

Sex effect on meat quality and carcass traits of foals slaughtered at 15 months of age

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The effect of sex on carcass measurement, physico-chemical properties, nutritional value and sensory characteristics of foal meat slaughtered at 15 months was investigated. Twelve foals (six females and six males) from an extensive production system in freedom regimen were used for this study. Sex had no statistical influence on carcass measurements, chemical composition, colour parameters, textural properties, amino acid content and sensory characteristics. In contrast, there was a clear effect on the fatty acid profile of longissimus dorsi. Slaughter weight was not significantly (P > 0.05) different between sexes, although higher values were observed in male group compared with female group (194 v. 184 kg). As a consequence, this trend affected carcass weight being slightly (P > 0.05) heavier in the male group than in the female group. On the other hand, cooking loss samples from males showed significantly higher values than those from females (21.50% v. 14.96%, P < 0.05). From a nutritional point of view, the n-6/n-3 ratio in both sexes was within the recommended range for the human diet and this ratio was ostensibly different between the sexes (1.83 v. 1.36, P < 0.05, for male and female, respectively) and it showed a strong correlation (r = -0.91, P < 0.01) with C18:3n-3 content.

Keywords: Foal, carcass characteristics, meat quality, nutritional value, sensory properties

Implications

This study provides practical and useful information on carcass characteristics and the nutritional quality of *longissimus dorsi* (LD) from foal meat that are widely consumed in Europe. It will also be useful for nutritionists to describe tables of the food composition.

Introduction

Today, population is more diet conscious, having special concerns about fat and cholesterol, both associated with meat consumption. For the modern consumer, taste and nutritional value are important quality attributes of meat (Webb and O'Neill, 2008), with increased expectations in meat and meat products from extensive production systems. This meat is perceived as healthy because of the friendly extensive system that is used on animal production, and the consumer's decision to purchase. This kind of meat is mainly guided by its high intrinsic quality and healthiness, which in the case of meat is largely related to its fat properties and

to the absence of chemical residues. On the other hand, extensive foal livestock has always been important in mountain areas from the social, economic and environmental points of view: (i) well adapted to the land; (ii) keeping the ecosystem of pasturages; (iii) protecting the area against fire and erosion; and (iv) finally, maintaining population in rural areas.

Horse meat production in Spain has grown in the recent years, being the fourth largest producer in the UE in 2010 with 6500 tonnes (FAOSTAT, 2010). Although the consumption in Spain is limited, a high percentage is exported to other countries, mainly to Italy (Mercasa, 2011). In 2010, worldwide horse meat production reached 741 000 tonnes. The main producers were Asia, with 45% of worldwide production, followed by Europe (19%), South America (12%), Central America (11%) and North America (6%). The greatest importers of horse meat were Italy, Belgium, Russia and France, and the most important exporters were Argentina, Belgium, Canada and Poland (FAOSTAT, 2010).

The aim of this work was to study the sex effect on carcass characteristics, physico-chemical properties (chemical composition, colour parameters and textural profile), nutritional value (fatty acid and amino acid content) and sensory characteristics of foal meat slaughtered at 15 months of age.

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Material and methods

Experimental design and animal management

Twelve foals (six females and six males) of 'Galician Mountain' breed were obtained from 'Monte Cabalar' (agricultural cooperative of 'Galician Mountain' breed) located in a mountain (A Estrada, Pontevedra, Spain) and were used for this study. The majority of the foals were born in the months of April and May 2010. Animals were reared with their mothers on pasture and they kept suckling and grazing until the weaning age of 6 to 7 months. After weaning, foals were fed mainly with ryegrass (Lolium perenne), Ulex europaeus L. and *Pteridium aquilinum* (L.) Kuhn, receiving complementary grass silage ad libitum when the grass available was limited, especially in the summer and winter time, but they were never given concentrates. All foals were reared with their mothers in an extensive production system in freedom regimen, according to an extensive production system on wood pasture. These animals were slaughtered when they were 15 months old. They were transported to the abattoir (20 km) the day before slaughter. Foals from different groups were not mixed at any time, and stress was minimizing as much as possible. Animals were stunned with a captive bolt and slaughtered and dressed according to current European Union regulations (Council Directive of the European Union 95/221EC), in an accredited abattoir.

Carcass characteristics and sample collection

Immediately after slaughter, carcasses were weighed (CW) and chilled at 4°C in a cold chamber for 24 h. The killing-out percentage was calculated as the ratio between CW and slaughter weight. At this point, the left half-carcasses were moved to the research centre pilot plant and the following carcass measurements were made: length of carcass (LC), length of leg (LL), width of leg (WL), internal depth of chest (IDC), external depth of chest (EDC) and perimeter of leg (PL) (Supplementary Figure S1). In addition, carcass compactness index (CCI) = (CW/LC) and hindlimb compactness index (LTI) = (LL/WL) were also calculated. The left half-carcass was dividing in front quarter (FQ) and hind quarter (HQ), and 19 primal cuts were obtained, which are indicated in Supplementary Figure S2 and Table 1. Finally, tissue composition was obtained by the sum of all lean muscle (meat). sum of all bones (bone) and sum of all fat (fat).

The LD muscle was cut into seven 2.5-cm-thick steaks. The first three steaks were used to determine pH, colour, proximate composition and fatty acid and amino acid profile. The fourth and fifth steaks were packed under vacuum conditions (99%) (FRIMAQ, V-900, Lorca, Spain) during 4 days at 4°C. Water-holding capacity (WHC) and texture parameter were obtained after this period. The last ones were used for sensory analysis.

Analytical methods

Reagents. Fatty acid methyl esters standard mixtures and non-adecanoic acid methyl esters were acquired from Supelco Inc. (Bellefonte, PA, USA), and cholesterol standards

were supplied by Sigma Chemical Co. (St Louis, MO, USA). Analytical grade and liquid chromatographic grade chemicals were purchased from Merck Biosciences (Darmstadt, Germany). Boron trifluoride (14% solution in methanol) was obtained from Panreac (Castellar del Vallès, Barcelona, Spain). AccQ.Fluor reagent kit (AQC, borate buffer) and AccQ.Tag Eluent A concentrate were acquired from Waters (Milford, MA, USA). Acetonitrile (MeCN), disodium ethylenediaminetetraacetic acid (EDTA), phosphoric acid, sodium acetate trihydrate and sodium azide came from Baker (Phillipsburg, PA, USA), and triethylamine (TEA) was purchased from Aldrich (Milwaukee, WI, USA). Amino acid standards, taurine and hydroxyproline were acquired from Sigma (St. Louis, MO, USA).

Physico-chemical, fatty acid and amino acid profile. pH was measured using a digital pH meter (Thermo Orion 710 A+, Cambridgeshire, UK) equipped with a penetration probe. A portable colorimeter (Konica Minolta CR-600d Osaka, Japan) with pulsed xenon arc lamp, 0° viewing angle geometry and 8 mm aperture size was used to estimate meat colour in the CIELAB space (lightness, L*; redness, a*; yellowness, b* (CIE, 1976)). Haem iron was measured in duplicate following Hornsey (1956) methodology according to this formula (Merck Index, 1989):

Haematin (μ g haematin/g muscle) = Absorbance × 342.44 Haem iron (mg/100 g meat) = (Haematin × 8.82)/100

Moisture, fat, protein (Kjeldahl N \times 6.25) and ash were quantified according to International Organization for Standardization (ISO)-recommended standards 1442:1997 (ISO, 1997), 1443:1973 (ISO, 1973), 937:1978 (ISO, 1978) and 936:1998 (ISO, 1998), respectively.

Steaks were cooked placing vacuum package bags in a water bath with automatic temperature control (JP Selecta, Precisdq, Barcelona, Spain) until they reached 70°C in quore, controlling the heat by thermocouples type K (Comark, PK23M, Vienna Court, UK) connected to a data logger (Comark Dilligence, EVG N3014, Vienna Court, UK). After this stage, samples were cooled in a circulatory water bath set at 18°C for 30 min and cooking loss percentage was recorded. Seven meat pieces of $1 \times 1 \times 2.5$ cm (height \times width \times length) were removed parallel to the muscle fibre direction and were completely cut using a Warner-Bratzler (WB) shear blade with a triangular slot cutting edge (1-mm-thick). Maximum shear force, shear firmness and total necessary cutting work were obtained. Texture profile analysis (TPA) was measured by compressing to 60% (19.85 cm² contact surface compression). Force-time curves were recorded at 3.33 mm/s cross-head speed. Hardness (kg), cohesiveness, springiness (mm) and chewiness (kg \times mm) were obtained by means of a texture Analyzer (TA.XT.plus of Stable Micro Systems, Vienna Court, UK) and the available computer software (Texture Exponent 32 (version 1.0.0.68), Stable Micro Systems).

The WHC was measured in two ways: cooking loss (CL) and drips loss (DL). CL was evaluated by cooking as

described in texture analysis, measuring the difference in weight between cooked and raw samples. To determine DL, an intact meat sample in a variable range of 80 to 100 g and 1.5 cm thick was weighed and put on top of a net, inside of a container, which was closed after filling to avoid evaporation. This container was placed in a refrigerated chamber at 4°C for 48 h and it was weighed again after this period.

The saponification, extraction and simultaneous identification of cholesterol in meat were carried out in normal phase following the procedure described by Prates *et al.* (2006). Intramuscular extraction of lipid from LD, transesterification and determination of fatty acid profile were carried out according to Lorenzo *et al.* (2010). The hydrolysis of the protein, derivatization and identification of hydrolyzated amino acid were carried out following the procedure described by Franco *et al.* (2012), with the difference that free amino acids were not separated from constitutive amino acid.

Sensory analysis. The taste panel evaluation was conducted with eight panellists selected from the Meat Technology Centre of Galicia. The panellists were trained during 1 year with the attributes and the scale to be used. During the sensory evaluation, the panellists were situated in a private cabinet illuminated with red light. Water to clean the palates and remove residual flavours was given to the panel at the beginning of the session and in between samples. The sensory evaluation consisted of two sessions: one to visually evaluate the attribute of the fresh foal meat, and a second to evaluate all the sensory attributes of the cooked foal meat. The samples were individually labelled with three-digit random numbers and were served one at a time in random order. To rate the samples, the panellist used nine-point scales having word anchors at the extreme ends.

The fresh foal meat sensory traits were assessed at 24 h postmortem. Before being presented to the panellists, the samples (25-mm-thick) were exposed to air for 30 min at 4°C to allow for complete bloom. Subjective measures for colour (1 = pale pinkish-grey to white; 9 = dark purplish-red) wereevaluated. The samples for the cooked foal meat sensory evaluation were cut into segments \sim 25 mm thick. The steaks were grilled in a frying pan at internal temperature of 68°C to 70°C, which was measured using a thermometer with a handheld probe (HI-985011, Hanna Instruments, Eibar, Spain). The cooked foal steaks were cut into $10 \times 10 \times 25 \text{ mm}^3$ pieces, placed on white plastic trays covered with aluminium foil and served immediately to each panellist. The cooked foal samples were evaluated for intensity odour (1 = little)intensity; 9 = very intensity), intensity rancid (1 = little)rancid; 9 = very rancid, abnormal flavour (1 = very weak; 9 = very strong, taste (1 = very unacceptable; 9 = veryacceptable), sweetness (1 = little sweet; 9 = very sweet), juiciness (1 = very dry; 9 = very juicy), hardness (1 = very tender; 9 = very tough) and fibrousness (1 = little fibrous; 9 =very fibrous).

Statistical analysis. An ANOVA of one way using SPSS package (2008, SPSS/PC + Statistics, 19.0 SPSS Inc., Chicago, IL, USA) was performed for all variables considered in the study. The least squares mean (LSM) were separated using Duncan's *t*-test. All statistical tests of LSM were conducted for a significance level $\alpha < 0.05$. Correlations between variables were determined by correlation analyses using the Pearson's linear correlation coefficient with the above statistical software package mentioned.

Results and discussion

Carcass parameters

Carcass characteristics, commercial cuts and tisular composition of foals are shown in Table 1. No significant differences (P > 0.05) between sexes were found in any trait. Slaughter weight was not significantly (P > 0.05) different between sexes, although higher values were observed in the male group (+10 kg) compared with the female group. As a consequence, this trend affected carcass weight as the carcass weight of the male group was slightly higher compared with the female group. Our results were lesser that those reported by Sarriés and Beriain (2005) who observed carcass weights at around 275 kg in male and female Burguete foals slaughtered at 16 months of age, and those found by Lanza et al. (2009) who reported carcass weights ranged between 244 kg for Sanfratelano and 208 kg for Haflinger foals slaughtered at 18 months of age. Obviously, these differences can be attributed because of the type of foal carcasses used in these studies that have been obtained from old animals and/or specialized breeds for meat production.

Killing-out percentage was similar between sexes (around 48%), and this value was lower than that found (around 63%) by Sarriés and Beriain (2005) in foals of Burguete breed slaughtered at 16 months of age, and smaller than the value observed (around 59% to 60%) by Lanza *et al.* (2009) in foals of Italian breed slaughtered at 18 months of age.

The division of the half-carcass in front and hind quarters did not reveal differences because of sex. Hind quarter is the part of the carcass where several of the most valuable primal cuts are located, and, again, percentage of most valued pieces (loin, tenderloin, topside and eye round) was higher in males, although differences were very small and not statistically significant. Franco *et al.* (2011a) studied carcass from 'Galician Mountain' foals breed assigned to similar production system but slaughtered at 12 months of age. No differences in killing-out percentage or in carcass percentage for front and hind quarter were found.

Regarding CCI, comparison with other studies can be made, but again our figures cannot be easily compared with the data obtained from other breeds. Sarriés and Beriain (2005) found values of 1.63 in 16-month-old Burguete foals, and Juárez *et al.* (2009) reported levels of 2.4 for foals of Hispano-Breton breed slaughtered at 24 months of age. Foal carcasses are high in meat content in the present study, with 69.25% of mean value, which is slightly higher than that observed by Znamirowska (2005), published for 6- to 10-year-old horses.

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Table 1	Effect of sex on	slaughter weigl	nt, carcass weight and	carcass measurements	in i	foals

	Male	Female	s.e.m.	P-values
Age (days)	432.6	429.8	2.8	ns
Slaughter weight (kg)	194.8	184.7	8.4	ns
Carcass weight (kg)	93.3	87.5	4.6	ns
Killing out (%)	47.7	47.2	0.6	ns
Carcass measurements (cm)				
LL	94.7	94.6	1.2	ns
LC	69.2	68.5	0.8	ns
WL	15.8	15.5	0.4	ns
PL	77.4	76.6	1.3	ns
EDC	49.4	49.7	0.6	ns
IDC	34.2	35.1	1.0	ns
CCI	0.9	0.9	0.1	ns
LTI	4.3	4.4	0.1	ns
Primal cuts (%)				
Front quarter				
Shoulder clod	4.9	4.8	0.1	ns
Top blade	1.3	1.2	0.1	ns
Chuck tender	1.1	1.1	0.1	ns
Chuck	3.1	3.2	0.1	ns
Neck	4.8	5.3	0.2	ns
Blade	0.2	0.2	0.1	ns
Fore shank	3.7	3.5	0.1	ns
Brisket	2.8	3.0	0.1	ns
Lean	1.6	1.8	0.1	ns
Fat	1.8	1.6	0.1	ns
Bone	10.7	10.8	0.3	ns
Hind quarter				
Full plate	8.3	9.7	0.4	ns
Loin	7.3	7.1	0.2	ns
Tenderloin	2.5	2.3	0.1	ns
Topside	5.7	5.6	0.1	ns
Eye round	2.0	1.9	0.1	ns
Hind shank	1.7	1.6	0.1	ns
Thick flank	4.2	4.0	0.1	ns
Flank steak	4.5	4.3	0.1	ns
Rump	1.1	1.1	0.1	ns
Silverside	4.9	4.7	0.1	ns
Heel of round	1.2	1.2	0.1	ns
Brisket bone	1.0	1.0	0.1	ns
Loin bone	1.9	1.7	0.1	ns
Hip bone	4.6	4.1	0.1	ns
Fat	0.7	1.0	0.1	ns
Carcass percentage and tissue composition (%)				
Front quarter	36.6	37.0	0.7	ns
Hind quarter	62.8	63.5	1.1	ns
Meat	69.3	69.2	0.7	ns
Bone	27.2	26.7	0.6	ns
Fat	3.4	3.9	0.3	ns
Meat/bone in carcass	2.5	2.6	0.1	ns

s.e.m. = standard error of the mean; ns = not significant; LL = length of leg; LC = length of carcass; WL = width of leg; PL = perimeter of leg; EDC = external depth of chest; IDC = internal depth of chest; CCI = carcass compactness index; LTI = hindlimb compactness index.

Physico-chemical properties

Chemical composition, colour, WHC and textural parameters of LD from foals are shown in Table 2. No significant differences (P > 0.05) between sexes were observed except for cooking loss (P < 0.05), as the male group presented the

highest values. Local slaughter practices tended to minimize stress factors. Foal meat acidification process took place in a similar way for both sexes as it is described in the literature (Franco *et al.*, 2011b; Sarriés and Beriain, 2005; Tateo *et al.*, 2008). Our values of meat pH were similar to those described

Table 2 Effect of sex on meat quality from longissimus dorsi of foal meat

	Male	Female	s.e.m.	<i>P</i> -values
рН	5.6	5.6	0.1	ns
Chemical composition (%)				
Water	76.6	76.2	0.2	ns
Protein	22.3	22.3	0.2	ns
Intramuscular fat	0.1	0.1	0.1	ns
Ashes	1.2	1.2	0.1	ns
Fe-haemo (mg/100 g wet meat)	1.7	1.5	0.1	ns
Cholesterol (mg/100 g wet meat)	0.6	0.6	0.1	ns
Colour parameters				
Luminosity (L*)	40.4	38.2	1.1	ns
Redness (a*)	17.6	17.1	0.4	ns
Yellowness (b*)	10.6	11.3	0.3	ns
Water holding capacity				
Drip loss (%)	3.1	3.9	0.2	ns
Cooking loss (%)	21.5	14.9	1.7	*
Textural parameters				
Shear force (kg/cm ²)	3.8	3.0	0.5	ns
Firmness (kg/cm ²)	0.5	0.4	0.1	ns
Total work (kg $ imes$ s)	18.3	14.6	2.2	ns
TPA-test				
Hardness (kg)	3.9	4.2	0.3	ns
Springiness (mm)	0.4	0.4	0.1	ns
Chewiness (kg $ imes$ mm)	0.9	1.0	0.1	ns
Gumminess(kg)	2.1	2.3	0.2	ns
Cohesiveness	0.5	0.5	0.1	ns

s.e.m. = standard error of the mean; ns = not significant.

**P*<0.05.

by Polidori *et al.* (2008) in donkey meat and by Sarriés and Beriain (2005) and Lanza *et al.* (2009) in meat from foal of Burguete and Haflinger breed, respectively.

The source of variability and sex did not influence the component moisture, protein, intramuscular fat (IMF), ashes and Fe-haemo (P > 0.05, Table 2). Similar values of moisture were obtained in both groups (76.28% v. 76.63%, for female and male groups, respectively, P > 0.05). This result is in disagreement with those reported by Tateo et al. (2008) who found higher moisture content in meat foal samples from females than males. Mean values of moisture content observed in the present study (around 76.5%) were higher to those reported for equine meat of 11 to 24 months of age (Sarriés and Beriain, 2005; Tateo et al., 2008; Juárez et al., 2009; Lanza et al., 2009), with mean values close to 72%. The IMF content was slightly higher in female than in male (Table 2) as it has been previously established in foal meat by Sarriés and Beriain (2005), although our values were lower than those reported by other authors in horse meat (Sarriés and Beriain, 2005: Tateo et al., 2008: Juárez et al., 2009: Lanza et al., 2009) who found values above 2.5%. The low levels of IMF of animals in the present study might be attributed to the fact that these animals were not fed a concentrate as finishing diet. These low contents of IMF are to be recommended in terms of human consumption to reduce fat intake and they are consistent with a favourable image from a dietetic point of view. The protein content (around 22%) was similar to that described by other authors (Badiani *et al.*, 1997; Sarriés and Beriain, 2005) in equine meat. With regard to iron content, foal meat showed a very high bioavailable amount of this element (mean value of 1.68 mg/100 g meat). However, Badiani *et al.* (1997) and Tateo *et al.* (2008) found iron values higher than the values found in the present work, 3.49 to 4.58 mg in thigh muscles and 3.20 mg in LD muscle, respectively, but this value was comparable with 'Rubia Gallega' beef of 18 months of age (1.86 mg/100 g meat) (Varela *et al.*, 2004) and lower than that of Holstein-Friesian cows of 6 years of age (2.86 mg/100 g meat) (Franco *et al.*, 2009).

The colorimetric characteristics of this foal meat were not significantly affected by sex, although the males had slightly greater L^* and a^* values as it was found by Tateo *et al.* (2008). This could arise from the fact, as postulated by Field (1971), that bulls had darker meat because of their temperament; bulls may be more easily stressed than steers and therefore are candidates for dark cutters. Our values of L^* were higher than those reported by Polidori *et al.* (2008), Sarriés and Beriain (2006) and Tateo *et al.* (2008) who reported L^* values below 37, but the findings of the present study were similar to those obtained by Lanza *et al.* (2009) who found L^* values ranging from 38.8 to 40.8.

The WHC, which is measured by drip loss, was not influenced by sex, whereas the cooking loss variable was affected by sex. WHC was greater in female than in male (Table 2) and disagree with the results found by Tateo *et al.* (2008) who reported higher values in male samples. With regard to cooking loss samples from male animals showed significantly higher values than those from female animals (Table 2) and agree with those reported by Tateo *et al.* (2008) in foal meat.

Analysing the textural parameters, differences were not noticeable between sexes. Berry (1993) reported that a consumer was sure of getting the loin steaks of suitable tenderness if the shear force measured by WB test did not exceed 3.9 kg. However, Shackelford *et al.* (1991) claimed that the shear force threshold value in commercial beef was 4.6 kg, and therefore meat from foal will satisfy consumer requirements.

The cholesterol content did not show significant differences (P > 0.05) between sexes. Our values were similar to those reported by Badiani *et al.* (1997) who found values of 0.61 mg/100 g in thigh muscle. The mean cholesterol content recorded in this study exceeds the only data that can be found in the literature for horse meat: 40 mg/100 g fresh in the LD of milk-fed foals (Catalano and Quarantelli, 1979), and 55 mg/100 g in the hind leg muscles of nature horses (Sinclair *et al.*, 1982). On the basis of a daily consumption of a 150 g steak, trimmed of all visible fat, except for IMF, foal meat provides 96 to 90 mg of cholesterol, which represents 32% to 30% of the maximum daily cholesterol recommendations (<300 mg/day) (USDA, 2010).

Intramuscular fatty acid composition

The intramuscular fatty acid composition, expressed both as mg/g fat and percentage is shown in Table 3. No statistically significant differences (P > 0.05) between the sexes were found regarding total saturated fatty acids (SFA), mono-unsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA). The foal meat fatty acids in this study are predominated by PUFA and their levels were ~41% of total methyl esters, followed by SFA, ~39.7% of total methyl esters and finally, MUFA, ~19.3% of total methyl esters. These results are in agreement with those reported by other authors for foal meat (Jankowska *et al.*, 1996) as PUFAs were the most abundant of fatty acids. Other authors have found SFA (Sarriés *et al.*, 2006; Tateo *et al.*, 2008; Juárez *et al.*, 2009; Lanza et al., 2009; Lorenzo *et al.*, 2010) or MUFA (Badiani *et al.*, 1997) as the predominant fatty acids in horse meat.

Within the PUFA, the predominant fatty acid was linoleic acid (Table 3), with similar results to those reported by Juárez *et al.* (2009) in 24-month-old Hispano-Bretón breed male foals and by Sarriés *et al.* (2006) in Burguete breed

Table 3 Effect of sex on the intramuscular fatty acid profile from longissimus dorsi of foal meat

	Fat (mg/g)				FAME (g/100 g)			
Fatty acids	Male	Female	s.e.m.	P-values	Male	Female	s.e.m	P-values
C12:0	4.3	3.6	0.5	ns	0.3	0.3	0.1	ns
C14:0	20.5	24.8	1.9	ns	2.4	2.6	0.2	ns
C15:0	43.5	37.1	1.6	*	5.2	3.5	0.3	*
C16:0	196.8	231.6	9.5	ns	23.0	24.3	0.3	ns
C16:1 <i>cis-</i> 9	20.4	32.0	2.2	* *	2.6	3.0	0.2	ns
C17:0	16.9	17.3	0.8	ns	2.0	1.6	0.1	ns
C17:1	11.9	10.8	0.4	ns	1.4	1.1	0.1	*
C18:0	54.6	60.8	2.5	ns	6.6	6.5	0.3	ns
C18:1 <i>cis-</i> 9	114.7	142.3	9.9	ns	14.0	15.9	1.3	ns
C18:2 <i>n</i> -6	174.3	167.2	7.8	ns	20.6	18.9	0.8	ns
C20:1	0.4	1.6	0.2	*	0.1	0.1	0.1	ns
C18:3 <i>n</i> -3	97.5	136.7	9.0	*	11.8	14.5	0.7	ns
C20:2	2.8	2.7	0.1	ns	0.3	0.2	0.1	ns
C20:3 <i>n</i> -6	6.9	6.1	0.4	ns	0.8	0.6	0.1	ns
C20:3 <i>n</i> -3	5.7	6.2	0.2	ns	0.6	0.6	0.1	ns
C20:4 <i>n</i> -6	41.1	32.3	2.1	*	4.9	3.4	0.3	*
C23:0	2.6	0.5	0.3	* * *	0.2	0.1	0.1	ns
C20:5 <i>n</i> -3	11.6	9.6	0.4	*	1.3	1.0	0.1	ns
C22:6 <i>n</i> -3	7.2	6.2	0.3	ns	0.8	0.7	0.1	ns
SFA	339.4	375.9	11.4	ns	40.2	39.1	0.3	ns
MUFA	147.5	186.8	11.6	ns	18.1	20.3	1.4	ns
PUFA	347.3	367.4	14.2	ns	41.5	40.5	2.1	ns
Σ <i>п</i> -6	222.3	205.7	9.2	ns	26.4	23.0	1.2	ns
Σ <i>n</i> -3	122.1	158.9	8.9	*	14.7	17.1	0.7	ns
<i>n</i> -6/ <i>n</i> -3	1.8	1.3	0.1	**	1.8	1.3	0.1	*
PUFA/SFA	1.0	1.0	0.1	ns	1.0	1.0	0.1	ns

s.e.m. = standard error of the mean; ns = not significant; FAME's = fatty acid methyl esters; SFA = $\sum (C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C23:0)$; MUFA = $\sum (C16:1 + C17:1 + C18:1 + C20:1)$; PUFA = $\sum (C18:2n6 + C18:3n3 + C20:2 + C20:4n6 + C20:3n6 + C22:6n3 + C20:3n3)$. ***P < 0.001, *P < 0.01, *P < 0.05. 24-month-old foals. However, others authors showed levels of \sim 20% in Burguete breed slaughtered at 24 months of age (Juárez et al., 2009), and in Sanfratellano and Haflinger breed slaughtered at 18 months of age (Lanza et al., 2009), whereas results reported by Badiani et al. (1997) showed levels of 12%. The second main PUFA was linolenic acid (C18:3n-3). Forages such as grass and clover contain a high proportion (50% to 75%) of total acids as linolenic acid (Dewhurst et al., 2006) and its content in tissues is directly related to the dietary intake of the animal. The greater proportion of C18:3n-3 that is present in foal samples from semi-extensive production system can be attributed to them having only grazed until they were slaughtered. The contents of α -linolenic acid were higher than those reported by Sarriés et al. (2006) who observed values of 0.75% in LD from foals slaughtered at 16 months of age and those found by Badiani et al. (1997) and Tateo et al. (2008), who showed levels of 4.92% and 4.53%, respectively.

On the other hand, arachidonic acid (C20:4n-6) levels point out significant differences between sexes (4.92% v. 3.41%; P < 0.05; for male and female, respectively) and agree with those reported by Sarriés et al. (2006) who found higher contents in male than female, although their values were lesser (>2.60%). The levels of C20:5n-3, EPA obtained in our study were also higher than those reported by Sarriés et al. (2006) and Lanza et al. (2009) who detected values of EPA above 0.50%. Finally, the proportions of C22:6n-3 DHA we found were also higher that those reported by the aforementioned authors, whereas Badiani et al. (1997) and Tateo et al. (2008) did not detect linolenic acid n-3 series derivatives in horse meat. It was found from Pearson correlation test that the higher level of PUFA content that was obtained in our study from foal meat samples in freedom-extensive production system had a significant (r = 0.63, P < 0.05) correlation with C20:3n-3 content and it is significantly related (P < 0.05) to C20:4n-6 content (*r* = 0.65).

Within the SFA, the main fatty acid was palmitic, \sim 60% of total intramuscular SFA, followed by C18:0, results in agreement with those reported by other authors for equine meat (Badiani *et al.*, 1997; Sarriés *et al.*, 2006; Polidori, *et al.*, 2008; Tateo *et al.*, 2008; Lanza *et al.*, 2009; Lorenzo *et al.*, 2010). Finally, within MUFA, oleic was the most abundant one, showing levels of \sim 77% of total MUFA. Similar proportion was reported by Juárez *et al.* (2009), but other authors obtained higher levels (86%) (Polidori *et al.*, 2008; Tateo *et al.*, 2008), although lower proportions were also described (71% to 74%; Sarriés *et al.*, 2006; Lanza *et al.*, 2009).

The high level of PUFA that was found in foal meat samples from extensive production system accounted for a favourable PUFA/SFA ratio (1.03), which was higher than the recommended ratio of 0.45 by the British Department of Health (1994). The n-6/n-3 ratio should not exceed 4.0 (British Department of Health, 1994). In our study, this proportion was within the nutritional recommendations for the human diet in both sexes and its value was significantly different between the sexes (Table 3) and significantly correlated (r = -0.91, P < 0.01) with C18:3n-3 content. It is interesting to note that

n-6/n-3 values found in our experiment were more favourable than those (8 to 15.6) reported by Sarriés *et al.* (2006) in foals slaughtered at 16 and 24 months of age, and they were better when compared with values (\sim 7) reported in a monogastric species as pork (Wood *et al.*, 2008).

Amino acid composition

The hydrolyzated amino acid profile of Galician foal, expressed both as g/100 g edible portion and g/100 g protein is shown in Table 4. No statistically significant differences (P > 0.05) in amino acid contents were found between sexes. In the light of the recently revised estimates of the amino acid requirements for adults proposed by the Institute of Medicine and Food and Nutrition Board (2002) and still referring to a 100 g edible portion, foal meat appears to be an excellent source of high biological value proteins because it contains essential amino acids in an appropriate ratio. These amino acids are very important in a diet of poor nutritional guality when the caloric intake is low, or for certain population groups with specific nutritional requirements, such as children, invalids and old people (Reig and Toldrá, 1998). The presence of animal proteins in the diet favours the absorption of minerals such as haem iron and trace elements. In this case, protein content in foal samples is about 22 g/100 g. Both male and female had higher essential amino acid percentages (<50%) when compared with the total amino acid contents. Arginine was included between the essential amino acids, as done by Hoffman et al. (2005), because arginine is considered a conditionally essential amino acid (Arienti, 2003).

The essential amino acids at the highest concentration in Galician foal meat samples were lysine (about 2.04 g/100 g) and leucine (about 1.90 g/100 g). These values were higher than those obtained by Polidori *et al.* (2008) who reported values of 1.77 and 1.51 g/100 g for lysine and leucine, respectively, in donkey meat, and they were also higher than those given by Badiani *et al.* (1997) who showed values of 1.57 and 1.52 g/100 g for lysine and leucine, respectively, in horse meat. Lysine represented about 18.25% of total essential amino acids. The essential amino acid requirement for an adult man weighing 70 kg is about 12.90 g/day (FAO/WHO/UNU, 2007). Our results indicated that 100 g of foal meat covered 15.5% of the daily requirement for essential amino acids.

Glutamic acid, aspartic acid and alanine were the most abundant amino acids found in the non-essential fraction representing a mean value of 15.3%, 9.60% and 5.97% of the protein, respectively, whereas the lowest mean values were found out in tyrosine (3.45%), proline (3.92%) and serine (4.05%). In other red meat; such as lamb, goat and camel (Elgasim and Alkanhal, 1991), glutamic and aspartic acid in the non-essential fraction and lysine and leucine in the essential fraction were also the major amino acids.

Some of the amino acids present in foal meat may produce additional benefits for the nervous system (Gaull, 1990), and glutamic acid, which has relevance for metabolic processes, has potential preventive effects for certain diseases (Neu *et al.*, 1996). A particularly highly essential amino acid/ non-essential amino acid ratio (<1%) was also recorded.

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	Muscle (g/100 g)				Protein (g/100 g)			
Amino acids	Male	Female	s.e.m.	P-values	Male	Female	s.e.m.	P-values
Essential								
Arginine	1.4	1.3	0.1	ns	6.6	6.2	0.1	ns
Histidine	1.0	1.0	0.1	ns	4.5	4.7	0.1	ns
Isoleucine	1.1	1.1	0.1	ns	5.2	5.2	0.1	ns
Leucine	1.9	1.9	0.1	ns	8.5	8.5	0.1	ns
Lysine	2.0	2.0	0.1	ns	9.1	9.1	0.1	ns
Methionine	0.2	0.3	0.1	ns	1.3	1.5	0.1	ns
Phenylalanine	0.9	0.9	0.1	ns	4.3	4.3	0.1	ns
Threonine	1.1	1.1	0.1	ns	5.0	5.0	0.1	ns
Valine	1.1	1.1	0.1	ns	5.3	5.3	0.1	ns
Total E	11.1	11.2	0.1	ns	50.1	50.2	0.1	ns
Non essential								
Alanine	1.3	1.3	0.1	ns	5.9	5.9	0.1	ns
Aspartic acid	2.1	2.1	0.1	ns	9.6	9.5	0.1	ns
Glutamic acid	3.4	3.4	0.1	ns	15.3	15.2	0.1	ns
Glycine	0.9	0.9	0.1	ns	4.3	4.3	0.1	ns
Proline	0.8	0.8	0.1	ns	3.9	3.9	0.1	ns
Serine	0.9	0.9	0.1	ns	4.0	4.0	0.1	ns
Tyrosine	0.7	0.7	0.1	ns	3.5	3.3	0.1	ns
Total NE	10.4	10.3	0.1	ns	46.8	46.5	0.2	ns
E/NE*	1.0	1.0	0.1	ns	1.0	1.0	0.1	ns

 Table 4 Effect of sex on the amino acid composition from longissimus dorsi of foal meat

s.e.m. = standard error of the mean; ns = not significant; E/NE* = essential to non-essential amino acid ratio.

Sensory properties

Mean scores given by the panellists for foal meat is shown in Supplementary Figure S3. Sensory traits of LD from foals were not significantly (P > 0.05) influenced by sex. Colour is one of the most critical characteristics that consumers consider when making a decision to purchase meat (Nam et al., 2009). Panellists observed similar scores for foal meat colour (around 5.7). This result was slightly higher than that showed in a previous report (Franco et al., 2011b). According to Risvik (1994), flavour is of great importance for the overall sensory trait of meat, and the absence of abnormal flavour is thought to be critical for acceptability. Meat flavour difference (5.1 v. 5.9 for male and female, respectively) could be related to the sex or different IMF contents (Table 2). In our study, samples from foal meat showed low values (around 0.4) for this attribute. Huff-Lonergan et al. (2002) suggested that flavour is positively correlated with tenderness in pork meat, but we did not find any correlation with flavour. On the other hand, juiciness is the amount of perceived juices in the meat during chewing or mastication and thus it is one of the major meat characteristics influencing eating quality (Maltin et al., 1997). Several studies have reported that juiciness is also negatively correlated with cooking loss (Huff-Lonergan et al., 2002). However, cooking loss was not significantly correlated in this study, which is consistent with results obtained by Brewer et al. (2002).

Among the sensory quality traits, tenderness is the most important factor affecting overall meat acceptability (Maltin *et al.*, 1997). The tenderness score was positively correlated with cooking loss (r = 0.40, P < 0.05) and WBS (r = 0.43, P < 0.05). According to Tornberg (1996), of the instrumental

techniques that measure meat tenderness, WBS shows the best correlation with the subjective tenderness scores of sensory panellists; we also found a correlation between WBS and hardness.

Conclusions

The sex effect had no statistical significance on carcass measurements, chemical composition, colour parameters, textural properties, amino acid content and sensory characteristics. On the other hand, there was a significant effect on the intramuscular fatty acid profile of LD muscle. Male foal showed a slightly higher slaughter weight than female foal and this parameter affected carcass weight, which was slightly higher in the male group compared with the female group. If we consider cooking loss, this feature was clearly higher in male animals than in female animals. Finally, foal meat from the female group had better nutritional properties than the male group.

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Supplementary material

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References

Arienti G 2003. Le basi molecolari della nutrizione. 2nd edition. Piccin Nuova Libraria S.p.A, Padova.

Badiani A, Nanni N, Gatta P, Tolomelli B and Manfredini M 1997. Nutrient profile of horsemeat. Journal of Food Composition and Analysis 10, 254–269.

Berry WE 1993. Tenderness of beef loin steaks as influenced by marbling level, removal of subcutaneous fat, and cooking method. Journal of Animal Science 71, 2412–2419.

Brewer MS, Jensen J, Sosnicki AA, Fields B, Wilson E and McKeith FK 2002. The effect of pig genetics on palatability, color and physical characteristics of fresh pork loin chops. Meat Science 61, 249–256.

British Department of Health 1994. Nutritional aspects of cardiovascular diseases. Report on health and social subjects No. 46. H.M. Stationery Office, London.

Catalano AL and Quarantelli A 1979. Carcass characteristic and chemical composition of the meat from milk-fed foals. La Clinica Veterinaria 102, 498–506.

CIE 1976. Colorimetry: official recommendations of the international commission on illumination. Comisión Internationale de l'Èclairage (International Commission on Illumination), Paris, CIE No. 15 (E-1.3.1).

Dewhurst RJ, Shingfield KJ, Lee MRF and Scollan ND 2006. Increasing levels of beneficial polyunsaturated fatty acids in milk produced in high-forage system. Animal Feed Science and Technology 131, 168–206.

Elgasim EA and Alkanhal MA 1991. Proximate composition, amino acids and inorganic mineral content of Arabian camel meat: comparative study. Food Chemistry 45, 1–4.

FAO/WHO/UNU 2007. Amino acid requirements of adults. In Protein and amino acids requirements in human nutrition. United Nations University, Geneva, Switzerland, pp. 135–159.

FAOSTAT 2010. Online database of the Food and Agriculture Organization of the United Nations. http://faostat.fao.org: Production>livestock primary and Trade> TradeSTAT> Crops and livestock products.

Field RA 1971. Effect of castration on meat quality and quantity. Journal of Animal Science 32, 849–858.

Franco D, Bispo E, González L, Vázquez JA and Moreno T 2009. Effect of finishing and ageing time on quality attributes of loin from the meat of Holstein–Friesian cull cows. Meat Science 83, 484–491.

Franco D, Fernández M, Temperán S, Garcia L and Lorenzo JM 2011a. Carcass quality of Galician mountain foals. Archivos de Zootecnia 60, 385–388.

Franco D, Rodríguez E, Purriños L, Crecente S, Bermúdez R and Lorenzo JM 2011b. Meat quality of 'Galician Mountain' foals breed. Effect of sex, slaughter age and livestock production system. Meat Science 88, 292–298.

Franco D, Rois D, Vázquez JA, Purriños L, González R and Lorenzo JM 2012. Breed effect between Mos rooster (Galician indigenous breed) and Sasso T-44 line and finishing feed effect of commercial fodder or corn. Poultry Science 91, 487–498.

Gaull GE 1990. Taurine in pediatric nutrition: a review and update. Pediatrics 83, 433–442.

Hoffman LC, Kritzinger B and Ferreira AV 2005. The effects of region and gender on the fatty acid, amino acid, mineral, myoglobin and collagen contents of impala (*Aepyceros melampus*) meat. Meat Science 69, 551–558.

Huff-Lonergan E, Baas TJ, Malek M, Dekkers JC, Prusa K and Rothschild MF 2002. Correlations among selected pork quality traits. Journal of Animal Science 80, 617–627.

Institute of Medicine, Food and Nutrition Board 2002. Dietary reference intakes for energy, carbohydrate, fibre, fat, fatty acids cholesterol, protein and amino acids. Prepublication copy. National Academy Press, Washington, DC.

International Organization for Standardization (ISO) 1973. Determination of total fat content, ISO 1443:1973 standard. In International standards meat and meat products. International Organization for Standardization, Genève, Switzerland.

ISO 1978. Determination of nitrogen content, ISO 937:1978 standard. In International standards meat and meat products. International Organization for Standardization, Genève, Switzerland.

ISO 1997. Determination of moisture content, ISO 1442:1997 standard. In International standards meat and meat products. International Organization for Standardization, Genève, Switzerland.

ISO 1998. Determination of ash content, ISO 936:1998 standard. In International standards meat and meat products. International Organization for Standardization, Genève, Switzerland.

Jankowska B, Korzeniowski W and Kwiatkowska A 1996. Fatty acid composition of horses tissues depending on their position in the carcass. Polish Journal of Food and Nutrition Sciences 5, 41–49.

Juárez M, Polvillo O, Gómez MD, Alcalde MJ, Romero F and Varela M 2009. Breed effect on carcass and meat quality of foals slaughtered at 24 months of age. Meat Science 83, 224–228.

Lanza M, Landi C, Scerra M, Galofaro V and Pennisi P 2009. Meat quality and intramuscular fatty acid composition of Sanfratellano and Haflinger foals. Meat Science 81, 142–147.

Lorenzo JM, Fuciños C, Purriños L and Franco D 2010. Intramuscular fatty acid composition of 'Galician Mountain' foals breed. Effect of sex, slaughtered age and livestock production system. Meat Science 86, 825–831.

Maltin CA, Warkup CC, Matthews KR, Grant CM, Porter AD and Delday MI 1997. Pig muscle fibre characteristics as a source of variation in eating quality. Meat Science 47, 237–248.

MERCASA 2011. Alimentación en España 2011. Carnes y productos cárnicos. Retrieved March 15, 2012, from http://www.munimerca.es/mercasa/alimentacion_ 2011/pdfs/pag_247-282_Carne.pdf.

Merck Index 1989. An encyclopaedia of chemicals, drugs and biological, 11th edition. Merck and Company, Rahway, NJ.

Nam YJ, Choi YM, Jeong DW and Kim BC 2009. A comparison of postmortem meat quality and consumer sensory characteristic evaluations, according to porcine quality classification. Food Science and Biotechnology 18, 307–311.

Neu J, Shenoy V and Chakrabarti R 1996. Glutamine nutrition and metabolism: Where do we go from here? FASEB Journal 10, 829–837.

Polidori P, Vincenzetti S, Cavallucci C and Beghelli D 2008. Quality of donkey meat and carcass characteristics. Meat Science 80, 1222–1224.

Prates JA, Gonçalves Quaresma MARJ, Branquinho Bessa C, Andrade Fontes C and Mateus Alfaia C 2006. Simultaneous HPLC quantification of total cholesterol, tocopherols and β -carotene in Barrosã-PDO veal. Food Chemistry 94, 469–477.

Reig M and Toldrá F 1998. Protein nutritional quality of muscle foods. Recent Research Development of Agriculture in Food Chemistry 2, 71–78.

Risvik E 1994. Sensory properties and preferences. Meat Science 36, 67–77.

Sarriés MV and Beriain MJ 2005. Carcass characteristics and meat quality of male and female foals. Meat Science 70, 141–152.

Sarriés MV and Beriain MJ 2006. Colour and texture characteristics in meat of male and female foals. Meat Science 74, 738–745.

Sarriés MV, Murray BE, Troy D and Beriain MJ 2006. Intramuscular and subcutaneous lipid fatty acid profile composition in male and female foals. Meat Science 72, 475–485.

Shackelford SD, Morgan JB, Cross HR and Savell JW 1991. Identification of threshold levels for Warner–Bratzler shear force in beef top loin steaks. Journal of Muscle Foods 2, 289–296.

Sinclair AJ, Slattery WJ and O'Dea K 1982. The analysis of polyunsaturated fatty acids in meat by capillary gas-liquid chromatography. Journal of Food Science and Agriculture 33, 771–776.

Tateo A, De Palo P, Ceci E and Centoducati P 2008. Physicochemical properties of meat of Italian heavy draft horses slaughtered at the age of eleven months. Journal of Animal Science 86, 1205–1214.

Tornberg E 1996. Biophysical aspects of meat tenderness. Meat Science 43, S175–S191.

USDA 2010. Dietary guidelines for Americans 2010. Department of health and human services (HHS) and the department of agriculture (USDA). Retrieved November 15, 2011, from http://health.gov/dietaryguidelines/.

Varela A, Oliete B, Moreno T, Portela C, Monserrat L, Carballo JA and Sánchez L 2004. Effect of pasture finishing on meat characteristics and intramuscular fatty acid profile of steers of the Rubia Gallega breed. Meat Science 67, 515–522.

Webb EC and O'Neill HA 2008. The animal fat paradox and meat quality. Meat Science 80, 28–36.

Wood JD, Enser M, Fisher AV, Nute GR, Sheard PR and Richardson RI 2008. Fat deposition, fatty acid composition and meat quality: a review. Meat Science 78, 343–358.

Znamirowska A 2005. Prediction of horse carcass composition using linear measurements. Meat Science 69, 567–570.