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Breed effect on quality veal production in mountain areas: emphasis on meat fatty acid composition

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ABSTRACT

This study was designed to compare the quality of veal produced from 'Tudanca x Charolais' cross (n=6) and Limousin (n=6) breeds when allowed to feed freely on mountain pastures and suckle naturally from birth to 7 months of age. After 80 days of age calves also had access to concentrate (maximum of 3 Kg/day), while mothers did not. At slaughter, Limousin calves were heavier ($P<0.01$) and provided better carcass yield ($P<0.05$) and conformation ($P<0.001$) than Tudanca calves. Tudanca beef provided higher fat content ($P<0.05$) was less tough ($P<0.05$), and was scored as more tender and juicy ($P<0.1$) with higher acceptability than Limousin beef ($P<0.1$). In general, Tudanca had a better fatty acid profile than Limousin beef, especially in terms of the content of polyunsaturated ($P<0.05$), long-chain polyunsaturated fatty acids ($P<0.05$) and their n-6/n-3 ratios ($P<0.1$), as well as vaccenic acid ($P<0.1$) and the overall *trans*-18:1 isomer profile.

Key Words: carcass traits, fatty acids, meat quality, *trans*, 'Tudanca', veal.

1. Introduction

Mountain areas of northern Spain are traditionally dedicated to beef production utilizing mostly local breeds, including crossbred animals (Vieira, García, Cerdeño, & Mantecón, 2005; Bispo et al., 2011; Humada, Serrano, Sañudo, Rolland, & Dugan, 2011; Lavín, Jaroso, Palencia, & Mantecón, 2011a). Such a production system meets a number of expectations in terms of sustainability and multifunctionality in rural areas. The most common beef production system in this mountain region (steep topography; between 520-580 m above sea level; longitude -4º 51', latitude 43º 25') is centered on calf production and farmers then selling them to bigger feedlots for final intensive-fattening and commercialization; calves are generally 8-9 months of age at slaughter. According to recent findings (Lavín, Jaroso, Palencia, & Mantecón, 2011b) it was concluded that this system did not provide local farmers with significant economic benefits, and therefore it was decided to evaluate an alternative system. The alternative production system focused on producing veal locally instead of calves for intensive fattening. Calves would be reared outdoors on local pastures and suckled naturally by their mothers from birth to 6-7 months of age, and were subsequently slaughtered.

It is known that breed or genotype and production system are determinant factors of the carcass and meat quality (Piedrafita et al., 2003; Vieira et al., 2005; Martínez et al., 2010), and these will also affect the fatty acid composition of the meat (Aldai et al., 2006, 2011). In order to test the present local production system and evaluate the quality of the meat, two breeds were investigated reared under the same mountain pasture conditions to evaluate the quality of the final beef produced. The study included a local cross ('Tudanca x Charolais') and a foreign breed that has been well-adapted to the area (Limousin). These two breeds have different maternal traits (personal communication).

Economical comparisons associated with raising each breed under this local production system have been reported elsewhere (Lavín et al., 2011b). In the present study a comparison was undertaken of the carcass (*i.e.*, EU classification) and meat quality (*i.e.*, colour, tenderness, and sensory analysis) characteristics with special emphasis of fatty acid (FA) in meat having nutritional implications.

2. Materials and methods

2.1. Animals, management and diet composition

Twelve male calves from 'Tudanca x Charolais' cross (n = 6) and Limousin (n = 6) were studied. From birth (March-April 2010), calves were naturally suckled by their mothers in mountain areas of Cantabria (Nansa Valey, northern Spain). The major botanic species in the fields were *Lolium perenne, Agrostis capillaris* and *Trifolium repens*. After an average of 79.3±1.55 days of age calves received *ad libitum* access to concentrate up to a maximum of 3 Kg/day/head, while mothers did not have access to concentrate (only access to pasture).

The concentrate meal was composed approximately by 40 % corn meal, 45 % barley meal, 10 % soya meal, 2 % fat, 3 % minerals, vitamins and oligoelements. Samples were analyzed for dry matter (DM; ISO, 1999), ash (ISO, 2002), and crude protein (CP; ISO, 2005). Ether extract (EE) was determined using the Ankom filter bag technology (American Oil Chemists' Society Official Procedure Am 5-04; AOCS, 2008) while the fatty acid composition was determined using a direct transesterification procedure as detailed by Alves, Cabrita, Fonseca, & Bessa (2008). Therefore, on DM basis, chemical composition of the concentrate was as follows: 16.2 % CP, 6.7 % ash, and 3.9 % EE, while the percentages of major FAs were as follows: 18 % 16:0, 2.1 % 18:0, 20 % 9*c*-18:1, 50 % 18:2n-6, and 3.3 % 18:3n-3.

Calves were slaughtered in October at an average age of 7 months. At this point the calves were subjectively inspected to see whether they reached an adequate conformation and degree of fat cover. Live weight at slaughter (LWS) was recorded.

2.2. Carcass measurements and sample collection

Slaughtering was performed in a commercial abattoir according to standard procedures. After dressing, carcasses were chilled at 2 ºC for 24 hours (h). Twenty-four h *post-mortem*, cold carcass weight (Kg) and length (cm) were recorded. The carcass yield (%) was calculated based on LWS and cold carcass weight, while carcass compactness was calculated based on carcass weight and length as described in De Boer, Dumont, Pomeroy, & Weniger (1974). Carcasses were classified by visual assessment on conformation and fat cover degree by a trained and experienced evaluator. For conformation, development of carcass profiles was taken into consideration according to SEUROP classification (S: super, E: excellent, U: very good, R: good, O: fair, P: poor), and for fat cover degree the amount of fat on the outside of the carcass and in the thoracic cavity using a classification range from 1 to 5 (1: low, 2: slight, 3: average, 4: high, 5: very high; (OJEC, 1981a,b). Each level of both scales (conformation and fat cover) was subdivided in 3 sub-classes (*i.e.*, conformation: R+, R, R− and fat cover: 3+, 3, 3−) to a transformed scale ranging from 1 to 18 for conformation (18 being the best conformation) and from 1 to 15 for fat cover (15 being the thickest fat cover). Carcass pH (penetration portable pHMeter, Metrohm®, Switzerland) and colour (portable Minolta® CM2002, Konica-Minolta Sensing, Inc., Germany) were also measured on the left half carcass at 24 h *post-mortem*. Two pH measurements were taken in the *longissimus thoracis et lumborum* muscle (LTL; 3rd lumbar vertebrae). Colour (D65 illuminant and 10º standard observer; L*, brightness; a*, red-green axis; b*, yellow-blue axis; Commission Internationale de l'Eclairage, 1978) was measured at the *pectoralis profundus* muscle and subcutaneous fat (6th to 10th rib area) with 3 measurements per tissue.

After 5 days of ageing at 2 ºC in the abattoir cooler, commercial carcass fabrication was performed and the percent of boxed beef (*i.e.*, saleable meat) calculated relative to the cold carcass weight. At 11 days *post-mortem*, the rib joint between the 5th to the 9th ribs of the left half carcass was cut and transported to the laboratory for further analyses.

2.3. Meat quality

Drip loss was determined (Hönikel, 1998) on the first steak of the LTL muscle of the rib joint. Approximately two 50 g samples of raw meat were sampled from the 5th rib and weighed. The two portions were placed within a container with a supporting mesh that was then sealed in order to avoid water evaporation. After a period of 72 h at 4 ºC, the samples were weighed again to determine water loss, and that weight difference was expressed as the percentage of the initial weight. From the second steak (LTL muscle), colour measurements were recorded after exposing the muscle to atmospheric oxygen for 20 min and using the equipment and procedure described above. Then, the LT was ground and freeze-dried, and percentages of moisture, EE, CP and ash were determined using standard procedures described in section 2.1 as per feedstuff. A subsample of 15-20 g of freeze-dried meat was stored at -80 ºC for subsequent FA determination.

From the last LTL portion three steaks of approximately 2 cm thickness were cut. The first steak was used to determine shear force in cooked meat according to the Warner-Bratzler test (Hönikel, 1997). Sensory analysis was performed using the other two steaks with an eight-member trained panel who evaluated the samples for odour intensity, tenderness, juiciness, flavour intensity, and overall acceptability (5-point scale). Details regarding shear force, including equipment description and sensory analysis have been previously described by Vieira, Cerdeño, Serrano, Lavín, & Mantecón (2007).

2.4. Fatty acid analysis

Lipids were extracted from 1g of freeze-dried muscle using a mixture of chloroform - methanol (1:1, v/v) (Kramer et al., 1998). Details of this procedure have been published elsewhere (Aldai, Dugan, Rolland, & Kramer, 2009). Lipid aliquots (~10 mg) from each steak were methylated separately using acidic (methanolic HCl) and basic (sodium methoxide) reagents to ensure complete methylation of all lipids and avoid isomerisation of conjugated linoleic acids (CLAs), respectively (Aldai, Murray, Nájera, Troy, & Osoro, 2005; Kramer, Hernandez, Cruz-Hernandez, Kraft, & Dugan, 2008). For quantitative purposes, 1 mL of internal standard (1 mg / mL of 23:0 methyl ester, N-23-M from Nu-Chek Prep Inc., Elysian, MN, USA) was added prior to methylation. The contents of fatty acid methyl esters (FAMEs) were expressed as mg per 100 g of fresh meat, and as percentage (%) of total FAME quantified.

The FAMEs were analyzed using a gas chromatograph equipped with a flame ionization detector (Agilent Technologies, Model 7890A, Wilmington, DE, USA) and an automatic injector (Agilent Technologies, Model 7693 Autosampler). The FAMEs, including the *trans*-18:1 isomers, were analyzed using a 100 m SP-2560 column (Supelco, Bellefonte, PA, USA) and two complementary gas chromatography (GC) temperature programs plateauing at 175 ºC and 150 ºC (Kramer et al., 2008) and a split ratio of 50:1. The CLA isomers were separated and identified using a 100 m SLB-IL111 ionic liquid stationary phase column (Supelco, Bellefonte, PA, USA) as described by Delmonte et al. (2011). On the ionic liquid column the FAMEs were injected using a 20:1 split ratio and the following temperature program: 168 ºC for 40 min, increased 6 ºC / min to 185 ºC, and maintained for 35 min. With both columns hydrogen was used as carrier gas with a flow rate of 1 mL / min, and the injector and detector temperatures were set at 250 ºC.

For identification of the FAMEs, reference standards #463 and #603, individual FAMEs 21:0 and 23:0, and CLA mixture #UC-59M (9*c*,11*t*-/8*t*,10*c*-/11*c*,13*t*-/10*t*,12*c*-/8*c*,10*c*-/9*c*,11*c*-

/10*c*,12*c*-/11*c*,13*c*-/11*t*,13*t*-/10*t*,12*t*-/9*t*,11*t*-/8*t*,10*t*-18:2 isomers) were used, all obtained from Nu-Chek Prep Inc. (Elysian, MN, USA). Branched-chain FAs (BCFA) were identified using a bacterial FAME mixture purchased from Matreya (Pleasant Gap, PA, USA). Many of the *trans*-18:1 and CLA isomers, not included in the standard mixtures, were identified by their retention times and elution orders as reported in the literature (Cruz-Hernandez et al., 2004; Cruz-Hernandez et al., 2006; Kramer et al., 2008; Alves & Bessa, 2009; Rego et al., 2009; Delmonte et al., 2011). In general, only FAMEs representing over 0.05 % of the total FAME content were included in the Tables and Figures, except for CLA that includes all quantified isomers.

2.5. Statistical analysis

The statistical analysis was conducted using SPSS 19 for Windows (SPSS Inc., IBM Corporation, NY, USA). One-way ANOVA analysis was applied to test differences between breeds ('Tudanca x Charolais' cross, Limousin) for all variables studied. Significance was declared at $P<0.05$ and trend was declared at $P<0.1$.

For abbreviation purposes, the 'Tudanca x Charolais' cross is referred to simply as 'Tudanca' throughout the text.

3. Results

3.1. Carcass measurements

At the time of slaughter (7 months of age), calves from the Limousin breed were heavier (318 Kg) than those from Tudanca cross (256 Kg; $P<0.01$; Table 1). After harvest and 24 h *post-mortem*, significant differences were also found in carcass weight ($P<0.01$), yield ($P<0.05$) and compactness ($P=0.001$) with Limousin calves showing higher values, while the carcass length of the two breeds was similar ($P>0.05$). Calves from the Limousin breed had better conformation according to the EU classification system ($P<0.001$) while the degree of fat cover was similar in both breeds (Table 1).

The pH and colour measurements taken on the carcasses at 24 h *post-mortem*, showed only few significant differences between the two breeds. The pH values measured in the LTL muscle of the two genotypes were not statistically different ($P>0.05$). *Pectoralis profundus* muscle was significantly lighter (L* = 42.5) and tended to have greater redness (a* value = 14.6) in Limousin carcasses compared to Tudanca carcasses (L* = 36.3, $P<0.01$ and a* = 13.2, $P<0.1$), while no differences were found in yellowness ($P>0.05$). In terms of backfat colour, however, Tudanca presented greater redness (a* = 4.1) in comparison to Limousin carcasses (a* = 1.88; $P=0.001$), while no differences were found in other colour parameters (Table 1).

3.2. Meat quality

Carcasses from both breeds showed similar boxed beef (average of 78.6 %) and drip loss percentages (average of 2.12 %; Table 2). After 11 days of ageing, Tudanca calves presented a LTL muscle with darker colour ($P<0.001$), and increased redness ($P=0.001$), but decreased yellowness ($P<0.05$) in comparison to Limousin calves (Table 2).

In general, there were no significant differences in chemical composition of the meat except for fat content (EE, $P<0.05$). Tudanca contained 2.46 % fat compared to 1.44 % in Limousin meat. According to Warner-Bratzler shear force values, beef obtained from the Limousin breed was tougher ($P<0.05$) and had significantly less odour intensity ($P<0.05$) in comparison to Tudanca meat. Tudanca beef was tended to be judged ($P<0.1$) as more tender, juicier, more flavourful and more acceptable than Limousin beef (Table 2).

3.3. Fatty acid composition of intramuscular fat

Beef obtained from Tudanca calves had significantly greater amount of total FAMEs per 100 g of fresh meat (Table 3) than in Limousin. In absolute amount all FAs (individual and groups reported in Table 3) were significantly higher in Tudanca beef with few exceptions. Two of the calculated ratios (n-6/n-3, P/S) were higher ($P<0.1$) in Limousin beef.

In addition, the 10*t*-18:1 isomer tended to be greater in Limousin (11.3 mg / 100 g meat) than in Tudanca beef (7.2 mg / 100 g meat, $P<0.1$) and the 11*t*-18:1 isomer (vaccenic acid, VA), tended to be greater in Tudanca (57 mg / 100 g meat) than in Limousin beef (28 mg / 100 g meat; $P < 0.1$). No significant differences ($P>0.05$) were found in the content of arachidonic acid (20:4n-6, ArA), docosahexaenoic acid (22:6n-3, DHA), and total CLA (Table 3). Most of the total CLA consisted of rumenic acid (RA, 9*c*,11*t*-18:2), which represented over 76 % of the total CLA with no significant differences between breeds ($P>0.05$).

When the results were expressed on a percentage basis (Table 4), not many significant differences were observed except for plasmalogenic lipids, identified mostly as their dimetylacetals (DMA) after methylation. Meat from Limousin calves showed a greater relative abundance of total and individual DMAs, while the sum of saturated FAs (SFA) was significantly higher in Tudanca (47 %) in comparison to Limousin beef (43 %, $P<0.05$). This was mainly influenced by the significantly higher level of 18:0 in Tudanca (17 %) than in Limousin meat (14 %) ($P<0.05$). There were no differences in the level of BCFAs between the two breeds.

The relative abundance of total monounsaturated FAs (MUFA) expressed as percent were not statistically different between the two breeds (Table 5). Significant differences were only found for the total *cis*-18:1 ($P<0.05$) and several individual *cis*-MUFA like 12*c*-16:1 ($P<0.05$), 9*c*-17:1 ($P=0.01$), 9*c*-18:1 ($P<0.05$), 11*c*-18:1 ($P<0.05$), 16*c*-18:1 ($P<0.01$) and 11*c*-20:1 ($P<0.05$). This compared to the *trans* isomers that showed no significant differences between breeds either in total *trans*-MUFA, or total *trans*-16:1 and *trans*-18:1 (Table 5). The relative abundance of all the *trans*-18:1 isomers to total *trans*-18:1 are shown in Figure 1. Several differences were found. Interestingly, 10*t*-18:1 was significantly lower ($P<0.01$) in Tudanca compared to the Limousin breed. Moreover, 6*t*/7*t*/8*t*-18:1 also tended to be lower in

Tudanca, while other isomers like 12*t*- ($P<0.05$), 13*t*/14*t*- ($P<0.01$), 15*t*- and 16*t*- 18:1 were significantly or numerically higher in Tudanca.

The polyunsaturated FAs (PUFA), long-chain PUFAs (20-to-22 carbon FAs; LC-PUFA), CLAs and non-conjugated 18:2 acids (NC-18:2) are presented in Table 6. In general, total PUFA and LC-PUFA were significantly higher ($P<0.05$) in Limousin compared to Tudanca beef. All n-6 PUFAs were significantly higher ($P<0.05$) in Limousin compared to Tudanca, except for 18:3n-6, 20:2n-6, 22:2n-6 and 22:4n-6 ($P>0.05$). Within the n-3 PUFA group, docosapentaenoic acid (22:5n-3, DPA) was significantly higher in Limousin ($P<0.05$), while DHA (22:6n-3) only tended to be higher ($P<0.1$). No significant breed differences were found for linolenic (LNA) and eicosapentaenoic (EPA) acids ($P>0.05$). In Figure 2, absolute amounts of selected PUFAs and LC-PUFAs are compared between the two breeds. In general, all n-6 and n-3 PUFA and LC-PUFAs were either numerically or statistically higher in Tudanca compared to Limousin breed.

There were no significant differences in total CLA content (1.3 to 1.4 %; Table 6), and only one isomer (11*t*,13*c*-) was significantly different between breeds when representing the individual isomers relative to total CLA (Figure 3). Although not significant, the relative abundance of most *c*/*t* –CLA isomers tended to be higher in Limousin, while the *t*/*t* –CLA isomers tended to be more abundant in the Tudanca.

4. Discussion

To understand how different breeds behave under the same management conditions and to choose the most advantageous from a profitability and nutritional standpoint is extremely important when providing advice to producers in rural and mountain areas. In these regions, calf production under intensive fattening will require special facilities and a larger herd size. On the other hand, utilizing natural milking, local pastures and partial supplementation of concentrate to produce veal directly was shown to be a more economical

option (Lavín et al., 2011b). If it is also accompanied by an improved meat quality it could provide an added benefit to local beef producers and consumers. This study was initiated based on a previous observation of breed differences in profitability when conducted under a direct meat production system.

The present results showed that Limousin breed had better carcass characteristics attributed mainly to the higher LWS at the selected age of slaughter (7 months) compared to Tudanca. This confirmed earlier studies that compared rustic or local breeds to genetically more improved beef cattle breeds (Piedrafita et al., 2003; Aldai et al., 2006, 2007). There was increased interest in the current study to evaluate the hitherto untested Tudanca breed that was crossed with Charolais, which potentially provided the calves with improved growth and good daily live weight gains.

The pH values of the LTL muscle of both breeds at 24h were not statistically different (Table 1), but the slightly lower pH values of Limousin carcasses could be related to carcass size and, therefore, slower temperature decreases with the subsequent more rapid metabolism. The slight darkening observed in Tudanca meat (*pectoralis profundus*) could be related to a lower extent of pH decline as previously reported by others (Aalhus, Janz, Tong, Jones, & Robertson, 2001) but the speed or the kinetics of pH were not measured in the present study. Unfortunately, carcass pH and colour were not measured in the same muscle.

After 11 days of ageing (Table 2), LTL muscle from Tudanca carcasses were less bright than muscle obtained from Limousin carcasses. For a similar fat cover degree, Tudanca calves have more intramuscular fat than the Limousin calves which could imply that the processes of fat tissue distributions were different. The higher fat content in Tudanca calves could have been related to increased number and size of adipocytes compared to Limousin calves as shown by Mendizabal et al. (1999) for other Spanish cattle breeds. The higher intramuscular fat content might explain the smaller shear force values obtained in Tudanca compared to

Limousin beef. The increase in fat would dilute the relative protein content in meat, thereby lowering the bulk density. In addition, the fat within the connective tissue could reduce the force required to cut the meat although several studies (Smith et al., 1985) have reported inconsistent results when linking fat content and texture / shear force. Apart from the fat content, an explanation for the tougher meat obtained from Limousin calves is not immediately apparent since the chilling rates were not fast enough to induce cold-shortening. Interestingly, Smulders, Marsh, Swartz, Russell, & Hoenecke (1990) and Marsh, Ringkob, Russell, Swartz, & Pagel (1987) have shown tenderness to be related to the rate of glycolysis, and independent of the rate of chilling, which might have been the case in the present study.

The lubrication effect of marbling relies upon higher fat levels in marbled meat that stimulates salivation giving the perception of increased juiciness of meat whilst chewing. This is in agreement with earlier studies that found different fat levels play an important role in juiciness and acceptability (Cross, Berry, & Wells, 1980; Savell et al., 1989), which may have been the reason why Tudanca veal tended to show improved sensory scores (Table 2). In contrast, Dikeman (1987) reviewed the literature on the relationship between marbling and tenderness and reported that marbling accounted for only 5 % to 10 % of the variability in beef palatability. In another extensive study, Wheeler, Cundiff and Koch (1994) evaluated 1667 steers and heifers and concluded that marbling explained at most 5% of the variation in palatability traits.

The content and composition of specific FAs in meats has generally been an important factor in assessing its nutritional quality. Of particular interest has been the type of *trans* FAs present (Leheska et al., 2008; Aldai et al., 2009), the content of LC-PUFAs specifically EPA and DHA, the type and amount of CLA, and the level of SFAs. Each will be discussed in turn between these two breeds. The higher intramuscular fat content in Tudanca compared to the Limousin (Table 3) affected the comparisons of all FAs (De Smet, Raes, & Demeyer, 2004),

and for that reason both, the amount of selected FAs (or FA groups) per serving size (100 g of meat), as well as their relative compositions, are presented. The FA composition of the meat in this study could have been the result of cow's milk composition, the supplement available to the calves after 80 days of age, and any subsequent metabolism or synthesis of dietary FAs in the calves. In fact, Lavín et al. (2011a) showed that Limousin calves consumed significantly higher amounts of concentrate (346 Kg/head) over the period from 80 days to 7 months when concentrate was available to the calves than the Tudanca calves (253 Kg/head) over the same time period.

It is well known that during the early stage of development the reticular groove in calves is normally closed, delivering suckled milk directly into the abomasum bypassing the rumen (Ørskov, Benzie, & Kay, 1970; Hornick, Clinquart, Van Eenaeme, Diez, & Istasse, 1996). We hypothesize that would, in part, explain the presence of *trans* FAs in veal since the calves derived their complete diet during the initial suckling period from the cow's milk. Among the *trans*-FAs, VA (11*t*-18:1) would have been the predominant *trans*-18:1 isomer in the milk because the dams of both breeds were exclusively pasture-fed with no access to concentrate at any time. And, in the absence of a fully functioning rumen in the calves, the FA composition of cow's milk would not be expected to be altered by rumen bacteria. After 80 days of age, all calves had free access to concentrate that provided them with dietary 18:2n-6 and 18:3n-3 from the barley and soybean meal and oil in the diet. These PUFAs could be converted to either 11*t*- and/or 10*t*-18:1 in the developing rumen of the calves, depending on the amount of concentrate consumed. A 10*t*- shift, also expressed as a lower 11*t*-/10*t*-18:1 ratio, is well recognized when barley based diets are fed to ruminants because of its content of rapidly fermentable starch (Dugan et al., 2007; Aldai et al., 2010; Mohammed et al., 2010). Increased dietary PUFA are known to exacerbate the 10*t*- shift (Griinari et al., 1998; Cruz-Hernandez et al., 2007). The content of 10*t*-18:1 isomer tended to

be higher in Limousin compared to Tudanca meat when expressed as mg / 100 g of meat (Table 3), and that difference was significant when expressed in terms of relative percent (Figure 1). The higher level of 10*t*-18:1 was consistent with the greater consumption of concentrate by Limousin calves. The increased consumption of concentrate by the Limousin calves could have been a consequence of the lower milk production of their dams compared to Tudanca dams (personal communication). Moreover, Limousin calves were also larger in size. Tudanca calves were smaller in size (breed-related) and the milk production of their dams was greater decreasing their need for additional energy (Lavín et al., 2011a), which was also observed with other northern Spanish breeds (*e.g.*, Galician Blonde; Bispo et al., 2011). As a consequence, it could be hypothesized that Limousin calves would probably had a more developed rumen at the time of slaughter compared to Tudanca calves because of their higher consumption of concentrate and PUFAs. This would also explain the trend to higher level of 10*t*-18:1 (Figure 1, Table 3), lower 11*t*-/10*t*-18:1 ratio (Table 3), and higher ratios of n-6/n-3 PUFA and P/S (Table 3) compared to Tudanca beef (Table 3, Figure 1).

There were also differences in the relative amounts of several of the other *trans*-18:1 isomers. In Tudanca veal 11*t*-, 12*t*-, 13*t*/14*t*-, 15*t*- and 16*t*-18:1 were either numerically or statistically higher than in Limousin meat, while 6*t*/7*t*/8*t*-, 9*t*- and 10*t*-18:1 were higher in Limousin meat (Figure 1). At this time it is not possible to assess the health implication of each of all the individual *trans*-18:1 isomers apart from VA (11*t*-18:1), the major *trans*-18:1 isomer in both meats (Gebauer, Psota, & Kris-Etherton, 2007; Field, Blewett, Proctor, & Vine, 2009). For example, VA has been shown to suppress the development of premalignant lesions in rat mammary gland (Banni et al., 2001), and produce a hypocholesterolaemic effects in rabbits (Bauchart et al., 2007). It has been well established that the other *trans*-18:1 isomers are associated with negative health effects (Mensink, Zock, Kester, & Katan, 2003). Therefore, in view of our current understanding of the health effects of *trans* FAs, though

incomplete, one could conclude that the meat with the highest absolute quantities of VA and least absolute quantities of the other *trans*-18:1 isomers should be considered healthier.

It was interesting to note that neither the absolute nor the relative content of RA (9*c*11*t*-18:2) or total CLA were significantly different between these two breeds (Table 3 and 6). However, Tudanca meat had numerically, and occasionally significantly higher levels of NC-18:2 metabolites compared to the Limousin breed, whether expressed on an absolute (Table 3) and relative basis (Table 6). Jerónimo et al. (2011) recently showed that *trans* containing metabolites found in ruminants are preferentially incorporated into neutral lipids, which explains why there is little difference whether the results are presented as absolute or relative percent. Tudanca veal also provided significantly higher contents of recognized metabolites of LNA (18:3n-3) including dienes (9*c*,13*t*-18:2; Table 6), CLA (11*t*,13*c*-18:2; Figure 3) and monoenes (13*t*/14*t*-18:1; Figure 1). Other LNA recognized metabolites, even not statistically significant, were also numerically higher in Tudanca meat as identified in a number of other studies (Destaillats, Trottier, Galvez, & Angers, 2005; Bessa et al., 2007; Nassu et al., 2011). Potential health effects of all these new metabolites required further investigation (Dugan, Aldai, Aalhus, Rolland, & Kramer, 2011).

An evaluation of meats for its content of essential FA should involve an assessment of both the absolute and relative amounts of the n-6 and n-3 PUFAs and the LC-PUFA metabolites derived from 18:2n-6 and 18:3n-3 (Gebauer, Harris, Kris-Etherton, & Etherton, 2005). The n-3 LC-PUFAs are of special interest because of the limited conversion of 18:3n-3 to 22:6n-3 in humans (Barcelo-Coblijn & Murphy 2009), and the need to find alternate sources of n-3 LC-PUFAs other than marine products because of increased demand, decreasing availability, and concern about contamination (Hibbeln et al., 2007; Brunner, Jones, Friel, & Bartley, 2009). In general, the content of n-3 PUFAs in beef meat is low even when they are pasture-fed that is high in 18:3n-3 (De Smet et al., 2004; Scollan et al., 2006),

because of extensive rumen biohydrogenation (Harfoot & Hazlewood, 1997). However, the results of this study showed that the content of total n-3 PUFAs, 18:3n-3, and the n-3 LC-PUFA 20:5n-3 and 22:5n-3 in the meat was significantly higher in the Tudanca compared to the Limousin breed, except for 22:6n-3 (Table 3). This breed difference in the n-3 FAs content of meat, except 22:6n-3, were unlikely due to the concentrate available to both calves, since it was not particularly high in 18:3n-3 (3.3 %; 2.1. section). In fact, Limousin calves who consumed more concentrate (Lavín et al., 2011a) still had less 18:3n-3 in their meat compared to Tudanca calves (Table 3). This would support the hypothesis that these breed differences could be primarily due to differences in milk consumption and its fat composition, which was the main source of food for these calves. Perhaps a bigger substitution effect of concentrates in Limousin calves could have been another reason to explain a higher L* values in Limousin meat as reported by Realini, Duckett, Brito, Dalla Rizza, & De Mattos (2004) when pasture versus concentrate fed beef was compared.

The fact that there were no differences in the content of 22:6n-3 in meat between breeds appears to indicate that the metabolism of 18:3n-3 to 22:6n-3 was low in both, cows and calves. It is difficult to assess whether there are differences in the *de novo* desaturation and chain elongation of 18:3n-3 between these two breeds that could have contributed to differences in the n-3 LC-PUFA in meat, since Tudanca had a significantly higher FAME content than Limousin beef (2039 mg compared to 1191 mg per 100 g meat; Table 3). A comparison of 18:3n-3 and its long-chain metabolites shows that all of them were significantly higher in 100 g of Tudanca than in Limousin veal (Figure 2). However, the quantitative ratio of n-3 LC-PUFA to 18:3n-3 is greater in Limousin (1.9) than in Tudanca (1.4) (Table 3), which would suggest a higher conversion rate of 18:3n-3 to n-3 LC-PUFA in Limousin than in Tudanca, provided none of the n-3 LC-PUFA were diet derived. When the FAs were expressed as percent of total FAMEs, the reverse trend was evident (Table 6).

Higher levels of fat in meats are generally due to increased levels of neutral rather than phospholipids, while LC-PUFAs are mainly associated with the phospholipid fraction in beef muscle (Fritsche, Rumsey, Yurawecz, Ku, & Fritsche, 2001). This would explain the decreases in the relative proportion of the LC-PUFAs in Tudanca meat when expressed on a percentage basis (Table 6).

Similar breed differences were observed when 18:2n-6 and the n-6 LC-PUFAs were compared. Tudanca veal tended to have higher levels of these FAs in 100 g of meat than were found in Limousin veal (Figure 2), but those differences were smaller when these FAs were expressed as percent of total FAMEs (Table 6). The n-6/n-3 PUFA and LC-PUFA ratios were generally lower in Tudanca compared to Limousin meat (Table 3). Therefore, based on the amount of n-3 LC-PUFA and their n-6/n-3 in the meats, the Tudanca appears to provide a meat with a healthier FA profile. On the other hand, the Limousin breed, known for their high muscle and low adipocyte cells, had a lower content of LC-PUFA compared to the Tudanca both in absolute (Table 3) and relative amount (Figure 2), which appears to be related to the lower total fat content in that breed. The age of the animals could also be a factor that might explain the low LC-PUFA content in the calves. Potential differences between calves and mature animals in terms of adipocity, muscle density, desaturation and elongation capacity, and final FA profile of meat was previously demonstrated between Limousin and several other beef cattle breeds (Mendizabal et al., 1999; Kraft, Kramer, Schoene, Chambers, & Jahreis, 2008). To establish differences in the *de novo* desaturation and chain elongation between these calves would require an assessment of the conversion of the two essential FA families by the Δ^6- and Δ^5-elongases.

The fat in meat from ruminants is known to be high in SFA, but it also has a wider range of different chain length FAs compared to other meats (Woods & Fearon, 2009). Since the individual SFA cause different serum lipid responses (Mensink et al., 2003), the

composition of SFAs needs to be considered as well as their interaction with other dietary FAs. For instance, the main SFA in veal was 16:0 that has generally been implicated in increasing total and low density lipoprotein cholesterol concentrations. However, it was shown that this effect was reversed in the presence of an adequate supply of 18:2n-6 in the human diet (Clandinin, Cook, Konrad, & French, 2000). Furthermore, 18:0 that comprises about one third of the SFAs in calf meats (33 % in Tudanca and 36 % in Limousin), is a FA known to lower total cholesterol and show a favorable total : HDL cholesterol ratio (Mensink et al., 2003). The high content of 18:0 in these meats appears to be related to the high consumption of milk by the calves from cows that were solely pasture-fed (Enser et al., 1998). Tudanca cows produce more milk than Limousin cows, and are thus able to provide their calves with more milk. The higher milk consumption would also be consistent with the backfat color in Tudanca carcasses possibly due to the carotenoid pigments from the milk obtained from the pasture-fed cows (Yang, Larsen, & Tume, 1992).

Meat has additional minor lipid components such as the BCFAs. Higher levels of BCFAs typically result when readily fermentable carbohydrate sources are available, causing an increase in propionate production (Wood, 1984). It seemed that the level of concentrate ingested by the animals in the present study was not enough to provide differences in the BCFA percentages (Table 4). The plasmalogenic lipids are also minor lipid constituents present in beef. Previous results reported that the Limousin breed studied under intensive feeding conditions showed the highest relative percent of plasmalogenic lipid among the four breeds examined, but not on an absolute basis (Kraft et al., 2008). In the current study, veal from the Limousin breed did not show higher levels of plasmalogenic lipids on absolute bases (Table 3), but the difference was significant when expressed in relative amounts (Table 4). Differences on the percent basis would be expected since plasmalogens occur primarily as phospholipids (Horrocks, 1972), and the lean Limousin meat would be higher in these polar

lipids. The results of this study also showed the presence of *trans* double bonds in the aldehyde moiety of the plasmalogenic lipids, evidenced by the presence of 11*t*-18:1 DMA (Table 4). These findings are consistent with those reported by Wolff (2002), and later confirmed by Kraft et al. (2008) and Aldai et al. (2011).

When assessing the overall nutritional value of meat, health regulatory agencies are recognizing that there are inherent limitations when only specific FAs or FA groups are considered in developing dietary recommendations (FAO, 2010). FAs with unique biological properties and health effects also need to be assessed in terms of the energy intake of individuals, and their relationship to the whole diet consumed. In the case of these veal products, this includes the physical properties of the meat discussed above, and other nutrients not assessed such as protein quality and the mineral content. For instance, it is evident that one serving size of 100 g of fresh meat alone does not meet the recommended intake of 5-8 % of daily energy for n-6 and 1-2 % of energy for n-3 PUFA (FAO/WHO, 2003; Gebauer et al., 2005). However, veal contributes to the total n-6 (about 120 mg) and n-3 PUFA content (about 40 mg), and more importantly to the n-6 (about 30 mg) and n-3 LC-PUFA content (about 20 mg). Furthermore, veal from both breeds have a favorable balance of total n-6 to n-3 PUFAs of less than 2.8, and an n-6/n-3 LC-PUFA ratio of less than 1.2 (Table 3), which is below the recommended ratio of 5:1 or 3:1. But in each assessment, Tudanca veal provided more of these essential FAs than Limousin veal and a slightly better ratio.

Currently the *trans* issue is of special concern. Most regulatory agencies have excluded ruminant meat or dairy products from mandatory labeling of the *trans* FA content based on the absence of a negative response for VA (11*t*-18:1) and RA (9*c*,11*t*-18:2) to changes in serum lipoproteins (Department of Health and Human Services, U.S. Food and Drug Administration. 2003; Department of Health, 2003; Health Canada, 2006).

Furthermore, there is an assumption that the main *trans*-18:1 isomer in ruminant fats is VA and the major CLA isomer is RA, and both of these FAs have reported beneficial effects (Gebauer et al., 2007; Field et al., 2009). However, this assumption may not be valid under some feeding practices when ruminants are fed high concentrate diets (Dugan et al., 2007; Leheska et al., 2008; Aldai et al., 2009). If total *trans* from ruminant fats would need to be declared per serving size, the total *trans* would be 138 mg and 75 mg for Tudanca and Limousin meat, respectively (Table 3). Even including VA, the total *trans* would be below the *trans* regulation limits of 0.2 g per serving size in Canada and 0.5 g per serving size in the USA.

5. Conclusions

From the present study it can be concluded that even though most carcass parameters of Limousin calves are better, the meat obtained from Tudanca calves tend to have an improved sensorial acceptability with a better FA profile especially in terms of the content of highly unsaturated long-chain fatty acid metabolites, vaccenic and rumenic acids, as well as the ratio of n-6/n-3 highly unsaturated fatty acids, and overall *trans*-18:1 isomer profile. In general, meat obtained from calves under the described mountain production system, is of high nutritional quality according to the present nutritional guidelines. Interestingly, considering the amount of concentrate consumed by these calves (2.6 Kg/day/head Limousin vs 2.1 Kg/day/head Tudanca cross), the price of cereals, and lack of fat cover degree differences obtained between the studied genotypes, it might be concluded that Limousin calves, being a late-maturing breed, could be a more suitable option if heavier carcass is the target or meat quality parameters are not taken into consideration.

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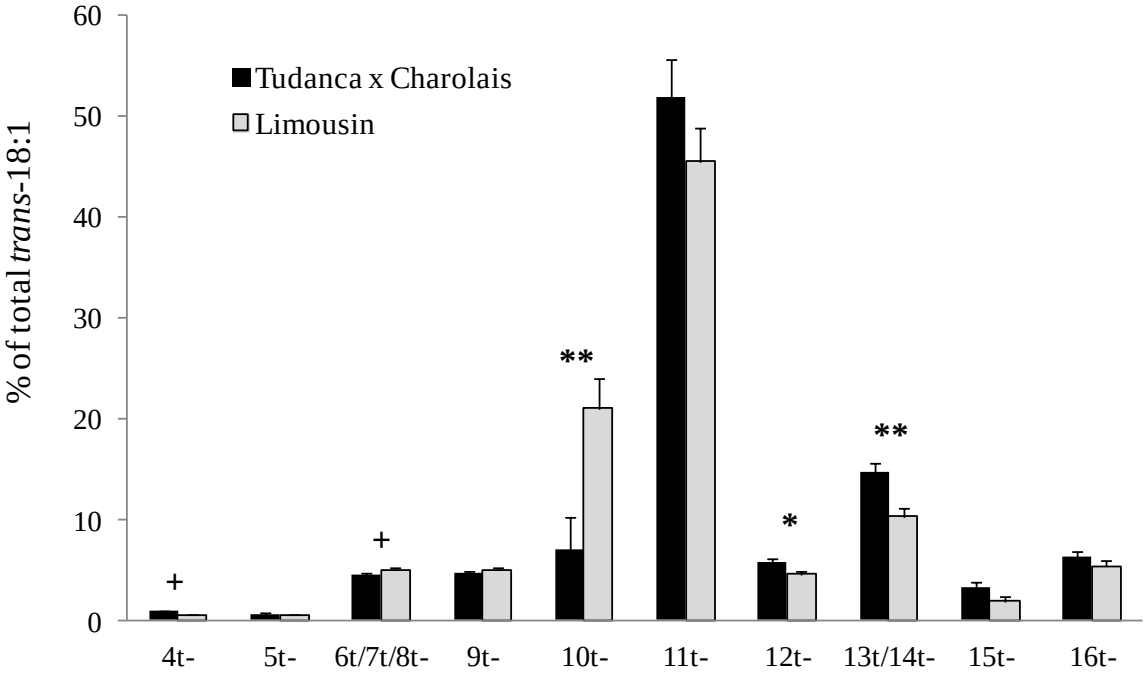
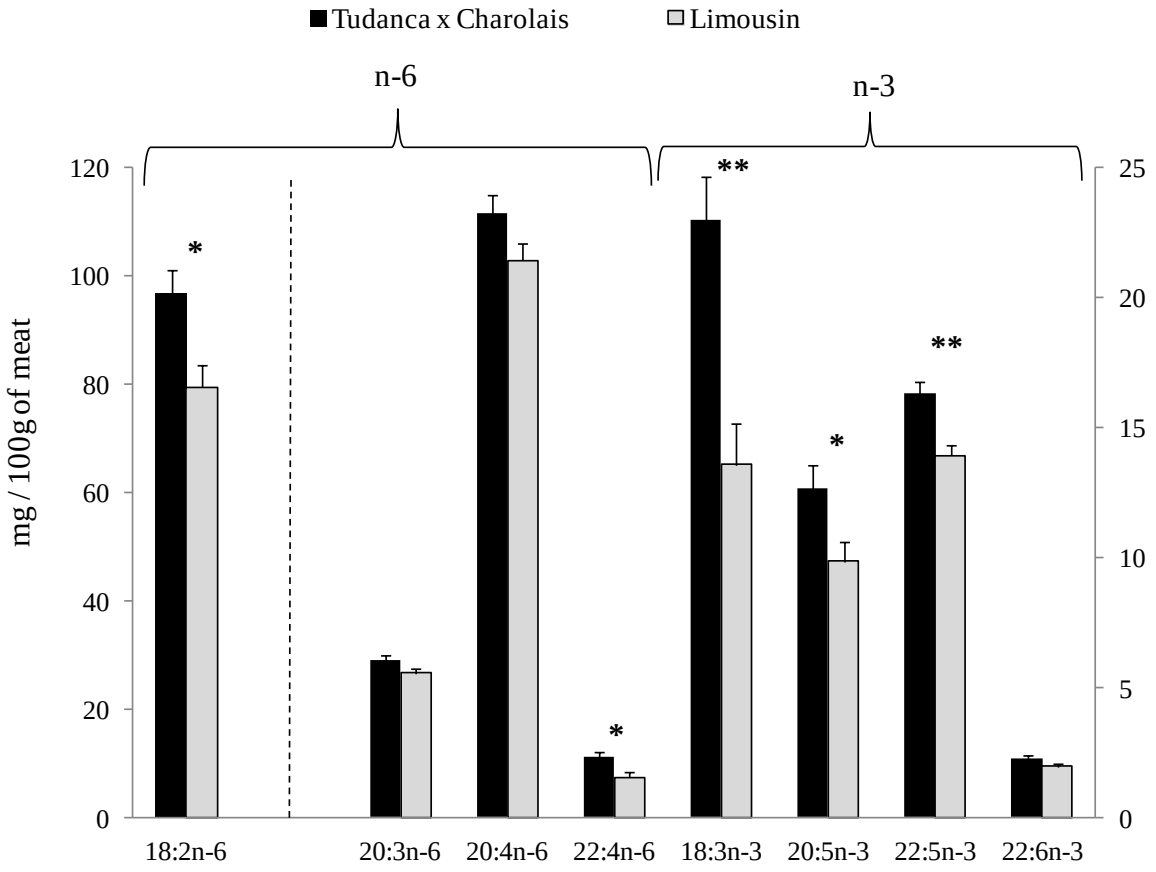
Figure 1. Effect of breed ('Tudanca x Charolais' cross and Limousin) on the relative isomeric distribution of individual *trans*-18:1 isomers in the *longissimus thoracis et lumborum* muscle of calves (n = 6 per breed)[1].



[1]Mean values and standard error.

**, $P<0.01$; *, $P<0.05$; +, $P<0.1$.

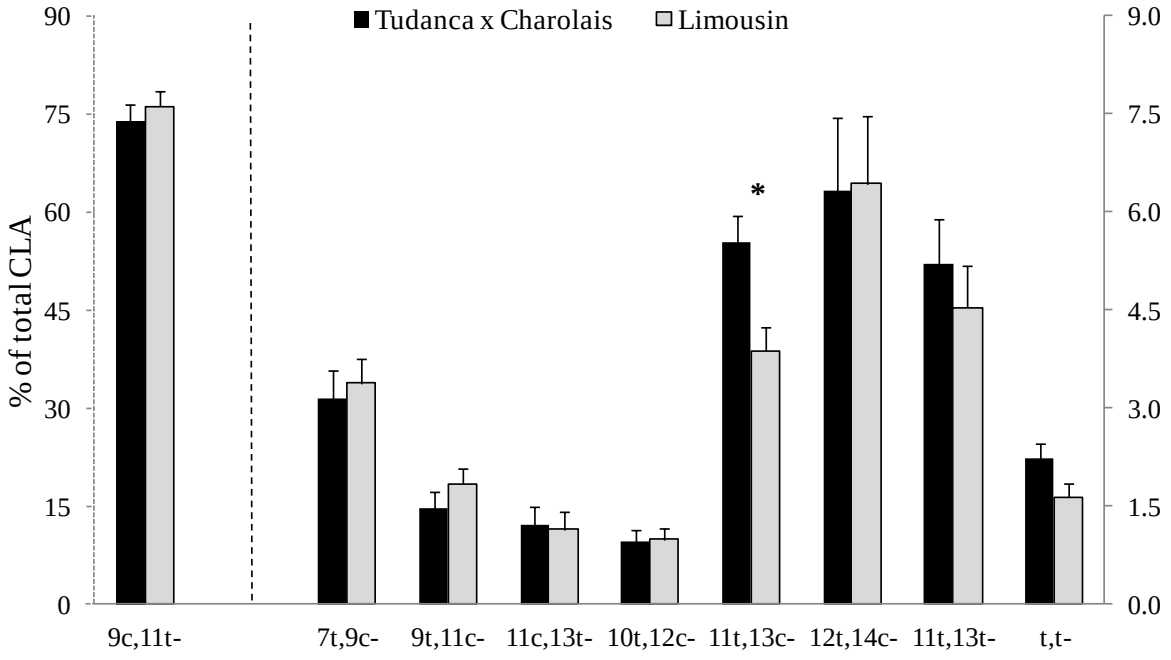
Figure 2. Effect of breed ('Tudanca x Charolais' cross and Limousin) on the distribution of selected n-6 and n-3 PUFA and LC-PUFA (mg / 100 g of meat) in the *longissimus thoracis et lumborum* muscle of calves (n = 6 per breed)[1]. Linoleic acid (18:2n-6) is been represented in the primary or left axis, while other FAMEs are represented in the secondary or right axis.



[1]Mean values and standard error. FAME, fatty acid methyl ester; PUFA, polyunsaturated fatty acid; LC-PUFA, long-chain PUFA.

**, $P<0.01$; *, $P<0.05$.

Figure 3. Effect of breed ('Tudanca x Charolais' cross and Limousin) on the relative isomeric distribution of individual CLA isomers in the *longissimus thoracis et lumborum* muscle of calves (n = 6 per breed)[1]. Rumenic acid (9*c*,11*t*-18:2) is been represented in the primary or left axis, while other CLA isomers are represented in the secondary or right axis.



[1]Mean values and standard error. CLA, conjugated linoleic acid.

*, $P<0.05$.

Table 1. Effect of breed ('Tudanca x Charolais' cross and Limousin) on live weight at slaughter and carcass measurements at 24 hours *post-mortem* of calves (n = 6 per breed)[1].

	Tudanca x Charolais	**Limousin**	***P* value**
Live weight at slaughter (Kg)	255.80 ± 10.50	318.00 ± 14.53	0.009
Cold carcass weight (Kg)	144.00 ± 8.32	192.50 ± 9.52	0.005
Carcass yield (%)	56.16 ± 1.24	60.51 ± 0.69	0.011
Carcass length (cm)	106.80 ± 1.50	105.00 ± 1.84	0.480
Compactness index (Kg/cm)	1.37 ± 0.06	1.87 ± 0.07	0.001
Conformation[+]	6.60 ± 0.40	10.50 ± 0.43	<0.001
Fat cover degree[++]	5.00 ± 0.00	4.33 ± 0.49	0.254
pH, LTL	5.68 ± 0.07	5.45 ± 0.06	0.100
L, pectoralis profundus*	36.33 ± 1.49	42.45 ± 0.94	0.002
*a**	13.21 ± 0.83	14.61 ± 0.33	0.076
*b**	3.99 ± 0.72	5.50 ± 0.59	0.128
*L**, subcutaneous fat	69.46 ± 1.26	69.77 ± 1.12	0.856
*a**	4.07 ± 0.46	1.88 ± 0.34	0.001
*b**	13.26 ± 0.87	11.19 ± 1.06	0.151

[1]Mean values ± standard error.

LTL, *longissimus thoracis et lumborum*.

[+] 1 to 18 scale (18 being the best conformation).

[++] 1 to 15 scale (15 being the thickest fat cover).

Table 2. Effect of breed ('Tudanca x Charolais' cross and Limousin) on boxed beef percentage and meat quality attributes of the *longissimus thoracis et lumborum* muscle of calves after 11 days of ageing (n = 6 per breed)[1].

	Tudanca x Charolais	**Limousin**	***P* value**
Boxed beef (%)	77.55 ± 0.88	79.56 ± 1.03	0.161
Drip loss (%)	2.34 ± 0.33	1.90 ± 0.27	0.311
*L**, LTL	43.30 ± 0.24	47.14 ± 0.59	<0.001
*a**	11.99 ± 0.38	7.99 ± 0.82	0.001
*b**	4.25 ± 0.22	5.25 ± 0.37	0.037
Moisture (%)	75.59 ± 0.14	75.86 ± 0.22	0.353
Ether extract (%)	2.46 ± 0.38	1.44 ± 0.11	0.022
Crude protein (%)	21.74 ± 0.34	22.19 ± 0.61	0.555
Ash (%)	1.37 ± 0.04	1.29 ± 0.03	0.201
Shear force (Kg)	3.94 ± 0.31	5.10 ± 0.30	0.026
Odour intensity[+]	3.88 ± 0.07	3.59 ± 0.08	0.022
Tenderness[+]	4.50 ± 0.13	4.02 ± 0.19	0.077
Juiciness[+]	4.00 ± 0.23	3.38 ± 0.20	0.072
Flavour intensity[+]	3.91 ± 0.03	3.77 ± 0.06	0.077
Overall acceptabilily[+]	4.18 ± 0.07	3.79 ± 0.17	0.081

[1]Mean values ± standard error.

LTL, *longissimus thoracis et lumborum*.

[+] Sensory parameters: a scale from 1 (low) to 5 (high) was used.

Table 3. Effect of breed ('Tudanca x Charolais' cross and Limousin) on total FAME content (mg / 100 g meat) and summary of FAMEs and ratios of nutritional interest (mg / 100 g meat) in the *longissimus thoracis et lumborum* muscle of calves (n = 6 per breed)[1].

Fatty acids (mg/100g)	Tudanca x Charolais	Limousin	*P* value
FAME	2039.41 ± 185.03	1190.51 ± 168.91	0.008
SFA	971.06 ± 105.91	513.03 ± 96.68	0.011
BCFA	37.31 ± 4.71	20.39 ± 4.30	0.026
AME&DMA	64.40 ± 1.07	61.63 ± 0.97	0.088
MUFA	753.48 ± 69.70	431.64 ± 63.62	0.008
cis-MUFA	639.21 ± 56.74	367.06 ± 51.80	0.006
trans-MUFA	114.27 ± 14.00	64.59 ± 12.78	0.028
10*t*-18:1	7.22 ± 1.41	11.33 ± 1.28	0.059
11*t*-18:1	56.63 ± 9.56	27.77 ± 8.72	0.053
11*t*-/10*t*-18:1	7.64 ± 1.17	3.05 ± 1.06	0.017
PUFA	186.77 ± 6.71	150.02 ± 6.12	0.003
n-6	130.88 ± 5.01	109.75 ± 4.57	0.012
18:2n-6	96.82 ± 4.27	79.50 ± 3.90	0.015
n-3	54.83 ± 2.53	39.69 ± 2.31	0.002
18:3n-3	22.95 ± 1.71	13.58 ± 1.56	0.003
n-6/n-3	2.41 ± 0.13	2.78 ± 0.12	0.060
LC-PUFA	64.94 ± 1.97	55.69 ± 1.80	0.007
n-6 LC-PUFA	33.07 ± 0.96	29.59 ± 0.88	0.025
20:4n-6	23.23 ± 0.73	21.43 ± 0.67	0.103
n-3 LC-PUFA	31.88 ± 1.19	26.11 ± 1.09	0.006
20:5n-3	12.68 ± 0.87	9.84 ± 0.79	0.038
22:5n-3	16.30 ± 0.45	13.92 ± 0.41	0.003
22:6n-3	2.25 ± 0.14	1.97 ± 0.12	0.161
n-6/n-3 LC-PUFA	1.04 ± 0.03	1.14 ± 0.03	0.060
P/S	0.21 ± 0.04	0.31 ± 0.03	0.048
CLA	27.88 ± 5.38	17.29 ± 4.91	0.180
9*c*,11*t*-18:2	21.18 ± 4.73	13.47 ± 4.32	0.259
NC-18:2	22.11 ± 2.38	9.62 ± 2.17	0.004
trans FA	138.20 ± 16.43	75.24 ± 15.00	0.020

[1]Mean values ± standard error. FAME, fatty acid methyl ester; SFA, saturated fatty acid; BCFA, branched-chain fatty acid; AME, alk-1-enyl methyl ether; DMA, dimethyl acetal; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; LC-PUFA, long-chain PUFA; CLA, conjugated linoleic acid; NC-18:2, non-conjugated 18:2 acid.

See Tables 4, 5, and 6 for group details.

Table 4. Effect of breed ('Tudanca x Charolais' cross and Limousin) on SFAs, BCFAs and plasmalogenic lipids in the *longissimus thoracis et lumborum* muscle of calves (n = 6 per breed)[1].

Moiety (%)	Tudanca x Charolais	Limousin	*P* value
10:0	0.12 ± 0.02	0.08 ± 0.01	0.120
12:0	0.24 ± 0.03	0.17 ± 0.02	0.063
13:0	0.05 ± 0.06	0.11 ± 0.05	0.462
14:0	4.11 ± 0.35	3.21 ± 0.32	0.092
15:0	0.61 ± 0.06	0.63 ± 0.05	0.811
16:0	21.70 ± 0.45	21.12 ± 0.41	0.361
17:0	0.90 ± 0.03	0.99 ± 0.03	0.061
18:0	17.11 ± 0.90	14.21 ± 0.83	0.042
19:0	0.09 ± 0.01	0.07 ± 0.01	0.068
20:0	0.12 ± 0.01	0.12 ± 0.01	0.818
21:0	0.07 ± 0.01	0.05 ± 0.01	0.128
22:0	0.07 ± 0.004	0.08 ± 0.004	0.498
24:0	0.07 ± 0.01	0.09 ± 0.01	0.139
*iso*14:0	0.10 ± 0.01	0.09 ± 0.01	0.447
*iso*15:0	0.21 ± 0.02	0.17 ± 0.02	0.120
*anteiso*15:0	0.28 ± 0.03	0.26 ± 0.03	0.575
*iso*16:0	0.23 ± 0.02	0.22 ± 0.02	0.650
*iso*17:0	0.38 ± 0.03	0.36 ± 0.02	0.555
*anteiso*17:0	0.46 ± 0.03	0.43 ± 0.03	0.407
*iso*18:0	0.14 ± 0.01	0.13 ± 0.01	0.633
15:0DMA	0.05 ± 0.01	0.08 ± 0.005	0.003
16:0AME	0.05 ± 0.01	0.06 ± 0.01	0.423
16:0DMA	1.54 ± 0.23	2.79 ± 0.21	0.003
9*c*-16:1DMA	0.09 ± 0.01	0.13 ± 0.01	0.022
11*c*-16:1DMA	0.09 ± 0.01	0.14 ± 0.01	0.015
17:0DMA	0.15 ± 0.01	0.23 ± 0.01	0.003
18:0DMA	0.98 ± 0.12	1.37 ± 0.11	0.043
11*t*-18:1DMA	0.09 ± 0.01	0.13 ± 0.01	0.004
9*c*-18:1DMA	0.31 ± 0.05	0.43 ± 0.05	0.112
16:0 ALDE	0.07 ± 0.02	0.13 ± 0.02	0.044
18:0 ALDE	0.05 ± 0.01	0.05 ± 0.01	0.755
17:0-cyclo[2]	0.10 ± 0.01	0.07 ± 0.01	0.004
SFA	47.08 ± 1.36	42.57 ± 1.24	0.037
BCFA	1.81 ± 0.13	1.66 ± 0.12	0.423
AME&DMA	3.34 ± 0.43	5.35 ± 0.39	0.007
ALDE	0.12 ± 0.02	0.18 ± 0.02	0.089

[1]Mean values ± standard error.

[2]Cyclohexylundecanoic acid.

SFA, saturated fatty acid: sum of 10:0, 12:0, 13:0, 14:0, 15:0, 16:0, 17:0, 18:0, 19:0, 20:0, 21:0, 22:0, 24:0, *iso*14:0, *iso*15:0, *anteiso*15:0, *iso*16:0, *iso*17:0, *anteiso*17:0, *iso*18:0.

BCFA, branched-chain fatty acid: sum of *iso*14:0, *iso*15:0, *anteiso*15:0, *iso*16:0, *iso*17:0, *anteiso*17:0, *iso*18:0.

AME, alk-1-enyl methyl ether & DMA, dimethyl acetal: sum of 15:0DMA, 16:0AME, 16:0DMA, 9*c*-16:1DMA, 11*c*-16:1DMA, 17:0DMA, 18:0DMA, 11*t*-18:1DMA, 9*c*-18:1DMA.

ALDE, aldehyde: sum of 16:0 aldehyde, 18:0 aldehyde.

Table 5. Effect of breed ('Tudanca x Charolais' cross and Limousin) on *cis*- and *trans*-MUFAs (% of total FAME) in the *longissimus thoracis et lumborum* muscle of calves (n = 6 per breed)[1].

Fatty acids (%)	Tudanca x Charolais	Limousin	*P* value
9*c*-14:1	0.37 ± 0.05	0.49 ± 0.05	0.133
7*c*-16:1[2]	0.31 ± 0.02	0.31 ± 0.01	0.995
9*c*-16:1[3]	1.86 ± 0.08	1.84 ± 0.08	0.886
11*c*-16:1	0.08 ± 0.01	0.09 ± 0.01	0.320
12*c*-16:1	0.08 ± 0.01	0.05 ± 0.01	0.049
13*c*-16:1	0.07 ± 0.01	0.07 ± 0.01	0.607
7*c*-17:1	0.09 ± 0.01	0.09 ± 0.01	0.599
9*c*-17:1	0.43 ± 0.03	0.58 ± 0.03	0.010
9*c*-18:1[4]	25.87 ± 0.28	24.88 ± 0.26	0.030
11*c*-18:1	1.17 ± 0.09	1.44 ± 0.08	0.048
12*c*-18:1	0.22 ± 0.02	0.20 ± 0.02	0.404
13*c*-18:1	0.12 ± 0.01	0.16 ± 0.01	0.050
14*c*-18:1	0.09 ± 0.02	0.02 ± 0.02	0.060
15*c*-18:1	0.18 ± 0.01	0.15 ± 0.01	0.051
16*c*-18:1	0.08 ± 0.01	0.05 ± 0.01	0.007
11*c*-19:1	0.05 ± 0.01	0.06 ± 0.01	0.484
9*c*-20:1	0.10 ± 0.01	0.09 ± 0.01	0.702
11*c*-20:1[5]	0.09 ± 0.01	0.11 ± 0.005	0.021
15*c*-24:1[6]	0.05 ± 0.01	0.06 ± 0.01	0.581
cis-16:1	2.43 ± 0.09	2.38 ± 0.09	0.702
cis-18:1	27.72 ± 0.26	26.89 ± 0.23	0.041
cis-MUFA	31.39 ± 0.30	30.80 ± 0.27	0.168
trans-16:1	0.38 ± 0.03	0.44 ± 0.03	0.159
10*t*-18:1	0.36 ± 0.14	1.01 ± 0.13	0.008
11*t*-18:1	2.68 ± 0.31	2.24 ± 0.28	0.319
trans-18:1	5.08 ± 0.29	4.88 ± 0.26	0.620
trans-MUFA	5.51 ± 0.30	5.36 ± 0.27	0.711
MUFA	36.91 ± 0.34	36.15 ± 0.31	0.139
trans-FA	6.68 ± 0.34	6.25 ± 0.31	0.370

[1]Mean values ± standard error. FAME, fatty acid methyl ester.

Coelutions: [2]13*t*/14*t*-16:1, [3]phytanic acid, [4]10*c*-18:1, [5]*t*-20:1, and [6]*t*-20:1.

MUFA, monounsaturated fatty acid: sum of *cis*- and *trans*-MUFA.

cis-MUFA: sum of 9*c*-14:1, 9*c*-15:1, 7*c*-16:1, 9*c*-16:1, 10*c*-16:1, 11*c*-16:1, 12*c*-16:1, 13*c*-16:1, 7*c*-17:1, 9*c*-17:1, 11*c*-17:1, 9*c*-18:1, 11*c*-18:1, 12*c*-18:1, 13*c*-18:1, 14*c*-18:1, 15*c*-18:1, 16*c*-18:1, 11*c*-19:1, 9*c*-20:1, 11*c*-20:1, 15*c*-24:1.

trans-MUFA: sum of 6*t*/7*t*/8*t*-16:1, 9*t*-16:1, 10*t*-16:1, 11*t*-16:1, 4*t*-18:1, 5*t*-18:1, 6*t*/7*t*/8*t*-18:1, 9*t*-18:1, 10*t*-18:1, 11*t*-18:1, 12*t*-18:1, 13*t*/14*t*-18:1, 15*t*-18:1, 16*t*-18:1, *t*-20:1.

trans FA: *trans*-MUFA plus other non-conjugated (*t*,*t*-/*c*,*t*)-18:2.

Table 6. Effect of breed ('Tudanca x Charolais' cross and Limousin) on PUFA, LC-PUFA, CLA and NC-18:2 isomers (% of total FAME) in the *longissimus thoracis et lumborum* muscle of calves (n = 6 per breed)[1].

Fatty acids (%)	Tudanca x Charolais	Limousin	*P* value
PUFA	9.58 ± 1.14	13.09 ± 1.04	0.049
20:3n-9	0.05 ± 0.01	0.05 ± 0.01	0.563
18:2n-6	4.96 ± 0.63	6.94 ± 0.57	0.045
18:3n-6	0.05 ± 0.01	0.06 ± 0.01	0.340
20:2n-6	0.06 ± 0.01	0.07 ± 0.01	0.267
20:3n-6	0.31 ± 0.04	0.48 ± 0.04	0.019
20:4n-6	1.21 ± 0.19	1.88 ± 0.17	0.027
22:2n-6	0.02 ± 0.003	0.02 ± 0.002	0.402
22:4n-6	0.11 ± 0.01	0.14 ± 0.01	0.250
n-6	6.72 ± 0.87	9.59 ± 0.79	0.037
18:3n-3	1.15 ± 0.08	1.17 ± 0.07	0.879
20:3n-3	0.03 ± 0.003	0.03 ± 0.002	0.918
20:5n-3	0.66 ± 0.10	0.86 ± 0.09	0.181
22:5n-3	0.85 ± 0.11	1.22 ± 0.10	0.038
22:6n-3	0.12 ± 0.02	0.18 ± 0.02	0.087
n-3	2.81 ± 0.30	3.45 ± 0.28	0.148
LC-PUFA	3.37 ± 0.47	4.87 ± 0.43	0.041
n-6 LC-PUFA	1.71 ± 0.25	2.59 ± 0.23	0.027
n-3 LC-PUFA	1.66 ± 0.23	2.28 ± 0.21	0.073
9*c*,11*t*-18:2	1.00 ± 0.17	1.09 ± 0.16	0.705
CLA	1.32 ± 0.18	1.41 ± 0.16	0.714
t,*t*-18:2	0.08 ± 0.02	0.06 ± 0.02	0.475
t,*t*-18:2	0.07 ± 0.01	0.05 ± 0.01	0.098
9*c*,13*t*-/8*t*,12*c*-18:2	0.28 ± 0.01	0.18 ± 0.01	<0.001
8*t*,13*c*/9*c*,12*t*-18:2	0.17 ± 0.01	0.12 ± 0.005	<0.001
9*t*,12*c*-18:2	0.06 ± 0.01	0.05 ± 0.005	0.198
11*t*,15*c*-18:2	0.33 ± 0.04	0.27 ± 0.03	0.250
9*c*,15*c*-18:2	0.05 ± 0.01	0.05 ± 0.01	0.589
NC-18:2	1.08 ± 0.05	0.80 ± 0.05	0.003

[1]Mean values ± standard error. FAME, fatty acid methyl ester.

PUFA, polyunsaturated fatty acid: sum of 20:3n-9, 18:2n-6, 18:3n-6, 20:2n-6, 20:3n-6, 20:4n-6, 22:2n-6, 22:4n-6, 18:3n-3, 20:3n-3, 20:5n-3, 22:5n-3, 22:6n-3.

n-6, sum of 18:2n-6, 18:3n-6, 20:2n-6, 20:3n-6, 20:4n-6, 22:2n-6, 22:4n-6.

n-3, sum of 18:3n-3, 20:3n-3, 20:5n-3, 22:5n-3, 22:6n-3.

LC-PUFA, long-chain PUFA: sum of 20:2n-6, 20:3n-6, 20:4n-6, 22:2n-6, 22:4n-6, 20:3n-3, 20:5n-3, 22:5n-3, 22:6n-3.

n-6 LC-PUFA, sum of 20:2n-6, 20:3n-6, 20:4n-6, 22:2n-6, 22:4n-6.

n-3 LC-PUFA, sum of 20:3n-3, 20:5n-3, 22:5n-3, 22:6n-3.

CLA, conjugated linoleic acid: sum of 9*c*,11*t*-18:2, 7*t*,9*c*-18:2, 9*t*,11*c*-18:2, 11*c*,13*t*-18:2, 10*t*,12*c*-18:2, 11*t*,13*c*-18:2, 12*t*,14*c*-18:2, 11*t*,13*t*-18:2, *t*,*t*-18:2.

NC-18:2, non-conjugated 18:2 acid: sum of *t*,*t*-18:2 (2 different isomers), 9*t*,12*t*-18:2, 9*c*,13*t*-/8*t*,12*c*-18:2, 8*t*,13*c*-/9*c*,12*t*-18:2, 9*t*,12*c*-18:2, 11*t*,15*c*-18:2, 9*c*,15*c*-18:2.

Highlights

- Veal production in mountain areas using an economically more profitable production system for local producers.
- Genotype comparison (Tudanca x Charolais and Limousin) in mountain conditions: carcass and meat quality, sensory analysis and muscle fatty acid composition.
- Very few differences on carcass and meat quality between genotypes.
- Veal obtained from Tudanca x Charolais tended to be more acceptable according to the sensory panel and provided nutritionally healthier profile in terms of *trans*-18:1, CLA and polyunsaturated fatty acids.