement with straw and concentrate can be replaced by supplementation with concentrate in grazing.

Table 5. Correlation coefficients between intramuscular fat percentage and fatty acid proportions in *Longissimus thoracis*

Fatty acid	Correlation coefficient [a]	*p* value
C10:0	–0.82	0.0003
C14:0	0.84	0.0002
C16:0	0.75	0.0022
C17:0	0.65	0.012
C18:1 n-9	0.73	0.003
C18:2 n-6	–0.80	0.0006
C18:3 n-3	–0.56	0.038
C20:4 n-6	–0.86	0.0001
C20:5 n-3	–0.88	0.0001
ΣSFA	0.79	0.0008
ΣMUFA	0.74	0.0026
ΣPUFA	–0.81	0.0004
Σn-6	–0.90	0.0001
Σn-3	–0.73	0.0033
ΣPUFA/ΣSFA	–0.86	0.0001

[a] The correlation coefficients between intramuscular fat percentage and the remaining fatty acids studied were not significant ($p > 0.05$).

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