Carcass and meat quality in Brown fattened young bulls: effect of rearing method and slaughter weight

A. Cerdeño[1], C. Vieira[2], E. Serrano[1], A.R. Mantecón[1]

[1]Experimental Agricultural Station, Spanish National Research Council, León, Spain
[2]Meat Technological Station, Agronomic Technological Institute, Salamanca, Spain

ABSTRACT: Three groups of Brown fattened young bulls were studied, comparing the effects of rearing method (suckled vs. bucket reared) and of slaughter weight (400 vs. 480 kg). Suckled animals had higher fatness scores (2.2 vs. 1.3), more dissectible fat (14.5 vs. 9.1%), and higher intramuscular fat content (7.8 vs. 4.6%DM), accompanied by better scores in sensory tenderness (5.2 vs. 3.8) than did the bucket-reared ones. Animals slaughtered at a heavier weight showed a higher dressing percentage (57.5 vs. 53.8%), conformation score (9.2 vs. 6.2), and fat content (fatness score, dissectible fat and intramuscular fat). The meat from animals in the heavier group had lower a* (12.4 vs. 14.2) and higher b* (10.8 vs. 12.9) indexes, as well as higher scores in most sensory traits than the lighter ones.

Keywords: Brown cattle; carcass composition; meat colour; sensory evaluation

In several areas within European Mediterranean countries, beef consumption is predominantly based on beef obtained from young animals that are less than or about one year of age, which results in the pale meat that is mainly demanded in these regions, contrasting with the northern European countries, where red beef is preferred. In general, in areas that use young animals, most of the beef comes from intensive production systems in which animals are weaned early and receive high quantities of concentrate diet until slaughter. An alternative system, which is quite common in those countries, is based on suckler cows in which calves are suckled by their dams for 5–7 months and gradually switched to a growing-finishing period. Most beef cattle are slaughtered as calves (about 10 months of age and 200–250 kg carcass weight) or as yearlings (between 12 and 15 months of age and 300–380 kg carcass weight).

Brown cattle are a medium- to large-sized dual-purpose breed used for beef production in northern Spain and other mountainous areas in Europe. A better understanding of the breed is desirable because of its good maternal attitude and adaptability to mountain areas, the benefit of helping to maintain biodiversity and sustainability in those areas, and the increasing consumer demand for meat of a known origin and produced under natural conditions (Grunert et al., 2004). Although the Brown breed was the subject of some research (Albertí et al., 2000; Serra et al., 2004), further information about the product obtained from this breed in response to different production factors, such as type of feeding and slaughter weight, is needed.

It is well known that slaughter weight has an important effect on carcass value and meat quality (Cross et al., 1984; Powell, 1991; Keane and Allen, 1998), but most of the research on this subject focused on animals slaughtered at a relatively late age and, consequently, at a higher weight. On the other hand, although an effect of weaning age on meat quality is known (Myers et al., 1999; Fluharty et al., 2000), little information is available about this effect on beef cattle under 10 months of age, in which the effect of natural milking could persist until slaughter.

Therefore, the aim of this experiment was to evaluate the effect of rearing system and slaughter weight on carcass and meat characteristics in young Brown bulls.

Table 1. Ingredients and chemical composition of feeds

Concentrate ingredients	(g/kg as fed)		
Maize	361		
Barley	289		
Soybean meal	148		
Middlings	80		
Gluten feed	70		
Molasses	30		
Mineral-vitamin supplement	22		
Chemical composition	**Milk replacer**	**Concentrate**	**Barley straw**
Dry matter (DM) (g/kg)	970.7	876.0	905.8
Crude protein (g/kg DM)	244.0	141.2	36.5
FND (g/kg DM)	–	–	730.7
FAD (g/kg DM)	–	–	448.4
Ash (g/kg DM)	67.2	60.0	57.0

MATERIAL AND METHODS

Eighteen Brown male calves were assigned to one of the three groups. In the SL (suckled-light) group, calves were suckled twice a day by their dams until 150 days of age, having free access to growing concentrate and straw. After weaning, animals received *ad libitum* finishing concentrate and straw until slaughter at a target weight of 400 kg (9–10 months of age). In the BL (bucket-light) group, calves stayed with their dams for 15 days before receiving an individual allowance of 4 kg/day of warm (38°C) commercial milk replacer, which was offered by bucket until the growing concentrate intake was 1.5 kg (at approximately 45 days). During and following the rearing period until slaughter, all of the animals had *ad libitum* access to concentrate and barley straw. Animals in BL group were slaughtered at an average live weight of 400 kg. In the BH (bucket-heavy) group, calves were bucket-reared and intensively fed as described above, but the target slaughter weight was 480 kg (12–13 months of age). The composition of the feeds offered is provided in Table 1. Each month, all of the animals were weighed and daily live weight gain was calculated by linear regression.

Carcasses were weighed and the EUROP beef carcass grading system was used to assess visually the conformation and fatness of each carcass. To obtain dressing percentages, cold carcass weight was expressed as a percentage of the live weight before slaughter. The following measurements were recorded from the left side of the carcass: carcass length, hind-limb length, hind-limb width and hind-limb perimeter. The 6th rib was dissected into bone, muscle, subcutaneous fat, intermuscular fat and other tissues (vessels, tendons, fascia and *Ligamentum nuchae*). We expressed the weight of each tissue as a percentage of the total dissectible tissue weight. The *masculus longissimus thoracis* area was measured planimetrically at the 7th rib section.

pH was measured at 24 hours *post mortem* in the *m. longissimus thoracis* at the 5th rib level using a "penetration" pH-electrode. Meat colour was measured on the surface of the *m. longissimus thoracis* corresponding to the 6th rib section using a Minolta CM2002 spectrophotometer and the CIE L* a* b* colour space.

To evaluate the other measures of meat quality, a sample cut of *m. longissimus thoracis*, from 7th to 11th ribs, was taken from the left carcass side. The cranial part of this sample was used for chemical analysis, drip loss and press loss measurements. Its medium part was used for cooking loss and Warner-Bratzler shear force measurements. The caudal part of the sample was used for sensory analysis.

The portion used in the chemical composition analyses was freeze-dried and ground. These analyses included the determination of dry matter, ashes, crude protein and ether extract following official procedures (AOAC, 1990). Drip loss was assessed according to Honikel (1998), using two slices (approx. weight 80 g) collected 24 hours after slaughter and stored at 4°C for 48 hours. For cooking loss measurements, a 5-cm thick slice, aged at 4°C for 7 days, vacuum-packed and stored at –20°C, was used. After thawing at 4°C for 24 h, the samples were heated in a water bath until an internal temperature of 75°C was reached, as described by Honikel (1998). Press loss was determined using the filter paper method, pressing four 300-mg replicates for 10 minutes under a 2.5 kg weight. Warner-Bratzler shear force (WBSF) test was performed on those cooked samples, with a minimum of 10 replicates (rectangular cross-section cores of 1 cm thick × 1 cm wide × 2 cm long), cutting perpendicularly to the fibre direction with a Texture Analyser TA-XT2_i.

To evaluate the eating quality of meat, a group of eight trained panellists scored from 1 to 10 the intensity of the following characteristics: beef odour, tenderness, juiciness, beef flavour and overall acceptability. In those tests, we used samples that had been aged for 7 days, vacuum-packed and frozen at –20°C. At the time of testing, we thawed the samples at 4°C for 24 h. Samples were cut into 2 cm-thick steaks, which were cooked at 220°C in an electric oven to an internal temperature of 70°C.

Data were analysed using the GLM procedure of SAS (1989), comparing, separately, SL vs. BL groups with the method of rearing as the only source of variation, and BL vs. BH, with weight at slaughter as the only source of variation. Data are expressed as mean values and standard deviations.

RESULTS

Performance and carcass characteristics

As shown in Table 2, average daily gain (ADG) was not significantly different between SL and BL groups. For both groups, we calculated ADG in two phases: from birth to 150 days (weaning age for SL group) and from 150 days to slaughter. In the first phase, the ADG of the groups did not differ significantly (1.19 ± 0.056 kg/day vs. 1.20 ± 0.110 kg/day for SL and BL, respectively; $P > 0.05$). During the second phase, the ADG in the SL group (1.43 ± 0.057 kg/day) was significantly higher ($P < 0.05$) than that in the BL group (1.13 ± 0.090 kg/day).

SL and BL groups did not differ significantly ($P > 0.05$) in cooling shrinkage, dressing percentage, conformation score, or any of the morphological carcass measurements. Fatness score was significantly higher ($P < 0.05$) in suckled calves than in bucket-reared calves.

Table 2. Effect of treatments on performance and carcass characteristics

Parameter	SL		BL		BH		SL vs. BL	BL vs. BH
	$\bar{x}$	$S_{\bar{x}}$	$\bar{x}$	$S_{\bar{x}}$	$\bar{x}$	$S_{\bar{x}}$		
Slaughter live weight (kg)	407.0	15.27	400.6	16.68	472.8	35.22	n.s.	**
Average daily gain (kg/day)	1.28	0.164	1.16	0.174	1.27	0.166	n.s.	n.s.
Hot carcass weight (kg)	229.5	7.01	219.6	9.56	276.6	16.82	n.s.	***
Cooling shrinkage (%)	2.6	0.93	1.9	0.16	1.8	0.86	n.s.	n.s.
Dressing percentage (%)	54.6	1.09	53.8	3.15	57.5	0.58	n.s.	*
EUROP classification								
Conformation score^{+}	7.7	1.37	6.2	1.83	9.2	0.98	n.s.	**
Fatness score^{++}	2.2	0.75	1.3	0.52	2.2	0.41	*	*
Carcass measurements (cm)								
Carcass length	119.4	1.63	121.5	2.49	124.3	4.26	n.s.	n.s.
Hind-limb length	79.9	2.87	78.5	0.89	81.2	4.75	n.s.	n.s.
Hind-limb width	24.6	1.24	23.8	1.04	26.1	0.66	n.s.	***
Hind-limb perimeter	106.0	2.81	105.8	1.86	112.9	2.84	n.s.	***

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; n.s. = $P > 0.05$

$^{+}$15-point scale: 15 = E^{+} (very good conformation), ... , 1 = P^{-} (very poor conformation)

$^{++}$5-point scale: 5 = very fat, ..., 1 = very lean

Table 3. Effect of treatments on tissue composition

Parameter	SL		BL		BH		SL vs. BL	BL vs. BH
	$\bar{x}$	$S_{\bar{x}}$	$\bar{x}$	$S_{\bar{x}}$	$\bar{x}$	$S_{\bar{x}}$		
Bone (%)	21.0	4.44	22.5	4.45	19.0	3.15	n.s.	n.s.
Muscle (%)	62.3	2.61	65.8	3.95	66.1	5.14	n.s.	n.s.
Subcutaneous fat (%)	3.8	1.69	1.7	1.24	3.3	1.32	*	*
Intermuscular fat (%)	10.8	2.28	7.4	1.38	9.9	1.83	**	*
Total dissectible fat (%)	14.5	3.74	9.1	2.24	13.2	2.20	*	**
Other tissues (%)	2.1	0.58	2.6	0.80	1.6	0.26	n.s.	*
LT area (cm^2)+	42.7	2.07	43.8	5.27	55.0	4.73	n.s.	**
LT area (cm^2/kg)+	0.38	0.022	0.40	0.058	0.41	0.050	n.s.	n.s.

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; n.s. = $P > 0.05$

+LT area: *m. longissimus thoracis* area (expressed as an absolute value and relative to half-carcass weight)

Regarding the slaughter weight effect, BH group had a higher dressing percentage ($P < 0.05$) and higher score of conformation ($P < 0.01$), reflected in a higher hind-limb width and perimeter ($P < 0.001$) than did the BL group. BH group also showed a higher fatness score ($P < 0.05$).

Table 4. Effect of treatments on meat quality characteristics

Parameter	SL		BL		BH		SL vs. BL	BL vs. BH
	$\bar{x}$	$S_{\bar{x}}$	$\bar{x}$	$S_{\bar{x}}$	$\bar{x}$	$S_{\bar{x}}$		
pH LT	5.65	0.056	5.67	0.060	5.61	0.198	n.s.	n.s.
Meat colour								
L*	39.5	1.07	36.1	1.34	37.4	1.67	n.s.	n.s.
a*	11.7	1.53	14.2	0.80	12.4	0.90	n.s.	**
b*	12.1	1.50	12.9	1.07	10.8	0.99	n.s.	***
Chemical composition								
dry matter (DM, %)	26.3	1.25	26.6	0.65	26.6	1.47	n.s.	n.s.
ash (%, DM)	4.2	0.13	4.3	0.33	4.6	0.33	n.s.	n.s.
crude protein (%, DM)	89.8	1.93	91.2	1.92	88.1	3.01	n.s.	n.s.
ether extract (%, DM)	7.8	1.60	4.6	1.01	9.3	2.87	**	**
Water-holding capacity								
drip loss (%)	1.5	0.21	1.5	0.22	1.5	0.14	n.s.	n.s.
press loss (%)	16.5	1.32	15.2	1.68	15.3	3.29	n.s.	n.s.
cooking loss (%)	21.7	3.89	24.0	1.95	23.0	2.61	n.s.	n.s.
Shear force (kg)	6.4	1.52	8.0	1.12	5.6	1.10	n.s.	**
Sensory traits+								
beef odour	5.0	0.84	6.0	0.64	5.0	0.63	*	*
tenderness	5.2	1.17	3.8	0.60	6.4	0.93	*	***
juiciness	4.5	0.77	4.2	0.79	5.6	0.81	n.s.	*
beef flavour	5.0	0.42	5.0	0.37	5.7	0.63	n.s.	n.s.
overall acceptability	4.5	1.00	3.5	0.70	5.7	0.82	n.s.	***

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; n.s. = $P > 0.05$

+all measured on a 10-point scale (1 = the lowest intensity, ..., 10 = the highest intensity)

Dissection results (Table 3) revealed a significantly higher proportion of total dissectible fat ($P < 0.05$) in SL compared to BL animals. A higher slaughter weight (BH vs. BL) led to a higher fat content ($P < 0.01$) and an increase in the *masculus longissimus thoracis* area ($P < 0.05$). However, when we express the size of this area relative to the half-carcass weight, the difference is not statistically significant ($P > 0.05$).

Meat quality

The SL and BL groups did not differ significantly ($P > 0.05$) in pH, colorimetric parameters or water-holding capacity (Table 4), though SL animals had significantly higher ($P < 0.01$) ether extract content. This group had lower shear force values than the BL ones, although the difference fell short of statistical significance ($P = 0.062$), which might be due to the relatively large standard errors associated with the mean values. Among the sensory traits, the suckled animals had lower values ($P < 0.05$) for beef odour intensity and higher ($P < 0.05$) tenderness scores than did the BL group.

BH animals exhibited lower a* ($P < 0.01$) and b* ($P < 0.001$) values, and had a higher ether extract content ($P < 0.01$) than did animals in the BL group, but the groups did not differ significantly ($P > 0.05$) in water-holding capacity values. Higher slaughter weights resulted in lower shear force values ($P < 0.01$), higher sensory tenderness ($P < 0.001$) and juiciness ($P < 0.05$), and higher overall acceptability ($P < 0.001$).

DISCUSSION

Effect of rearing system

The absence of differences in average daily gain between groups until 150 days of age could be related to the efficiency of the use of metabolizable energy and fat deposition, as will be discussed later. On the other hand, regarding the higher ADG after weaning in SL group, though there is no clear explanation, we can hypothesize that natural milking plus *ad libitum* intake of solid feeds could affect the gastrointestinal tract development, as indicated by the higher proportion of rumen in empty body weight in this group (2.5 ± 0.29% vs. 1.8 ± 0.09%, in SL and BL respectively; $P < 0.05$). This result might correspond to an increase in feed intake and/or to changes in the efficiency of feed utilization after weaning, leading to the corresponding increase in ADG.

High growth rates can lead to greater fat deposition (Aberle et al., 1981), and in our study the higher fatness score and fat content of the suckled animals are probably related to the higher growth rate before slaughter that was observed in the SL group. It is well known that management practices, such as rearing method, can alter carcass composition through differences in diet composition (Keane et al., 1990; Fiems et al., 2000). Moreover, in our study, that phenomenon is favoured by the relatively low slaughter weight, which can contribute to the persistence of differences in tissue composition derived from the rearing period. A longer finishing period might ameliorate those differences (Berge, 1991).

Our results are similar to those of Lunt and Orme (1987), who compared weanling and yearling calves slaughtered at the same live weight (440 kg) and found that weanlings had higher fatness scores than did yearlings. These authors concluded that carcass composition was impacted by the way the cattle were managed, which refutes the idea that cattle have the same body composition at a given weight regardless of age at slaughter or nutrient density of the diet.

Notwithstanding our observations, it cannot be discarded that the higher fatness scores of SL animals are influenced by the consumption of milk in addition to concentrate. According to Vermorel et al. (1980), when suckling animals receive high quantities of concentrate, the efficiency of the transformation of metabolizable energy into net energy for growth can be diminished by a higher fat deposition, which is not paralleled by a higher average daily gain. Similarly, Tikofsky et al. (2001) increased the concentration of dietary fat in veal calves fed under isocaloric and isonitrogenous intake conditions and observed higher carcass fat content, but no effect on live weight gain. Tikofsky et al. (2001) attributed that result to variations in the metabolism of fat and carbohydrate energy sources related to differences in the efficiency of the use of metabolizable energy for retained energy.

Differences between rearing methods in instrumental and sensory tenderness might be due to differences in the fatness scores between groups. Numerous studies indicate that the insulating effect of subcutaneous fat causes carcasses to chill slowly, which increases meat tenderness (May et al., 1992; Fiems et al., 2000). Although Wheeler et al. (1994) indicated that intramuscular fat accounted for a small percentage of the variation observed in meat tenderness, they also reported a positive correlation between tenderness and intramuscular fat levels between 3 and 7%, and no effect beyond 7%, our values being within the cited range.

The decrease in shear force in SL compared to BL group may also be related to the higher ADG presented by that group during the finishing period prior to slaughter. Aberle et al. (1981) suggested that the preslaughter growth rate affected the stability of connective tissue and ease of myofibril fragmentation, along with differences in chilling rate derived from differences in fat cover thickness.

Effect of slaughter weight

Dressing percentage increased with increasing slaughter weight, which agrees with results reported by May et al. (1992), Albertí et al. (2000) and Bruns et al. (2004). Albertí et al. (2000) indicated that the dressing percentage of young Brown Swiss bulls increased from 57.4% in animals slaughtered at 322 kg to 60.4% in animals slaughtered at 542 kg. Unlike our results, these authors observed no differences in conformation and fatness scores between slaughter groups (being R2 in both).

There is a general agreement in literature indicating that an increase in slaughter weight leads to an increase in fat content and a slight decrease in bone and muscle proportions (Berg and Butterfield, 1968; Thompson and Barlow, 1981). In the present experiment only an increase in fat content was detected, probably due to the relatively narrow range of considered weights (70 kg).

Similarly to the findings of Albertí et al. (2000) and Bruns et al. (2004), we found that the *longissimus* muscle area was significantly larger in BH group, though no differences appeared when this area was expressed as a proportion of half-carcass weight. Similarly, Thompson and Barlow (1981) found that the LT area increased at a proportionally lower rate than did carcass weight.

Renerre (1982) and Vestergaard et al. (2000a) found an increase in meat pigments as slaughter weight increased. Though, in general, pigmentation is positively correlated with a* index, this relationship does not always occur, as indicated by Vestergaard et al. (2000a). In our experiment, the a* index was lower in BH group, which was probably related to the relatively small difference in weight between groups; thus, the hypothetical increase in pigment concentration, far from being reflected in an increase in a*, might be compensated by the higher intramuscular fat content in this group. That interpretation is supported by the strong correlation between intramuscular fat content and a* parameter ($r = -0.97$; $P = 0.0012$). Furthermore, Wilson et al. (1995) observed a tendency towards lighter carcasses with increasing weight, and in the Brown breed Sañudo et al. (2001) obtained a significant negative slope in the regression between haematin content and conformation score, indicating a higher muscle development would represent lighter meat.

As in other studies (Keane and Allen, 1998; Vestergaard et al., 2000b; Bruns et al., 2004), we found intramuscular fat to increase as the carcass weight increased. At the same time, high fatness scores, which reflect the amount of subcutaneous fat on a carcass, are usually accompanied by increases in marbling fat.

Higher slaughter weight was found to improve tenderness, decreasing the shear force value and increasing the sensory tenderness score in BH group. This effect is likely mediated by the higher fatness observed in the mentioned group, as supported by the results of many other studies (Keane and Allen, 1998; Macíe et al., 2000), reporting an improvement in meat tenderness with increasing slaughter weight and relating it to the higher muscle lipid concentration in animals of the heavier group. Wood et al. (1999) suggested that the relation between tenderness and fat content was due to the insulation effect of subcutaneous and intermuscular fat and to the effect of a high intramuscular fat content diluting the fibrous protein by soft fat and opening up the muscle structure.

CONCLUSIONS

Firstly, the main impact of the rearing system was to produce a higher total fat content in suckled animals, which seems to contribute to an improvement of tenderness in this group.

Secondly, artificially reared and early weaned Brown young bulls when slaughtered at light weights did not achieve the necessary fatness level to assure optimal meat quality traits. Consequently, a higher slaughter weight, like that in our study or even slightly higher, seems imposed in this genotype, which, at the same time, maximizes the profitability of each animal.

REFERENCES

Aberle E.D., Reeves E.S., Judge M.D., Hunsley R.E., Perry T.W. (1981): Palatability and muscle characteristics of cattle with controlled weight gain: time on a high energy diet. J. Anim. Sci., *52*, 757–763.

Albertí P., Sañudo C., Olleta J.L., Lahoz F., Campo M.M., Panea B., Macie E.S. (2000): Effect of slaughter weight on carcass composition and commercial cuts of yearlings of seven beef breeds. In: Proc. 46th ICoMST, Buenos Aires, 350–351.

AOAC (1990): Official methods of analysis of the Association of Official Agricultural Chemists. 15th ed. Washington DC.

Berg R.T., Butterfield R.M. (1968): Growth patterns of bovine muscle, fat and bone. J. Anim. Sci., *27*, 611–619.

Berge P. (1991): Long-term effects of feeding during calfhood on subsequent performance in beef cattle (a review). Livest. Prod. Sci., *28*, 179–201.

Bruns K.W., Pritchard R.H., Boggs D.L. (2004): The relationship among body weight, body composition, and intramuscular fat content in steers. J. Anim. Sci., *82*, 1315–1322.

Cross H.R., Crouse J.D., MacNeil M.D. (1984): Influence of breed, sex, age and electrical stimulation on carcass and palatability traits of three bovine muscles. J. Anim. Sci., *58*, 1358–1365.

Fiems L.O., Campeneere S. De, Smet S. De, Voorde G. Van De, Vanacker J.M., Boucqué Ch.V. (2000): Relationship between fat depots in carcasses of beef bulls and effect on meat colour and tenderness. Meat Sci., *56*, 41–47.

Fluharty F.L., Loerch S.C., Turner T.B., Moeller S.J., Lowe G.D. (2000): Effects of weaning age and diet on growth and carcass characteristics in steers. J. Anim. Sci., *78*, 1759–1767.

Grunert K.G., Bredahl L., Bunsæ K. (2004): Consumer perception of meat quality and implications for product development in the meat sector (a review). Meat Sci., *66*, 259–272.

Honikel K.O. (1998): Reference methods for the assessment of physical characteristics of meat. Meat Sci., *49*, 447–457.

Keane M.G., Allen P. (1998): Effects of production system intensity on performance, carcass composition and meat quality of beef cattle. Livest. Prod. Sci., *56*, 203–214.

Keane M.G., More O'Ferrall G.J., Connolly J., Allen P. (1990): Carcass composition of serially slaughtered Friesian, Hereford × Friesian and Charolais × Friesian steers finished on two dietary energy levels. Anim. Prod., *50*, 231–243.

Lunt D.K., Orme L.E. (1987): Feedlot performance and carcass evaluation of heifers fed finishing diets as weanling calves or as yearlings. Meat Sci., *20*, 159–164.

Macíe S.E., Sañudo C., Olleta J.L., Panea B., Campo M.M., Albertí P. (2000): Slaughter weight and breed group effects on consumer beef meat quality appraisal throughout ageing. In: Proc. 46th ICoMST, Buenos Aires, 62–63.

May S.G., Dolezal H.G., Gill D.R., Ray F.K., Buchanan D.S. (1992): Effects of days fed, carcass grade traits, and subcutaneous fat removal on postmortem muscle characteristics and beef palatability. J. Anim. Sci., *70*, 444–453.

Myers S.E., Faulkner D.B., Ireland F.A., Parrett D.F. (1999): Comparison of three weaning ages on cow-calf performance and steer carcass traits. J. Anim. Sci., *77*, 323–329.

Powell V.H. (1991): Quality of beef loin steaks as influenced by animal age, electrical stimulation and ageing. Meat Sci., *30*, 195–205.

Renerre M. (1982): Influence de l'âge et du poids à l'abattage sur la couleur des viandes bovines (races Frisonne et Charolaise). Sci. Aliments, *2*, 17–30.

Sañudo C., Olleta J.L., Renand G., Campo M.M., Panea B., Oliván M., García D., Oliver M.A., Espejo M., Piedrafita J. (2001): Productive and carcass classification traits on chemical and instrumental meat quality characteristics of ten local cattle breeds of the Southwest of Europe. Proc. Brit. Soc. Anim. Sci., 70.

SAS (1989): SAS/STAT User's Guide Int. Version 6, 4th ed. Statistical Analysis Systems Institute Inc., Cary, NC.

Serra X., Gil M., Gispert M., Guerrero L., Oliver M.A., Sañudo C., Campo M.M., Panea B., Olleta J.L., Piedrafita J. (2004): Characterization of young bulls of the *Bruna dels Pirineus* cattle breed (selected from old Brown Swiss) in relation to carcass, meat quality and biochemical traits. Meat. Sci., *66*, 425–436.

Thompson J.M., Barlow R. (1981): Growth and carcass characteristics of crossbred and straightbred Hereford steers. II. Carcass measurements and composition. Austr. J. Agric. Res., *32*, 171–181.

Tikofsky J.N., Van Amburg M.E., Ross D.A. (2001): Effect of varying carbohydrate and fat content of milk replacer on body composition of Holstein bull calves. J. Anim. Sci., *79*, 2260–2267.

Vermorel M., Bouvier J.C., Geay Y. (1980): Utilisation de l'énergie des aliments par le veau ruminant. Influence de l'apport de lait, du niveau d'alimentation et de l'âge du veau. Ann. Zootech., *29*, 65–86.

Vestergaard M., Oksbjerg N., Henckel P. (2000a): Influence of feeding intensity, grazing and finishing feeding on muscle fibre characteristics and meat colour of semitendinosus, longissimus dorsi and supraspinatus muscles of young bulls. Meat Sci., *54*, 177–185.

Vestergaard M., Therkildsen M., Henckel P., Jensen L.R., Andersen H.R., Sejrsen K. (2000b): Influence of feeding intensity, grazing and finishing feeding on meat and eating quality of young bulls and the relationship between muscle fibre characteristics, fibre fragmentation and meat tenderness. Meat Sci., *54*, 187–195.

Wheeler T.L., Cundiff L.V., Koch R.M. (1994): Effect of marbling degree on beef palatability in *Bos taurus* and *Bos indicus* cattle. J. Anim. Sci., *72*, 3145–3151.

Wilson L.L., Egan C.L., Henning W.R., Mills E.W. (1995): Effects of live animal performance and haemoglobin level on special-fed veal carcass characteristics. Meat Sci., *41*, 89–96.

Wood J.D., Enser M., Fisher A.V., Nute G.R., Richardson R.I., Sheard P.R. (1999): Manipulating meat quality and composition. Proc. Nutr. Soc., *58*, 363–370.

Received: 2005–10–24
Accepted after correction: 2005–12–20

Corresponding Author

Dra. Ana Cerdeño, Experimental Agricultural Station, Spanish National Research Council, Apdo. 788, 240 80 León, Spain
Tel. +34 670 781 193, e-mail: anacerdeno@yahoo.es