Effects of the forage content of the winter diet on the growth performance and carcass quality of steers finished on mountain pasture with a barley supplement

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Abstract. Eighteen Parda de Montaña steers (366 kg liveweight, 10 months of age) received diets of either forage (F; lucerne hay + straw) or forage and concentrate (FC; lucerne hay + straw + barley) during the winter feeding period, which lasted 118 days. Thereafter, steers continuously grazed in meadows in a dry mountain area until the end of the grazing period in September (160–167 days) and received 4.1 kg DM barley per head for the final 103–110 days of the grazing season. The steers that received the FC winter diet were heavier (491 vs 457 kg, respectively; \( P < 0.05 \)) and had deposited more fat (7.2 vs 5.8 mm, \( P < 0.05 \)) and muscle (63 vs 54 mm, \( P < 0.05 \)) at the end of the winter than the steers that received the F winter diet. During the grazing period, the steers from both groups had similar weight gains (0.728 and 0.756 kg/day for FC and F diet, respectively). At slaughter, the steers from both groups were of similar age (590 vs 599 days, for FC and F diet, respectively) and had similar liveweights (560 vs 539 kg), muscle depths (54 vs 63 mm) and subcutaneous fat thicknesses (7.3 vs 7.2 mm). The serum leptin concentration differed only at the end of the winter period, when steers on the FC diet had higher leptin concentrations than did steers on the F diet (\( P < 0.05 \)), reflecting differences in fatness. The carotenoid concentration in the plasma during the winter feeding period was higher in steers on the F than on the FC winter diet, but this difference was not seen during the grazing period. Carcasses from steers on the FC winter diet were heavier (324 vs 300 kg; \( P < 0.05 \)) and had a higher dressing percentage (57.3\% vs 56.1\%, \( P < 0.05 \)) than those reared on the F winter diet, but the fatness and conformation scores were similar between the groups. The percentages of fat, muscle and bone in the commercial dissection and 10th rib dissection did not differ between the winter diet groups. In conclusion, the differences resulting from the winter feeding period disappeared after the grazing period, and the carcass quality did not differ between the diets. Therefore, both strategies are equally technically advisable.

Additional keywords: beef cattle, performance.

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Introduction

In the past five decades in the Mediterranean countries, young bulls have usually been fattened on concentrates and straw before slaughter at 12–14 months of age. Recently, beef producers have shown increased interest in high-forage systems because of the rise in cereal prices and consumer demand for environmentally friendly and healthy products (Gil et al. 2000). This change is also a particular concern for organic producers, who have to adopt forage-based diets rather than conventional concentrates for fattening to comply with EC Regulation 889/2008, which states that at least 60\% of the daily rations of ruminants should consist of forage.

An interesting alternative in dry mountain areas, such as the Spanish Pyrenees (Casasús et al. 2002), could be to finish steers on pasture after feeding them a forage-based diet during the winter housing period. The pre-pubertal castration of bulls would be required to reduce the expression of sexual and aggressive behaviour of entire males because the production cycle is longer than the abovementioned concentrate-based fattening system. This system should be restricted to one winter feeding period vs the two or three, common in other European countries with humid continental climates (Hoch et al. 2005; Hessle et al. 2007; Keane and Drennan 2009) because Mediterranean consumers prefer meat from young animals.

The wintering phase, which is necessary in most temperate regions, is generally based on expensive, harvested feedstuffs, while more cost-efficient gains are seen on pasture. Therefore, if animals restricted during the housing period exhibit compensatory growth during the grazing period, a reduction in winter feeding costs, by restriction of either diet quality or diet quantity, may increase system production efficiency (Lewis et al. 1990). The choice of winter diet depends on feedstuff availability
and cost, the length of the winter and the grazing periods, the desired slaughter time and the type of carcass to be produced (Wright et al. 1986). The degree of compensatory growth is affected by multiple factors, such as the severity and length of the restriction period, the quantity and quality of the forage available during the re-feeding period and the length of the re-feeding period (Hoch et al. 2003), which during grazing may be limited to the season of vegetative growth. In this phase, compensating animals may have different liveweight gains, but the relative accretion of the different body tissues may also differ, with a higher deposition of lean, high-protein tissues (Hornick et al. 2000). This phenomenon could be used to manipulate carcass quality (Sainz et al. 1995), although some authors have described only weak effects on the final carcass composition (Patterson et al. 1995; Hoch et al. 2003).

The physiological mechanisms underlying compensatory growth can be analysed by a study of feeding strategy-related differences in the metabolites and hormones involved in the deposition or mobilisation of muscle and fat (Hornick et al. 1998b). On one hand, serum non-esterified fatty acids (NEFA) reflect fat mobilisation, and leptin concentration is related to adiposity and feed intake (Chilliard et al. 1999). On the other hand, serum carotenoid concentrations reflect differences in forage intake (Serrano et al. 2006), as these metabolites are present at high concentrations in green herbage and, therefore, could be useful as evidence of differences in pasture utilisation between groups.

The effects of winter diet on the growth rate of cattle have been studied in regions with a humid continental climate, which thus have high forage availability (Hessle et al. 2007; Keane and Drennan 2009); however, there is no information on diet in dry mountain areas. Therefore, the aim of the present study was to evaluate the effects of two different winter diets based on lucerne hay with or without grain supplementation, followed by a grazing period in mountain meadows, on the growth and carcass quality of steers.

**Materials and methods**

**Animals and general management**

The 18 Parda de Montaña male calves used in the study were born in winter in La Gercipollera Research Station, in the mountains of the southern Pyrenees (Spain, 42°37′N, 0°30′W, 945 m above sea level, 10-year average temperature and rainfall 10.9°C and 999 mm, respectively). The calves remained indoors with their dams for the first 90 days and suckled from their dams. Afterwards, they grazed in high mountain pastures with their dams until they were weaned at 8 months of age. The calves did not receive any concentrates during the suckling period.

After weaning, the calves were transported 180 km away, to the Research Station in Zaragoza (41°43′N, 0°48′W, 225 m above sea level). The calves were housed in a feedlot facility and received alfalfa hay and barley straw on an ad libitum basis and 0.5 kg DM barley during a 1-month transition period. Seven days after their arrival, the calves were surgically castrated using local anaesthesia and analgesia and local antibiotics. The recovery period lasted 20 days.

After the recovery period, the steers were blocked by liveweight and weight gain during suckling and randomly distributed into two treatment groups which were assigned different winter diets. Each group was placed in a separate pen. The forage group (F) was fed lucerne hay and straw from December to April (118 days). In the forage plus concentrate group (FC), lucerne hay, straw and barley were fed restrictedly to attain at a minimum forage : concentrate ratio of 60 : 40, which is compulsory in organic production. Lucerne hay, straw and barley were offered separately once daily, and refusals were removed and weighed daily. These data were used to estimate intake. The amount offered daily was calculated as 110% of the intake of the previous day.

In mid-April, the steers were transported back to La Gercipollera Research Station, where they were finished on pastures until the end of the grazing season (163 days), when they were 20 months old. The steers were set-stocked on natural Pyrenean meadows, at a stocking rate of six steers per hectare. The meadows were irrigated fortnightly during the summer. The pasture height was kept above 11 cm during the grazing period. The steers diets were supplemented daily with 4.1 kg DM barley from mid-June to slaughter (103 and 110 days for FC and F steers, respectively). During the year of the study, the total precipitation was 102 mm in the winter and 106 mm in the summer, being lower than the averages recorded for those seasons in the previous 5 years (254 mm and 224 mm, respectively; Spanish Meteorological Agency, unpubl. data), but the average temperatures were within the normal range.

**Feedstuffs and pastures**

During the winter feeding period, lucerne hay, straw and barley were offered daily. Refusals were recorded, and intakes were estimated daily on a per-group basis. During the grazing season, forage mass was measured by clipping (with an electrical mower) all plant material at 2 cm above ground level in 20 0.25-m² quadrats randomly located in the pasture. At the beginning and end of the grazing season, the forage mass of 12 0.25-m² quadrats was clipped to study the botanical composition of the pasture. The plants were classified into grasses, legumes and other species and weighed separately to obtain the proportions of each class. Monthly samples of the feed and pasture were collected to determine their quality. The samples were immediately dried at 60°C to a constant weight. Then, they were ground-milled to 1 mm and kept at a constant temperature (20°C) in the laboratory, until they were analysed.

In **vivo measurements**

The steers were weighed weekly throughout the experimental period at 0800 hours, with calibrated scales used at both research stations. The steers were also weighed the day before slaughter. Dorsal fat thickness and muscle depth were measured by ultrasonography with a multi-frequency probe (7.5 MHz; Aloka SSD-900, Aloka Co. Ltd, Brighton, UK) at the 13th thoracic vertebra. Skin contact with the transducer was achieved using ultrasound contact gel. The measurements were recorded at the end of the winter feeding period and at the end of the grazing period, which was the day before slaughter.

Blood samples were taken from all steers at monthly intervals at 0800 hours by puncture of the coccygeal vein, to determine carotenoid, leptin and NEFA concentrations. Weekly samples...
were also obtained during the first 2 months of the grazing period, to study changes in the carotenoids in the plasma. Samples for the measurement of carotenoids and NEFA were collected in test tubes containing EDTA to obtain plasma. Samples for leptin measurement were collected in test tubes with no anti-coagulant to obtain serum. Blood samples for carotenoid quantification were immediately wrapped in aluminium foil to protect them from natural light. Then, the carotenoid and NEFA samples were centrifuged at 2122g for 5 min, and the plasma from each was extracted and frozen at −80°C and −20°C, respectively, for subsequent assays. Samples for leptin analysis were allowed to clot for 24 h at room temperature, and the serum was stored at −20°C.

Slaughtering and carcass measures
The steers were slaughtered at the end of the grazing season at the nearest EU-licenced abattoir, to minimise the effect of transport stress on meat quality. The steers were stunned by captive-bolt pistol and dressed according to standard commercial practices. The carcasses were weighed after dressing to obtain the hot carcass weight. The dressing percentage was calculated by dividing the hot carcass weight by slaughter weight. After the carcasses were chilled at 4°C ± 1°C for 24 h, they were classified using the S-EUROP classification scale (EU n. 1208/1981 and EU n. 1026/1991). The carcass conformation score was based on a visual assessment of the development of carcass profiles, particularly the essential parts (round, back, shoulder). Conformation was scored on an 18-point scale, from 1 for (all profiles concave to very concave and poor muscle development) to 18 for (all profiles extremely convex and exceptional muscle development (double-muscled carcass type)). The degree of fat cover takes into account the amount of fat on the outside of the carcass and in the thoracic cavity. Fat cover was scored on a 15-point scale, from 1 for (none up to low fat cover) to 15 (entire carcass covered with fat and heavy fat deposits in the thoracic cavity).

The right half of the carcass was dissected into edible meat in different commercial cuts (Carballo et al. 2005). fat and bone. Commercial cuts were grouped into economic classes on the basis of retail value: extra (sirloin), 1st (loin, thick flank, topside, silverside, rump, eye round, heel chuck roll, shoulder blade, chuck tender), 2nd (blade, shank, shin) and 3rd (flank, breast rib, brisket, neck, thin skirt) class percentages as meat yield index. The proportion of edible meat, fat and bone as well as the ratios of edible meat to bone and fat to bone were calculated. The 10th rib was removed from the left half of the carcass, then weighed and dissected into muscle, fat (subcutaneous and intermuscular), bone and other parts (tendons and noticeable blood vessels).

Chemical analyses
Feedstuffs were oven-dried to determine DM content, and crude protein content was determined following the Dumas Procedure (AOAC 1999), using a nitrogen-and-protein analyser (Model NA 2100, CE Instruments, Thermoquest SA, Barcelona, Spain). Neutral detergent fibre analysis was carried out following the procedure of van Soest et al. (1991), using the Ankom fibre analyser (Model 200/220, Ankom Technology, Gomensoro, Madrid, Spain). Ash content was determined by dividing the weight before and after ignition in a muffle for 8 h (AOAC 1999). Metabolisable energy was estimated using the data proposed for each feedstuff, according to the chemical composition, by Albé and Tisserand (1990).

Plasma carotenoid concentrations were determined by spectrophotometry, following the procedures of Prache et al. (2003). Leptin concentrations were determined using a competitive enzyme immunoassay for leptin in domestic animals (Sauerwein et al. 2004), with 6.6% and 11.5% intra- and inter-assay coefficients of variation, respectively. A commercial enzymatic colourimetric kit (Randox Laboratories Ltd, Crumlin, UK) was used to quantify NEFA concentrations, with 5.1% and 7.4% intra- and inter-assay coefficients of variation, respectively.

Statistical analyses
Statistical analyses were performed in SAS v. 9.1. (SAS Institute Inc., Cary, NC, USA). Before further analyses, the normality of the residuals of all variables was tested with the Shapiro–Wilk test. The residues of BW, subcutaneous fat thickness, serum leptin concentration, fat colour and carcass traits were normally distributed. Bodyweight and leptin concentrations were analysed using mixed models for repeated-measures, including the winter diet, time and their interaction as fixed effects and animal as the random effect. The degrees of freedom were corrected with the Kenward–Roger adjustment because of the small sample size, to take into account that the standard errors are linear combinations of variances and to account for possible missing values or unequal observations per steer (Kaps and Lamberson 2009). A first-order autoregressive structure with heterogeneous variances for each date was used to model heterogeneous residual error. In the case of plasma carotenoids and NEFA concentrations, the normal distribution of the residues could not be verified, so mixed models with repeated-measurements could not be used. The differences between groups for each measurement date were tested with the Kruskal–Wallis non-parametric test of the NPARIWAY procedure in SAS.

Weight gains, calculated by linear regression of bodyweight against the date within each animal, and carcass traits were tested by ANOVA using the general linear model (GLM) procedure, with the winter diet as the fixed effect. Feed intake and composition were analysed with the winter diet and month (considering daily data as replication) and their interaction as fixed effects. For all above-mentioned variables, least-squares means (LS means) were estimated, and the differences were tested using a Student’s t-test. Pearson’s correlation coefficients between the variables were calculated. For all tests, the level of significance was set at P = 0.05.

Results and discussion
Feedstuffs and pasture
The quality of the feedstuffs offered is presented in Table 1. The chemical composition of the barley, lucerne hay and straw did not change during the winter feeding period.

Pasture chemical composition changed throughout the grazing season; i.e. protein content decreased from 23% at the beginning to 17% at the end of this period, and neutral detergent fibre
increased from 50% to 61% (Fig. 1). The botanical composition of the meadow changed from the beginning to the end of the grazing season. At the beginning, the meadow was composed of grasses (LS means ± s.e., 95.5% ± 0.67, mainly *Festuca arundinacea*, *Festuca pratensis* and *Dactylis glomerata*), legumes (2.7% ± 0.72, mainly *Trifolium repens*) and other species (1.7% ± 0.43, such as *Rumex acetosa* and *Ranunculus bulbosus*). At the end of the grazing season, the proportion of grasses decreased to 66.9% (±7.22), while the proportion of legumes remained similar (4.4% ± 1.69), and the proportion of other species increased up to 28.7% (±6.86). The average forage availability was 1191 kg DM/ha, with no significant ($P > 0.05$) differences among months because of the high intra-month variability (Fig. 1).

During the winter feeding period, the total daily dry matter intake did not differ between the two groups of steers because the greater daily intake of lucerne hay of the F steers was counterbalanced by the intake of barley of the FC steers (Table 2). The FC steers, however, had a greater energy intake but a lower protein intake than did the F steers ($P < 0.001$).

**Animal performance**

Steers on the FC winter diet had a 37% greater average daily gain ($P < 0.01$) during the winter and thus were heavier ($P < 0.01$) than their counterparts at the end of this period (Table 3). The effects of winter diet on winter gains and final weight have been reported previously in steers and heifers (Lowman *et al.* 1994; Hessle *et al.* 2007; Keane and Drennan 2009). The reported differences in gains between forage diets with or without concentrates range from 15% for heifers fed silage supplemented with 2 kg grain versus those fed silage alone (Hessle *et al.* 2007) to 66% for steers fed silage with 0.5 or 3 kg concentrate versus those fed silage alone (Lowman *et al.* 1994).

Liveweights at the beginning of the grazing season, recorded after a week on pasture, were almost 10% lower than the final winter weights (Fig. 2). The observed liveweight loss was probably the result of transportation stress (reported by Warriss *et al.* 1995 to be 5%), adaptation to grazing conditions and reduction in gut fill due to the higher digestibility of pasture than hay (Hoch *et al.* 2005). Both groups of steers needed more than

### Table 1. Chemical composition of the feeds offered in the experiment (mean ± s.d.)

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Winter</th>
<th>Winter and grazing season (from 15 June to slaughter)</th>
<th>Grazing season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lucerne hay</td>
<td>Straw</td>
<td>Barley</td>
</tr>
<tr>
<td>DM (%)</td>
<td>89.6 ± 3.56</td>
<td>87.4 ± 1.80</td>
<td>91.2 ± 0.84</td>
</tr>
<tr>
<td>CP (%)</td>
<td>20.5 ± 0.89</td>
<td>1.7 ± 0.83</td>
<td>9.3 ± 0.67</td>
</tr>
<tr>
<td>NDF (%)</td>
<td>36.8 ± 2.97</td>
<td>79.7 ± 3.59</td>
<td>25.2 ± 0.97</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>10.3 ± 0.76</td>
<td>5.9 ± 1.01</td>
<td>2.7 ± 0.11</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>8.4</td>
<td>6.4</td>
<td>11.7</td>
</tr>
</tbody>
</table>

Table 2. Effect of the forage content of the winter diet on the intake of the steers during the winter period

<table>
<thead>
<tr>
<th>Diet component</th>
<th>Daily intake (kg/day)</th>
<th>s.e.</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FC</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Lucerne hay</td>
<td>5.4</td>
<td>8.3</td>
<td>0.10</td>
</tr>
<tr>
<td>Straw</td>
<td>0.3</td>
<td>0.3</td>
<td>0.02</td>
</tr>
<tr>
<td>Barley</td>
<td>3.0</td>
<td>0.0</td>
<td>0.02</td>
</tr>
<tr>
<td>Total</td>
<td>8.7</td>
<td>8.6</td>
<td>0.10</td>
</tr>
<tr>
<td>Daily energy intake (MJ ME/day)</td>
<td>91.6</td>
<td>78.3</td>
<td>0.90</td>
</tr>
<tr>
<td>Daily protein intake (CP g/day)</td>
<td>1394</td>
<td>1706</td>
<td>21.4</td>
</tr>
</tbody>
</table>

**Fig. 1.** Pasture quality and mass throughout the grazing period. Within a parameter, means with different letters differ at $P = 0.05$. The error bars shown in the figures represent the standard error.
2 months to attain the liveweight measured at the end of the grazing season because weight gains during the first 2 months were low (Table 3). Most probably because energy intake was low, with weight gain increasing an average of 40% with barley supplementation ($P < 0.001$).

The content of forage in the winter diet had no effect on weight gains during the grazing period (Table 3). Despite this lack of difference in growth rate, when the animals were slaughtered at the end of the grazing season (590 vs 599 days of age; s.e. = 11.8, $P > 0.05$), the difference in liveweight between the groups was not significant (Table 3). These results differ from those of Lewis et al. (1990), who reported that weight gain during grazing tended to decrease as winter gain increased, and also from those of Sainz et al. (1995), who observed compensatory growth in restricted re-fed steers. Our results, however, agree with the observations of Hersom et al. (2004), who reported that winter diets leading to different gains had no effect on weight gains or gain efficiency during the finishing phase of steers. Heifers receiving silage or silage plus grain during the winter (with energy intakes similar to those of the steers in the present experiment) had similar weight gains during the grazing season on semi-natural grasslands (Hessle et al. 2007) of similar quality to the meadows grazed in the current study. Larger differences in weight gains between winter energy densities (Hessle et al. 2007) or winter growth rates (Neel et al. 2007) induced a compensatory growth during the grazing period, although previously restricted animals were not always able to catch up completely by the end of the grazing season (Neel et al. 2007).

In the current study, the compensatory index (Hornick et al. 2000) of the F steers was 38.3%, which means that at slaughter they had caught up 38.3% of the weight difference seen at the end of the restricted feeding period. Therefore, despite liveweight gains during the grazing not being significantly different between the two groups, it cannot be concluded that there was no compensatory growth.

Complete compensation was probably not observed because forage availability during the grazing season was insufficient. According to Nielsen et al. (2003), a reduction in the energy of the winter diet increased weight gains during the following grazing season through an increase in intake on pasture. This shift did not occur in the current experiment, as evidenced by the similar concentrations of carotenoids in the plasma of animals (Serrano et al. 2006) fed both winter diets (cf. below). Sainz et al. (1995) indicated that with high-concentrate diets offered at feedlots,
increased intake was the main factor triggering a compensatory growth response, which was also influenced by the reduced maintenance requirements of previously restricted animals. In our case, however, the higher forage content of the F winter diet may have induced a greater accretion of visceral organ mass, which would result in higher maintenance energy requirements in the finishing phase (McCurdy et al. 2010b).

Another reason for the incomplete compensation could be forage quality, as the observed growth rates were lower than those obtained in other experiments with grazing animals of the same breed. Parda de Montaña bulls had weight gains above 1.2 kg/day grazing on mountain meadows with 3 kg DM barley (Casasús et al. 2011), above 1.3 kg/day grazing on lucerne with 1.8 kg DM barley (Blanco et al. 2011) and above 1.6 kg/day in conventional fattening systems based on ad libitum concentrate plus straw (Blanco et al. 2009). Various factors could explain this lower performance. On the one hand, steers usually have lower gains and feed conversion rates than do intact males (Kirkland et al. 1986; Lowman et al. 2006). On the other hand, the forage availability and diet quality were lower than those observed in the abovementioned studies.

At the end of the winter feeding period, steers on the FC diet had greater muscle depth (P < 0.01) and subcutaneous fat thickness (P < 0.001) than did those on the F diet (Table 4). From the end of winter to slaughter, muscle depth and subcutaneous fat thickness did not change on the FC diet (P > 0.05), while both parameters increased in the steers on the F diet (P < 0.01). Consequently, both groups had similar muscle depth (P>0.05) and subcutaneous fat thickness (P<0.05) at slaughter. Similarly, in the study by Neel et al. (2007), the weight gain during the winter feeding period affected the m. longissimus dorsi area, as measured by ultrasonography at the end of the winter feeding period; however, the difference vanished after the grazing period. Similarly, the winter feeding treatment affected the condition score at the end of the winter feeding period (Wright et al. 1986; Lowman et al. 1994) but not at the end of the subsequent grazing period (Wright et al. 1986; Lowman et al. 1996). Steers on the F treatment had likely reached a lower proportion of their mature weight at turnout than FC steers, but they caught up after the grazing season in terms of lean and fat tissue accretion and reached a comparable maturity level at slaughter, as Neel et al. (2007) suggested. Hence, a different composition in the weight gained may have eliminated eventual differences at the end of the restriction period (Hoch et al. 2003). According to McCurdy et al. (2010a), the degree of fatness at feedlot entry following a different growth rate during the previous growing phase influenced the composition of the weight gained. The similarity in the measures obtained by ultrasonography at slaughter in this experiment is in agreement with the results on circulating leptin and carcass and 10th-rib compositions, which also did not differ at slaughter (see below).

**Plasma NEFA, leptin and carotenoid concentrations**

Monthly NEFA concentrations were similar between the groups throughout the experimental period (Fig. 3). When average values were calculated for each phase, NEFA concentrations during the winter were lower in steers on the FC winter diet than in those on the F winter diet (0.39 vs 0.47 mmol/L, respectively; P < 0.05), as reported previously in growing bulls on different diets (Ellenberger et al. 1989; Hornick et al. 1998a). The values were, however, similar during the grazing period (0.41 vs 0.42 mmol/L, respectively; P>0.05), reflecting a similar energy status that is consistent with the observed growth rates. The first samples obtained during the grazing period have the highest NEFA values in both treatments (1.22 and 0.93 mmol/L, respectively; P>0.05), reflecting the lipolysis induced by catecholamines associated with the stress of transportation (Sartorelli et al. 1992; Swanson and Morrow-Tesch 2001), and adaptation to grazing conditions.

The leptin concentration in steers on the FC diet was greater in the last 2 months of the winter period than that in steers on the F diet (Fig. 3), reflecting the greater fat deposition observed in this treatment (Chilliard et al. 2001; Geary et al. 2003; Bellmann et al. 2004). Thereafter, leptin concentrations did not differ between diets and were similar to the values reported by Blanco et al. (2011) in young bulls of the same breed grazing on lucerne supplemented with 1.8 kg DM barley. The changes in the leptin concentration on both diets are in agreement with the results reported for NEFA concentrations and subcutaneous fat thickness.

Carotenoid concentrations were similar during the first month of the winter feeding period (Fig. 3), but steers on the F winter diet had higher carotenoid concentrations than did steers on the FC winter diet during the following months of the winter feeding period. The carotenoid concentration in the serum is related to forage intake (Serrano et al. 2006). In the winter feeding period, this parameter clearly responded to the lucerne hay intake, which differed between the groups throughout the winter feeding period, with lower differences between the groups in the first month (8.5%, P < 0.05) than in the following months (above 50%, P < 0.01).

During the grazing period, no differences in carotenoid concentrations appeared between the groups on different winter diets; such differences would indicate a similar pasture intake. Only 3 days after turnout, there was a two-fold increase in carotenoid concentrations, which may be related to the higher carotenoid concentration of fresh forage than hay (Prache et al. 2003; Serrano et al. 2006; Dunne et al. 2009). The carotenoid concentration increased sharply until the beginning of barley supplementation, which caused a sharp decrease because of barley’s low carotenoid concentration (Dunne et al. 2009).

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**Table 4. Muscle depth and subcutaneous fat thickness at the end of winter and at slaughter, according to the forage content of the winter diet (WD)**

<table>
<thead>
<tr>
<th>Time</th>
<th>FC</th>
<th>F</th>
<th>s.e.</th>
<th>WD Date</th>
<th>P-value WD × Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Muscle depth (mm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of winter</td>
<td>63a</td>
<td>54bx</td>
<td>1.03</td>
<td>0.01</td>
<td>0.002</td>
</tr>
<tr>
<td>Slaughter</td>
<td>64</td>
<td>63y</td>
<td>1.12</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td><strong>Subcutaneous fat thickness (mm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of winter</td>
<td>7.2a</td>
<td>5.8bx</td>
<td>0.13</td>
<td>0.001</td>
<td>0.002</td>
</tr>
<tr>
<td>Slaughter</td>
<td>7.3</td>
<td>7.2y</td>
<td>0.14</td>
<td>0.72</td>
<td></td>
</tr>
</tbody>
</table>
Similarly, Blanco et al. (2011) reported that serum carotenoid concentration decreased rapidly in young bulls finished on concentrates after grazing in lucerne paddocks; however, the carotenoid concentration during the period of grazing supplemented with 4.1 kg DM barley was greater than the concentration observed during the winter feeding period on the FC (199 vs 63 µg/L, respectively; \( P < 0.001 \)) and F (239 vs 82 µg/L, respectively; \( P < 0.001 \)) treatments.

**Carcass quality**

The hot carcass weight and dressing percentage were greater in the FC group than in the F group (Table 5). These results agree with those of Neel et al. (2007) but only partially agree with those reported by Hessle et al. (2007) and Keane and Drennan (2009), who reported that the winter diet affected carcass weight but not dressing percentage. In the abovementioned studies, the slaughter and carcass weights were different between the diets, whereas in the current study, the difference in liveweight at slaughter was not significant. The slight difference in dressing percentage between treatments may be a residual effect of the forage content of the winter diets, reflecting a different visceral organ mass (McCurdy et al. 2010b); however, both values were within the normal range described for the breed (Blanco et al. 2009; Blanco et al. 2010).

The conformation and fatness score were not affected by the content of forage in the winter diet (Table 5), as Keane and Drennan (2009) reported in steers finished on pastures after two winter diets. The values obtained in the current experiment were within the range presented for this breed and slaughter weight by Alberti et al. (2005), in a comparison of seven Spanish beef genotypes, who described the breed as a medium meat producer with medium maturing rates and values of blockiness, conformation and fat cover; however, the subcutaneous fat cover of steers in the current experiment was slightly lower than that observed for young bulls by these authors (6.3); a finishing period on a high-concentrate diet could improve their condition.

No differences between winter diets were found in the commercial dissection of the carcass (Table 5), with resulting values for meat and the proportion of commercial cuts comparable to those reported by Alberti et al. (2001) in Parda de Montaña bulls slaughtered at a similar weight (550 kg); however, the percentage of fat was lower than that reported in the abovementioned study because young bulls were fed concentrates throughout the fattening period, which increases fat deposition. As in the commercial carcass dissection, no differences were found in the dissection of the 10th rib (Table 5). Similarly, Duckett et al. (2007) indicated that the growth rate during the winter stocker period did not influence rib composition, and Hinks et al. (1999) found that winter diet-related differences in rib fatness and saleable meat at the start of the grazing season had resolved at the point of slaughter in September. Conversely, Keane and Drennan (2009) reported that rib-joint composition differed with winter diet, as steers fed silage plus 4 kg of concentrates (high-energy diet) had higher fat percentages and lower bone percentages than those fed silage plus 0.91 kg of concentrates (low-energy diet). The
Table 5. Effect of the winter diet on carcass characteristics, the commercial dissection and 10th-rib dissection of steers finished on pasture

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FC</th>
<th>F</th>
<th>s.e.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carcass characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot carcass weight (kg)</td>
<td>32.4</td>
<td>30.0</td>
<td>10.6</td>
<td>0.04</td>
</tr>
<tr>
<td>Dressing percentage (%)</td>
<td>57.3</td>
<td>56.1</td>
<td>0.53</td>
<td>0.03</td>
</tr>
<tr>
<td>Conformation score (1–18)</td>
<td>8.9</td>
<td>8.3</td>
<td>0.41</td>
<td>0.21</td>
</tr>
<tr>
<td>Fatness score (1–15)</td>
<td>5.1</td>
<td>4.9</td>
<td>0.56</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>Carcass dissection (%) carcass weight</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edible meat</td>
<td>71.3</td>
<td>71.0</td>
<td>0.74</td>
<td>0.74</td>
</tr>
<tr>
<td>Fat</td>
<td>6.5</td>
<td>6.0</td>
<td>0.41</td>
<td>0.34</td>
</tr>
<tr>
<td>Bone</td>
<td>22.3</td>
<td>22.9</td>
<td>0.62</td>
<td>0.31</td>
</tr>
<tr>
<td>Edible meat: bone</td>
<td>3.20</td>
<td>3.10</td>
<td>0.112</td>
<td>0.38</td>
</tr>
<tr>
<td>Fat: bone</td>
<td>0.29</td>
<td>0.26</td>
<td>0.019</td>
<td>0.23</td>
</tr>
<tr>
<td>Extra-quality meat</td>
<td>2.0</td>
<td>2.1</td>
<td>0.1</td>
<td>0.27</td>
</tr>
<tr>
<td>1st-quality meat</td>
<td>44.0</td>
<td>43.8</td>
<td>0.4</td>
<td>0.72</td>
</tr>
<tr>
<td>2nd-quality meat</td>
<td>6.1</td>
<td>6.0</td>
<td>0.1</td>
<td>0.49</td>
</tr>
<tr>
<td>3rd-quality meat</td>
<td>19.2</td>
<td>19.1</td>
<td>0.5</td>
<td>0.96</td>
</tr>
<tr>
<td><strong>10th rib dissection (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle</td>
<td>65.5</td>
<td>68.0</td>
<td>1.91</td>
<td>0.20</td>
</tr>
<tr>
<td>Subcutaneous fat</td>
<td>3.4</td>
<td>2.5</td>
<td>0.71</td>
<td>0.23</td>
</tr>
<tr>
<td>Intramuscular fat</td>
<td>9.8</td>
<td>9.0</td>
<td>1.24</td>
<td>0.51</td>
</tr>
<tr>
<td>Total fat</td>
<td>13.2</td>
<td>11.5</td>
<td>1.83</td>
<td>0.37</td>
</tr>
<tr>
<td>Bone</td>
<td>21.3</td>
<td>20.5</td>
<td>1.11</td>
<td>0.47</td>
</tr>
</tbody>
</table>

steers, however, had higher fatness scores than those in the current experiment, probably because they were older at slaughter (24 months old) and because of differences in the breeds used. The percentage of subcutaneous fat on the 10th rib was strongly correlated with the percentage of fat on the carcass ($r = 0.65$, $P < 0.01$), but no correlations were found between the muscle percentage on the 10th rib and the carcass or between bone percentages.

In conclusion, a different winter feeding strategy influenced the steer growth rate during this period, but the gains during the grazing period were similar; additionally, the different winter treatments resulted only in slight differences in carcass weight. The forage content of the winter diet did not significantly influence conformation, fatness or carcass composition, the first two attributes being those on which payment per kg of carcass is based in the European beef market. The 24-kg heavier carcasses of steers from the FC treatment would, however, result in a higher income per carcass. The effect of these parameters on net return depends on the relative costs of forage and concentrates used in the winter diets, both of which have been subject to sudden fluctuations in recent years.

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References


Effects of winter diet on performance and carcass quality


