Live weight, body size and carcass characteristics of young bulls of fifteen European breeds

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Abstract

A total of 436 young bulls from fifteen Western European breeds, including beef, dairy and local types from five countries, were studied to assess variability in live weight, live weight gain, body measurements and carcass traits. Animals were weighed indoors, and fed a diet based on concentrate and straw offered ad libitum from 9 months of age to slaughter at 15 months of age. The weight, body length, height at withers and pelvis width, of the animals were recorded at 9, 12 and 15 months of age. After slaughter, 15 carcass variables were recorded, including carcass weight, EU classification scores, morphological measurements and dissection data. Data were analysed by GLM, regression and principal component analysis procedures.

Significant differences were found between breeds for all variables studied, however, the body size measurements and the carcass traits were more useful to discriminate among cattle breeds, than either live weight or daily gain. With respect to the body size and carcass traits the studied breeds could be grouped as:

– Specialized beef breeds, comprising Piemontese, Asturiana de los Valles, Pirenaica, Limousin, South Devon, Charolais and Aberdeen Angus, all of which were characterized by high musculature, wide pelvis and medium height and a low to medium level of fatness.

– Local and dairy breeds, comprising Jersey, Casina, Highland, Holstein and Danish Red, the latter two breeds were tall animals, while the former three breeds were small in size. In general the group was poorly muscled and tended to have a high or medium level of fat.

– Intermediate group, Avileña, Marchigiana and Simmental: these breeds were characterized by an intermediate muscle conformation and fatness level and were relatively tall.

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This study provides a detailed assessment or a wide range of variables in the major breeds, and several minor breeds, that are used in breeding programmes across Europe and elsewhere, and will provide information that will be of use to define breeding strategies to meet the demands of the European beef market.

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1. Introduction

A large number of breeds of cattle exist in Western Europe many of which are well known and some are wide spread. These breeds have been a great source of genetic diversity and have been used for crossbreeding throughout the world. Rigorous selection of specialized breeds has produced extreme dairy and beef breeds that are widely used, while many local and hardy breeds that exist now have decreasing numbers. It is likely that this genetic diversity could produce meat with many different qualities; however, this has not been studied in detail.

It is well known that the optimal slaughter ages and weights vary widely among cattle breed types (Long et al., 1979) depending on how rapidly they mature, which is characterized by laying down of fat during a “finishing” period. In general, animals that produce longer carcasses tend to have a poorer conformation and a higher level of fat in their carcass (Piedrafita et al., 2003), however, for some small breeds this observation is not always the case. Variations in the yield of carcass components are related to the genetic composition and body size differences, which are inherent breed differences (Jenkins et al., 1981). Alberti et al. (2005) suggested that diverse beef breeds could be considered in three broad groups: high meat producing animals, that correspond to late maturing animals with short carcass size and high “blockiness”; medium meat producing breeds, with intermediate characteristics, and low meat producing breeds, that correspond to early maturing animals with large carcass size and low “blockiness”. Different types of breed require different production systems and the combination of breed and production system result in products differentiated by diverse attributes, such as meat colour or fat content (Gil et al., 2001). These attributes of the meat are very important for the consumer.

Current selection programmes are aimed at increasing adult weight and size of beef breeds. It is known that growth rate is positively associated with adult body weight (Kempster et al., 1982) and that animals with a high weight gain produce more muscle fibres with greater glycolytic activity, which is likely to favour meat ageing and hence tenderness (Jurie et al., 1995), which is a major factor in the meat preference of consumers. Selective breeding in cattle has been very successful in increasing the quantity of beef production, but up to now there has been little attention paid to product quality. If the genes controlling various aspects of meat quality are identified, they could be included in selection programmes to enhance meat quality that could, potentially, take into account regional variations in consumer preferences. Hence, body size and carcass composition should be considered as well as beef quality traits, in order to take the biological relationships between these parameters into consideration. Understanding the relationship between these different traits is being facilitated by the recent rapid increase in information available on the bovine genome and the tools to study gene expression (Bouley et al., 2005; Sudre et al., 2005). Several studies to characterize production and carcass traits of European beef breeds have been reported (Piedrafita et al., 2003; Chambaz et al., 2003; Keane, 2003; Özlütürk et al., 2004; Alberti et al., 2005; Cuvelier et al., 2006), however, most of these examined a small number of breeds and so are not representative of the European cattle breeds.

The study presented here defines the variation in live animal, carcass and meat characteristics in 15 European breeds of cattle reared under comparable management conditions, and so represents one of the most comprehensive comparisons of variation among European breeds.

2. Material and methods

2.1. Animals

A total of 436 pure-breed bulls from the fifteen breeds were reared in five experimental research centres: breeds were from the United Kingdom, 31 Jersey, 27 South Devon, 30 Aberdeen Angus and 29 Highland; from Denmark, 29 Holstein, 29 Danish Red Cattle and 20 Simmental; from Spain, 30 Asturiana de los Valles, 31 Casina, 30 Avileña and 31 Pirenaica; from Italy, 30 Piemontese and 28 Marchigiana and from France, 31 Limousin and 30 Charolais.
2.2. Rearing conditions

Animals were selected to be as unrelated as possible to ensure that the full range of genetic diversity present within breeds was included in the study. The bulls were purchased between 6 and 9 months of age on average for beef breeds, while for dairy breeds; the bulls were purchased as young calves (on average 7 days for Jersey and 1 to 1.5 months for Holstein and Danish Red). Dairy calves were fed with milk substitute and rolled concentrate until 2 months of age and then pelleted concentrate and hay ad libitum until 9 months of age.

At 9 months of age, all the animals were transferred to the experimental farms, where they were weighed and quarantined for 15 to 30 days to adapt to their new environment. After this they were divided into groups of 7 to 8 animals, and put onto the standardised diet, which consisted of a concentrate compounded from barley flakes (80 to 84%), soya bean meal (7.5 to 11%) sodium bicarbonate (0.6%) with suitable vitamin supplements (1.5%) and barley straw, all fed ad libitum. The energy density ratio ranged from 12.9 ME/kg DM for most of the breeds, to 13.5 ME/kg DM for British breeds. The protein content was 160 g CP/kg DM up to 10 months of age and then decreased to 150 g CP/kg DM to slaughter.

2.3. Weight and body size measurements

National welfare and animal experimental regulations were observed when handling the animals. Animals were weighed at the beginning of the experimental period and at 9, 12, 15 months of age and prior to slaughter. Average daily gain (ADG) was calculated between the initial weight and weight at slaughter and the 365-day weight calculated by linear regression. Body measurements were recorded, 9, 12 and 15 months of age. These were: height at withers (measured from the highest point of the shoulder blade to the ground), pelvis width (measured at the trochanter major ossis femoris) and body length (measured from humerus breastbone articulation to the ischium tuberosity).

2.4. Carcass evaluation

At 75% mature bull weight, which was about 15 months of age, animals were slaughtered by captive bolt pistol and exsanguination in either commercial or experimental slaughterhouses, depending on the experimental facilities of each country. Carcass dressing followed a standardised project protocol, without use of electrical stimulation, and with the removal of the remaining subcutaneous fat cover and testicles. Carcasses were split into two sides with tail on the right side of the carcass and chilled at 4±1 °C for 24 h. Temperature in the centre of M. longissimus thoracis, at the 10th thoracic rib, was not allowed to fall below 10 °C within the first 10 h.

Immediately after slaughter, the following measurements were recorded from the left half-side of carcass: hot carcass weight; hot kidney knob and channel fat weight (KKCW); dressing percentage, calculated as (hot carcass weight/slaughter live weight) × 100; conformation score was graded according to the SEUROP classification (EEC, 1991) with a scale ranging from 1 (very poor conformation) to 18 (very good conformation); fatness score was measured by UE classification, with a 15-point scale (1, very low fat to 15, very high fat). Morphological measures were taken according to the methodology described by De Boer et al. (1974). Variables recorded were: carcass length, from the anterior edge of symphysis pubis to the middle of the anterior edge of the visible part of the first rib; internal depth of breast, at the level of the fifth rib from the ventral edge of the spinal canal of the posterior aspect of the body of the fifth thoracic vertebra to ventral aspect of the middle of the body of the sixth sternebra; limb length, from the medial malleolus of the tibia in a straight line to the anterior edge of the symphysis pubis. From these measurements a carcass blockiness index was calculated. This index expresses the relationship between hot carcass weight (kg) and carcass length (cm) as follows: Blockiness index = hot carcass weight × 100/carcass length. High values indicate high muscular development (Albertí et al., 2001).

The area of the M. longissimus thoracis (LT), at the 5th to 6th rib level, was calculated by planimetry, recorded by tracing: an acetate sheet was placed on the cranial side of surface of the loin, and the border of the muscle marked on the sheet using glass marker pen. Medium-lateral and dorso-ventral diameters (maximum and minimum diameters, respectively) were also measured (Hammond, 1936).

2.5. Tissue composition

The 6th thoracic rib joint was collected 24 h post-mortem, weighed and dissected into muscle, fat and bone, tendons and noticeable blood vessels according to the method described by Robelin and Geay (1975). Results are expressed as percentage of the entire rib weight.

2.6. Statistical analysis

Differences among breeds for slaughter weight, age at slaughter, average daily gains and carcass traits were
determined by variance analysis, using the GLM procedure, considering breed as an unique effect, and the Duncan method at $\alpha=0.05$ used to test differences among breeds. Weight and morphological measurements for body length, wither height and pelvis width were estimated at 365 days from the linear regression, and the Duncan method at $\alpha=0.01$ used to test differences among breeds. For carcass traits a principal components analysis procedure adjusted by mean of quartimax rotation was performed to represent the diversity among the 15 cattle populations. All these statistical analyses were carried out using the SAS statistical package v. 8.02 (SAS, 1997).

3. Results

3.1. Live characteristics

The average daily gain (ADG) of young bulls from 9 months of age to slaughter showed significant differences among breeds (Table 1). Aberdeen Angus and South Devon had a high daily gain of 1.97 and 1.84 kg/day respectively. Holstein, Casina, Danish Red, Jersey and Highland had the lowest ADG (1.1–1.0 kg/day), whereas Charolais, Simmental, Limousin, Pirenaica, Avileña, Asturiana de los Valles, Marchigiana and Piemontese, had an intermediate ADG (1.5–1.2 kg/day).

The mean slaughter age for all breeds was 450.6±39.0 days, but some breeds were slightly younger at slaughter (398–429 days): South Devon, Jersey, Limousin, and Aberdeen Angus, while Highland was older, with a slaughter age of 511 days. Therefore, breeds were compared on the adjusted weights at 365 days calculated by regression. A within breed linear regression was fitted, as the age scarce coefficients were not significant on this age interval. The adjusted weights at 365 days of age estimated from a linear regression are showed in Table 2.

The South Devon with an average weight of 510 kg was the heaviest breed at 365 days, while the intermediate breeds included both beef and dairy breeds: Holstein, Aberdeen Angus, Danish Red, Pirenaica, Simmental, Charolais, and Limousin with an average weight of 483 kg. The Asturiana de los Valles, Avileña, Piemontese and Marchigiana weighed between 422 kg and 395 kg. The lightest breeds were Highland, Jersey and Casina. The Charolais was the heaviest breed at slaughter with an average weight of 634 kg at 461 days and the lightest was the Jersey with a weight of 378 kg at 415 days, but really breeds keep the same group as commented previously at 365 days of age.

Differences between most breeds in body size measurements, height at withers, pelvis width and

### Table 1

<table>
<thead>
<tr>
<th>Breed</th>
<th>$n$</th>
<th>Average daily gain (kg/day) ± S.E.</th>
<th>Slaughter weight (kg) ± S.E.</th>
<th>Slaughter age (days) ± S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA, Aberdeen Angus</td>
<td>30</td>
<td>1.97 ± 0.05</td>
<td>597.7 ± 4.6</td>
<td>428.6 ± 8.8</td>
</tr>
<tr>
<td>ASV, Asturiana de los Valles</td>
<td>30</td>
<td>1.30 ± 0.03</td>
<td>557.2 ± 8.8</td>
<td>450.6 ± 5.5</td>
</tr>
<tr>
<td>AVI, Avileña</td>
<td>30</td>
<td>1.34 ± 0.03</td>
<td>512.0 ± 13.4</td>
<td>462.2 ± 4.4</td>
</tr>
<tr>
<td>CAS, Casina</td>
<td>30</td>
<td>1.12 ± 0.03</td>
<td>523.0 ± 7.3</td>
<td>471.0 ± 3.4</td>
</tr>
<tr>
<td>CHA, Charolais</td>
<td>31</td>
<td>1.12 ± 0.02</td>
<td>538.5 ± 5.0</td>
<td>472.0 ± 4.4</td>
</tr>
<tr>
<td>HOL, Holstein</td>
<td>30</td>
<td>1.18 ± 0.02</td>
<td>506.4 ± 9.3</td>
<td>493.5 ± 5.8</td>
</tr>
<tr>
<td>JER, Jersey</td>
<td>31</td>
<td>1.22 ± 0.02</td>
<td>543.5 ± 9.6</td>
<td>513.5 ± 5.8</td>
</tr>
<tr>
<td>LIM, Limousin</td>
<td>29</td>
<td>1.08 ± 0.01</td>
<td>523.5 ± 7.3</td>
<td>441.5 ± 4.6</td>
</tr>
<tr>
<td>MAR, Marchigiana</td>
<td>29</td>
<td>1.06 ± 0.01</td>
<td>500.0 ± 6.2</td>
<td>444.5 ± 5.8</td>
</tr>
<tr>
<td>PIE, Piemontese</td>
<td>27</td>
<td>1.09 ± 0.01</td>
<td>490.0 ± 7.2</td>
<td>448.5 ± 5.8</td>
</tr>
<tr>
<td>PIR, Pirenaica</td>
<td>20</td>
<td>0.56 ± 0.10</td>
<td>390.5 ± 6.2</td>
<td>433.5 ± 5.6</td>
</tr>
</tbody>
</table>

*Note for all parameters, $P<0.001$. Different superscript letters in the same row indicate differences between breeds at least 1%.
body length, adjusted to 365 days of age were highly significant for each morphological trait (see Table 2). At 365 days, the pelvis width correlated with wither height ($r=0.50$, $P<0.001$) and with body length ($r=0.42$, $P<0.001$) while no correlation was found between body length and wither height. Jersey, Casina and Highland had a low withers height, between 113 cm and 103 cm, while Holstein had the greatest (133 cm). Simmental, Danish Red, Marchigiana and Avileña breeds ranged between 126 and 123 cm, whereas the others breeds had intermediate values (120 cm to 118 cm). Three breeds, Casina, Jersey and Highland had a small pelvis width with values between 41 and 38 cm, Charolais had the widest pelvis (53 cm). Highland had the shorter body length of 122 cm, whereas Asturiana de los Valles, Pirenaica and Avileña, had greatest body lengths (152 to 149 cm).

When the relationship between breeds is explored using the morphological traits, wither height and pelvis width, three main groups can be defined based on frame or mature size (see Fig. 1), these are: small breeds (Highland, Jersey and Casina); beef breeds, characterized by their muscularity, wide pelvis and medium height (Charolais, Limousin, South Devon, Pirenaica, Asturiana de los Valles, Piemontese and Aberdeen Angus), and tall breeds with average muscle development (Holstein, Simmental, Danish Red, Marchigiana and Avileña).

### 3.2. Carcass characteristics

Carcass characteristics for each breed showed highly significant differences among breeds for all variables studied (see Table 3). Carcass weights ranged from 189.7 kg for Jersey to 386.6 kg for Charolais. In general, dairy breeds and local breeds produced lighter weight carcasses than specialized beef breeds. In addition, the dairy and local breeds had low dressing percentage; the lowest for Jersey (50.1%), while the specialized beef breeds (Charolais, Pirenaica, Asturiana de los Valles, Piemontese and Limousin) had values over 60%. The breed type was also reflected in conformation and fatness. The highest conformation score was 14.6 for the double muscled Piemontese and the lowest 4.4 for Jersey, whereas fatness scores ranged from 3.6 for the Piemontese to 11.0 in the Aberdeen Angus. Similarly, kidney knob and channel fat weight (KKCW) ranged from 0.8 kg in Piemontese to 8.4 kg in Highland. Comparing the morphological traits, carcass length varied from 119.1 cm in Highland to 135.1 cm in Holstein, and hind-limb length varied from 64.4 cm in Highland to 86.0 in Holstein and internal depth of breast varied from 33.4 cm in Asturiana de los Valles to...
43.0 cm in Holstein. The blockiness index, ranged from 1.6 kg/cm for Jersey to 2.9 kg/cm for Charolais.

Muscle depth measured in the loin area was highest for Asturiana de los Valles and Piemontese (more than 52 cm²) and lowest for Jersey (24.9 cm²), the greater differences among breeds were due to the differences in the dorso-ventral diameter (minimum diameter) rather than in the medium-lateral dimension (maximum diameter). Muscle percentage measured from the dissection of the 6th rib dissection ranged from 58.9% in Holstein to 79.9% in Piemontese, whereas fat percentage varied from 3.2% in Piemontese to 21.7% in Aberdeen Angus. Again the dairy and the local breeds had the highest values for fat and the lowest values for muscle percentages, as would be expected. Limousin had the lowest bone percentage (15.0%).

3.3. Principal components analysis

The first two dimensions of the PCA analysis (factor 1, 48.8%, factor 2, 24.6%) explained 73.4% of the variation among breeds (see Fig. 2). The first dimension was related to the blockiness index, carcass weight, loin area, minimum diameter of the loin, dressing percentage and conformation score, while the second dimension was positively influenced by fat percentage measured at dissection, fatness score and KKCW, and was negatively related to muscle percentage at dissection. Therefore, a breed with high muscularity and low fatness, e.g., the Piemontese, appears in the right-bottom square of the plot.

4. Discussion

4.1. Weight and growth rate

The fifteen cattle breeds analysed here originate in Europe where, currently, animals are slaughtered in the early stage of maturity to produce beef. Commercial requirements for each country and the local markets differ, so beef is produced from both bulls and steers. In the study reported here, only entire bulls were studied. Considerable variation was observed among the 15 breeds for live weight gain, weight at all ages and morphological traits. This study underlines the large differences seen between dairy breeds and specialized beef breeds as well among local breeds, which were reflected in all the traits recorded. Previous research has shown that when cattle of diverse breeds are compared at a similar age, with similar management, some variation will be found in carcass weight, while carcass composition will depend on the range of target weights and differences in growth curves of each breed (Kempster et al., 1982). The diet offered during the fattening period will influence the growth rate and carcass characteristics, especially fatness. In a study where breeds were compared at a constant fat thickness, breed group differences in composition were reduced by more than 50% relative to differences at a constant age (Koch et al., 1979). Therefore, in this study fat cover, which is a parameter used commercially to select bulls for slaughter was not used, instead slaughter was at a fixed weight within a target slaughter age. A high energy/protein diet was offered ad libitum through the fattening period, and the bulls studied exhibited an almost linear average daily gain. Two of the breeds, the Aberdeen Angus and South Devon showed a very high live weight gain during the experimental period (9 to 12 months of age, data not shown). This may have been a result of compensatory growth, following period on a restricted diet prior to the animals entering the study. The high average daily gain in these breeds was unexpected, but has also been observed in another study. Chambaz et al. (2003) found that Angus steers, reared until they reached the same intramuscular fat content, had a 6 to 26% higher growth rate than Limousin, Simmental or Charolais breeds, supporting the higher growth rate of this breed as observed in our animals. Although this was not observed by others (e.g., Cuvelier et al., 2006). Asturiana de los Valles, Piemontese and Marchigiana showed a moderate average daily gain compared to other beef breeds. It is known, that for some beef breeds, gut and digestive system capacity, can limit intake and hence reduce live weight gain. Cima (1996) observed a lower weight of the rumen (−30%) and of the whole gut (−13%), for Asturiana de los Valles breed, than would be expected of animals of this size, this limits their feed intake capacity and hence is likely to impact on growth rate compared with other breeds.

If the breeds used in this study were raised under different management systems or diets, they could exhibit higher live gain: Asturiana de los Valles has achieved 1.5 kg/day, Avileña 1.6 kg/day, Pirenaica...
<table>
<thead>
<tr>
<th>Breed</th>
<th>AA</th>
<th>ASV</th>
<th>AVI</th>
<th>CAS</th>
<th>CHA</th>
<th>HIG</th>
<th>HOL</th>
<th>JER</th>
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<th>MAR</th>
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<td>31</td>
<td>29</td>
<td>27</td>
<td>20</td>
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</tr>
<tr>
<td>Carcass weight (kg)</td>
<td>335.7de</td>
<td>348.7cd</td>
<td>324.7ef</td>
<td>244.7h</td>
<td>386.6a</td>
<td>320.0efg</td>
<td>245.1h</td>
<td>307.5g</td>
<td>360.0bc</td>
<td>371.5ab</td>
<td>318.7fg</td>
<td>346.9cd</td>
<td>344.4cd</td>
<td>29.46</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Dressing percentage</td>
<td>56.2ef</td>
<td>62.6ab</td>
<td>58.8d</td>
<td>56.2e</td>
<td>61.0f</td>
<td>55.2f</td>
<td>55.7g</td>
<td>50.1h</td>
<td>63.7a</td>
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<td>61.1bc</td>
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<td>58.7a</td>
<td>55.5ef</td>
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<tr>
<td>Kidney fat weight (kg)</td>
<td>7.1abc</td>
<td>2.3ge</td>
<td>3.9f</td>
<td>3.9f</td>
<td>5.8de</td>
<td>8.4e</td>
<td>6.1cd</td>
<td>7.5b</td>
<td>5.1e</td>
<td>1.4b</td>
<td>0.8h</td>
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<td>6.2ed</td>
<td>5.4de</td>
<td>2.4d</td>
<td>1.79</td>
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<td>Conformation score (1–18)</td>
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<td>12.1b</td>
<td>8.0f</td>
<td>7.6g</td>
<td>9.9d</td>
<td>8.2e</td>
<td>4.6f</td>
<td>4.4f</td>
<td>10.2d</td>
<td>11.1c</td>
<td>14.6f</td>
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<td>10.2d</td>
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<td>Fatness score (1–15)</td>
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<td>4.1gh</td>
<td>5.8i</td>
<td>5.9g</td>
<td>8.9fg</td>
<td>6.8d</td>
<td>8.2e</td>
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<td>8.4e</td>
<td>5.0f</td>
<td>3.6h</td>
<td>4.9f</td>
<td>9.1b</td>
<td>6.0d</td>
<td>7.2d</td>
<td>1.40</td>
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<tr>
<td>Carcass length (cm)</td>
<td>130.3e</td>
<td>127.1d</td>
<td>133.1ab</td>
<td>121.1f</td>
<td>133.0ab</td>
<td>119.1f</td>
<td>135.1a</td>
<td>119.8c</td>
<td>126.6d</td>
<td>123.9e</td>
<td>123.3ef</td>
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<td>132.1bc</td>
<td>130.7bc</td>
<td>130.4e</td>
<td>4.30</td>
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<tr>
<td>Internal depth of breast (cm)</td>
<td>40.3d</td>
<td>33.4f</td>
<td>37.0f</td>
<td>33.8ef</td>
<td>34.4ef</td>
<td>37.4ef</td>
<td>43.0h</td>
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<td>34.7e</td>
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<td>37.3d</td>
<td>34.7e</td>
<td>41.7b</td>
<td>37.3d</td>
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<td>1.99</td>
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<td>Hind-limb length (cm)</td>
<td>70.8f</td>
<td>81.0g</td>
<td>83.4h</td>
<td>75.3i</td>
<td>82.3h</td>
<td>64.4j</td>
<td>86.0k</td>
<td>67.1l</td>
<td>81.5de</td>
<td>72.8e</td>
<td>70.4j</td>
<td>82.1hde</td>
<td>81.8de</td>
<td>72.8e</td>
<td>83.0hde</td>
<td>2.61</td>
</tr>
<tr>
<td>Blockiness index (kg/cm)</td>
<td>2.6ef</td>
<td>2.7ef</td>
<td>2.4h</td>
<td>2.0i</td>
<td>2.9j</td>
<td>2.1k</td>
<td>2.4l</td>
<td>1.6m</td>
<td>2.8h</td>
<td>2.5h</td>
<td>2.7de</td>
<td>2.8abc</td>
<td>2.4hi</td>
<td>2.7def</td>
<td>2.6f</td>
<td>0.19</td>
</tr>
<tr>
<td>Maximum diameter (cm)</td>
<td>10.1f</td>
<td>9.1g</td>
<td>9.1i</td>
<td>8.6j</td>
<td>10.2h</td>
<td>9.4f</td>
<td>9.6de</td>
<td>8.1h</td>
<td>9.6de</td>
<td>10.2de</td>
<td>10.3f</td>
<td>9.2fe</td>
<td>9.9fed</td>
<td>11.0o</td>
<td>9.6fed</td>
<td>0.78</td>
</tr>
<tr>
<td>Minimum diameter (cm)</td>
<td>5.1f</td>
<td>6.7a</td>
<td>5.3ef</td>
<td>5.2ef</td>
<td>5.8ed</td>
<td>4.6e</td>
<td>4.8d</td>
<td>3.7e</td>
<td>6.1bc</td>
<td>5.9de</td>
<td>6.1bc</td>
<td>6.2h</td>
<td>4.6g</td>
<td>5.7ed</td>
<td>5.5de</td>
<td>0.70</td>
</tr>
<tr>
<td>LT area, (cm²)</td>
<td>41.8ef</td>
<td>52.7a</td>
<td>40.3e</td>
<td>35.9b</td>
<td>35.0h</td>
<td>35.6h</td>
<td>24.9j</td>
<td>44.7de</td>
<td>47.8ef</td>
<td>52.2a</td>
<td>48.7e</td>
<td>37.8gh</td>
<td>51.6ab</td>
<td>42.1ef</td>
<td>6.17</td>
<td></td>
</tr>
<tr>
<td>Fat (%)</td>
<td>21.7a</td>
<td>7.8g</td>
<td>12.6f</td>
<td>14.7e</td>
<td>15.4i</td>
<td>19.3d</td>
<td>19.9b</td>
<td>13.0def</td>
<td>13.2def</td>
<td>8.9e</td>
<td>3.2g</td>
<td>9.7e</td>
<td>19.5f</td>
<td>14.2de</td>
<td>11.7e</td>
<td>3.53</td>
</tr>
<tr>
<td>Bone and others (%)</td>
<td>16.9f</td>
<td>17.2ef</td>
<td>18.3e</td>
<td>18.9d</td>
<td>16.9f</td>
<td>17.6ef</td>
<td>21.8a</td>
<td>20.4bc</td>
<td>15.0e</td>
<td>21.0mb</td>
<td>16.9f</td>
<td>17.5ef</td>
<td>19.4de</td>
<td>17.3ef</td>
<td>20.5bc</td>
<td>2.35</td>
</tr>
<tr>
<td>Muscle (%)</td>
<td>61.5b</td>
<td>75.8g</td>
<td>69.1ab</td>
<td>66.3e</td>
<td>67.7ge</td>
<td>62.8b</td>
<td>58.9f</td>
<td>66.5gc</td>
<td>71.9a</td>
<td>70.0fh</td>
<td>79.9a</td>
<td>72.9b</td>
<td>61.1h</td>
<td>68.5de</td>
<td>67.8fg</td>
<td>3.49</td>
</tr>
</tbody>
</table>

AA, Aberdeen Angus; ASV, Asturiana de los Valles; AVI, Avileña; CAS, Castina; CHA, Charolais; HIG, Highland; HOL, Holstein; JER, Jersey; LIM, Limousin; MAR, Marchigiana; PIR, Piemontese; RED, Danish Red; SD, Simmental; SE, South Devon.

*Note for all parameters, *P* < 0.001. Different superscript letters in the same row indicate differences between breeds for at least 5%.

† Measured on longissimus thoracis (LT) at 6th rib level.

‡ Percentages from the 6th rib dissection.
1.7 kg/day (Albertí et al., 2001; Piedrafita et al., 2003); Limousin 1.62 kg/day, Holstein 1.23 kg/day (Andersen et al., 2001) and Danish Red 1.14 kg/day (Andersen, 1974). They could also exhibit lower live gain, Aberdeen Angus only achieved 1.66 kg/day when fattened with a pulp or a cereal-based diet (Cuvelier et al., 2006), while Charolais had an average daily gain of 1.3 kg/day and Limousin 1.2 kg/day when they were fed with sugar beet pulp silage plus hay complemented with concentrate (Jurie et al., 2005).

The high rates of growth for Charolais and Simmental seen in our study are in agreement with the work of Andersen et al. (1977) and Cundiff et al. (1986) who used these sire breeds in a cross breeding study. The difference...
between the lighter weight breeds (Jersey, Highland and Casina), which had the lowest ADG (about 1.1 kg/day), and the heavy-weight breeds (Aberdeen Angus, South Devon, Charolais, Simmental and Limousin) which had the highest ADG (2.0 to 1.5 kg/day) are in agreement with the positive correlation with adult body weight observed by Klosterman (1972). However, the use of ADG rate and live weight is not a consistent parameter to sort breeds by type (dairy, beef, or local) as dairy breeds (Holstein and Danish Red) grew more slowly and fattened later than would be expected from their target weights, when compared with others breeds (Kempster et al., 1982).

4.2. Morphological measurements

The significant differences found among breeds for the morphological measurements regressed to a standardised age of 365 days, confirmed the large phenotypic variability between breeds and provided the basis for objective classification in different breed types or groups. Jersey, Casina and Highland represent the small mature size breeds, this group typically has narrow pelvis development, which indicates slow skeletal development and low muscling. Buchanan and Dolezal (1999) classified Jersey and Highland breeds as small by size and growth. In this respect, the Jersey breed would have the typical shape of dairy breeds, but its narrow pelvis is emphasized by its small mature size. As would be predicted from their small size, the slaughter weights were lower for this group than for other breeds, in addition, the average daily gain was also very low. In this study, the dairy breeds and local breeds such as Holstein, Simmental, Danish Red, Avileña and Marchigiana are classified as tall animals with an intermediate pelvis width. The Holstein breed was also classified as a tall and heavy breed by Long et al. (1979) in comparison with Angus, Brahman, Hereford and Jersey. The other breeds (Charolais, Aberdeen Angus, South Devon, Limousin, Piemontese, Asturiana de los Valles and Pirenaica) represent the specialized beef breeds, which were characterized by their wider pelvis, and medium wither height. Overall, the grouping of breeds presented in this paper is in agreement with other studies (Buchanan and Dolezal, 1999).

4.3. Carcass traits

The differences found between breeds in carcass weight were expected. In the same way, the differences found among breeds for dressing percentage are in agreement with those given by several authors for the same breeds: Wulf et al. (1996) for Limousin; Barton and Pleasants (1997) for Angus and Jersey, Piedrafita et al. (1999) and Alberti et al. (2000) for Asturiana de los Valles, Avileña, Casina and Pirenaica, Cepin et al. (2000) for Holstein; Short et al. (2002) for Piemontese; Trombetta et al. (2005) for Marchigiana; Subrt and Divis (2002) for Charolais; Sami et al. (2004) for Simmental. Hence, with in limits, the carcass weight and dressing percentage are more strongly influenced by the genetic type of the animal, reflected in the breed type, than by the environment. The present study is the only one to have compared such a wide range of pure breeds and different genetic types and aptitudes. Additionally, it is the only work in which some local or hardy breeds from different countries were compared with each other, i.e., Highland (UK) and Casina (Spain).

In the present study, Piemontese and Asturiana de los Valles breeds (also some of the South Devon) display the double muscling phenotype, which is more marked in hind-limbs than in forelimbs (Arthur, 1995). This explains why conformation scores for these breeds were higher than other breeds, as muscling and conformation score is assessed from the roundness of limbs and shoulders. This also explains why conformation score is not exactly reflected in blockiness index. In this study, Avileña, and Marchigiana showed similar blockiness indexes and the same percentage of muscle in dissection, therefore it may be expected that conformation scores would be the same, however, the conformation scorers of these breeds differed by more than 3 points, as the Avileña had longer hind-limbs than Marchigiana.

If the breeds are ranked by morphological measures, four breeds, Highland, Casina, Jersey and Piemontese, are found to have short carcasses and hind-limbs, however, Jersey, Casina and Highland had a low blockiness index, because of their lower slaughter weight, Piemontese had a high value for this trait, which was also reflected in the conformation scores. Similarly, Holstein, Danish Red, Avileña, Charolais and Pirenaica, did not change their relative positions in the ranking of both carcass length and hind-limb length, but dairy and local breeds had low blockiness indexes and poor conformation scores, while specialized meat breeds remained at the top for the latter two traits. In the European market, carcasses are valued by conformation (Drennan et al., 2002), which suggests that the blockiness index would be a complementary tool to classify carcasses, especially when very different types of breeds are compared in the same market Díez et al. (2006).

Although variables related to muscular development were good discriminators of breed type, variables defining fatness were not. Hence, if breeds are ranked by their fatness score, Jersey would be placed among
Piemontese, Asturiana de los Valles and Pirenaica. Conversely, Limousine and Charolais would be placed between Holstein and Danish Red. Ranking breeds by fat percentage in the dissection gave a group that consisted of beef breeds (Piemontese, Asturiana de los Valles, Marchigiana and Pirenaica) but Limousin was unexpectedly positioned between Jersey and South Devon, and Charolais was placed between Casina and Holstein. The same pattern was observed when ranking breeds by KKCW. This indicates that fat variability was higher than muscle variability. From the dissection data the coefficient of variation of fat percentage was nearly five times higher than that of muscle percentage.

Kempster et al. (1982) demonstrated that there is an important genetic variation in partitioning of fat between different depots, and Casasús et al. (2000) reported that in cattle this occurs even under similar nutritional conditions. Beef cattle are characterized by their ability to transform the nutrients mainly into proteins, whereas dairy breeds, which have a different hormonal and metabolic status, tend to deposit more intra-abdominal fat (Kempster et al., 1982). Nevertheless, the variability of fat tissue could also depend on the differences in the physiological ages of breeds at the same chronological age (Kempster et al., 1982; Micol et al., 1993), or on the differences in the growth potential between breeds (Jenkins et al., 1991; Arthur, 1995; Arthur et al., 1995; Alberti et al., 2000; Subrt and Divis, 2002; and Oliván et al., 2004). Therefore, since fat tissue development is affected by multiple factors and there is not a clear relationship between fatness and breed type.

4.4. Principal components analysis of breeds

The distribution of breeds plotted by PCA analysis reflected their production aptitude. Muscularity variables, which influenced the first dimension, were independent of fatness measures, which strongly influenced the second dimension. Therefore, breeds naturally fell into three groups: the specialized beef breeds are clustered spotted on the right side of the PCA plot, and included Piemontese, Asturiana de los Valles, Pirenaica, Limousin, South Devon, Charolais and Aberdeen Angus. All these breeds had a high muscle score as expected for the beef breeds, however, they differ in fatness level. Aberdeen Angus was the fattest, in spite of its good conformation; and Piemontese was the leanest breed. The local and dairy breeds are placed on the left side of the plot and are represented by Jersey, Casina, Holstein, Highland and Danish Red. They had low muscling and medium (Casina) or highly fattened (Holstein, Simmental, Danish Red) carcases. Jersey had low muscling. A third group of breeds fell between the two previous groups, as an “intermediate” group (Avileña, Marchigiana, Simmental). These are meat producing but not highly specialized breeds. Although originally considered as local, hardy or dairy breeds, they have undergone some selection and have improved conformation characteristics. Therefore, they have intermediate features: medium conformation and medium fatness level.

These results are consistent with those of Barton and Pleasants (1997) who reported the same pattern of breed distribution related to function. They found that the main variables explaining breed differences were bone or lean weights for the first axis and KKCW or rib eye (LT) for the second axis. Similarly, Alberti et al. (2005) in a study of seven Spanish breeds reported that the most influential variables for classifying breeds were shape and conformation for the first axis and measurements of length and fat cover in the second axis.

Therefore, our results show that carcass traits and body size measurements are useful to discriminate between breeds, probably because the muscle to bone ratio is little affected by differences in degree of maturity, and each breed has a distinctive value over quite a wide range of fatness (Kempster et al., 1982). However, the use of ADG rate and live weight is not a consistent parameter to group breeds by type (dairy, beef, or local) as within a short interval of weight it was possible to find dairy breeds (Holstein and Danish Red) that grow slowly and fatten later than expected from their target weight in comparison with others breeds (Kempster et al., 1982).

For beef cattle breeds, the genetic selection for large size, growth, or muscle development in European countries is likely to have affected muscle biochemical characteristics (Sudre et al., 2005), which could have some impact on meat quality. This important question, which has been examined in the animals used in this study, will be reported elsewhere.

5. Conclusions

The present study reports an interesting approach to objectively describe morphological differences among a representative sample of cattle breeds from Western Europe. The traditional types of cattle grouped as dairy breeds, specialized beef breeds and local breeds, can be complemented by grouping the breeds according to their slaughter weight (i.e., heavy, medium, and light) and animal size (i.e., small/short/narrow, medium, and tall/large/wide). Indeed, these measurements together with the carcass traits have provided a more useful method to classify cattle breeds, than live weight or daily gain.
The present study has demonstrated that body dimensions and carcass traits differ between breeds, and that animal types are clearly defined by these characters. These results provide valuable information when devising breeding strategies to meet the demands of the European markets.

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References


