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.* 1998*b*). 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 Garcipollera 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 Garcipollera 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 2122*g* 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 Alibés 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 residues 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–Rogers 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 NPAR1WAY 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

Table 1.   Chemical composition of the feeds offered in the experiment (mean ± s.d.)
DM, dry matter; CP, crude protein; NDF, neutral detergent fibre; ME, metabolisable energy

Chemical composition	Winter		Winter and grazing season (from 15 June to slaughter)	Grazing season
	Lucerne hay	Straw	Barley	Pasture
DM (%)	89.6 ± 3.56	87.4 ± 1.80	91.2 ± 0.84	24.2 ± 9.03
CP (%)	20.5 ± 0.89	1.7 ± 0.83	9.3 ± 0.67	19.7 ± 2.70
NDF (%)	36.8 ± 2.97	79.7 ± 3.59	25.2 ± 0.97	55.3 ± 5.00
Ash (%)	10.3 ± 0.76	5.9 ± 1.01	2.7 ± 0.11	10.0 ± 1.14
ME (MJ/kg DM)	8.4	6.4	11.7	10.5

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
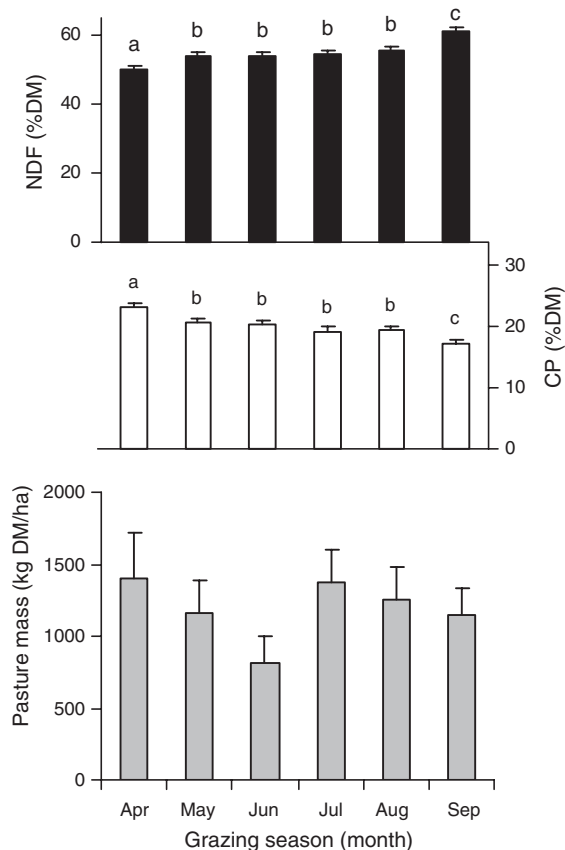
forage availability was 1191 kg DM/ha, with no significant (*P* > 0.05) differences among months because of the high intra-month variability (Fig. 1).

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

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.

Table 2.   Effect of the forage content of the winter diet on the intake of the steers during the winter period
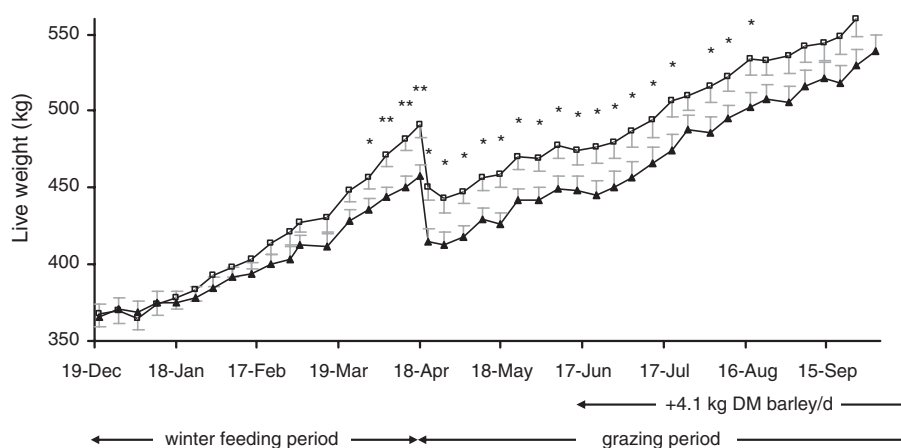FC, lucerne hay + straw + barley; F, lucerne hay + straw during the winter feeding period. Statistical analyses were performed considering the group as a fixed effect and daily intakes as replicates. *n* = 118 observations for both FC and F

Diet component	Daily intake		s.e.	*P*-value
	FC	F		
Lucerne hay (kg/day)	5.4	8.3	0.10	0.001
Straw (kg/day)	0.3	0.3	0.02	0.51
Barley (kg/day)	3.0	0.0	0.02	0.001
Total (kg/day)	8.7	8.6	0.10	0.58
Daily energy intake (MJ ME/day)	91.6	78.3	0.90	0.001
Daily protein intake (CP g/day)	1394	1706	21.4	0.001

Table 3.   Effect of the forage content of the winter diet on liveweight and weight gain of the steers during the winter and grazing periods

FC, lucerne hay + straw + barley; F, lucerne hay + straw during the winter feeding period. *n* = 9 animals per group

Parameter	FC	F	s.e.	*P*-value
Winter period (December to April, 118 days)				
Liveweight at start (kg)	368	365	4.6	0.86
Liveweight at end (kg)	491	457	4.3	0.0073
Weight gain (kg/day)	1.069	0.779	0.0797	0.002
Grazing period (April to September, 160–167 days)				
Liveweight at start (kg)	450	414	4.6	0.005
Liveweight at end (kg)	560	539	6.7	0.17
Gain (kg/day)	0.704	0.756	0.0694	0.69
Gain without supplement (57 days) (kg/day)	0.572	0.643	0.1263	0.58
Gain with supplement (103–110 days) (kg/day)	0.837	0.861	0.0875	0.79

Fig. 2.   Liveweight of steers finished on pasture supplemented with barley according to the forage content of the winter diet. 65F : 35C, lucerne hay + straw + barley, with a forage (F) : concentrate (C) ratio of 65 : 35 (□); 100F, lucerne hay + straw (▲). Within a date: **, $P < 0.01$; *, $P < 0.05$. The error bars shown represent the s.e.

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.* 2010*b*).

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.* 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

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)

FC, lucerne hay + straw + barley; F, lucerne hay + straw during the winter feeding period. Within a row, means followed by the same letter are not different at $P = 0.05$. Within a column and parameter, means followed by the same letter are not significantly different from each other at $P = 0.05$

Time	FC	F	s.e.	*P*-value		
				WD	Date	WD × Date
Muscle depth (mm)						
End of winter	63a	54bx	1.03	0.01	0.002	0.02
Slaughter	64	63y	1.12	0.75		
Subcutaneous fat thickness (mm)						
End of winter	7.2a	5.8bx	0.13	0.001	0.002	0.006
Slaughter	7.3	7.2y	0.14	0.72		

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.* (2010*a*), 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.* 1998*a*). 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.
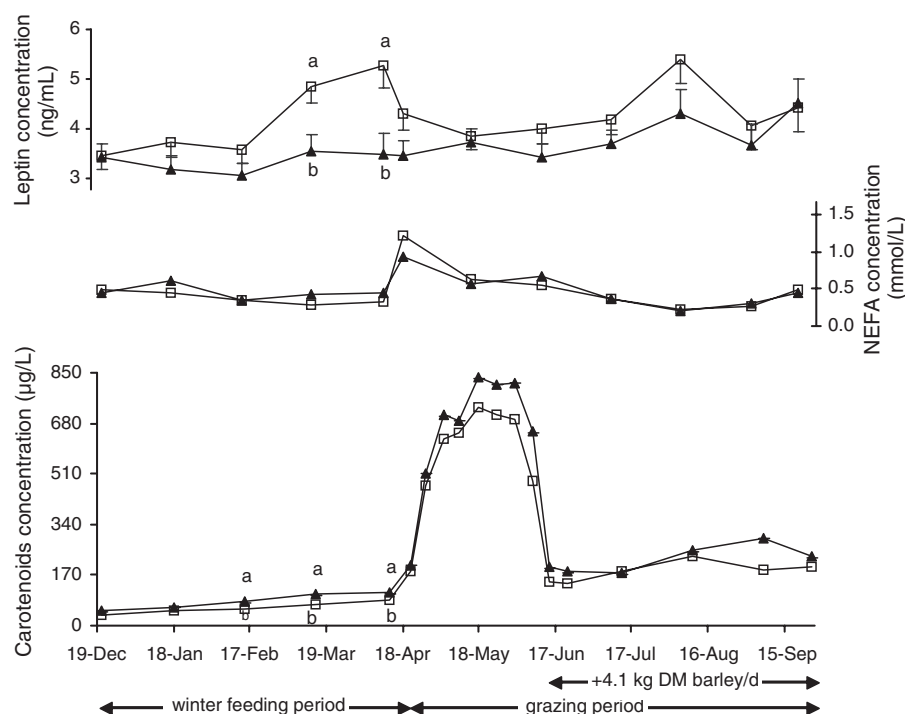
Carotenoid concentrations were similar during the first month of the winter feeding period (Fig. 3), but steers on the F winter diet had higher carotenoid concentrations than did steers on the FC winter diet during the following months of the winter feeding period. The carotenoid concentration in the 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).

Fig. 3. Effect of the forage content of the winter diet on the concentration of serum leptin, serum non-esterified fatty acids (NEFA) and carotenoids in steers finished on pasture supplemented with barley. FC, lucerne hay + straw + barley (□); F, lucerne hay + straw (▲). Within a parameter, means with different letters differ at $P = 0.05$. The error bars shown represent the s.e.

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.* 2010*b*); 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 Albertí *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 Albertí *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

FC, lucerne hay + straw + barley; F, lucerne hay + straw during the winter feeding period. Extra-quality meat: sirloin; 1st-quality meat: loin, thick flank, topside, silverside, rump, eye round, heel chuck roll, shoulder blade, chuck tender; 2nd-quality meat: blade, shank, shin; and 3rd-quality meat: flank, breast rib, brisket, neck, thin skirt

Parameter	FC	F	s.e.	*P*-value
Carcass characteristics				
Hot carcass weight (kg)	324	300	10.6	0.04
Dressing percentage (%)	57.3	56.1	0.53	0.03
Conformation score (1–18)	8.9	8.3	0.41	0.21
Fatness score (1–15)	5.1	4.9	0.56	0.68
Carcass dissection (% carcass weight)				
Edible meat	71.3	71.0	0.74	0.74
Fat	6.5	6.0	0.41	0.34
Bone	22.3	22.9	0.62	0.31
Edible meat : bone	3.20	3.10	0.112	0.38
Fat : bone	0.29	0.26	0.019	0.23
Extra-quality meat	2.0	2.1	0.1	0.27
1st-quality meat	44.0	43.8	0.4	0.72
2nd-quality meat	6.1	6.0	0.1	0.49
3rd-quality meat	19.2	19.1	0.5	0.96
10th rib dissection (%)				
Muscle	65.5	68.0	1.91	0.20
Subcutaneous fat	3.4	2.5	0.71	0.23
Intermuscular fat	9.8	9.0	1.24	0.51
Total fat	13.2	11.5	1.83	0.37
Bone	21.3	20.5	1.11	0.47

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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