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Effect of ageing time on beef quality of rustic type and rustic x Charolais crossbreed cattle slaughtered at the same finishing grade

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Abstract

The objective was to determine the effect of ageing period on beef meat from young bulls of a rustic genotype (Morucha) and an improved crossbreed (Charolais x Morucha). The ageing periods were 3, 7, 10, and 14 days. Carcass quality, pH, meat chemical composition, myoglobin content, colour, water-holding capacity, textural parameters (20%, 80% compression, and Warner-Bratzler test) and sensory characteristics were determined. Regarding carcass quality, better results were observed in crossbreed genotype than in Morucha pure breed. Myoglobin concentrations and a* values were higher in the rustic pure breed than in the crossbreed. Although no differences were observed between genotypes in cooking losses, crossbreed animals provided higher values in thawing losses. Textural parameters did not differ significantly between genotypes. For both genotypes 20% compression and Warner-Bratzler tests showed that longer ageing periods promoted more tender meat. However, sensory analysis indicated that meat from the rustic breed may require a longer ageing period than meat from the crossbreed.

Additional key words: beef tenderness, crossbreeding, texture.

Resumen

Efecto del periodo de maduración sobre la calidad de la carne de ganado rústico y su cruce con Charolés sacrificados al mismo grado de acabado

El objetivo de este estudio fue determinar el periodo óptimo de maduración en carne de vacuno procedente de animales de genotipo rústico (Morucha), y del cruce mejorante Morucha x Charolés. Se valoraron los siguientes parámetros: la calidad de la canal, el pH, la composición química del músculo, el contenido en mioglobina, el color, la capacidad de retención de agua, la textura de forma instrumental (compresión al 20% y 80% y test de Warner-Braztler) y las características sensoriales. En relación con la calidad de la canal, se obtuvieron mejores resultados en los animales cruzados que en los de raza Morucha en pureza. La concentración de mioglobina y el valor del índice de rojo fueron superiores en los animales de genotipo rústico que en los cruzados. Aunque no se encontraron diferencias en las pérdidas por cocinado, los animales cruzados dieron lugar a mayores pérdidas por congelación. Los parámetros de textura no reflejaron diferencias entre genotipos. Para ambos genotipos, la compresión al 20% y el test Warner-Braztler mostraron que periodos más largos de maduración daban lugar a carne más tierna. Sin embargo, el análisis sensorial indicó que la carne de los animales de raza rústica en pureza puede requerir periodos de maduración más largos que los de animales procedentes del cruce.

Palabras clave adicionales: cruzamiento, terneza en vacuno, textura.

Introduction

In some European areas, the natural constraints from the climate and the geography seem to be unfavourable for low cost mass meat production; so, alternatives for a profitable use of the territory are required. The use of local breeds produced under traditional systems and following quality trademark regulations could be an interesting alternative in these areas. In the case of Spain, one important Protected Geographical Indication is based on Morucha, a rustic breed traditionally

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reared in the Spanish wooded rangeland (*dehesa*) located in the western region of Spain. Morucha is used as a meat breed and is characterised by medium adult size, early maturation, high fat and a low lean meat content (Sañudo *et al.,* 1998; Piedrafita *et al.*, 2003). To improve carcass characteristics, Morucha are often crossbred with meat-improved breeds. In fact, although the PGI only admits pure breed animals, nowadays, the possibility of including crosses with meat-specialised breeds such as Charolais is being considered. In view of trademark regulations, it is important to understand the effect of crossbreeding meat-specialised breeds with native breeds in order to improve carcass quality but keeping the standard of quality that characterize this type of meat. In this sense, inadequate tenderness is the most important cause of consumer dissatisfaction and any improvement in tenderness would increase the value of the final product.

Bearing in mind that tenderness is the most relevant consequence of ageing, it is necessary to know how crossbreeding can affect the changes induced by ageing. Throughout ageing, the structure of myofibrilar and associated proteins, and, to a lesser extent, of collagen, weakens during the ageing process (Etherington, 1987; Stanton and Light, 1987, 1988, 1990; Dransfield, 1994; Campo *et al.,* 1998; Ngapo *et al.*, 2002; Nishimura *et al.*, 2002). In addition, factors such as the age of the animal, feeding regimen and the production system also determine the time required for optimal ageing because of changes in the structure and distribution of the muscle components during growth (Koohmaraie *et al.*, 2002). Therefore, potential tenderness depends on the effect of ageing period (Shackelford and Wheeler, 1997; Chambaz *et al.*, 2003). Hence, Campo *et al.* (1999), Monsón *et al.* (2004) and Revilla and Vivar-Quintana (2006) considered the breed or the type of crossbreeding as one of the factors that govern the response of muscle during the ageing process, owing to the influence of genetics on the activity of proteases and on muscle structure. Indeed, Espejo *et al.* (1998) and Ciria *et al.* (2000) reported that meat from rustic breeds require a longer ageing period than meat from breeds specialised in meat production. But, there are still few papers to date, that have analysed the comparison between both types of animals, at the same finishing grade.

The objective of this experiment was to determine the breed-specific characteristics of a pure rustic breed and its cross with Charolais slaughtered at the same finishing grade, and to determine the optimum ageing period required to produce high quality meat from both genotypes.

Material and Methods

Animals

In this study, two types of entire male animals were used: 10 Morucha pure breed (MO) and 10 from crossing Charolais with Morucha breed dams. All of the animals were reared under the traditional production system. Thus, calves were reared with their dams until weaning (approx. 7-8 months of age) in the «*dehesa*» ecosystem. After weaning, and until slaughter, the calves were fed *ad libitum* with concentrate and cereal straw. The facilities were comprised by two different parts: indoors area with straw bedding concrete floor and an adjacent open area (ground exercise yard). The main ingredients of the concentrate were cereals (barley and corn) and soybean meal. The animals were slaughtered in an authorised EU slaughterhouse. Taking into account local market preferences, slaughtering was established according to a finishing grade, in accordance with an age range of 13-14 months. The finishing grade was evaluated subjectively by experimented assessors belonging to the quality trademark.

Carcass characteristics

Once the animals were slaughtered, on the left carcass side, the following parameters were recorded:

— Hot carcass weight, including testicles, but without kidney and pelvic fat and tail.

— Cold carcass weight after chilling at 3 ± 1ºC for 24 h.

— Carcass yield was calculated as the relation between cold carcass weight and slaughter body weight.

— Carcass grading was determined by trained slaughterhouse staff following the European Normative R (CEE) 1208/81 of the Council (OJ, 1981a) and 2930/81 of the Commission (OJ, 1981b). However, in order to be more precise, conformation carcass score was evaluated with a EUROP scale ranking ranging from 15 (the best conformation) to 1 (the worst conformation). Fatness carcass score was based on a 5 point-scale from 5 (very high fat) to 1 (very low fat).

— Carcass length was measured using the method of Espejo *et al.* (2000). The carcass compactness index was calculated as the relation between cold carcass weight and carcass length.

— At 24 h *post mortem* after removing 6th rib section, *longissimus thoracis* perimeter was drawn on acetate and the area was measured with a planimeter (Area Meter MK2) to estimate retail carcass yield.

Meat characteristics

A Metrohm 704 pH-meter with a «penetration» pH-electrode was used to measure pH values 45 min and 24 h after slaughtering in *longissimus lumborum* muscle (3rd lumbar vertebral level). At 24 h after slaughtering, the 6th rib was removed and frozen (–18ºC) for further chemical analysis. The *longissimus thoracis* muscle between the 7th and 11th ribs was removed and used to carry out the ageing process. All boneless sections were sliced into 5 cm thick portions and vacuum-packed. These samples were kept at 4ºC for 3, 7, 10 and 14 days. After ageing, each vacuum-packed section was divided into two steaks. One of them, about 3 cm thick, was assigned for water loss determination and textural analyses, so were weighed to obtain the initial weight to subsequently calculate freezing and thawing losses. The remaining steak, about 2 cm thick, was used for sensory analyses. All steaks were packed under vacuum again, and frozen and stored at –18ºC until further analysis.

After thawing the 6th rib section in a water bath at 18ºC for 4 h (Hamm, 1986), proximate chemical composition and haeminic pigment content were analysed on the *longissimus thoracis.* Moisture, fat and protein contents were determined using near infrared spectroscopy in transmittance (NIT-Tecator®) and the concentration of haem pigments, expressed in mg g^{-1} muscle, was measured by spectrophotometry (Beckam®) using the Hornsey (1956) method.

The steaks assigned for water loss determinations and textural analyses corresponding to each ageing time, were also thawed in a water bath at 18ºC for 4 h (Hamm, 1986), and removed from the vacuum bags. Before colour evaluation, steaks were allowed to oxygenate myoglobin for approximately 1 h at 4ºC. In each steak the colorimetric parameters L*, a*, b*, C* and H* were determined using a CM2002 Minolta spectrophotometer (Osaka, Japan) in the CIEL*a*b* space under D65, 10º and SCI conditions. Four readings were used to calculate an average value for each sample.

Losses caused by the freezing and thawing process were determined from the difference between the initial weight and the weight after thawing. In addition, cooking losses were determined by weighing the samples before and after heating and cooling. Heating was performed in an open polyethylene bag in a water bath tempered at 75ºC, until the temperature of the sample reached 70ºC, measured using a thermocouple placed in the centre of the sample (Honikel, 1998). The samples used to determine cooking losses were also used in Warner-Bratzler Shear Force test.

The instrumental parameters of texture, compression at 20% and 80% in raw meat, and Warner-Bratzler test (Honikel, 1998) in heated meat, were determined using the texture analyser TA-XT2 (Stable Micro Systems, Surrey, England). From each steak, a minimum of 8 strips were obtained, each with a 1 × 1 cm cross-section and the fibre parallel to a long dimension of at least 2 cm, so that the fibre axis was perpendicular to the direction of the compression plunger. The TA-XT2 was used with a cylindrical, flat-end plunger (diameter 2.5 cm) that was driven vertically to 20% and 80% of the compression total. The compression procedure permitted transverse expansion of the samples and the speed of the probe was 50 mm min^{-1}. The value taken from the force deformation curve was the force required to achieve the corresponding compression level. For the Warner-Bratzler Shear Force test, the dimensions and cut characteristics of the sample strips required were the same as those used in the compression test. The value taken from the force deformation curve was the maximum force.

To perform sensory analyses, thawed steaks were cooked in a preheated electric convection oven (220ºC) until the sample temperature reached 70ºC, measured with a thermocouple placed in the approximate geometric centre of each steak. Every steak was trimmed of any external connective tissue, cut into 2 cm^2 samples and kept hot (60ºC approx.) until testing. In a homologated tester room, under red light, an eight-member trained sensory panel assessed four samples; one from each ageing period within the same genotype. Using a crescent 4-point scale, testers evaluated samples for odour intensity, tenderness, juiciness, flavour intensity, and overall acceptability.

Statistical analysis

Statistical analysis of carcass quality parameters, pH and chemical composition was performed using a one-way ANOVA (genotype).

Table 1. Carcass characteristics and *longissimus thoracis* muscle area (means ± standard deviation) in a sample of pure Morucha (n = 10), a rustic type breed, and Charolais x Morucha crossbreed (n = 10) genotypes

	Morucha	Charolais crossbreed	P
Slaughter age (days)	405.2 ± 12.56	398.7 ± 10.15	ns
Final live weight (kg)	489.4 ± 45.66	595.7 ± 35.33	***
Cold carcass weight (kg)	281.9 ± 26.23	342.0 ± 22.95	***
Carcass yield (%)	57.6 ± 1.02	57.4 ± 1.57	ns
Conformation score[1]	8.1 ± 0.57	10.4 ± 0.95	***
Fatness score[2]	2.3 ± 0.48	2.7 ± 0.52	ns
Carcass length (cm)	131.9 ± 8.40	133.9 ± 3.41	ns
Compactness index (kg cm^{-1})	2.13 ± 0.15	2.55 ± 0.13	***
Longissimus thoracis area (cm^2)	63.8 ± 13.35	60.8 ± 17.70	ns

[1] Conformation score: EUROP 15 point-scale (E: the best conformation - P: the worst conformation). [2] Fatness score: 5-point scale (1: very low fat, 5: very high fat). ***: $p \leq 0.001$. ns: differences not significant ($p > 0.05$).

The effect of genotype, period of ageing, and the interaction of both variables on colour parameters, texture, thawing losses, cooking losses were analysed using the GLM procedure. Analyses were performed using the split-plot method, with genotype as plot and ageing time as sub-plot. Sensory parameters were analysed using one-way ANOVA (ageing time) within genotype. Statistical analyses were performed using SPSS 13.0 package (SPSS, 2004).

Results

Carcass quality

Carcass characteristics results are shown in Table 1. Slaughter live weight, carcass weight, carcass evaluation of Charolais × Morucha crossbreed animals were significantly higher than the weights of pure Morucha animals. However, no statistically significant differences were found in carcass yield ($p > 0.05$) or in the *longissimus thoracis* area. In addition, conformation scores and compactness index of crossbreed animals were significantly higher than those of pure-breed animals. The fatness score of the pure and crossbreed animals was on average similar because animals were slaughtered at a similar fatness grade. Although no statistically differences were found in carcass length, carcass compactness index values were significantly higher ($p < 0.05$) in Charolais crossbreed than in Morucha pure breed.

pH and chemical composition

The pH values recorded 45 min and 24 h after slaughter did not differ significantly between genotypes (Table 2). Although some pH values were a bit high, all of the samples had pH values below 6.0. In relation to proximate chemical composition, the Morucha pure breed and crossbreed genotype did not differ significantly in moisture, fat, and protein content (Table 2). Mioglobin content was significantly higher ($p \leq 0.01$) in Morucha pure breed than in Charolais crossbreed.

Table 2. pH, measured after 45 min and 24 h, and chemical composition values (means ± standard deviation) of beef meat from a sample of pure Morucha (n = 10) and Charolais x Morucha crossbreed (n = 10) genotypes

	Morucha	Charolais crossbreed	P
pH (45min)	6.62 ± 0.312	6.50 ± 0.142	ns
pH (24h)	5.65 ± 0.201	5.73 ± 0.260	ns
Moisture (%)	75.25 ± 0.769	74.76 ± 0.777	ns
Protein (%)	22.40 ± 0.787	22.72 ± 0.938	ns
Fat (%)	2.17 ± 0.824	2.29 ± 0.811	ns
Haem pigments (mg g^{-1})	5.03 ± 0.990	3.56 ± 0.716	***

***: $p \leq 0.001$. ns: differences not significant ($p > 0.05$).

Table 3. Colorimetric parameters (1 h of blooming) of *longissimus thoracis* muscle (means ± standard deviation) as a function of genotype (G) and ageing time (A) in beef meat

	Morucha				Charolais crossbreed				P-level		
	3 days	7 days	10 days	14 days	3 days	7 days	10 days	14 days	G	A	G × A
Lightness (L*)	34.6 ± 2.27	35.4 ± 1.71	35.6 ± 2.50	35.4 ± 2.50	37.9 ± 2.27	37.7 ± 2.07	38.7 ± 3.76	39.9 ± 2.58	**	ns	ns
Redness (a*)	15.9 ± 1.04	16.4 ± 1.65	16.4 ± 1.83	16.4 ± 1.51	14.6 ± 0.99	13.4 ± 1.65	14.9 ± 1.12	14.8 ± 1.64	**	ns	ns
Yellowness (b*)	9.6 ± 2.20	10.8 ± 2.17	10.0 ± 2.90	10.7 ± 2.36	11.7 ± 1.67	11.6 ± 2.40	11.3 ± 2.32	10.9 ± 1.98	ns	ns	ns
Hue angle (H*)	31.8 ± 3.41	34.2 ± 2.33	32.3 ± 4.81	33.7 ± 3.03	37.1 ± 2.97	36.5 ± 5.99	36.2 ± 4.69	35.9 ± 4.04	*	ns	ns
Chroma (C*)	17.9 ± 2.57	19.2 ± 3.12	18.4 ± 3.71	19.2 ± 3.04	19.5 ± 1.92	19.6 ± 1.84	18.9 ± 2.22	18.5 ± 2.21	ns	ns	ns

**: $p \leq 0.01$. *: $p \leq 0.05$. ns: differences not significant ($p > 0.05$).

Colour measurements

The highest lightness values and the lowest a* values were found in the *longissimus thoracis* muscle of crossbreed animals. Morucha pure breed and crossbreed animals did not differ significantly in yellowness (b*). In addition, no differences were recorded in relation to H* and C* parameters (Table 3). No effect of ageing was recorded on any of the colorimetric parameters measured ($p > 0.05$).

Thawing, cooking losses and textural parameters

Table 4 shows the textural and water holding capacity values throughout ageing in each genotype. The effect of heating on weight loss was not significantly related to genotype or ageing period, but losses due to freezing and thawing were significantly higher in crossbreed animal meat. A significant interaction was not observed for any of the textural parameters in which breed and ageing effects were studied, so both effects are shown separately ($p > 0.05$). Therefore, no breed effect was found in any of textural parameters studied ($p > 0.05$). However, a significant effect of ageing was found for compression of 20% and Warner-Braztler data ($p \leq 0.05$). Compression values of 20% decreased from the 10th day of ageing and Warner-Braztler values decreased from the 7th day of ageing.

Sensorial attributes

Sensorial scores given for rustic pure breed and for crossbreed throughout ageing period are shown in Table 5. In both genotypes, the duration of the ageing period had a significant effect on all of the sensory parameters, except odour intensity. Regarding tenderness, meat from the Morucha breed animals increased significantly until 14 days, whereas the meat from the crossbreed animals did not improve significantly beyond 10 days of ageing. In the same way, although juiciness increased throughout the ageing process in both genotypes, in Morucha pure breed the scores decreased significantly until 10 days of ageing, whereas in the Charolais crossbreed juiciness did not increase significantly from 7 day of ageing. In both

Table 4. Texture parameters, thawing and cooking losses of *longissimus thoracis* muscle (means ± standard deviation) as a function of genotype (G) and ageing time (A) in beef meat

	Morucha				Charolais crossbreed				P-level		
	3 days	7 days	10 days	14 days	3 days	7 days	10 days	14 days	G	A	G × A
Cooking losses (%)	14.2 ± 6.62	15.8 ± 3.81	14.6 ± 5.93	13.6 ± 6.88	12.4 ± 3.22	13.5 ± 3.26	14.0 ± 2.55	14.4 ± 5.49	ns	ns	ns
Thawing losses (%)	3.3 ± 1.73	2.8 ± 0.67	2.6 ± 1.09	3.0 ± 1.38	4.3 ± 1.56	4.1 ± 1.47	4.3 ± 1.73	4.0 ± 1.83	*	ns	ns
Compression 20% (N)	2.3 ± 1.06^a	2.0 ± 0.60^a	1.57 ± 0.56^b	2.1 ± 0.98^a	2.2 ± 0.38^a	2.4 ± 1.25^a	1.5 ± 0.51^b	1.6 ± 0.39^b	ns	**	ns
Compression 80% (N)	108.4 ± 24.80	106.8 ± 15.78	109.2 ± 23.47	120.3 ± 25.3	102.3 ± 15.21	104.5 ± 24.01	114.4 ± 17.8	112.5 ± 15.6	ns	ns	ns
Warner-Bratzler (kg)	6.6 ± 2.67^a	5.1 ± 2.26^b	4.7 ± 1.66^b	4.4 ± 1.22^b	5.9 ± 2.18^a	5.3 ± 1.94^b	4.5 ± 1.39^b	4.5 ± 1.73^b	ns	*	ns

**: $p \leq 0.01$. *: $p \leq 0.05$. ns: differences not significant ($p > 0.05$). ^{a,b}: indicate significant differences between ageing periods, inside the same genotype.

Table 5. Sensory meat quality traits (means ± standard deviation) as a function of ageing time inside each genotype

	Morucha					Charolais crossbreed				
	3 days	7 days	10 days	14 days	p	3 days	7 days	10 days	14 days	p
Odour[1]	2.4 ± 1.17	1.8 ± 0.92	3.0 ± 1.05	2.8 ± 1.25	ns	2.4 ± 1.07	2.5 ± 1.26	2.4 ± 1.07	2.7 ± 1.25	ns
Tenderness[1]	1.0 ± 0.00^{a}	2.4 ± 0.71^{b}	2.6 ± 0.52^{b}	3.9 ± 0.32^{c}	***	1.1 ± 0.32^{a}	2.1 ± 0.56^{b}	3.1 ± 0.57^{c}	3.7 ± 0.32^{c}	***
Juiciness[1]	1.3 ± 0.48^{a}	2.2 ± 0.79^{ab}	2.9 ± 0.74^{b}	3.6 ± 0.97^{c}	***	1.8 ± 1.10^{a}	2.4 ± 1.17^{b}	2.6 ± 0.96^{b}	3.1 ± 1.10^{b}	*
Flavour[1]	1.8 ± 1.03^{a}	1.9 ± 0.57^{a}	2.9 ± 1.10^{ab}	3.4 ± 0.97^{b}	**	2.1 ± 1.10^{a}	2.6 ± 1.1 7^{a}	2.6 ± 0.84^{a}	3.7 ± 1.42^{b}	*
Acceptability[1]	1.1 ± 0.32^{a}	2.0 ± 0.47^{b}	2.9 ± 0.32^{c}	4.0 ± 0.00^{d}	***	1.2 ± 0.42^{a}	2.0 ± 0.67^{b}	3.1 ± 0.57^{c}	3.7 ± 0.67^{c}	***

[1] Increasing scale 1-4. $^{a, b, c}$: indicate significant differences between ageing periods, inside genotype. ***: $p \leq 0.001$. *: $p \leq 0.05$. ns: differences not significant ($p > 0.05$).

genotypes, flavour intensity increased significantly throughout ageing period, but in Morucha the differences became more evident from day 7 ($p < 0.01$), whereas in the Charolais crossbreed they only became statistically significant from day 10.

Discussion

Carcass quality

Results obtained for slaughter live weight are consistent with the findings of other authors who have worked with breeds not specialised in meat production such as Friesians, and improved crossbreeds (Keane *et al.*, 1990; Mendizabal *et al.,* 2005). The crossing of improved breeds with rustic breeds produces animals with higher weights at slaughter, particularly when the same maturing grade (fatness) is required. A tendency toward higher conformation scores among animals with greater weight at the same maturity grade, compared to more precocious breeds, was reported by More O'Ferrall and Keane (1990), Albertí *et al.* (2000) and Mendizabal *et al.,* 2005).

The relatively high pH values could be partially explained because Morucha, which is genetically related with bull fighting breeds, tends to show more aggressive behaviour than beef-specialised breeds, so that its glycogen reserves at slaughter could have been low. In fact, values in a similar range (5.5-5.8) have been obtained in a Morucha breed in a previous work (García-Cachán and Cruz-Sagredo, 1999a) and in Morucha crossbreeds with Charolais and Limousin (data unpublished).

The lack of differences in proximate chemical composition between genotypes can presumably be explained, because of their similar finishing grade at slaughter (Wood, 1983; Webster, 1986; Perry and Arthur, 2000). Haem pigment concentrations in the *longissimus thoracis* muscle were significantly higher in Morucha breed animals than in crossbreed animals. The Morucha breed is known to exhibit high myoglobin concentrations (Sañudo *et al.*, 1998; Albertí *et al.,* 1999; García-Cachán and Cruz-Sagredo, 1999a). Another Spanish rustic breed, Avileña Negra Iberica, reared in similar conditions to Morucha, is known to exhibit slightly lower haem pigment concentrations than those observed in Morucha pure breed but still higher than in the Charolais crossbreed (Sañudo *et al.*, 1998; García-Cachán and Cruz-Sagredo, 1999b).

The higher values of redness (a*) observed in the Morucha breed might be due, in part, to the higher myoglobin content of the *longissimus thoracis* muscle in this breed. Also, Lynch *et al.* (2002) and Albertí *et al.* (2005) reported breed-specific differences in a* values. However, genotypic differences in a* are not as marked as the differences observed in pigment concentration, as reported by Krzywicki (1979), Renerre (1990), and Young *et al.* (1999), who showed that other factors are involved in the determination of meat colour. Hue angle, which in meat samples is related to the relative percentage of yellow and red colours, was higher in crossbreed animals than in rustic animals. However, Chroma, which shows the degree of colour saturation, did not differ between genotypes.

Neither ageing period nor the interaction between genotype and ageing period had a significant effect on the colorimetric parameters of *longissimus thoracis* muscle. Similarly, Carballo *et al.* (2001) and Chambaz *et al.* (2003) did not find differences in meat colour when measured at 7 and 14 days of ageing, with a constant blooming time, suggesting that blooming time is more important than ageing *per se*. Ledward (1985), Renerre (1990), and Hernández *et al.* (1999) showed that as the period of blooming progresses the colour of the meat changes significantly as myoglobin oxidation proceeds. The differences in the response of parameters used to estimate water holding capacity might be due to differences in the origins of the liquid lost in each process. During cooking, the lost liquid comes from constitutive water and from the fat melted during heating, so the difference between breeds is attenuated (Mandell *et al.*, 1997; King *et al.,* 2003). Losses due to thawing, however, come mainly from constitutive water and, because of the effect of genotype on muscle structure and, hence, its capacity to retain water, observed differences between genotypes in water loss are more pronounced. In this respect, Sañudo *et al.* (1998) in several breeds of Spanish cattle, obtained similar results in cooking losses but higher values in thawing losses. Nevertheless, their results supported the lowest water losses obtained for the Morucha breed measured by the different methods.

The absence of breed significant differences in textural parameters might be explained by the fact that animals of both genotypes were slaughtered at similar maturity grade. The interaction between breed and ageing was not significant for any of the textural variables analyzed. In this sense, Monsón *et al.* (2004) reported that meat from Holstein, Brown Swiss, Limousin and Blonde d'Aquitanie aged for 1, 3, 7, 14, 21 and 35 days only showed differences between breeds at shorter times, but the differences disappeared from 14 days of ageing. In this regard, several authors have associated differences in the ageing process with differences in the biochemical characteristics of muscle that are dependent on the state of maturation (Bailey, 1985; Gazzola *et al.*, 1999; Stolowski *et al.,* 2006) or muscular enzymatic potential activity (Sañudo *et al.*, 2003; Monson *et al.*, 2004). However, the magnitude of these potential differences in biochemical characteristics between both genotypes was not sufficient to modify the effect of ageing on instrumentally-measured texture variables.

A decrease in resistance to 20% compression force in raw meat was detected between samples tested on days 7 and 10 of ageing, but no significant changes were found between samples tested on days 3 and 7 or between days 10 and 14. In raw meat samples, resistance to 80% compression force did not vary significantly throughout ageing period.

Differences in the response to 20% and 80% compression occurred because each test measures different components of muscle. In this line, several studies (Lepetit and Culioli, 1994; Campo *et al.*, 2000) have considered that low strain primarily measures the myofibrilar mechanical resistance because connective fibres are not modified. On the other hand, the mechanical resistance of collagen can only be measured using high compression tests. It is noteworthy, however, that the absolute values obtained by Lepetit *et al.* (1986) and Campo *et al.* (2000) are lower than the values obtained in this study. The reason for this difference is that, unlike this study, Lepetit *et al.* (1986) and Campo *et al.* (2000) used a modified compression device with 1 cm^2 of surface and avoided transversal expansion of the sample. In spite of the fact that similar strips were used, because of the differences in methodology, the amount of sample tested was greater in our study, giving rise to higher absolute values of maximum force.

In the present study, the decreased resistance of the meat to 20% compression could reflect the denaturing of myofibrilar and other associated proteins by proteolytic enzymes. A higher decrease in the resistance of meat to 20% compression at short ageing periods was also observed by Campo *et al.* (2000), who suggested that after 10 days of ageing the structure of the myofibrils has degraded to a level at which the process tends to stabilise.

However, according to the present results, ageing did not affect 80% compression values. These results agree with those of Nishimura *et al.* (1998), Kolczal *et al.* (2003), and Monsón *et al.* (2004) who reported that connective tissue did not change during ageing. In contrast, some authors have reported a certain degree of collagen rupture when the ageing period is longer than 10 days (Huff and Parrish, 1993; Palka, 2003).

The maximum resistance obtained in the Warner-Bratzler test in cooked meat decreased significantly between 3 and 7 days of ageing; thereafter, values remained unchanged up to 14 days. Lepetit *et al.* (1986), Campo *et al.* (2000) and Monsón *et al.* (2004) showed that the desirable texture in meat from adult animals might not be reached until after several weeks of ageing, but the highest percentage (75-80%) of the potential improvement in tenderness occurs during the first days of ageing, when resistance to cutting decreases exponentially. Ónega *et al.* (2001) and Monsón *et al.* (2004) also observed a similar decrease in hardness in the first week *postmortem.*

The absence of any significant effect of ageing on 80% compression in raw meat, together with differences in the Warner-Braztler test in cooked meat, suggests that both tests might have different sensitivities in detecting ageing-related changes, which might occur because ageing affects the miofibrillar component, the main tissue responsible for hardness in meat cooked at 70ºC (Bouton *et al.,* 1975; Christensen *et al.,* 2000; Revilla and Vivar, 2006). Moreover, Ngapo *et al.* (2002) suggested that the myofibrilar contribution is the primary factor influencing the texture of non-aged meat, but the relative importance of connective tissue to toughness is greater in aged meat.

The results obtained from the sensory analysis are consistent with those reported by Ciria *et al.* (2000) and Monsón *et al.* (2005), who concluded that meat from rustic or dual purpose breeds require a longer ageing than meat from pure meat-specialised breeds or its crosses. Therefore, recent studies (Wulf *et al.,* 1996; Monsón *et al.,* 2005; Stolowoski *et al.,* 2006), suggested that genetic differences in beef tenderness are associated with variations in the rate and extent of muscle proteolysis that occur during port-mortem storage of fresh meat. In the same way, although in both genotypes juiciness increased throughout ageing, in Morucha pure breed the scores increased significantly until 10 days of ageing, whereas in the Charolais crossbreed juiciness did not increase significantly from day 7 of ageing. In both genotypes, flavour intensity increased significantly until day 14. Regarding the flavour, Campo *et al.* (2003) indicated that the delayed increase in flavour intensity is a result of the accumulation of products, which can be considered as flavour precursors, derived from proteolysis that occurs after long periods of ageing. Notwithstanding this phenomenon, the overall acceptability increased progressively with an increase in the time that samples were aged.

In view of obtained results regarding carcass quality, if can be concluded that better results were observed in the crossbreed genotype than in Morucha pure breed when they were slaughtered at a similar finishing grade. Meat textural properties improved throughout the ageing period at a similar rate in both genotypes. In contrast, based on the sensory analysis, the changes throughout ageing seem to be a function of the animal's genotype, with tenderness increasing up to 14 days in meat from rustic breed (Morucha) yearlings, while no changes were observed from 10 days in meat from the crossbreed (Charolais x Morucha). In either case, it will be necessary to assess the economic costs involved in this process to achieve a compromise between the costs of prolonging the ageing period and the improvements in quality.

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