RESEARCH ARTICLE

Influence of production system and finishing feeding on meat quality of Rubia Gallega calves

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Abstract

Aim of study: Beef quality is mainly affected by finishing feeding (FF) and production system (PS). The effects of PS (extensive, semi-extensive, traditional and intensive systems) and FF from Rubia Gallega calves were compared in terms of meat quality.

Area of study: Galicia (NW Spain)

Material and methods: Calves (n=10 per treatment) were slaughtered at nine months of age and meat samples were assessed in terms of meat quality attributes such as physicochemical, nutritional and sensory analysis performed by a trained panel.

Main results: Meat chemical composition varied ($p<0.01$) with PS and FF. The semi-extensive system showed the lowest values ($p<0.05$) for cooking loss (22.8%) and for shear force (26.0 N) while the extensive system presented the lowest contents of saturated fatty acids (SFA) and the highest contents of linolenic acid ($p<0.001$). The SFA and polyunsaturated fatty acid (PUFA) contents varied with FF ($p<0.05$). The lowest and highest values for SFA and PUFA were displayed in extensive group finished with Pasture/Concentrate, meanwhile feedlot group finished with Concentrate/Straw showed and opposite trend. The n-6/n-3 ratio was lower than 4 for extensive and semi-extensive systems ($p<0.001$). In addition, tenderness and juiciness showed significant differences mainly due to FF.

Research highlights: This study showed that meat of calves reared in extensive systems was the healthiest, regarding total fat and fatty acid composition. It can be concluded that finishing feeding, and PS affected meat quality. Hence the potential usefulness of these results is to improve meat quality and safety according to market demands.

Additional key words: beef; chemical composition; fatty acid profile; final diet

Abbreviations used: a* (redness); b* (yellowness); CDA (canonical discriminant analysis); FAME (fatty acid methyl esters); FF (finishing feeding); h/H (hypocholesterolemic/hypercholesterolemic ratio); IMF (intramuscular fat); L* (lightness); LDL (low-density lipoprotein); LT (*longissimus thoracis*); LSM (least square mean); MUFA (monounsaturated fatty acids); PS (production systems); PUFA (polyunsaturated fatty acids); RG (Rubia Gallega); SEM (standard error of the mean); SFA (saturated fatty acids); TPA (texture profile analysis); WB (Warner-Bratzler); WHC (water holding capacity).

Introduction

Several factors impact beef meat quality; among those, production systems (PS) and diet stand out by having an important influence (Mennecke *et al.*, 2007; Dunne *et al.*, 2009); In addition, consumers are increasingly concerned about the influence of PS on diet, welfare and, finally, on meat quality. The most common PS of cattle in Spain can be classified into extensive, semi-extensive, traditional or intensive systems. In the extensive system, calves are reared with their dams, having access to pasture and can be supplemented with concentrate or silage during the last months before slaughter. In this PS, cattle are well adapted to environment and can use natural resources through grazing, minimizing production costs. Similarly, in the semi-extensive system, calves are supplemented, with concentrate, especially in the finishing period (Humada *et al.*, 2014). Alternative modalities include supplementation with concentrate and silage or with farm resources during the finishing period. On the other hand, traditional systems are based on rearing small herds of cattle with calves weaned at around 7 months of age. After weaning, calves are fed with concentrate supplemented with concentrate or with farm resources until slaughter. Finally, the intensive system is based on feedlots, where calves are fed *ad libitum* using commercial concentrates supplemented with straw (Guerrero *et al.*, 2013) or with silage combined with straw.

The main attributes to measure beef meat quality are color, nutritional value and sensory attributes (odor, flavor, juiciness and tenderness). All of them are considered as important criteria of meat acceptance by consumers (Robbins *et al.*, 2003). Animal feeding clearly has an impact on tenderness, lipid and color stability, chemical composition, flavor and nutritional profile (Scollan *et al.*, 2001; Realini *et al.*, 2004). Nutritional value concerns consumers' evaluation of meat quality in terms of health benefits (Banović *et al.*, 2009). In fact, it is widely accepted that an increase of polyunsaturated fatty acids (PUFA) –especially of long chain *n*-3 fatty acids– accompanied by a decrease of saturated fatty acids (SFA) in meat composition leads to a lower incidence of metabolic and cardiovascular diseases, some types of cancer and obesity (EFSA, 2010; FAO, 2010; USDA, 2010). Consequently, PUFA/SFA and *n*-6/*n*-3 ratios are considered the main indicators of coronary disease risk and are useful to assess the nutritional value of fat (Simopoulos, 2008). Many factors influence fatty acid composition (Rhee, 2000; Varela *et al.*, 2004) such as the finishing feeding (FF). The FF based on grains allows obtaining meat with high levels of intramuscular fat (IMF), monounsaturated fatty acids (MUFA) and *n*-6 fatty acids (Dannenberger *et al.*, 2005; Marino *et al.*, 2006). Compared to intensive production systems, grass feeding leads to higher concentrations of beneficial *n*-3 fatty acids (French *et al.*, 2000a; Varela *et al.*, 2004; Guerrero *et al.*, 2013). Finally, meat derived from semi-extensive systems, has low levels of SFA and high concentrations of *n*-3 fatty acids and conjugated linoleic acid (French *et al.*, 2000a; Humada *et al.*, 2012).

Rubia Gallega (RG) is one of the most important autochthonous breeds of Spanish meat industry (MAPA-MA, 2018). The influence of weaning status (Bispo *et al.*, 2010a,b) and pasture consumption during the finishing period (Varela *et al.*, 2004) on RG meat quality has been studied in detail. However, the available data about the influence of PS and FF on meat quality of this breed is very scarce. In recent years, beef studies have focused on finding the suitable PS and FF which would allow to obtain benefits for animal-welfare, healthier meats and an optimal balance between economic viability and environment impact (Provenza *et al.*, 2019; Kamilaris *et al.*, 2020). For this reason, this study attempts to evaluate nine types of FF and four different PS which cover a wide range of economic, environmentally sustainable and animal-welfare scenarios. The novelty of this study lies in the simultaneous evaluation of the effect of PS (extensive, semi-extensive, traditional and intensive systems) and FF at different levels on physicochemical, nutritional and sensory characteristics of meat derived from RG, opening a new way to find out the best strategy for future development meat industry in autochthonous breeds.

Material and methods

Experimental design and animal management

For this study, 90 RG male calves, registered in the Record of Births of the RG Stud-Book, were obtained from different farms of the PS under study (extensive, semi-extensive, traditional and intensive systems) in Galicia (NW Spain) in two consecutive years (45 calves per year). Calves from extensive and semi-extensive farms from the experimental herd of Agricultural Research Centre of Mabegondo were used for this study, while calves from traditional and intensive farms were raised on private farms under control of P.G.I. "Ternera Gallega". All births took place from summer to autumn.

In the extensive system, three types of FF were evaluated: pasture exclusively, pasture supplemented in winter with concentrate (Pasture/Concentrate) and pasture supplemented in winter with corn silage (Pasture/Corn silage). Calves were raised with their dams and fed pasture in autumn/spring. During the winter the three extensive groups received grass silage. In the semi-extensive system, two types of FF were evaluated: pasture supple-

mented with concentrate and corn silage in winter (Pasture/Concentrate/Corn silage) and pasture supplemented with farm resources (Pasture/Farm resources). The farm resources were based on grass, dry grass, grass silage, corn silage, cereal and grain. Calves were raised with their dams and fed pasture in autumn/spring. In the traditional system, calves were housed indoors with their dams and weaned at 7 months of age. Afterwards, calves were fed concentrate supplemented with concentrate to complete their feeding (concentrate) or with farm resources. Calves were reared in different familiar exploitations according to P.G.I. "Ternera Gallega" normative for feeding requirements. Finally, in the intensive system, calves were reared in feedlots with commercial concentrate. Two groups were evaluated based on supplement feeding during the last 3 months before slaughter: straw (Concentrate/Straw) or corn silage combined with straw (Concentrate/Straw/Corn silage).

In total, nine groups (*n*=5 calves by group in 2 years; n=10 in total) were assessed and slaughtered at 9 months of age. Cattle were transported to the abattoir the day before slaughter according to EU regulation (Council Directive 93/119/EC; OJ, 1993), in an accredited slaughterhouse. Animals were stunned by captive bolt gun, exsanguinated and dressed following commercial dressing-out procedures at the abattoir. Immediately after slaughter, carcasses were chilled at 2°C (relative humidity of 98%) for 24 h. At this point, the muscle *longissimus thoracis* (LT) was extracted from the left half of each carcass, between the fifth and the tenth rib, vacuum packed and refrigerated at a temperature of 4°C until cutting. The LT was cut into seven steaks of 2.5 cm thickness. The first three steaks were used to determine pH, color and proximate composition. The fourth and fifth steaks were used to determine water holding capacity (WHC) and shear force, respectively, whereas the sixth steak was used for the fatty acid analysis. Finally, the seventh steak was used for the sensory analysis.

Color, water holding capacity and instrumental texture

All physicochemical analyses were performed in duplicate for each muscle sample. The pH was measured at 24 h *post mortem* using a digital portable pH-meter (Hanna Instruments, Eibar, Spain) equipped with a penetration electrode. Before color measurements, LT samples were allowed to bloom directly in contact with air for 30 min. Objective measures of meat color, including lightness (L*), redness (a*) and yellowness (b*) were determined using a portable colorimeter (Konica Minolta CM-600d, Osaka, Japan). Chemical analysis (moisture, protein, IMF and ash) was quantified according to Pateiro *et al.* (2013). The WHC measured as

cooking loss and drip loss, shear force and texture profile analysis (TPA-test) were assessed following a previously described protocol (Pateiro *et al.* 2013). Shear force of meat pieces was analysed using a texturometer (TA-XT2, Stable Micro Systems, Godalming, UK) equipped with a triangular slot cutting edge. Seven pieces of meat of 1 × 1 × 2.5 cm (height × width × length) were removed parallel to the muscle fibre direction. Samples were completely cut using a Warner Bratzler shear blade with a triangular slot cutting edge (1-mm thickness) at a crosshead speed of 3.33 mm/s. Maximum shear force, shown by the highest peak of the force-time curve, represents the maximum resistance of the sample to the cut. Another seven pieces of meat of 1 × 1 × 1 cm (height × width × length) parallel to the muscle fibre direction were removed for TPA test. Textural parameters were measured by compressing to 80% with probe of 19.85 cm^2 of surface contact. Between the first and second compression, the probe waited for 2 seconds. Hardness, cohesiveness, springiness, gumminess and chewiness were obtained.

Fatty acid profile and health lipid indices

For the analysis of fatty acid methyl esters (FAME), total fat was extracted from 10 g of ground meat sample. Fifty milligrams of fat were used to determine the fatty acid profile. Total fatty acids were quantified according to Pateiro *et al.* (2013). Separation and quantification of FAME were carried out using a gas chromatograph (GC-Agilent 7890B; Agilent Technologies Spain, S.L., Madrid, Spain), equipped with a flame ionization detector and an automatic sample injector HP 7683 and using a Supelco SPTM-2560 fused silica capillary column (100 m, 0.25 mm of internal diameter, 0.2 μm of film thickness; Supelco Inc., Bellafonte, PA, USA). The chromatographic conditions were as follows: initial column temperature 120°C maintaining this temperature for 5 min, programmed to increase at a rate of 2°C/min up to 170°C maintaining this temperature for 15 min, then at 5°C/min up to 200°C maintaining this temperature for 5 min, and then increasing again at 2°C/min up to final temperature of 235°C hold 10 min. The injector and detector were maintained at 260°C and 280°C respectively. Helium was used as carrier gas at a constant flowrate of 1.1 mL/min, with the column head pressure set at 35.56 psi. The split ratio was 1:50, and 1 μL of solution was injected. Nonadecanoic acid methyl ester (C19:0) at 0.3 mg/mL was used as internal standard. Individual FAMEs were identified by comparing their retention times with those of authenticated standards. Fatty acids are expressed as percentage (g fatty acid/100 g of identified total fatty acids). Data were used to calculate the total content of SFA, MUFA and PUFA, *n*-6,

n-3, *n*-6/*n*-3 ratio, PUFA/SFA ratio and long chain *n*-3 PUFA. Additionally, nutritional value and hypocholesterolemic/hypercholesterolemic ratio (h/H) were calculated according to Estévez *et al.* (2004) and Santos-Silva *et al.* (2002), respectively.

Sensory analysis

Sensory analysis was carried out according to ISO regulation (ISO 8586-1, 1993). Twelve trained panellists (7 women and 5 men, with ages ranging from 25 to 45 years) from the Meat Technology Center of Galicia (Ourense, Spain) were trained for descriptive analysis according to ISO regulation (ISO 8586, 2012). Sensory evaluations were held in closed individual booths under red light. Frozen steaks of LT muscle (without previous ageing) were thawed at 4°C for 24 h prior to cooking. Steaks of 2-cm of thickness were cooked in a convection oven at 180 ºC until an internal temperature of 70 ºC was reached. Afterward, each steak was cut into pieces of 1.5 × 1.5 cm, covered with aluminium foil, labelled with three-digit aleatory numbers and randomly served one at a time. A randomized incomplete equilibrated blocks design was followed, where each panellist assessed six meat samples of nine studied treatments per session. The tasting order was designed to avoid first sample and carry over effects (MacFie *et al.*, 1989). Water and unsalted toasted bread were used at the beginning of session and between samples to clean the palate and remove residual flavors. Odour (overall and fat) and flavour (global and fat) were assessed. In addition, tenderness, juiciness, greasiness and amount of first swallowing completed the sensory attributes. The intensity of each attribute was measured on a lineal structured scale from 0 (sensation not perceived) to 10 (maximum sensation).

Statistical analysis

All statistical analyses were carried out using the SPSS package (SPSS 23.0, Chicago, IL, USA). Normal distribution and variance homogeneity were previously tested (Shapiro-Wilk). Data were subjected to analysis of variance (ANOVA) using a general linear model procedure, where the physicochemical parameters, fatty acid and sensory attributes were fixed as dependent variables, and PS and FF were included in the model as fixed factors. The models used were $y_{ijk} = \mu + P_i + F_j + \varepsilon_{ijk}$, where: y was the observation of dependent variables, μ was the overall mean, P was the effect of PS, F was the effect of FF and ε was the residual random error associated with the observation. The least square mean (LSM) was separated using the Duncan test. All statistical test

of LSM were performed for a significance level $p<0.05$. The standard error of the mean was obtained as the standard deviation divided by the square root of the sample size. Correlations between variables ($p<0.05$) were determined by correlation analyses using the Pearson's linear correlation coefficient with abovementioned statistical software package.

A canonical discriminant analysis (CDA) was developed using a stepwise method for all physicochemical and nutritional traits assessed to differentiate among groups, hence a stepwise discriminate analysis was done. This data set was subjected to the CDA according to the PS and FF ($n=10$). The leave-*on*-out cross validation was used to validate the results. An "a priori" equal probability for a sample to be in one group independently of the group size was considered the criterion for the selection of variables was Wilk's lambda (F-probability to-enter and out value of 0.05 and 0.10, respectively). A linear discriminant function containing an optimal subset of traits was done to determine the coefficients that maximize the differences among samples.

Results

Influence of production system and finishing feeding on physicochemical parameters of meat

The pH at 24 h *post mortem* was influenced by PS and FF ($p<0.05$), ranging from 5.61 to 5.79 (Table 1). Calves from the semi-extensive system showed the highest pH_{24} values with respect to calves reared in the other PS (5.78 *vs.* 5.68, $p=0.031$). Variations in L* and b* values were affected by PS and FF ($p<0.001$). Lightness parameter fluctuated between values of 36.8 and 46.0. The highest values for L* were shown in meat originated from the traditional system (44.0 as average), followed by the feedlot system (41.2 as average) and the extensive (38.4 as average) systems with the semi-extensive systems showing intermediate values (39.2 as average). Redness value was only affected by FF. In fact, the Concentrate/ Straw, Pasture/Farm resources, Pasture, Pasture/Concentrate/Corn silage and Farm resources groups showed a higher a* value than the other FF groups ($p=0.032$). Yellowness was affected by FF and PS ($p<0.001$). The highest values were shown in traditional and feedlot systems.

Chemical composition varied significantly with PS and FF ($p<0.01$). The average values in fresh meat for moisture, protein, IMF and ashes were 74.6, 23.9, 0.72 and 1.23%, respectively. Values for IMF content ranged from 0.24 to 1.27%, with values below 1%, except for calves reared in the intensive and in the traditional systems.

Table 1. Influence of production system and finishing feeding on pH at 24 h post mortem (pH24), color parameters and chemical composition of meat from Rubia Gallega calves.

PS	Extensive[1]			Semi-extensive[2]		Traditional[3]		Feedlot[4]		SEM[5]	p-value	
FF	Pasture	Pasture/Concentrate	Pasture/Corn silage	Pasture/Concentrate/Corn silage	Pasture/Farm resources	Concentrate	Farm resources	Concentrate/Straw	Concentrate/Straw/Corn silage		PS[6]	FF[7]
pH$_{24}$	5.66$^{Z.abc}$	5.78$^{Z.bc}$	5.61$^{Z.a}$	5.79$^{Y.c}$	5.77$^{Y.bc}$	5.65$^{Z.ab}$	5.71$^{Z.abc}$	5.66$^{Z.abc}$	5.66$^{Z.abc}$	0.014	0.031	0.021
Color parameters												
Lightness (L*)	37.9$^{Z.ab}$	36.8$^{Z.a}$	40.4$^{Z.bc}$	38.3$^{Z.ab}$	40.0$^{Z.bc}$	46.0$^{X.d}$	42.1$^{X.c}$	40.8$^{Y.c}$	41.5$^{Y.c}$	0.38	<0.001	<0.001
Redness (a*)	13.4^{bc}	10.4^{a}	11.3^{ab}	12.2^{abc}	11.9^{abc}	11.5^{ab}	12.0^{abc}	14.0^{c}	10.8^{a}	0.27	0.803	0.032
Yellowness (b*)	12.7$^{Z.bc}$	10.4$^{Z.a}$	12.2$^{Z.b}$	12.1$^{Z.b}$	12.4$^{Z.b}$	14.7$^{Y.d}$	14.0$^{Y.cd}$	14.3$^{Z.d}$	12.7$^{Y.bc}$	0.21	<0.001	<0.001
Chemical composition (%)												
Moisture	75.4$^{Y.bc}$	75.8$^{Y.c}$	74.5$^{Y.abc}$	74.6$^{Y.bc}$	74.6$^{Y.bc}$	74.4$^{ZY.ab}$	74.5$^{ZY.abc}$	74.2$^{Z.ab}$	73.2$^{Z.a}$	0.13	<0.001	<0.001
Protein	22.9$^{Z.a}$	23.3$^{Z.ab}$	23.7$^{Z.abc}$	24.3$^{Y.c}$	23.8$^{Y.bc}$	24.6$^{Y.c}$	24.4$^{Y.c}$	23.3$^{Y.ab}$	24.6$^{Y.c}$	0.06	<0.001	<0.001
Intramuscular fat	0.45$^{Z.a}$	0.24$^{Z.a}$	0.56$^{Z.ab}$	0.65$^{ZY.ab}$	0.55$^{ZY.ab}$	1.04$^{YX.bc}$	0.65$^{YX.ab}$	1.06$^{X.bc}$	1.27$^{X.c}$	0.111	<0.001	0.001
Ash	1.19$^{Y.ab}$	1.25$^{Y.bc}$	1.25$^{Y.c}$	1.24$^{ZY.abc}$	1.21$^{ZY.abc}$	1.33$^{Y.d}$	1.20$^{Y.abc}$	1.19$^{Z.a}$	1.19$^{Z.a}$	0.076	0.004	<0.001

[1] Pasture: extensive system fed pasture, Pasture/Concentrate: extensive system fed pasture supplemented with concentrate, Pasture/Corn silage: extensive system fed pasture supplemented with silage. [2] Pasture/Concentrate/Corn silage: semi-extensive system fed pasture supplemented with concentrate and silage; Pasture/Farm resources: semi-extensive system fed pasture supplemented with farm resources. [3] Concentrate: traditional system fed milk until weaning and thereafter, fed concentrate and supplemented with concentrate, Farm resources: traditional system fed milk until weaning and thereafter, fed concentrate and supplemented with farm resources. [4] Concentrate/Straw: feedlot system fed concentrate supplemented with straw, Concentrate/Straw/Corn silage: feedlot system fed concentrate supplemented with silage and straw. [5] Standard error of mean (*n*=10 for each FF). [6] PS: Production system. [7] FF: Finishing feeding. $^{Z-X}$ Mean values in the same row (different PS) with different number presented significant differences (p<0.05). $^{a-d}$ Mean values in the same row (different FF) with different letter presented significant differences (p<0.05).

Influence of production system and finishing feeding on WHC, shear force and TPA-test of meat

The cooking loss and drip loss ranged from 20.5 to 29.0% and from 1.68% to 6.24%, respectively (Table 2). Both were affected by FF (p<0.001) but only cooking loss was influenced by PS (p=0.031). The lowest cooking loss percentages were found for the semi-extensive system and for the Concentrate/Straw/Corn silage (22.8% as average and 20.5%, respectively), while extensive and traditional systems displayed percentages above 25% (26.3% and 27.0% as average, respectively), suggesting that juicer veal would be obtained from animals reared in Pasture/Concentrate/Corn silage, Pasture/Farm resources and Concentrate/Straw/Corn silage groups. Shear force was affected by PS (p=0.002) and by FF (p<0.001) and the lowest values were observed for the semi-extensive system compared with the other PS studied (26.0 *vs.* 41.4 N, respectively). The TPA-test showed differences (p<0.05) for hardness, gumminess and cohesiveness depending on PS and FF. Hardness and gumminess showed the lowest values in meat from the extensive and feedlot systems, meanwhile calves reared in the semi-extensive and feedlot systems had the lowest values for cohesiveness.

Influence of production system and finishing feeding on fatty acid profile of meat

Both, PS and FF influenced the fatty acid profile of LT muscle (Table 3). The SFA was predominant fraction with values that ranged between 34.8% and 44.7%, followed in importance by MUFA (31.5%) and PUFA (21.9%). Differences were found for SFA among the different PS and FF (p<0.001). The lowest values of SFA were observed for the extensive system and the highest for the feedlot system (38.8 *vs.* 43.8%, respectively; p<0.001). Palmitic (C16:0) and stearic (C18:0) acids were the most abundant in the SFA, representing around 54% and 38%, respectively of total SFA. The PS and FF also produced

Table 2. Influence of production system and finishing feeding on water holding capacity, shear force and texture profile analysis (TPA-test) of meat from Rubia Gallega calves.

PS	Extensive[1]			Semi-extensive[2]		Traditional[3]		Feedlot[4]		SEM[5]	p-value	
FF	Pasture	Pasture/ Concentrate	Pasture/ Corn silage	Pasture/ Concentrate/ Corn silage	Pasture/ Farm resources	Concentrate	Farm resources	Concentrate/ Straw	Concentrate/ Straw/ Corn silage		PS[6]	FF[7]
Water holding capacity (%)												
Cooking loss	27.0[Y,bc]	29.0[Y,c]	22.8[Y,ab]	23.0[Z,ab]	22.6[Z,a]	26.8[Y,bc]	27.1[Y,bc]	28.5[ZY,c]	20.5[ZY,a]	0.53	0.031	<0.001
Drip loss	5.34[cd]	4.80[cd]	2.02[ab]	3.64[bc]	1.68[a]	2.96[ab]	6.24[d]	5.02[cd]	1.72[a]	0.248	0.056	<0.001
Shear force (N)	47.6[Y,cd]	53.4[Y,d]	34.3[Y,abc]	22.5[Z,a]	29.5[Z,a]	28.0[Y,a]	44.3[Y,bcd]	50.2[Y,d]	32.0[Y,ab]	1.90	0.002	<0.001
TPA-test												
Hardness (N)	46.6[Z,a]	49.3[Z,ab]	52.4[Z,ab]	62.4[Y,bc]	56.8[Y,abc]	68.2[Y,c]	51.9[Y,ab]	52.3[ZY,ab]	51.1[ZY,ab]	1.54	0.018	0.018
Gumminess (N)	25.7[Z,a]	27.4[Z,a]	27.2[Z,a]	32.1[ZY,ab]	28.9[ZY,a]	36.9[Y,b]	28.2[Y,a]	28.7[Z,a]	26.1[Z,a]	0.85	0.045	0.043
Chewiness (N/mm)	12.5	13.4	13.1	15.2	14.3	17.7	14.3	14.3	11.7	0.48	0.070	0.150
Cohesiveness	0.55[Y,cd]	0.56[Y,d]	0.52[Y,abc]	0.51[Z,a]	0.51[Z,a]	0.55[Y,cd]	0.55[Y,bcd]	0.55[ZY,bcd]	0.51[ZY,ab]	0.004	0.006	0.004
Springiness (mm)	0.48	0.48	0.48	0.46	0.49	0.45	0.49	0.49	0.44	0.005	0.854	0.096

[1, 2, 3, 4, 5, 6,7:] See Table 1. [Z–Y] Mean values in the same row (different PS) with different number presented significant differences (*p*<0.05). [a–d] Mean values in the same row (different FF) with different letter presented significant differences (*p*<0.05).

differences (*p*<0.05) in other minor SFA (<4%) such as myristic (C14:0), pentadecanoic (C15:0) and margaric (C17:0) acids.

The MUFA content was not affected by PS or FF, with values ranging between 28.9% and 34.4%. Although no differences were detected among groups, oleic acid (C18:1*n*-9c) was the predominant MUFA, with mean values of 85% respect to total MUFA and of 27% respect to total fatty acid.

The PUFA content ranged between 16.9% and 29.4%. Calves finished with pasture and concentrate supplementation showed the highest PUFA level with respect to the other treatments (29.4 *vs*. 21.0% for pasture and concentrate supplementation and the others FF, respectively; *p*=0.024).

Within PUFA, the C18:2 *n*-6c was the predominant fatty acid (60% of total PUFA), followed by arachidonic acid (C20:4 *n*-6) (13% of total PUFA) and by C18:3 *n*-3 (9% of total PUFA). The level of C18:3 *n*-3 was influenced (*p*<0.001) by both treatments. Calves fed pasture and Pasture/Concentrate showed the highest contents of C18:3 *n*-3 (4.16 and 4.50% of total FAME, respectively), whereas the concentrate group displayed the highest values of C18:2 *n*-6c (15.4% of total FAME), although differences for C18:2 *n*-6c content did not reach significance by PS or FF. The differences found for the *n*-3 total content was affected by the C18:3 *n*-3 content in meat (3.42 *vs*.

2.05 *vs*. 0.89 *vs*. 0.69%, *p*<0.001 for calves reared in extensive, semi-extensive, traditional and feedlot systems, respectively).

Influence of production system and finishing feeding on sensory parameters quality of meat

Only two out of eight sensory characteristics that were evaluated showed differences among PS (juiciness and amount of first swallowing; *p*<0.05) and four of them showed differences among FF [(intensity global odour (*p*=0.002), tenderness (*p*=0.001), juiciness (*p*=0.003) and amount of first swallowing (*p*=0.002): Table 4].

Discriminant analysis

From the data set (all parameters, except sensory) subjected to discriminant analysis, the statistical program selected the following variables: L*, ash, drip loss, shear force, C14:0, C15:0, C17:1 *n*-7, C18:3 *n*-3, C18:3 *n*-6, C20:1, C20:3 *n*-6, C20:5 *n*-3, C21:0, *n*-3, *n*-6:*n*-3, PUFA/ SFA, nutritional value, h/H, and cohesiveness. These variables were retained at the end of the stepwise discriminant analysis and were linearly combined to form

Table 3. Influence of production system and finishing feeding on fatty acid profile of meat from Rubia Gallega calves (g/100 g of fatty acid methyl esters).

PS	Extensive[1]			Semi-extensive[2]		Traditional[3]		Feedlot[4]		SEM[5]	*p*-value	
FF	Pasture	Pasture/ Concentrate	Pasture/ Corn silage	Pasture/ Concentrate/ Corn silage	Pasture/ Farm resources	Concentrate	Farm resources	Concentrate/ Straw	Concentrate/ Straw/ Corn silage		PS[6]	FF[7]
C14:0	3.54[Y,e]	1.64[Y,a]	2.84[Y,d]	2.12Z[Y,abc]	2.83[ZY,d]	1.77[ZY,ab]	2.53[ZY,cd]	2.33[Z,bcd]	1.51[Z,a]	0.10	0.025	<0.001
C15:0	0.74[Y,d]	0.51[Y,c]	0.32[Y,ab]	0.38[Z,abc]	0.43[Z,bc]	0.34[Z,ab]	0.37[Z,ab]	0.36[Z,ab]	0.24[Z,a]	0.02	<0.001	<0.001
C16:0	21.4[Z,b]	18.8[Z,a]	23.1[Z,bc]	23.5[Y,c]	22.9[Y,bc]	22.5[Y,bc]	22.2[Y,bc]	23.4[Y,c]	21.9[Y,bc]	0.23	0.004	<0.001
C16:1 *n*-7	2.24[ZY,abc]	1.99[ZY,a]	2.52[ZY,bc]	2.59[Y,c]	2.15[Y,abc]	2.08[Z,ab]	1.99[Z,a]	2.05[Z,ab]	1.88[Z,a]	0.06	0.045	0.026
C17:0	0.93[Y,bc]	0.70[Y,a]	0.97[Y,c]	0.81[Y,ab]	0.97[Y,c]	0.81[ZY,ab]	0.80[ZY,ab]	0.74[Z,a]	0.69[Z,a]	0.02	0.014	<0.001
C17:1 *n*-7	0.59[W,b]	0.72[W,c]	0.72[W,c]	0.59[X,b]	0.60[X,b]	0.47[Y,a]	0.46[Y,a]	0.39[Z,a]	0.40[Z,a]	0.02	<0.001	<0.001
C18:0	14.4[Z,ab]	13.2[Z,a]	13.3[Z,a]	13.7[Z,a]	15.5[Z,abc]	17.1[Y,bcd]	16.1[Y,abcd]	17.9[Y,cd]	18.5[Y,d]	0.36	<0.001	<0.001
C18:1 *n*-9c	25.8	24.9	27.7	28.1	26.1	26.2	26.1	27.9	27.5	0.39	0.395	0.496
C18:1 *n*-11t	1.13[a]	1.15[a]	3.34[d]	2.31[bc]	1.37[ab]	3.08[cd]	1.28[a]	1.66[ab]	2.71[cd]	0.13	0.718	<0.001
C18:2 *n*-6c	10.4	13.6	12.9	13.8	10.4	15.4	14.8	12.1	15.3	0.47	0.101	0.061
C18:3 *n*-3	4.16[X,d]	4.50[X,d]	1.61[X,b]	1.20[Y,ab]	2.90[Y,c]	0.70[Z,a]	1.08[Z,ab]	0.85[Z,a]	0.53[Z,a]	0.17	<0.001	<0.001
C18:3 *n*-6	0.08	0.11	0.10	0.13	0.11	0.08	0.10	0.09	0.10	0.005	0.224	0.397
C20:1 *n*-9	0.12[Y,bc]	0.12[Y,bc]	0.14[Y,c]	0.12[Z,bc]	0.07[Z,a]	0.14[Y,bc]	0.11[Y,b]	0.11[Y,bc]	0.12[Y,bc]	0.01	0.004	<0.001
C20:3 *n*-6	0.79[Y,bc]	0.97[Y,c]	0.65[Y,ab]	0.73[Y,abc]	0.77[Y,bc]	0.75[Y,bc]	0.73[Y,abc]	0.44[Z,a]	0.66[Z,abc]	0.03	0.042	0.035
C20:4 *n*-6	3.05	3.80	2.60	2.54	3.52	2.59	3.28	1.99	2.88	0.16	0.401	0.175
C20:5 *n*-3	2.13[X,c]	3.36[X,d]	1.14[X,b]	0.98[Y,ab]	2.00[Y,c]	0.54[Z,ab]	0.89[Z,ab]	0.64[Z,a]	0.41[Z,ab]	0.12	<0.001	<0.001
C22:5 *n*-3	2.32[X,c]	3.07[X,d]	1.59[X,b]	1.49[X,b]	2.43[X,c]	1.03[Y,ab]	1.49[Y,b]	0.82[Z,a]	0.80[Z,a]	0.10	<0.001	<0.001
SFA	41.1[Z,b]	34.8[Z,a]	40.6[Z,b]	40.6[Y,b]	42.7[Y,bc]	42.6[Y,bc]	42.0[Y,bc]	44.7[Y,c]	42.9[Y,bc]	0.45	<0.001	<0.001
MUFA	29.8	28.9	34.4	33.7	30.3	32.0	30.0	32.2	32.6	0.48	0.659	0.081
PUFA	22.9[a]	29.4[b]	20.6[a]	20.9[a]	22.1[a]	21.1[a]	22.4[a]	16.9[a]	20.7[a]	0.76	0.065	0.024
$\sum$*n*-6	14.3	18.4	16.3	17.2	14.8	18.8	18.9	14.6	19.0	0.60	0.373	0.296
$\sum$*n*-3	8.61[X,d]	10.93[X,e]	4.34[X,c]	3.67[Y,bc]	7.34[Y,d]	2.26[Z,ab]	3.47[Z,abc]	2.30[Z,ab]	1.73[Z,a]	0.37	<0.001	<0.001
n-6/*n*-3	1.67[Z,a]	1.75[Z,a]	3.78[Z,ab]	4.72[Z,b]	1.99[Z,a]	10.10[Y,c]	5.70[Y,b]	10.04[X,c]	10.86[X,c]	0.44	<0.001	<0.001
PUFA/SFA	0.57[Y,a]	0.86[Y,b]	0.52[Y,a]	0.53[ZY,a]	0.55[ZY,a]	0.52[ZY,a]	0.55[ZY,a]	0.38[Z,a]	0.50[Z,a]	0.03	0.024	0.002
Nutritional value	0.69[d]	0.53[a]	0.64[cd]	0.61[bc]	0.70[d]	0.59[abc]	0.60[bc]	0.65[cd]	0.55[ab]	0.01	0.130	<0.001
h/H	1.97[a]	2.67[b]	1.88[a]	1.94[a]	1.94[a]	1.97[a]	1.98[a]	1.75[a]	2.09[a]	0.04	0.070	<0.001

SFA=saturated fatty acids; MUFA=monounsaturated fatty acid; PUFA=polyunsaturated fatty acids; h/H: ratio hypocholesterolemic/ hypercholesterolemic fatty acids. [1, 2, 3, 4, 5, 6,7]: See Table 1. [Z–W] Mean values in the same row (different PS) with different number presented significant differences ($p<0.05$). [a–e] Mean values in the same row (different FF) with different letter presented significant differences ($p<0.05$).

Table 4. Influence of production system and finishing feeding on sensorial parameters of meat from Rubia Gallega calves. Intensity scale for each parameter varied from 0 (sensation not perceived) to 10 (maximum sensation).

PS	Extensive[1]			Semi-extensive[2]		Traditional[3]		Feedlot[4]		SEM[5]	*p*-value	
FF	Pasture	Pasture/ Concentrate	Pasture/ Corn silage	Pasture/ Concentrate/ Corn silage	Pasture/ Farm resources	Concentrate	Farm resources	Concentrate/ Straw	Concentrate/ Straw/ Corn silage		PS[6]	FF[7]
Intensity global odor	5.93[cd]	6.43d	4.23[a]	5.37[bc]	4.67[ab]	6.47[d]	5.67[bcd]	5.67[bcd]	5.17[abc]	0.17	0.202	0.002
Intensity fatty odor	2.23	2.50	1.97	2.70	2.23	1.73	2.07	1.83	2.17	0.09	0.124	0.142
Intensity global flavor	4.23	4.70	3.83	4.07	3.77	4.23	4.20	3.47	3.63	0.12	0.132	0.362
Intensity fatty flavor	1.87	2.47	2.27	2.23	2.20	2.53	2.40	2.77	1.97	0.08	0.615	0.179
Tenderness	5.67[d]	5.70d	3.13[a]	4.20[abc]	4.53[bcd]	5.37[cd]	4.40[abcd]	3.63[ab]	3.23[ab]	0.22	0.068	0.001
Juiciness	5.43[Y.c]	5.27[Y.c]	2.90[Y.ab]	3.57[Z.Y.ab]	3.43[Z.Y.ab]	4.43[Y.bc]	4.37[Y.bc]	3.03[Z.ab]	2.57[Z.a]	0.23	0.016	0.003
Greasiness	2.13	2.27	1.53	1.90	1.83	1.80	2.33	2.00	1.37	0.09	0.541	0.172
Amount of first swallowing	2.83[ZY.a]	2.83[ZY.a]	4.60[ZY.d]	4.03[YX.bcd]	4.27[YX.cd]	3.20[Z.abc]	3.07[Z.ab]	4.17[X.cd]	4.77[X.d]	0.17	0.016	0.002

[1, 2, 3, 4, 5, 6, 7]: See Table 1. [Z–X] Mean values in the same row (different PS) with different number presented significant differences ($p<0.05$). [a–d] Mean values in the same row (different FF) with different letter presented significant differences ($p<0.05$).

canonical discriminant functions. Eight canonical discriminant functions were used in the analysis. The following first two discriminant functions of classification obtained were as follows:

F1=-0.049 [L*] + 0.193 [ash] + 0.343 [drip loss] - 1.295 [shear force] + 0.468 [cohesiveness] + 0.851 [C14:0] - 0.323 [C15:0] + 0.155 [C17:1] − 0.630 [C18:3 *n*-6] - 0.235 [C20:1] + 0.738 [C18:3 *n*-3] + 0.629 [C21:0] + 0.782 [C20:3 *n*-6] − 4.144 [C20:5 *n*-3] + 4.630 [*n*-3] + 0.242 [*n*-6/*n*-3] − 1.584 [PUFA/SFA] + 1.104 [nutritional value] + 2.153 [h/H]

F2=0.262 [L*] + 0.055 [ash] + 0.604 [drip loss] + 1.526 [shear force] + 0.295 [cohesiveness] − 0.233 [C14:0] + 0.422 [C15:0] − 0.182 [C17:1] − 0.556 [C18:3 *n*-6] - 0.017 [C20:1] + 3.232 [C18:3 *n*-3] + 0.074 [C21:0] − 0.011 [C20:3 *n*-6] + 4.578 [C20:5 *n*-3] − 8.241 [*n*-3] + 0.007 [*n*-6/*n*-3] + 0.197 [PUFA/SFA] − 0.634 [nutritional value] + 0.820 [h/H]

According to these coefficients, the parameters, which mostly accounted for the segregation of F1, were C20:5 *n*-3, *n*-3, PUFA/SFA and h/H while the variables accounting for group segregation of F2 were shear force, C18:3 *n*-3, C20:5 *n*-3 and *n*-3. This outcome allows obtaining more accurate results of beef quality regarding FF, because C18:3 *n*-3 and C20:5 *n*-3, total *n*-3 and h/H and PUFA/SFA index were highly influenced by the fatty acid composition of pastures and concentrates used in calf finishing. As expected, *n*-3 fatty

acids were a successful tool for discrimination in calves finished differently.

When results obtained for function F1 were plotted against results obtained from function F2 on coordinate axes for each beef sample (*n*=90), a good discrimination among extensive groups according to the FF was observed (Figure 1). The functions F1 and F2 explained 57.1 and 15.2%, respectively, of the variance reaching a total variance explained of 72.3%. Eigenvalues and canonical correlation values obtained for F1 were 21.34 and 0.977, respectively and 5.68 and 0.922 for F2, respectively. A cross validation was obtained only for those cases in the analysis, where each case was classified by the functions derived from all cases other than that case. The discriminant analysis correctly attributed each calf sample to its original group with an accuracy of 96.6%. The 83.1% of calf samples were cross validated correctly, where all samples were perfectly classified (100%) for groups such as Pasture/Corn silage and Pasture/Farm resources, while the poorest classification was obtained for Concentrate/ Straw (50%).

Discussion

Influence of production system and finishing feeding on physicochemical parameters of meat

The pH values are in agreement with those observed by other authors (Guerrero *et al.*, 2013; Humada
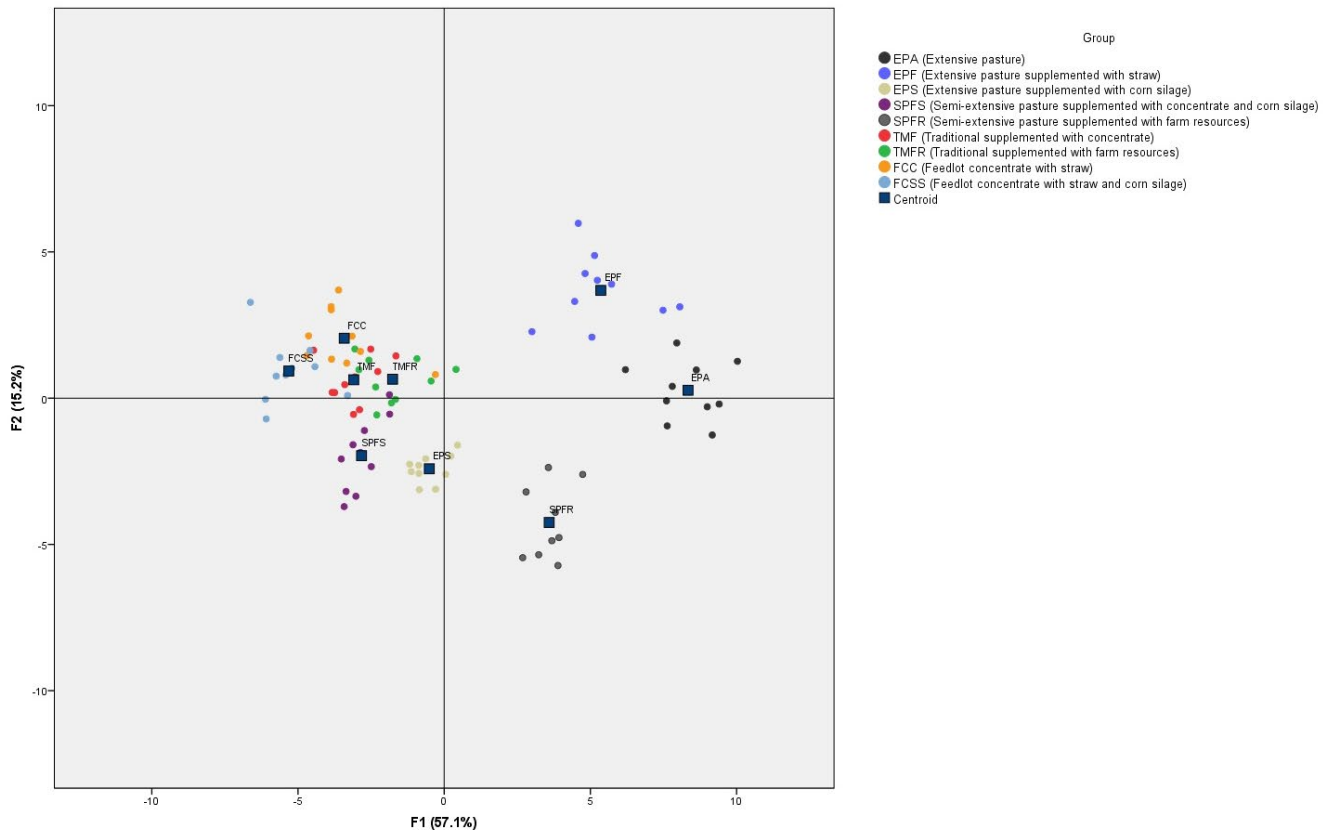
Figure 1. Plot of meat from Rubia Gallega calves on the axes representing the values of the two discriminating functions

et al., 2014) for the variation of the ultimate pH among the PS. Variations in the FF of cattle in each PS also could to contribute the differences observed in pH values, in accordance with Bispo *et al.* (2010a) that reported an influence of nutrition on pH values. Nevertheless, all treatments showed pH_{24} values below 5.8, being within the acceptable range for beef indicating absence of stress factors.

Meat color is an important attribute being considered as the main purchasing criterion with bright red being preferred to pale/dark red in relation with fresh meat (Troy & Kerry, 2010). Lightness interval agrees with the range reported by Guerrero *et al.* (2013). Values obtained for a* and b* were similar to those found in RG breed by Pateiro *et al.* (2013). In a general overview, color parameters were higher in traditional and feedlot systems while pasture-finished produced the darkest meat color, in accordance with other studies (Priolo *et al.*, 2001; Moloney *et al.*, 2011; Yüksel *et al.*, 2012). Moreover, IMF was higher in both traditional and feedlot systems which could contributed directly to an increase beef lightness (French *et al.*, 2001; Yüksel *et al.*, 2012). In agreement with our results, the physical activity could be considered a factor that affect to color, being darker in animals rared in finished pasture with having more physical activity (Vestergaard *et al.*, 2000; Priolo *et al.*, 2001).

Overall, despite exhibiting differences, the chemical composition across FF was in the range of expected values for RG veal (Bispo *et al.*, 2010a; Pateiro *et al.*, 2013; González *et al.*, 2014), showing low fat and high protein contents. As expected, cattle fed pasture provided lower IMF content in contrast with those fed grain or concentrate (IMF from Concentrate/ Straw/Corn silage calves were nearly 6-fold higher than that from Pasture/Concentrate calves). These results are consistent with those obtained by Mezgebo *et al.* (2017), who suggested that diet based on concentrates increases the IMF.

Influence of production system and finishing feeding on WHC, shear force and TPA-test of meat

The WHC has a great importance in the meat properties since it plays a key role in the muscle structure that could affect appearance, color, tenderness and juiciness after cooking (Pearce *et al.*, 2011; Hughes *et al.*, 2014). Previously, other authors (Oliete *et al.*, 2006; Bispo *et al.*, 2010a) did not find any impact of PS on drip loss in agreement with current results. In contrast to the present study, Del Campo *et al.* (2008) reported the lowest shear force values for pasture-fed cattle. According to tenderness

classification established by Belew *et al.* (2003), meat from calves reared in the semi-extensive system could be considered as "very tender" (shear force<31.4 N) while meat from calves reared in the traditional system could be classified as "tender" (31.4 N<shear force<38.2 N) and meat from calves reared in the feedlot and in the extensive system as "intermediate" (38.2 N<shear force<45.1 N). From the semi-extensive system provided meat with the greatest tenderness as well as meat with the lowest cooking loss. This fact indicates that meat from these calves lose less water during the cooking process, since the greater retention of water corresponds with a better tenderness. Indeed, shear force was correlated with cooking loss (r=0.437, p<0.01) and with drip loss (r=0.260, p<0.05). Moreover, both ways of measuring the water lost were correlated between them (p=0.243, p<0.05). However, this correlation was not strong because cooking loss is affected by denaturation of protein realising water while drip loss is produced by cutting the meat surface. As expected, no correlation was observed between shear force and hardness while a correlation between hardness and cooking loss (r=0.239, p<0.05) was found. Moreover, a moderate correlation was observed between cooking loss and cohesiveness and between cooking loss and gumminess (r=0.431 and 0.332, respectively, p<0.01).

Influence of production system and finishing feeding on fatty acid profile of meat

The influence of PS and FF on fatty acid profile has been previously evaluated by several authors (Varela *et al.*, 2004; Bispo *et al.*, 2010b; Guerrero *et al.*, 2013; Pateiro *et al.* 2013). In addition, variations in SFA among the different PS and FF are in agreement with other studies where the effect of PS on intramuscular fatty acid composition was evaluated (Humada *et al.*, 2012; Van Elswyk & McNeill, 2014). Despite the fact milk has an important SFA fraction, the content of these fatty acid in meat from the extensive group (suckling calves belong to Pasture/Concentrate group) did not increase. Within SFA, palmitic and stearic were the most predominant fatty acid in agreement with other researches who found lower contents of C16:0 in the fat of cattle fed with grass *vs.* grain (Alfaia *et al.*, 2009; Duckett *et al.*, 2013). The C16:0 is the major constituent of SFA and the major product from endogenous fatty acid synthesis. In the current study, the lowest SFA percentage of 16:0 was found in meat from calves fed pasture supplemented with concentrate (Pasture/Concentrate). These results indicate that synthesis *de novo* was somewhat inhibited with this FF. These results might be related to greater accumulations of PUFA which have been reported to have inhibitory effects on endogenous fatty acid synthesis in muscle (Waters *et al.*, 2009). The reduced SFA percentages have important and positive

implications because recommendations for human health include reducing SFA intake, especially SFA from lauric acid (C12:0) to C16:0 due to the raise of low-density lipoprotein (LDL)-cholesterol producing atherogenic and hypercholesterolemic effects (EFSA, 2010).

The C18:1 is an important fatty acid to human diet. Indeed, in western diets beef meat is considered the primary source of MUFA and a common source of C18:1 *n*-9c. However, it has been reported that C18:1 *n*-9c amount (and, consequently, the MUFA percentage) only could be modified when there are differences in marbling level produced by different feeding strategies (Van Elswyk & McNeill, 2014).

The absolute accumulations of PUFA in present study were limited, most likely related to the low total lipid content showed on RG veal. Specifically, for Pasture/Concentrate group, this finding must be interpreted with caution because of the low IMF content (0.24%). Indeed, this result is corroborated by the negative correlation observed between IMF and linoleic (C18:2 *n*-6c) and linolenic (C18:3 *n*-3) acid contents (r=-0.31 and-0.50, respectively; p<0.01). The low IMF and FAME contents were in the same range of those reported by Bispo *et al.* (2010b) for RG breed, a genetically late maturing breed. Given the differences found for the IMF, differences in tissue fatty acid composition could be related to both FF influence and ratio neutral/phospholipids.

Within PUFA, similar values have been reported by Guerrero *et al.* (2013) for linoleic, arachidonic and linolenic acids. Despite the fact that PUFA are bio-hydrogenated by rumen microbes resulting in a decrease in their muscle concentration, it has been described that feed based on grass leads to increases of C18:3 *n*-3 deposition in muscle in comparison to feed based on concentrates (Wood *et al.*, 2008). These facts support that PUFA content is highly dependent on calve diet (Scollan *et al.*, 2001; Wood *et al.*, 2008).

The sum of *n*-3 PUFA was affected (p<0.001) by PS and FF, as previously was reported (French *et al.*, 2000a; Humada *et al.*, 2012). In contrast, the *n*-6 content was not affected by PS according with previous studies (Humada *et al.*, 2012; Guerrero *et al.*, 2013). In the current study, the highest values obtained to total *n*-3 content corresponded to the extensive system while the lowest values were showed by the traditional and the feedlot systems. The semi-extensive systems were considered as intermediate. These results are in accordance with other studies where calves fed with pasture had a higher content of *n*-3 than calves fed with grain and concentrate (Wood *et al.*, 2008). In addition, based on extensive and semi-extensive systems causing increments in C18:3 *n*-3 contents (especially in Pasture/Concentrate group), it seems that this fatty acid was used at more extent as substrate for the complex enzymatic system consisting of desaturases and elongases by promoting *de novo* synthesis of long chain

n-3 (eicosapentaenoic or C20:5 *n*-3 and docosahexaenoic acids). This result agrees with those obtained by Cherfaoui *et al.* (2012) who evidenced that C18:3 *n*-3 was the main substrate for these enzymes. It has been reported that diets lower in forage and high in starch lead to a reduced rumen pH and shifts in the ruminal bacterial populations (Klieve *et al.*, 2003) changing the PUFA biohydrogenation pathways, suggesting that diets rich in C18:3 *n*-3 (pasture and forages) may have influenced these pathways. As positive effects of *n*-3 have been recognized (Wood *et al.*, 2008), it seems that, in the present study, the extensive system improved meat quality from a healthy point of view.

A low *n*-6/*n*–3 ratio is considered a target for meat fatty acid composition in the human diet since a balanced ratio could prevent cardiovascular and other chronic diseases such as prostate cancer (Simopoulos, 2008). In fact, higher proportions of *n*-3 have been recommended by EFSA (2010) and FAO (2010) in order to decrease the *n*–6/*n*–3 ratio for prevention of inflammation related diseases (Simopoulos, 2008). In the current study, calves reared in extensive and semi-extensive systems showed the healthiest (the lowest) values comparing with traditional and intensive systems (2.40, 3.36 *vs.* 7.90, 10.45, respectively; *p*<0.001), complying with the FAO (2010) nutritional recommendations for human diet (*n*-6/*n*-3<4). Again, these differences are clearly influenced by the fatty acid composition of diets, reflecting that C18:2 *n*-6c and C18:3 *n*-3 are the most abundant fatty acid in grain and grass, respectively and these fatty acid act as *n*–3 and *n*–6 precursor series, respectively (French *et al.*, 2000a; Raes *et al.*, 2004). In line with these results, supplementation strategies have recently reported to cause important changes in *n*-6/*n*-3 ratio (Scollan *et al.*, 2014).

The PUFA/SFA ratio is another important index to evaluate the nutritional properties of IMF. Recommendations of PUFA/SFA ratio for human diet are around 0.85 (FAO, 2010). In the current trial, differences for PUFA/SFA ratio were found among FF (*p*=0.002). Only the PUFA/SFA ratio observed in Pasture/Concentrate group, related to its lower IMF content compared to the other FF groups, was in the range recommended by FAO (2010). This value was higher than those found in other studies with beef (Guerrero *et al.*, 2013; Pateiro *et al.*, 2013). However, if the recommendation for unsaturated fatty acid/SFA ≥2 (EFSA, 2010) is considered, none FF from the current study achieved that level.

Influence of production system and finishing feeding on sensory parameters quality of meat

Within the effect of PS and FF on sensory attributes, our findings did not support previous researches, where differences in sensory attributes by PS (Guerrero *et al.*,

2013) or FF (Moloney *et al.*, 2011) effects were not observed, being other factors (such as age, pre-slaughter conditions or carcass fatness) could contribute to sensory quality. Regarding eating quality, tenderness and juiciness are the most influential attributes in consumer preferences (Font-i-Furnols & Guerrero, 2014). In the current study, results showed variation of tenderness with the FF effect. This outcome is controversial, because several studies did not find differences for tenderness between steers fed pasture or grain (French *et al.*, 2001; Realini *et al.*, 2004), whereas other authors (Kerth *et al.*, 2007; Resconi *et al.*, 2010) observed that meat tenderness was lower in grass than in grain-fed animals. Similarly for juiciness, some studies have found that cattle fed with grass were less juicy, whereas other studies did not find differences in juiciness between pasture and grain feed, suggesting that age, pre-slaughter management or carcass-weight could be major factors of influence as previously observed (French *et al.*, 2000b, 2001; Kerth *et al.*, 2007).

Fat level is a key factor to improve sensory parameters (such as tenderness and juiciness) since IMF is positively correlated with palatability (O'Quinn *et al.*, 2012, Corbin *et al.*, 2015). However, in the current study, no correlations were observed between IMF and textural or sensory parameters. This discrepancy could be attributed to the minimum differences in the IMF content observed among the PS groups that could have prevent differences observed by panelists in terms of tenderness or juiciness. Only intensity global flavor was negatively correlated with the IMF content (r=-0.398; p<0.05).

Results obtained showed that FF had a great influence on veal meat quality, while PS had a minor effect on most parameters evaluated. The fatty acid profile from calves reared in extensive and semi-extensive systems agree with the range of values proposed by the nutritional recommendations of the international organizations. In addition, meat obtained from extensive systems finished only with pasture and supplemented with concentrate turned out to have a great palatability. This type of meat produced using pasture in outdoor areas increases consumer expectations and satisfactions. Overall, it is important to stand out that this research allows to obtain further details with respect to the effect of PS with different FF of RG meat quality.

Discriminant analysis

Discriminant analysis allowed distinguishing among FF groups with a 72.3 % of the total variation. This study suggests that the calves fed with pasture could be efficiently separated in F1 axis. The variables C20:5 -n3 and n3 were the more important in this axis, suggesting that the study of FA profiles in calves might be efficiently used as a marker of FF in which calves are reared. This is in agree with previous studies which shown discriminant

ability among diets, using the fatty profile in lambs (Santos-Silva *et al.*, 2002) and young bulls (Horcada *et al.*, 2017).

Conclusions

The results obtained showed that finishing feeding had a great influence on meat quality, meanwhile production system had a minor effect on most parameters evaluated. The fatty acid profile from calves reared in extensive and semi-extensive systems agree with the values proposed by the nutritional recommendations of the international organizations. Additionally, meat obtained from extensive systems finished with pasture and supplemented with concentrate turned out a great palatability. This type of meat produced using pasture in outdoor areas increases consumer expectations and satisfactions. Overall, it is important to stand out that this research allowed to obtain further details about Rubia Gallega meat quality considering simultaneously different production systems with minor variations in terms of finishing feeding.

Acknowledgments

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