Eating quality of young bulls from three Spanish beef breed-production systems and its relationships with chemical and instrumental meat quality

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Abstract

Sensory characteristics of longissimus thoracis muscle from three local Spanish beef breed-production systems and their relationships with chemical and instrumental meat quality traits were studied. Young bulls of Bruna dels Pirineus (BP; n = 69), Avilená-Negra Ibérica (A-NI; n = 70) and Morucha (MO; n = 70) breeds were reared in their own production systems. MO breed showed the highest water holding capacity and also the highest thawing loss and haem pigment content (P < 0.001). No differences in moisture and protein contents were found among breeds. A-NI showed the highest intramuscular fat (IMF, P < 0.05) and total collagen (P < 0.001) contents, whereas BP showed the lowest IMF content (P < 0.05) and the highest collagen solubility (P < 0.001). Beef flavour, tenderness and juiciness accounted for the eating quality differences among the three breed-production systems. Meat from A-NI was rated significantly higher (P < 0.01) for beef flavour and tenderness than that from BP and MO animals. Furthermore, MO showed the lowest juiciness (P < 0.001) which could be due to its higher thawing loss. Within the three breeds, thawing loss was negatively correlated with juiciness and, likewise cooking loss with juiciness and tenderness (P < 0.05). The canonical discriminant analysis showed that the three breeds were significantly different (P < 0.05) from each other according to sensory attributes, which justifies their involvement in different protected geographical indications (PGI).

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Keywords: Beef; Sensory quality; Meat quality; Spanish breeds

1. Introduction

Beef production in Spain is based mainly on both intensive systems with calves from dairy breeds (mainly Friesian) and on semi-extensive or intensive systems with pure local breeds, i.e., Avilena-Negra Ibérica, Rubia Gallega, Asturiana, Pirenaica, Morucha, or crosses, mainly with Limousin and Charolais (MAPA, 2003). The use of local beef breeds, reared under traditional systems and commercialised under the labels of designation of origin (i.e., protected geographical indication, PGI) or quality trade marks, has become very important in Spain in recent years. Nonetheless, producers and retailers often lack the necessary objective information to promote and to make good use of the quality (i.e., nutritional and sensorial) of meat obtained from these breeds, in order to achieve product differentiation.

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Local breeds have different production systems, which depend on the geographical area of production, and different carcass characteristics, which depend on breed genetics and the implementation of improvement programmes (Piedrafita et al., 2003). The interest in local Spanish beef breeds is shown by several studies, focussed either on production and carcass quality (Albertí et al., 2005; Albertí et al., 1998) or on meat quality and sensory characteristics (Campos et al., 2000; Campo, Sanudo, Panea, Albertí, & Santolari, 1999; Insauti, Beriain, Gorraiz, & Purroy, 2002; Insauti et al., 1999; Insauti, Goni, Petri, Gorraiz, & Beriain, 2005; Sanudo et al., 2004). However, in all the above studies animals were intensively reared both under the same experimental conditions and the same diet, and not their typical production systems.

The objectives of this paper are to describe the sensory characteristics of three local Spanish beef breeds (i.e., Bruna dels Pirineus, Avilena-Negra Ibérica and Morucha) reared in their own production systems, and to study their relationships with chemical and instrumental meat quality traits. This paper is an outcome of a study carried out as part of the EU-FAIR1_CT95_0702 project to describe carcass and meat quality variability both among and within beef cattle breed-production systems from France and Spain (Gil et al., 2001; Oliván, Martínez, García, Noval, & Osoro, 2001; Oliván et al., 2004; Piedrafita et al., 2003; Serra et al., 2004), with the aim of getting a better knowledge of local breeds which could contribute to the breeds’ improvement as well as to help the marketing of differentiated beef products.

2. Materials and methods

2.1. Animals

This study was done on 209 yearlings (entire males) of three Spanish beef breeds: Bruna dels Pirineus (BP, also known as Parda de Montana or Old Brown Swiss; \( n = 69 \)), Avilena-Negra Ibérica (A-NI; \( n = 70 \)) and Morucha (MO; \( n = 70 \)). The geographical distribution of these breeds was described by Piedrafita et al. (2003). The BP is a medium-sized meat-type breed located in the Eastern Pyrenees and selected from Old Brown Swiss. The A-NI, a medium-sized breed, and MO, a small to medium-sized breed, are non-improved types located in Western and Central Spain. Animals were reared under local production systems in extensive conditions together with their mothers until weaning. Fattening started at an average age of 209.2 d for BP, 215.1 d for A-NI and 235.6 d for MO calves. Young bulls were fed ad libitum a breed-specific diet based on concentrated meal and cereal straw or hay and were evenly distributed over two consecutive years (35 animals per year, except for the BP second year: \( n = 34 \)). Yearlings were slaughtered in their areas of origin in commercial EU-licensed abattoirs. Further details about rearing, diet composition and slaughter conditions are described by Piedrafita et al. (2003).

2.2. Chemical, instrumental and sensory analyses

Carcasses were chilled at 12 °C for 3–4 h and then stored at 4 °C ± 1 °C for 24 h. Longissimus thoracis (LT) area was measured at the 6/7th-rib level at 24 h post-mortem. Muscle pH measurements were done at the centre of LT (5th rib) at 24 h post-mortem (\( \text{pH}_{4} \)) and at the 8th-rib level at seven days post-mortem (\( \text{pH}_{17} \)) with a xerolyt pH-meter. Details on instrumental meat quality measurements are described by Serra et al. (2004). Briefly, expressible juice was measured according to the method described by Pla (2005). Muscle chemical composition was analysed in LT samples: moisture (AOAC, 1990), total intramuscular fat (ISO 1443:1973) and protein (ISO 937:1978). Haem pigment concentration was measured according to Hornsey (1956). Total hydroxyproline concentration (ISO 3496:1994) was multiplied by the factor 8 to obtain total collagen content. Collagen solubility was measured by the method of Hill (1966).

Samples for sensory analysis were obtained by removing the loin joint between the 8th and 11th rib from the left side of the carcass at 24 h post-mortem. Loin meat was vacuum-packed and stored at 4 °C ± 1 °C for ageing. After 7 d ageing, steaks were cut 2 cm thick (from the 11th rib end), vacuum-packed and stored at 4 °C ± 1 °C to continue ageing. After 14 d ageing, vacuum-packed steaks were frozen and kept at −20 °C ± 2 °C until analysis. For the sensory evaluation (Guerrero, 2005), steaks were thawed overnight at 4 °C ± 1 °C (2 cm thick and 14 d ageing) and thawing loss was calculated as the difference (%) between initial and thawed weight. Thawed steaks were wrapped in aluminium foil and cooked to an internal temperature of 70 °C in a convection oven pre-heated to 200 °C. Sample internal temperature was monitored with a data logger and a thermocouple probe inserted horizontally at the steak mid-point. Cooking loss was calculated as the difference (%) between thawed and cooked weight. The core portion of each steak was cut into 10 samples. Each sample was immediately wrapped in aluminium foil and kept at 60 °C in a heater. Cooked steaks were assessed by the same 10-member expert panel trained following ASTM standards (ASTM, 1981) across the two years. Panellists evaluated the cooked samples in individual booths provided with red light and a heater (60 °C). The three beef breeds (BP, A-NI and MO) were evaluated in six sessions per breed and year. Within each year, each breed was assessed in five sessions of six steaks and one session of five steaks selected randomly, except for the BP second year (\( n = 34 \)) in which four sessions of six steaks and two sessions of five steaks were carried out. A single loin steak was assessed from each animal. A total of 17 sessions, one for each breed, were carried out within a day balancing the order of evaluation of the breeds across the six assessment days per year. Each panellist tasted the sample from each breed in a different order within each session according to a previous design (Guerrero & Guàrdia, 1997). Additionally, within a session, each panellist assessed the same steak-location sample in order to...
minimise any steak-location effect. Panellists were required to rate each sample for intensity in beef odour, livery odour, beef flavour, livery flavour, overall tenderness and overall juiciness. Each attribute was rated on a 10 cm unstructured line scale, with 0 cm being equivalent to no attribute intensity and 10 cm being equivalent to the highest intensity of the attribute. The mean of the 10 panellist scores for each steak was used for data analyses.

2.3. Statistical analysis

Data were analysed using the SAS statistical package (SAS, 1999). Within each breed, the residues of dependent variables were calculated through GLM procedure to correct the year effect, and corrected data for all variables were obtained. Regarding sensory attributes, scale differences across years were corrected with the year effect. Breed-production system differences for instrumental and chemical meat quality characteristics and sensory attributes were assessed through analysis of variance. Pearson’s correlation coefficients (r) were calculated to study the relationships within each breed-production system between instrumental and chemical meat quality characteristics and sensory attributes. A canonical discriminant analysis was performed to assess the proximity among breed-production system means based on sensory attributes.

3. Results and discussion

3.1. Effect of breed-production system on the instrumental and chemical meat quality

Age and weight at slaughter of BP, A-NI and MO breed-production systems are shown in Table 1. The MO yearlings were the oldest animals and also the ones with the lowest slaughter weight due to a low daily weight gain (1.11 kg/d) typical of non-improved breeds of a small adult size. In contrast, BP young bulls were the heaviest animals and showed a high daily weight gain (1.63 kg/d), like the A-NI ones (1.64 kg/d), as reported by Piedrafita et al. (2003). Longissimus thoracis muscle area of both MO and A-NI was significantly smaller than BP; in agreement with their lower carcass conformation scores (Piedrafita et al., 2003).

Least-square means of instrumental and chemical meat quality characteristics for the three breed-production systems are shown in Table 1. Ultimate pH at 24 h post-mortem (pHu7) was significantly higher in MO breed, whereas no differences were observed in pHu6 after 7 d ageing. This could be related to the difficult management of this breed due to its nervous behaviour. Besides, a significant breed-production system effect on the water holding capacity measured as expressible juice percentage was observed. The MO breed showed the highest water holding capacity – lowest percentage of expressible juice – in agreement with its higher pHu6. In contrast, steaks from MO showed significantly higher thawing loss than BP and A-NI; however, no significant differences were observed in cooking loss values.

<table>
<thead>
<tr>
<th>Breed-production system (least-squares means)</th>
<th>RMSEa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruna dels Pirineus (BP)</td>
<td>69</td>
</tr>
<tr>
<td>Avilena-Negra (A-NI)</td>
<td>70</td>
</tr>
<tr>
<td>Morucha (MO)</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 1

The higher thawing loss of MO could probably be related to its higher water holding capacity (i.e., lower expressible juice), and would explain the lower juiciness found in MO steaks. These results suggest that MO meat would be appropriate for ageing but less for freezing.

Haem pigment content was also affected by breed-production system – as previously reported by Gil et al. (2001) – probably due to age differences among animals, as described by several authors (Maltin et al., 1998; Renand, Picard, Touraille, Berge, & Lepetit, 2001; Vestergaard, Oksbjerg, & Henckel, 2000), who reported higher pigment content with increasing age. The MO young bulls (14.6 months slaughter age) showed the highest haem pigment content, which was approximately 23% higher than BP (12.6 months) and 33% higher than A-NI yearlings (12.1 months). A-NI showed the highest intramuscular fat content (IMF), whereas BP, which is leaner and better conformed than A-NI and MO (Piedrafita et al., 2003), showed the lowest IMF content. Campo et al. (1999) found no significant differences in IMF content among Old Brown Swiss (similar to BP; IMF = 3.03%), A-NI (IMF = 3.13%) and MO (IMF = 3.54%), although in their study the animals were intensively reared under similar conditions to similar slaughter weights. No differences in moisture and protein contents were found among breeds; however, a significant breed-production system effect was observed for collagen contents. A-NI yearlings showed the highest total collagen content and the lowest soluble collagen percentage. The BP and MO had similar total col-
lagen contents; however, BP showed the highest collagen solubility. The lower solubility of MO breed could be explained by the older age at slaughter (Hill, 1966; Sims & Bailey, 1981). Moreover, the lower collagen solubility of A-NI and MO could probably be related with their rusticity, i.e., non-improved type breeds. Similarly, in a study with intensively fed animals, Campo et al. (2000) reported significantly higher collagen solubility for Old Brown Swiss than for non-improved A-NI and MO breeds. Collagen determination is the least precise analysis (Dransfield et al., 1983), which could explain the low values of collagen content obtained in the present study compared with other studies.

3.2. Effect of the breed-production system on the sensory meat quality

Least-square means of sensory attributes for the three breed-production systems are presented in Table 2. Pearson’s correlation coefficients between sensory attributes and instrumental and chemical meat quality characteristics within each breed-production system are shown in Table 3. Sensory assessment of 14-d aged loin steaks showed no significant differences for beef and livery odour attributes among breed-production systems. These results agree with those of Monsón, Santudo, and Sierra (2005) who found no significant differences in odour intensity (at 7 d, 14 d, 21 d and 35 d ageing time) among Spanish Holstein (dairy; slaughter age: 419 d), Parda de Montaña (i.e., Bruna dels Pirineus or Old Brown Swiss, dual purpose; 411 d), French Limousin (fast growth; 426 d) and French Blonde d’Aquitaine (high muscularity; 432 d), which were intensively reared (fed the same diet ad libitum). However, Campo et al. (1999) reported a significant breed type effect on overall odour and liver odour intensity of beef strip loin steaks from male yearlings fed a common diet. These authors observed that odour intensity values fluctuated throughout ageing (1–21 d). In addition, their average values for overall odour and livery odour intensity at 14 d ageing were not

Table 2
Effect of breed-production system on sensory quality of muscle longissimus thoracis

<table>
<thead>
<tr>
<th>Sensory attributes</th>
<th>Breed-production system</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bruna dels Pirineus (BP)</td>
<td>Avileña-Negra Ibérica (A-NI)</td>
</tr>
<tr>
<td>Beef flavour</td>
<td>4.79b</td>
<td>5.00a</td>
</tr>
<tr>
<td>Livery odour</td>
<td>2.78</td>
<td>2.80</td>
</tr>
<tr>
<td>Beef odour</td>
<td>4.57</td>
<td>4.59</td>
</tr>
<tr>
<td>Livery odour</td>
<td>2.78</td>
<td>2.80</td>
</tr>
<tr>
<td>Beef flavour</td>
<td>4.79b</td>
<td>5.00a</td>
</tr>
<tr>
<td>Livery odour</td>
<td>2.78</td>
<td>2.80</td>
</tr>
<tr>
<td>Juiciness</td>
<td>4.68b</td>
<td>5.32a</td>
</tr>
</tbody>
</table>

Subject to a, b within a row, least-squares means with different superscripts differ (P < 0.001; beef flavour: P < 0.01).

Table 3
Pearson’s correlation coefficients between sensory attributes and instrumental and chemical meat quality characteristics of muscle longissimus thoracis for Bruna dels Pirineus, Avileña-Negra Ibérica and Morucha breed-production systems

<table>
<thead>
<tr>
<th>Sensory attributes</th>
<th>Breed-production system</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bruna dels Pirineus (BP)</td>
<td>Avileña-Negra Ibérica (A-NI)</td>
</tr>
<tr>
<td>Beef flavour</td>
<td>0.39</td>
<td>0.33</td>
</tr>
<tr>
<td>Livery flavour</td>
<td>0.38</td>
<td>0.33</td>
</tr>
<tr>
<td>Tenderness</td>
<td>0.58</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Significant at the 0.05 level.

Within a row, least-squares means with different superscripts differ (P < 0.001; beef flavour: P < 0.01).

Root mean square error.

10 cm unstructured line scale.
significantly different between BP (quoted as dual-purpose Brown Swiss) and rustic type groups (i.e., non-improved type), which included A-NI, MO and Retinta breeds. In our study, beef tenderness was positively correlated (Table 3) with: intramuscular fat (BP), haem pigment (A-NI), slaughter age (MO) and cooking loss (MO), and negatively with moisture content (MO). A significant breed-production system effect was observed for beef flavour (Table 2). The A-NI showed significantly higher scores on beef flavour than BP and MO breeds. This could be explained by the higher intramuscular fat content of the A-NI because the lipid fraction in meat is responsible for the characteristic species-specific flavours and aromas (Pearson & Young, 1989). A positive correlation (Table 3) between beef flavour and intramuscular fat was observed in BP, whereas A-NI and MO beef flavour was positively correlated with muscle area. Non-improved type animals, i.e., A-NI and MO, are less conformed, have smaller loin areas and need longer fattening periods to reach the target slaughter weight (Piedrafita et al., 2003), which could increase beef flavour. No significant differences were observed for livery flavour; however, it was positively correlated with cooking loss in both BP and A-NI. Furthermore, livery flavour was also positively correlated with haem pigment in A-NI breed. Campo et al. (1999) found a significant breed type effect on liver flavour intensity (i.e., A-NI and MO showed higher liver flavour values than BP), but not on global flavour intensity.

Concerning texture, A-NI loin steaks had the highest tenderness values ($P < 0.05$); whereas MO steaks showed the lowest tenderness and juiciness scores, which could be explained by their higher thawing losses (Table 2). Thawing loss was negatively correlated with overall juiciness in all three breed-production systems (Table 3), and also with overall tenderness in MO ($P < 0.05$). Similarly, cooking loss was negatively correlated with both tenderness and juiciness, and explained a juiciness variance of between 49% and 62% ($r^2 \times 100$), depending on the breed (i.e., Pearson’s correlation coefficients ranged from −0.70 to −0.79). The negative effect of cooking loss on beef tenderness in *m. longissimus thoracis et lumborum* has also been reported by Silva, Patarata, and Martins (1999) in Maronesa young bulls with different ultimate pH values and ageing times; and by Destefanis, Barge, Brugiapaglia, and Tassone (2000) in several breeds and crosses (Piemontese, Friesian, Belgian Blue and White), including normal and hypertrophied animals. In A-NI breed, both tenderness and juiciness were positively correlated with total collagen content but not with insoluble collagen (Table 3). In all breed-production systems, overall tenderness and juiciness were positively correlated ($r$ from +0.58 to +0.63). A positive relationship between tenderness and juiciness has been described in many studies (Campo, 1999; Crouse, Cross, & Seideman, 1985; Destefanis et al., 2000; Gregory, Cundiff, & Koch, 1995; Silva et al., 1999), and could be explained because the more tender the meat, the more quickly the juices are released by chewing and the more juicy the meat appears (Cross, 1988).

Squared Mahalanobis distances (obtained with canonical discriminant analysis) among breed-production system means showed that the three breeds were significantly different from each other according to sensory attributes evaluated on 14-d aged steaks. As shown in Fig. 1, the first canonical axis (total canonical structure plot) discriminated A-NI from BP and MO according to tenderness and beef flavour, whereas the second axis discriminated breeds according to juiciness and livery odour. The A-NI showed the largest squared Mahalanobis distance (SMD) with respect to the other breeds studied, i.e., vs BP (SMD = 1.35; $P < 0.001$) and vs MO (SMD = 1.29; $P < 0.001$), which indicated bigger differences in meat sensory characteristics, in agreement with results shown in Table 2. The SMD between BP and MO was 0.47 ($P < 0.05$). In contrast, the canonical discriminant analysis for biochemical and instrumental colour parameters reported by Gil et al. (2001) showed that A-NI and BP were the closest breeds among the seven local Spanish beef breeds studied. The A-NI higher tenderness and beef flavour, which explain the higher SMD with the other two breeds, could probably be related to its high IMF content and a higher tenderization rate. Similarly, Campo et al. (1999) reported higher tenderness scores at 14 d ageing in non-improved breeds (rustic type: A-NI and MO) than in BP. It is worth noting that other potential differences in sensory quality among breed-production systems could probably be detected if steaks were assessed at shorter ageing times than 14 d.

Fig. 1. Canonical discriminant analysis of Bruna dels Pirineus, Avileña-Negra Ibérica and Morucha breed-production systems according to odour, flavour and texture attributes. CAN$_1$ (%), percentage of the total canonical structure explained by the axis (■), breed centroid.
4. Conclusions

Beef flavour, tenderness and juiciness accounted for eating quality differences among the three breed-production systems, which reinforces their involvement in different protected geographical indications (PGI). Results suggest that Morucha meat would be appropriate for ageing and less for freezing due to its higher thawing loss. Both thawing and cooking losses affected negatively the overall tenderness and juiciness of steaks from the three breeds. This shows the importance of meat thawing and cooking processes with regard to eating quality. The 14-d aged steaks from Avileña-Negra Ibérica (A-NI) were rated higher for beef flavour and tenderness than those of Bruna dels Pirineus (BP) and Morucha (MO) animals. However, these differences would possibly change if steaks with various ageing times were assessed, in order to obtain the optimal sensory quality for each breed-production system.

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