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RESEARCH ARTICLE

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Effect of gender on growth performance, carcass characteristics and meat and fat quality of calves of Avileña-Negra Ibérica breed fattened under free-range conditions

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Abstract

The effect of gender (entire males *vs* females) on growth performance, carcass traits and meat and fat quality of Avileña-Negra Ibérica calves, fattened under free range conditions and supplemented with concentrate, were investigated. The average daily gain, leg width and thorax depth were higher in males than in females. Carcass conformation score, fore-quarter weight and percentage in carcass were higher in males than in females, whereas dressing percentege, loins and flank percentages in carcass and carcass fatness degree were higher in females than in males. Instrumental colour variables of muscle were not affected by gender at days 1, 3, 7 and 9 of refrigerated storage. In muscle, the L^*, a^*, b^*, chroma, oxymyoglobine and oxymyoglobine/metmyoglobine ratio values observed 9 days after slaughter were lower than those at days 1 and 3 after slaughter. Intramuscular fat percentage of *Longissimus thoracis* muscle was higher in females than in males. Gender had no effect on α-tocopherol content in intramuscular fat (IMF) from *Longissimus thoracis* muscle. The omental and IMF of females had lower C18:2 n-6, Σ n-6 and Σ PUFA proportions than those from the males. In IMF C16:1, C18:1 n-9 and Σ MUFA proportions were greater in females than in males. The IMF percentage in *Longissimus thoracis* affected significantly to its fatty acid composition.

Additional key words: fatty acids; intramuscular fat; meat colour; productive results; sex.

Introduction

The Avileña-Negra Ibérica cattle rustic breed (*Bos taurus*) is traditionally reared under extensive conditions in the Spanish wooded rangeland (*dehesa*) located in the middle and western region of Spain. Since year 2008 the meat of this breed is guaranteed by one Protected Geographical Indication. The most frequent product is the grazing calf weaned at approximately six months old and live weight around 200-230 kg (Daza, 1999). After weaning calves are generally fattened in confinement and fed with cereal, straw and concentrates until they reach around 13-14 months of age with approximately 500 kg of live weight (550 kg the entire males and 450 kg the females). Nevertheless, the production of fattened calves in grazing to reduce the production cost is a recent practice. This rearing model is very estimated by the Spanish consumers that relate positively the production system based in grazing with the organoleptic and sanitary quality of the cattle meat.

Some meat quality characteristics such as colour or intramuscular fat (IMF) contents play a practical important in the beef market. Although colour is only slightly related with the eating traits of meat (Priolo *et al.*, 2001), meat purchasing decision is fundamentally influenced by this factor because discoloration is considered as an indicator of freshness and whole-

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Abbreviations used: IMF (intramuscular fat); MUFA (monounsaturated fatty acids); PUFA (polyunsaturated fatty acids); SEM (standard error of the mean); SFA (saturated fatty acids).

someness by consumers (Mancini & Hunt, 2005). Moreover, meat colour, lipid stability and meat conservation time is positively influenced by vitamin E concentration (Faustman *et al.,* 1998). Similarly, variability in tenderness, juiciness and flavour which depends on IMF content and its fatty acid composition (Wood *et al*., 2008), influences the consumer's decision to repurchase beef (Dransfield *et al*., 1984). However, there is scarce information on the effect of gender on these quality parameters since most of the studies have been focused on the nutrition effect.

On the other hand, cattle producers think over weight gain and carcass quality of calves are of great economic importance. These variables are affected by breed, gender, age, weight at slaughter and feeding system (Albertí *et al*., 2008; Bures & Barton, 2012). Some previous experiments have studied the gender effect on growth performance and carcass quality of Avileña-Negra Ibérica calves fattened in confinement with straw and concentrates (Panea *et al*., 2011; Daza *et al*., 2012). However, to our knowledge there is not still enough information on such aspects when the calves are fattened under free-range conditions in the Spanish *dehesa*. Moreover, there are not reports that have studied the influence of gender on the muscle and fat quality from calves of this breed fattened in grazing but supplemented with concentrates. Therefore, this paper studies the effect of gender on growth performance, carcass, meat and fat quality in Avileña-Negra Ibérica breed fattened under free-range conditions but supplemented with a mixed diet.

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

Sixteen calves, eight entire males and eight females, of Avileña-Negra Ibérica breed from CIA "El Dehesón del Encinar" (39° 55' 9" N, 5° 10' 40" O) (Junta de Comunidades de Castilla-La Mancha, Oropesa Toledo, Spain) were used. The calves were born in December 2009 and were weaned at around seven months of age and 248.50 kg of weight (SEM=10.46 kg). After weaning, males and females were separated and grouped in two independent fences (stocking rate of 1 calf ha^{-1}), where a commercial prairie had been sowed. The prairie included the following grassland species: *Trifolium subterraneum* L, *Trifollium michelianum* Savi, *Trifollium incarnatum* L, *Trifollium resupinatum* L, *Ornithopus compressus*, L, *Biserrula pelecinus* L and *Lolium multiflorum* Lam. The calves were weighed at the beginning and at the end of the experiment and concentrate consumption was controlled in each fence. The duration of the fattening period was of 260 days (from July 18 of 2010 to April 4 of 2011). During this phase, all animals were supplemented with the same concentrate from July 18 to February 14 (average daily supplementation of 3.10 and 2.65 kg of concentrate for entire males and females, respectively). The concentrate composition was 600 g kg^{-1} barley, 97 g kg^{-1} wheat, 273 g kg^{-1} field pea and 30 g kg^{-1} % of minerals – premix and was given as milled meal. According to FEDNA (2010) the calculated composition of concentrate was 11.22 MJ of metabolic energy kg^{-1}, 123.73 g crude protein kg^{-1} and 2.30, 0.10, 1.86, 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.

Slaughtering, sampling and carcass measurements

The calves were slaughtered at 478.87 kg (SEM = 7.54 kg) of average live weight (entire males at 520.89 kg and females at 436.86 kg) in the slaughter house Carnicas Hermanos Alonso, Alcaudete de la Jara, Toledo (Spain). Carcasses were chilled (4°C) overnight. 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 carcasses classification criterion of the EEC (1991), by means of a subjective scale that ranged from 1 to 15 points. The carcasses were divided in four large joints: leg, fore-quarter, loin (sirloin and high and low loin) and flank (flank and lower area of the ribs). The carcass joints were weighed on a precision balance. Omental fat samples were taken to analyze their fatty acid composition. Samples approximately 10-cm thick from the *Longissimus*

thoracis muscle at the level of tenth rib was collected for muscle colour analysis, IMF percentage quantification, fatty acids profile and α-tocopherol content. Muscle and omental fat samples were vacuum-packed in low-oxygen permeable film and stored at -20°C until analysis.

Laboratorial determinations for meat and fat samples

A 2-cm thick muscle sample was displayed on polystyrene trays, overwrapped with an oxygen-permeable polyvinyl chloride wrap and kept at 4°C under fluorescent light for colour measurement. Muscle colour was evaluated at 1, 3, 7 and 9 days after slaughter, by means of a chromameter (CM 2002, Minolta, Camera, Osaka, Japan) previously calibrated against a white tile, according to manufacturer 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 arctan (b^* / a^*) respectively. Reflectance data at selected wavelenghts 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), and IMF from *Longissimus thoracis* 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 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 in α-tocopherol in *Longissimus thoracis* muscle was quantified according to 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 1050, with a UV detector HPIB 10; Hewlett Packard, Waldbronn, Germany).

Statistical analysis

Data obtained for growth performance were studied by means of covariance analysis, considering gender as fixed effect and calves weaning weight as covariate. The carcass characteristics and *Longissimus thoracis* composition were studied by means variance analysis (gender as fixed effect). The muscle colour was studied by means of variance analysis that included the gender and ageing time as fixed effects and the interaction between both factors. Correlation coefficients between muscle ageing time and instrumental variables of colour were calculed. The fatty acid composition of omental and IMF were studied by means of variance analysis that included the gender as fixed effect and IMF percentage as covariate for fatty acid composition of IMF. The covariates were considered significant when $p < 0.05$, removing them from statistical models when $p > 0.05$. Student test was used to compare means. Confirmation of the normal distribution of data was carried out by means of the Shaphiro-Wilk test. Data that were not adjusted to a normal distribution were subjected to arcsin $(x / 100)^{0.5}$. All the analyses were carried out by means of the statistical package SAS (1999).

Results

Growth performance and carcass quality

The growth performance and carcass quality are shown in Table 1. Entire males and females started the experiment and were slaughtered at a similar age. As expected, weight at slaughter and average daily gain during the experimental period were higher in males than in females. The covariate calves weaning weight had significant ($p < 0.05$) effect on slaughter weight but did not affect the average daily gain. Carcass and leg length, leg perimeter and width, thorax depth, legs and fore-quarter and loins weight, fore-quarter percentage regarding carcass weight and conformation score were significantly higher in males than in females. However, dressing percentage, loins and flank percentages with respect to carcass weight

Table 1. Effect of gender on growth performance and carcass quality

Variable	Males	Females	SEM	*p* value
Age at weaning (days)	216.62	218.25	5.25	0.83
Weight at weaning (kg)	255.25	241.75	10.46	0.41
Age at slaughter (days)	476.62	478.25	5.25	0.83
Weight at slaughter (kg)[1]	520.89	436.86	7.54	0.0001
Average daily gain (g)[1]	1.06	0.72	0.03	0.0001
Carcass weight (kg)	270.13	228.65	6.65	0.0006
Dressing percentage	52.13	54.99	0.83	0.028
Carcass length (cm)	134.50	128.14	1.39	0.006
Leg length (cm)	84.75	81.37	0.93	0.023
Leg perimeter (cm)	106.00	102.37	1.13	0.040
Leg width (cm)	50.00	44.62	1.08	0.0033
Thorax depth (cm)	44.44	41.19	0.61	0.0021
Legs weight (kg)	86.45	74.75	2.32	0.0032
Fore-quarter weight (kg)	104.06	78.23	2.34	0.0001
Loins weight (kg)	44.20	40.30	1.11	0.026
Flank weigth (kg)	35.16	35.26	1.50	0.96
% Leg	32.00	32.70	0.31	0.17
% Fore-quarter	38.52	34.22	0.41	0.0001
% Loins	16.36	17.63	0.15	0.0001
% Flank	13.01	15.39	0.30	0.0001
Conformation	6.37	3.94	0.32	0.0001
Fatness degree	2.63	3.41	0.08	0.0001

SEM = standard error of mean. [1] Covariate initial weight.

and carcass fat degree were higher for females than for males, while flank weight and leg percentages regarding carcass weight of males and females were similar. Positive and significant ($p < 0.05$) correlation coefficients were detected among carcass conformacion score and legs, fore-quarter and loins weights and fore-quarter percentage ($r = 0.92$, $r = 0.94$, $r = 0.85$ and $r = 0.64$ respectively), and negative and significant ($p < 0.05$) correlation coefficients were observed among carcass conformation and loins and flank percentages ($r = 0.75$ and $r = 0.55$ respectively). Significant ($p < 0.05$) correlation coefficients were obtained among carcass fatness degree and fore-quarter and flank weight ($r = –0.61$ and $r = 0.56$ respectively) and legs, fore-quarter, loins and flank percentages regarding carcass weight ($r = 0.55$, $r = –0.86$, $r = 0.67$ and $r = 0.81$ respectively).

Meat quality

The influence of gender, and ageing time on muscle instrumental colour are shown in Table 2. In the present experiment averaged values of a*, b* chroma and oxymyoglobine/metmyoglobine ratio were significantly higher in females than in males. Muscle ageing time had significant effect on muscle colour. The L^*, a^*, b^* chroma, oxymyoglobine and oxymyoglobine/metmyoglobine ratio values observed at day 9 after slaughter were lower than those found at day 1 and 3, whereas values for hue angle and metmyoglobine were higher 9 days after slaughter than those observed at day 1 and 3. The interaction *ageing time* × *gender* was not significant for any colour instrumental variable. To clarify results Pearson correlation coefficients between colour instrumental variables and ageing time were calculated (Table 3). Ageing time was correlated negatively with L^*, a^*, b*, chroma, oximyoglobine and oximyoglobine/ metmyoglobine ratio values ($p < 0.001$). However, positive and significant correlation coefficients ($p < 0.001$) between ageing time and hue and metmyoglobine values were detected. The correlation coefficients detected between L* value and carcass fatness ($r = 0.12$) and IMF percentage ($r = 0.20$) were not significant.

Intramuscular fat percentage from *Longissimus thoracis* muscle was significantly higher in females than in entire males ($p = 0.0001$) (Table 4). The concentration of α-tocopherol in *Longissimus thoracis* is also presented in Table 4. The gender had not significant influence on α-tocopherol content of IMF from *Longissimus thoracis*.

Table 2. Effect of gender (G), ageing time (AT) (days after slaughter) and interaction AT × gender on instrumental colour of muscle

G	Variables							
	L*	a*	b*	Chroma[1]	Hue[2]	Oxim[3]	Metm[4]	Oxim/Metm[5]
Males	37.13	12.41	12.26	17.64	46.07	2.15	0.85	2.56
Females	38.41	13.61	13.22	19.10	44.87	2.24	0.84	2.69
SEM[6]	0.47	0.40	0.26	0.37	1.16	0.03	0.01	0.04
p value	0.06	0.04	0.01	0.01	0.47	0.06	0.35	0.04
AT(days)								
1	38.90^{ab}	14.94^{a}	12.61^{b}	19.56^{b}	40.19^{b}	2.31^{b}	0.74^{c}	3.11^{a}
3	39.89^{a}	16.53^{a}	14.77^{a}	22.19^{a}	41.85^{b}	2.57^{a}	0.83^{b}	3.07^{a}
7	36.93^{bc}	12.46^{b}	12.47^{bc}	17.71^{b}	45.16^{b}	2.15^{b}	0.91^{a}	2.37^{b}
9	35.35^{c}	8.09^{c}	11.09^{c}	14.02^{c}	54.68^{a}	1.76^{c}	0.90^{a}	1.97^{c}
SEM[6]	0.67	0.55	0.37	0.52	1.63	0.05	0.01	0.06
p value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
AT × G								
p value	0.42	0.96	0.63	0.95	0.91	0.83	0.64	0.53

[1] Chroma = $(a^{*2} + b^{*2})^{0.5}$. [2] Hue = 57.29 · arctan (b* / a*). [3] Oxim = oximyoglobine. Metm = metmyoglobine. [5] Oxim/Metm = ratio oximyoglobine/metmyoglobine. [6] SEM = standard error of the mean. Means with different superscripts are significantly different ($p < 0.05$).

Table 3. Pearson correlation coefficients between colour instrumental variables and ageing time

Variable	n	*r* value	*p* value
L*	64	–0.50	0.0001
a*	64	–0.73	0.0001
b*	64	–0.42	0.0006
Chroma	64	–0.67	0.0001
Hue	64	0.60	0.0001
Oximyoglobine	64	–0.69	0.0001
Metmyoglobine	64	0.82	0.0001
Oximyoglobine/Metmyoglobine	64	–0.87	0.0001

n = number of observations pairs. *r* = correlation coefficient.

Table 4. Influence of gender on moisture (M), intramuscular fat (IMF) percentage and concentration (μg g^{-1}) of vitamin E in *Longissimus thoracis* muscle

	Males	Females	SEM	*p* value
M (%)	76.01	73.25	0.31	0.0011
IMF (%)	0.86	2.04	0.01	0.0001
Vitamin E	4.42	5.17	0.35	0.1579

SEM = standard error of the mean.

Fat quality

The effects of gender on fatty acid composition of omental fat and IMF from *Longissimus thoracis* muscle are shown in Tables 5 and 6, respectively. The omental fat of females had significantly higher C10:0, C14:0, C16:0, C16:1 n-7 and C17:1 and lower C18:2 n-6, Σ n-6 and Σ PUFA proportions than that from the entire

Table 5. Fatty acid composition of omental fat as affected by gender

Fatty acid[1]	Males	Females	SEM[2]	*p* value
C10:0	0.03	0.04	0.002	0.0095
C12:0	0.05	0.05	0.006	0.43
C14:0	2.01	2.52	0.14	0.021
C15:0	0.41	0.40	0.03	0.85
C16:0	19.31	23.19	0.80	0.0041
C16:1 n-9	0.24	0.23	0.02	0.74
C16:1 n-7	0.91	1.34	0.10	0.0011
C17:0	1.66	1.64	0.06	0.86
C17:1	0.38	0.51	0.04	0.026
C18:0	36.54	31.20	1.80	0.057
C18:1 n-9	32.26	33.66	1.30	0.46
C18:1 n-7	1.11	1.13	0.05	0.88
C18:2 n-6	3.19	2.37	0.12	0.0003
C18:3 n-3	0.52	0.54	0.03	0.57
C18:4 n-3	0.32	0.31	0.02	0.91
C20:0	0.51	0.34	0.06	0.062
C20:1	0.39	0.32	0.05	0.41
C20:3 n-9	0.12	0.09	0.03	0.52
C20:4 n-6	0.06	0.09	0.03	0.37
Σ SFA	60.50	59.40	1.50	0.60
Σ MUFA	35.30	37.19	1.41	0.36
Σ PUFA	4.20	3.41	0.15	0.0026
Σ n-6	3.25	2.46	0.12	0.0003
Σ n-3	0.84	0.86	0.05	0.72
C16:1/C16:0	0.05	0.06	0.004	0.062
C18:1 n-9/C18:0	0.92	1.10	0.08	0.14
Σ MUFA/Σ SFA	0.59	0.63	0.04	0.46
Σ n-6/Σ n-3	3.96	2.86	0.16	0.003
Σ PUFA/Σ SFA	0.07	0.06	0.004	0.032

[1] Σ SFA, Σ MUFA, Σ PUFA, Σ n-6, Σ n-3 = sum of all saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), n-6 and n-3 fatty acids. [2] SEM = standard error of the mean.

males. The Σ n-6/Σ n-3 ratio was lower ($p = 0.003$) in females than in entire males. In *Longissimus thoracis* muscle the IMF percentage had effect ($p < 0.05$) on C14:0, C16:0, C18:2 n-6, C18:3 n-3, C20:3 n-9, C20:4 n-6, Σ SFA, Σ PUFA, Σ n-6, Σ n-3 fatty acids proportions and Σ PUFA/Σ SFA ratio. The C12:0, C15:0, C16:1, C17:1, C18:1 n-9 and Σ MUFA were higher, and C10:0 and C18:0 proportions lower in females than in entire males. The C16:1/C16:0, C18:1 n-9/C18:1 and Σ MUFA/Σ SFA ratios were significantly higher and Σ n-6/Σ n-3 lower in females than in entire males**.** In the current experiment, when the covariate IMF percentage was removed from the statistical model, C18:2 n-6, Σ n-6 and Σ PUFA proportions were lower in females than in entire males, and a negative correlation coefficient ($r = –0.95$, $p < 0.0001$) between C18:2 n-6 proportion and IMF percentage was detected.

Discussion

Growth performance and carcass quality

A higher growth for entire males compared to females has been well documented in previous studies (Link *et al*., 2007; Bures & Barton, 2012; Daza *et al*., 2012). Other authors (Casas & Cundiff, 2006) also observed a faster growth in castrated males than in females. As in the current experiment, Daza *et al*. (2012) also observed that calves weaning weight was positively related with slaughter weight.

In common practice males and females of Avileña-Negra Iberica calves are usually slaughtered approximately at the same age, as was done in the present study. However, the carcass weight was higher in males

Table 6. Effect of gender on fatty acids composition of intramuscular fat from *Longissimus thoracis*

Fatty acid[1]	Males	Females	SEM[2]	*p* value	*p* value covariate [3]
C10:0	0.15	0.05	0.01	0.0003	0.16
C12:0	0.02	0.06	0.008	0.0032	0.62
C14:0	1.72	1.79	0.11	0.75	0.0005
C15:0	0.34	0.37	0.02	0.24	0.084
C16:0	19.71	21.45	0.74	0.22	0.0074
C16:1	1.98	3.07	0.10	0.0001	0.59
C17:0	1.05	1.25	0.07	0.052	0.071
C17:1	0.65	0.95	0.05	0.0014	0.71
C18:0	18.77	16.53	0.71	0.046	0.33
C18:1 n-9	29.72	40.79	0.92	0.0001	0.36
C18:1 n-7	2.04	1.68	0.40	0.54	0.70
C18:2 n-6	14.42	9.26	1.70	0.12	0.028
C18:3 n-3	1.77	1.42	0.17	0.28	0.011
C18:4 n-3	0.33	0.38	0.04	0.44	0.40
C20:0	0.21	0.19	0.05	0.70	0.57
C20:1	0.37	0.35	0.04	0.64	0.45
C20:3 n-9	0.78	0.69	0.09	0.38	0.015
C20:4 n-6	3.05	2.61	0.41	0.57	0.041
Σ SFA	43.22	40.45	1.58	0.35	0.016
Σ MUFA	34.77	46.84	0.90	0.0001	0.21
Σ PUFA	20.40	14.31	2.19	0.15	0.013
Σ n-6	17.47	11.87	2.10	0.16	0.019
Σ n-3	2.15	1.75	0.17	0.21	0.025
C16:1/C16:0	0.11	0.13	0.05	0.0086	0.34
C18:1 n-9/C18:0	1.60	2.49	0.10	0.0001	0.63
Σ MUFA/Σ SFA	0.88	1.07	0.03	0.0005	0.24
Σ n-6/Σ n-3	8.84	5.26	0.56	0.0005	0.15
Σ PUFA/Σ SFA	0.50	0.37	0.08	0.40	0.031

[1] Σ SFA, Σ MUFA, Σ PUFA, Σ n-6, Σ n-3 = sum of all saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), n-6 and n-3 fatty acids, respectively. [2] SEM = standard error of the mean. [3] Covariate intramuscular fat percentage. The fatty acids values with *p* covariate <0.05 are least square means.

than in females due to that males growth was higher than in females. Previous studies showed that dressing percentage is higher or similar in males than in females (Fiems *et al.,* 2003). In the current experiment the higher dressing percentage for females was mostly due to their higher deposition of internal fat compared to males. Daza *et al*. (2012) found in Avileña-Negra Iberica calves raised in intensive conditions that dressing percentage was similar in males than in females, but in that study the slaughter weight was included as covariate in the statistical model. The Avileña-Negra Iberica is a precocious breed to synthesize fat (Sánchez Belda, 1984). Other authors observed that in precocious breeds such as Hereford (Hedrick *et al.,* 1969), Wagyu, Friesian, Norwegian Red and Swedish Red and White (Casas & Cundiff, 2006) dressing percentage was higher in females than in males, as in the present experiment. Due to that carcass weight was higher in entier males than in females the most of the values of carcass traits were greater in males than in females. Only the values of carcass characteristics related positively with the fatness degree of the carcass were similar (flank weight, legs percentage) or lower (loins and flank percentages) in entier males than in females. These results were generally in agreement with data from Bures & Barton (2012) and with those obtained in other studies (Link *et al*., 2007).

The greater loins and flank percentages found in females can be due to their higher fatness degree. Other authors (Zea *et al*., 2001) reported that entire males carcasses fattened in grazing had higher conformation and fore-quarter weight and percentage and lower flank

percentage and fatness degree than those from females. Also Fiems *et al*. (2003) and Bures & Barton (2012) found that entire males' carcasses had less quantity of fat than those from females, and Casas & Cundiff (2006) reported similar results when castrated males and females were compared.

Meat quality

The L*, a* and b* values found in the present experiment were in agreement with those obtained by Albertí *et al*. (2001) in calves of the same breed and by Ruiz de Huidobro *et al*. (2003) in Avileña-Negra Iberica × Charolais or Avileña-Negra Ibérica × Brown Swiss calves. Meat colour plays an important role in a consumer's purchase decision and may be influenced by many factors such age, feeding systems, carcass fatness, ultimate pH, physical activity, carcass weight, IMF content, pre and post-slaughter management (Priolo *et al*., 2001; Mancini & Hunt, 2005). However, the gender effect on muscle colour has been scarcely studied. In relation to this variation factor, several studies have found controversial and little consistent results. Thus, it is considered that the males have less bright and more pigmented meat than the females due to their higher physical activity and myoglobine content (Lawrie, 1977). Monserrat *et al*. (2001) did not find effect of gender on muscle colour in calves of Rubia Gallega breed finished in confinement under intensive conditions. Likewise, Daza *et al*. (2012) did not observe influence of gender on a*, b*, chroma and hue values, but L* value was lower in entire males than in females calves of Avileña-Negra Ibérica breed fattened in confinement with straw and concentrate. Also, Bures & Barton (2012) observed similar results in Charolais × Simmental calves reared under intensive conditions. Panea *et al*. (2011) neither detected significant differences according to gender for a* and b* values in Avileña-Negra Ibérica × Charolais calves. However, Zea & Díaz (2008) reported that the myoglobine content was greater in females than in entire males calves slaughtered at the same age. Fiems *et al.* (2003) observed higher a* in females than in entire males. According to Renerre (1986) it seems that pigment content is increasing more rapidly in females than in males. A fatter carcass allows muscle slower cooling rate, which generates faster pH decline (Priolo *et al*., 2001). Slower postmortem chilling combined with lower muscle pH increased protein denaturation and consequently L* value (Bruce *et al*., 2004). On the other hand, IMF has lighter colour than lean and therefore its presence in muscle could contribute to increase L* value. However, even though in the current experiment females had fatter carcass (Table 1) and higher IMF percentage (Table 4) than entire males, gender had no statistical effect on L* value and only a trend ($p = 0.06$) was observed. According to Priolo *et al*. (2001) carcass fatness seems not to be extremely important for meat colour, and the IMF effect is variable according to each experiment. Likely in our study difference in the IMF percentage observed between females and entire males was not enough for being responsible on meat colour.

The effect of ageing time on muscle colour has been found to be very variable according to different experiments. Thus, Carballo *et al*. (2001) and Onega *et al*. (2001) observed an increase in b* value with the ageing time, while a* value did not change. On the contrary, Vieira *et al*. (2006) did not find significant influence of ageing time on colorimetric parameters in Morucha and Morucha × Charolais calves. Nevertheless, Albertí *et al*. (2011) reported that hue value increased with ageing time in calves from Gasconne breed which is in agreement with results of the present study. Daza *et al*. (2012) also found negative and positive correlation coefficients between ageing time and a* and hue values respectively, in Avileña-Negra Iberica calves. The increase of hue and metmyoglobine values with ageing time is related with meat discolouration. A decrease in the oxymyoglobine/metmyoglobine ratio below 3 is considered undesirable. This numerical value is because oxymyoglobin has a bright scarlet colour of fresh meat, whereas metmyoglobin, which results from the oxidation of myoglobin, has an undesirable brown colour (Purchas *et al*., 2010). Trout & Gutzke (1995) reported that the time of acceptable display colour at 5°C was 4.7 days for beef which is in accordance with the results obtained in the present experiment.

Concerning the higher IMF percentage found in females than in males, many studies have reported that females have more IMF content than the entire males at a similar slaughter age (Fiems *et al.*, 2003; Zea & Díaz, 2008; Velik *et al*., 2008; Bures & Barton, 2012).

The α-tocopherol values found in the present study were similar to those observed by Purchas & Zou (2008) in several groups of pasture-finished cattle. The α-tocopherol content in muscle depends essentially of grass or forage availability (Yang *et al*., 2002) and other factors such as muscle type and breed (Purchas

& Zou, 2008). Purchas *et al*. (2010) observed higher vitamin E concentration in *Longissimus* muscle from females of red deer than those from males, and Purchas & Zou (2008) found in *Longissimus* and *Infraspinatus* muscles a positive relation between IMF percentage and muscle α-tocopherol concentration. Since in the present experiment females had higher IMF, a higher α-tocopherol concentration would be expected. However, although α-tocopherol value in our study was numerically greater in females than in entire males, difference was not statistically significant ($p = 0.16$).

Fat quality

To our knowledge there are few works that studied the fatty acid profile of omental fat as affected by gender in beef cattle. The omental fat was more saturated and less insaturated than IMF. As in the present study in Avileña-Negra Ibérica calves reared under free-range conditions supplemented with concentrate, Daza *et al*. (2014) also observed that omental fat had higher Σ SFA and lower Σ PUFA proportions than IMF.

The higher C18:1 n-9 and lower C18:0 proportions detected in IMF from females suggest that delta-9-desaturase enzyme activity of IMF were higher in females than in males (Wood & Enser, 1997). Also Moreno *et al.* (2006) observed more content of C18:1 n-9 and Σ MUFA in IMF from females than that from entire males, and Zembayashi *et al.* (1995) and Kazala *et al.* (1999) also found higher monounsaturated proportions in IMF from females when females and castrated males were compared.

As in the present experiment, Kazala *et al.* (1999) also observed a negative correlation between C18:2 n-6 proportion in IMF and IMF percentage. It means that females have lower content of C18:2 n-6 because have higher IMF percentage in *Longissimus thoracis* muscle. Also Malau Aduli *et al.* (1998) reported that females had lower proportion of C18:2 n-6 and Σ PUFA in IMF than castrated males. In Avileña-Negra Ibérica calves fattened with straw and feed in confinement, Daza *et al.* (2012) also observed that females had higher C18:1 n-9 and MUFA and lower C18: 1 n-6, Σ PUFA and Σ n-6 proportions in subcutaneous fat.

It is concluded that gender affects on growth performance, carcass traits and meat and fat quality of Avileña-Negra Ibérica calves fattened under free-range conditions and supplemented with concentrate. Females have worse growth performance, higher carcass fatness degree and intramuscular fat percentage than entire males; however muscle colour is not influenced by gender with the display time. The intramuscular fat quality was better in females than in entire males.

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References

Albertí P, Sañudo C, Olleta JL, Panea B, Lahoz F, 2001. Efecto del peso al sacrifico en el rendimiento cárnico de terneros de siete razas bovinas españolas. ITEA 22: 511-513.

Albertí P, Panea B, Sañudo C, Olleta, JL, Ripoll G, Ertbjerg P, Christensen M, Gigli S, Failla, S, Concetti S *et al.,* 2008. Live weight, body size and carcass characteristics of young bulls of fifteen European breeds. Livest Sci 114: 19-30.

Albertí P, Ripoll G, Panea B, Guerrero A, Santolaria P, 2011. Color de la grasa subcutánea y evolución del color de la carne en film y en atmósfera protectora durante el periodo de venta de terneros de raza Gasconne. AIDA XIV Jornadas sobre Producción Animal, Zaragoza (Spain), 17-18 de Mayo. Tomo II, pp: 658-660.

Bligh EG, Dyer WJ, 1959. A rapid method of total lipid extraction and purification. Can J Biochem Phys 37: 911-917.

BOE, 2005. Real decreto español 1201/2005 sobre la protección de los animales utilizados para experimentación y otros fines científicos. Boletín Oficial del Estado 252: 34367-34391.

Bruce HL, Stark JL, Beiken SL, 2004. The effects of finishing diets and postmortem ageing on the eating quality of the M. longissimus thoracis of electrically stimulated Brahman steer carcass. Meat Sci 67: 261-268.

Bures D, Barton, L, 2012. Growth performance, carcass traits and meat quality of bulls and heifers slaughtered at different ages. Czech J Anim Sci 57: 34-43.

Carballo JA, Varela A, Oliete B, Monserrat L, Sánchez, L, 2001. Terneros de clase suprema acogibles a la IGP "Ternera Gallega": Efecto del tiempo de maduración sobre el color de la carne. ITEA 22: 556-558.

Casas E, Cundiff LV, 2006. Postweaning growth and carcass traits in crossbred cattle from Hereford, Angus, Norwegian Red, Swedisd Red and White, Friesian, and Wagyu maternal grandsires. J Anim Sci 84: 305-310.

CIE, 1976. Recomendations on uniform color spaces-color difference equations-psychometric color terms. Suppl. nº 2 to CIE. Publ. nº 15 (E-1.31)197/(TC-1.3). Bureau de la Commission Internationale de l'Eclairage, Paris.

Daza A, 1999. Producción de vacuno de carne en la dehesa. Monografía Bovis nº 87. Ed Luzán, Madrid, Spain. 100 pp.

Daza A, Rey AI, López-Carrasco C, López-Bote CJ, 2012. Effect of gender on growth performance, carcass traits and meat quality of calves of Avileña-Negra Ibérica breed. Span J Agric Res 10: 108-115.

Daza A, Rey AI, López-Carrasco C, López-Bote CJ, 2014. Influence of feeding system on growth performance carcass characteristics and meat and fat quality of Avileña-Negra Ibérica calves bred. Span J Agric Res 12: 409-418.

Dransfield E, Nute GR, Francombe MA, 1984. Comparison of eating quality of bulls and steers. Anim Prod 39: 37-50.

EEC, 1991. Council Regulation nº 1026/91 of 22 April amending Regulation (EEC) nº 1208/81 determining the Community scale for the classification of carcass of adult bovine animals.

Faustman C, Chan WKM, Schaefer DM, Havens A, 1998. Beef color update: the role of vitamin E. J Anim Sci 76: 1019-1026.

FEDNA, 2010. Tablas FEDNA de composición y valor nutritivo de alimentos para la fabricación de piensos compuestos (de Blas C, Mateos GG & García Rebollar P, coords.). Ed Fundación Española para el Desarrollo de la Nutrición Animal.

Fiems LO, De Campeneere S, Van Caelenbergh W, De Boever JL, Vanacker JM, 2003. Carcass and meat quality in double-muscled Belgian Blue bulls and cows. Meat Sci 63: 345-352.

Hedrick HB, Thompson GB, Krause GF, 1969. Comparison of feedlot performance and carcass characteristics of half-sib bulls, steers and heifers. J Anim Sci 29: 687-694.

Kazala EC, Lozeman FJ, Mir PS, Laroche A, Bailey DR, Weselake RJ, 1999. Relationship of fatty acid composition to intramuscular fat content in beef from crossbred Wgyu cattle. J Anim Sci 77: 1717-1725.

Lawrie RA, 1977. Ciencia de la carne. Ed Acribia, Zaragoza, Spain.

Link G, Willeke H, Golze M, Bergfeld U, 2007. Fattening and slaughter performance of bulls and heifers of beef breeds and the cross breed German Angus z Simmental. Archiv fur Terzucht 50: 356-362.

López Bote CJ, Rey A, Ruiz J, Isabel B, Sanz Arias R, 1997. Effects of feeding diets high in monounsaturated fatty acids and α-tocopherol acetate to rabbits on resulting carcass fatty acid profile and lipid oxidation. Anim Sci 64: 177-186.

Malau-Aduli AEO, Siebert BD, Botterna CDK, Pitchford WS, 1998. Breed comparison of the fatty acid composition of muscle phospholipids in Jersey and Limousine cattle. J Anim Sci 76: 766-773.

Mancini RA, Hunt, MC, 2005. Current research in meat color. Meat Sci 71: 100-121.

Marmer WN, Maxwell RJ, 1981. Dry column method for the quantitative extraction and simultaneous class separation of lipids from muscle tissue. Lipids 16: 365-371.

Monserrat L, Sánchez L, Varela A, Carballo JA, 2001. Producción de terneros de raza Rubia Gallega sin destetar: efecto de la extensificación del manejo sobre el color de la carne y de la grasa. ITEA 22: 559-561.

Moreno T, Varela A, Oliete B, Carballo JA, Sánchez L, Monserrat L, 2006. Nutrional characteristics of veal from weaned and unweaned calves: Discriminatory ability of the profile. Meat Sci 73: 209-217.

Onega E, Miguel E, Blázquez B, Ruiz de Huidobro F, 2001. Evolución de algunos parámetros de calidad de la carne de vacuno en los seis primeros días *postmortem*. ITEA 22: 568-570.

Panea B, Ripoll G, Olleta JL, Sañudo C, 2011. Efecto del sexo y del cruzamiento sobre la calidad instrumental y sensorial y sobre la aceptación de la carne de añojos de raza Avileña-Negra Ibérica. ITEA 107: 239-250.

Priolo A, Micol D, Agabriel J, 2001. Effect of grass feeding systems on ruminat meat colour and flavour. A review. Anim Res 50: 185-200.

Purchas RW, Zou M, 2008. Composition and quality differences between the longissimus and infraspinatus muscles for several groups of pasture-finished cattle. Meat Sci 80: 470-479.

Purchas RW, Trumf, EC, Egelandsdal B, 2010. Quality characteristics and composition of the longissimus dorsi muscle in the short-loin from male and female farmed red deer in New Zealand. Meat Sci 86: 505-510.

Renerre, M, 1986. Influence de facteurs biologiques et technologiques sur la couleur de la viande. Bull Techn CRZV. Theix, INRA 64: 41-45.

Rey A, López Bote CJ, 2001. Effect of dietary cooper and vitamin E supplementation, and extensive feeding with acorns and gras on *longissimus dorsi* composition and susceptibility to oxidation in Iberian pigs. J Anim Physiol Anim Nutr 85: 281-292.

Ruiz de Huidobro FR, Miguel E, Onega E, Blázquez B, 2003. Changes in meat quality characteristics of bovins meat during the firts 6 days post morten. Meat Sci 65: 1439-1446.

Sánchez Belda A, 1984. Razas bovinas españolas. Ed MAPA, 878 pp.

Sañudo C, Campo MM, 1998. Calidad de la canal por tipos. In: Vacuno de carne: aspectos claves (Buxadé C, ed). Mundi Prensa, Madrid (Spain), pp: 465-492.

SAS, 1999. SAS user's guide statistics. Stat Anal Syst Inst Inc, Cary, NC, USA.

Trout GR, Gutzke D, 1995. The relationship between discolouration rate during refrigerated display and the autooxidation rate of purified myoglobin. The effect of muscle type and species. Proc 41th Int Cong of Meat Science and Technology, pp. 404-405.

Velik M, Steinwidder A, Frickh JJ, Ibi G, Kolbe-Romer A, 2008. Effect of ration, sex and bred on carcass performance and meat quality of cattle from suckler cow systems. Zuchtungskunde 80: 378-388.

Vieira C, García-Cachán MD, Recio MD, Domínguez M, Sañudo C, 2006. Effect of ageing time on beef quality of rustic type and rustic × Charolais crossbreed cattle slaughtered at the same finishig grade. Span J Agric Res 4: 225-234.

Wood JD, Enser M, 1997. Factors influencing fatty acids in meat and the role of antioxidants in improwing meat quality. Br J Nutr 78: S49-S60.

Wood JD, Enser M, Fisher AV, Nute, GR, Sheard PR, Richardson RI, Hughes SI, Whittington FM, 2008. Fat deposition, fatty acid composition and meat quality: a review. Meat Sci 78: 343-358.

Yang A, Lanari MC, Brewster M, Tume RH, 2002. Lipid stability and meat colour of beef from pasture and grain-fed cattle with or without vitamin E supplement. Meat Sci 60: 41-50.

Zea J, Díaz MD, 2008. Producción de carne con forraxes ensiladas. Ed Consellería do Medio Rural, Xunta de Galicia. Santiago de Compostela, Galicia, Spain.

Zea J, Carballo JA, Díaz MD, 2001. Efecto del sexo y de la suplementación energética en raciones isoproteicas a base de ensilado de maíz para crecimiento y engorde de terneros Rubio Gallegos I. Parámetros productivos y características de las canales. Revista Portuguesa de Zootecnia VIII (1): 87-97.

Zembayashi M, Nishimura K, Luna DK, Smith SB, 1995. Effect of breed type and sex on the fatty acid composition of subcutaneous and intramuscular lipids of finishing steers and heifers. J Anim Sci 73: 3325-3332.