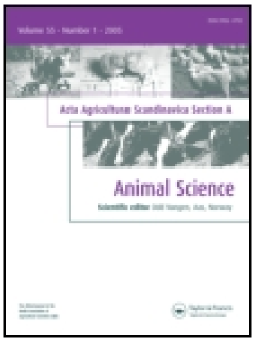

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ORIGINAL ARTICLE

Alternative production systems for male Charolais cross-bred cattle using semi-natural grasslands

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Abstract

The aim was to compare animal performance and carcass characteristics in Charolais cross-breds raised as bulls finished indoors to steers grazing semi-natural grasslands during summers combined with high, medium or low feed intensity during indoor periods. Bulls ($n = 15$) and high steers ($n = 13$) were fed grass-clover silage:barley (450:550 g kg^{-1} dry matter), medium steers ($n = 13$) silage *ad libitum* and low steers ($n = 12$) silage at a restricted intake. High and medium steers grazed semi-natural grasslands one summer, whereas low steers grazed two summers. From weaning to slaughter, liveweight gains were 1.72, 0.93, 0.72 and 0.60 kg day^{-1} for bulls, high steers, medium steers and low steers, respectively ($P < 0.05$). Bull carcasses had higher dressings, conformation scores and proportions of high-valued retail cuts than steers ($P < 0.001$). High and medium steers had highest fatness scores ($P < 0.02$) and most trim fat ($P < 0.03$), whereas medium and low steers had more marbling in *musculus longissimus dorsi* than bulls ($P < 0.03$).

Keywords: *Animal performance, carcass characteristics, feed intensity, grazing, nature conservation, semi-natural pasture, steer.*

Introduction

Semi-natural grasslands represent land of diverse landscape types, such as open grasslands, tree pastures, limestone plains and sea shores, all of which have been used continuously for fodder production for centuries (Olsson, 2008). These landscapes are characterised by a specific native flora and fauna, and are dependent on human management to be maintained (Olsson, 2008). Fodder production by grazing and mowing grass for haymaking was historically the sole reason for managing these areas. Today, the main reasons for managing the grasslands are the ecological aspects, as they contain many endangered species of several organism groups and also perform ecosystem services (Luoto et al., 2003; Olsson, 2008). Furthermore, they are representing traces of cultural heritage values, recreation possibilities and amenity values (Olsson, 2008). Unfortunately, all over Europe the semi-natural grasslands are threatened and the biggest single threat is ceased grazing management and subsequent abandonment (Luoto et al., 2003; Olsson, 2008).

To promote management of semi-natural grasslands, farmers in varying countries such as Austria, Czech Republic, Spain and Sweden can receive environmental payment to maintain grazing livestock on these areas (Deblitz, 2009). In Sweden, this payment has resulted in the country being one of a very few in Europe where the negative trend of increasing abandonment of grasslands has been mitigated (Olsson, 2008). The current levels of payment are about 130 and 280 € ha^{-1} for grasslands with, as it is called, general and specific values, respectively (Swedish Board of Agriculture, 2007). This payment makes extensive beef production on semi-natural grasslands more competitive compared to indoor rearing and grazing on cultivated leys and the payment usually composes a considerable proportion of the income in Swedish beef production enterprises. In 2008, on average 8% of the revenue for work and capital in Swedish cow-calf enterprises consisted of this payment, when not taking single

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farm payment for the areas into account (Deblitz, 2009). The main prerequisite to receive payment for an area of grassland is a short sward height at the end of the growing season ensuring that no dead herbage is accumulated onto the sward, ensuring no deleterious effect on the flora (Swedish Board of Agriculture, 2007).

For some time now The Common Agricultural Policy (CAP) of European Union (EU) has been regulating the production systems on individual beef enterprises in detail by the rules of the direct payments. For example, the slaughter age of steers have been uniformly adopted to the payments, resulting in slaughter no earlier than 22 months of age. The ongoing CAP reform decouples the direct payments and transfers some of the payment into measures based on environmental programmes (Commission of the European Communities, 2002). This encourages the EU member states to increase environmental payment measures to maintain their domestic beef production (Sarzeaud et al., 2008). Environmental payment to semi-natural grasslands could be one measure.

In Sweden, as in many other European countries, the supply of beef breed cattle for slaughter is dominated by young bulls finished in intensive indoor systems directly after weaning (Deblitz, 2009; Taurus, 2010). In 2009, 91% of the Swedish beef breed male progeny were slaughtered as entire bulls and the remaining 9% of the males were raised as less intensively fed steers with a slaughter age averaging 27 months (Taurus, 2010). The Swedish supply of beef from beef breeds is distributed irregularly throughout the year with a surplus in late spring and early summer (Taurus, 2010), whereas the demand for beef is relatively constant all through the year. The reform of CAP changes the prerequisites for different production systems. Alternative ways could be to rear the males as steers slaughtered at varying ages. Assuming carcass quality is maintained or increased, rearing male calves as steers in grazing systems using semi-natural grasslands may result in both increased areas of managed semi-natural grasslands and a greater profitability for the farmers when adapting to the new economical conditions with higher proportion of revenues from environmental payment. The beef supply over the year will also be in better balance with the consumer demand.

In this study the hypothesis was that alternative production systems with steers on semi-natural grasslands for male progeny of beef breed could be advantageous compared to traditional systems. The public would benefit from maintained or even increased areas of semi-natural grasslands, the farmer would benefit from increased profitability and the industry would benefit from a more even supply of beef over the year. However, a prerequisite for alternative systems to be successful is that carcass quality is maintained or increased. Therefore, the objective of this study was to compare animal performance and carcass characteristics of male Charolais cross-bred cattle in two traditional production systems and two alternative production systems.

Materials and methods

Investigated systems

The two traditional systems consisted of intensively fed entire bulls and a medium-intense steer rearing system approximately corresponding to the national average with slaughter at 25 months of age. The two alternative systems were the following: one intensive steer rearing system with no consideration taken to the former minimum age for direct payments but instead the steers were slaughtered as young as possible (at 20 months of age) with a high proportion of liveweight gain assumed to be achieved indoors. The second alternative was an extensive steer rearing system with low indoor-feeding costs and possibility to receive environmental payment for one further grazing period (GP) compared to the traditional 25-month steers and slaughter at 30 months of age. All four systems were prerequisite to deliver marketable carcasses with regards to carcass weight (275–400 kg), conformation score (at least *R*–; SJVFS 127 1998, EU Council Directive 2005) and fatness score (2+ to 3+; SJVFS 127 1998, EU Council Directive, 2005) resulting in receiving a premium. Suitable target slaughter weights to reach these criteria within the studied systems were destined. In addition, all steers had to graze semi-natural grasslands in the summers in order to yield environmental payment for semi-natural grasslands.

Experimental design

The experiment started in October 2006 and was conducted at Götala Research Station, The Swedish University of Agricultural Sciences, Skara, in south western Sweden (long 13°21′E, lat 58°42′N; elevation 150 m). Four production systems for beef cattle from weaning to slaughter were compared; one system for young bulls and three systems for steers. The steer systems differed in level of indoor feed intensity (high, medium vs. low), whereas all bulls were fed the high feed intensity. During indoor periods (IPs), the cattle were kept in three pens within each of the four treatments; bulls, high steers, medium steers and low steers, in total 12 pens with deep-straw bedding (5 × 8 m) in an uninsulated barn with natural ventilation. The animals were offered water *ad libitum* and there was at least 1.0 m feeding space per head at the feeding trough. The bulls were kept indoors throughout the experiment, whereas all steers were kept on semi-natural grasslands during the GPs, all animals from the three treatments in one group. High and medium steers grazed for one summer and low steers grazed for two summers. Animals were planned to be slaughtered on an individual basis when reaching specific liveweights, all within the most marketable carcass weight range from 275 to 400 kg and simultaneously assumed to reach the market criteria for conformation and fatness scores (Table I).

Animals

Fifteen bull and 45 steer spring-born calves of beef breeds, all with at least 75% Charolais breeding, were ordered in advance from four commercial suckler herds. During their first GP, all calves were kept on semi-natural grasslands together with their dams. The steers were castrated at 2–3 months of age. Seven ordered steer calves were unfortunately poisoned by yew and died, but all bull calves and 38 steer calves were successfully weaned and initiated into the experiment at, on average, 7.4 (SD 0.4) months of age. Within gender, groups of calves were arranged so that animals from the same farm were distributed to different groups as evenly as possible. The groups were then allocated completely at random into the pens. During the experiment, liveweights of the animals were recorded once every second week and on two consecutive days at the start and at the end of the experiment. The average daily liveweight gain of the animals was calculated from the start and end weights. Initially, there were 15 bulls, 13 high steers, 13 medium steers and 12 low steers. One of the medium steers was excluded from the experiment during the first GP because of foot rot and one of the low steers was excluded at turnout for the second GP because of a nervous temperament. Data from these animals were therefore excluded from further analyses. Except the steer with foot rot, all animals were healthy. Finally, there were 13, 12 and 11 animals involved in the high, medium and low steer system, respectively.

Diets during indoor periods (IPs)

Bulls and high steers were fed a total mixed ration consisting of 450 g kg^{-1} dry matter (DM) grass-clover silage and 550 g kg^{-1} DM rolled barley (Table II). The ration was fed *ad libitum*, defined as ≥ 105% of voluntary intake. Only grass-clover silage was fed to medium steers *ad libitum* and to low steers at a restricted intake, defined as 80 and 90% of intake for medium-fed steers at the same liveweight during IPs 1 and 2, respectively. For the high steers, the proportion of barley in the feed ration was gradually reduced to none during the 10 days before turnout to pasture and then regained to 55% during 20 days after housing for the second IP.

Grass-clover silage contained 90–95% grass (*Lolium perenne*, *Festuca pratensis* and *Phleum pratense*) and 5–10% clover (*Trifolium repens* and *Trifolium pratense*). Herbage was wilted to about 250 g kg^{-1} DM and a preservative containing formic acid, propionic acid and ammonium was used at 4 L ton^{-1} herbage (Promyr™, Perstorp Inc., Perstorp, Sweden). The herbage was ensiled in bunker silos and harvested at least 4 months before feeding.

Cattle were fed once a day. The feed rations were supplemented with vitaminised minerals to fulfil the requirements of the animals (Spörndly, 2003). Orts were weighed and disposed of three times a week and the net average feed consumption per pen was calculated weekly. Silage samples for analysis of chemical composition were taken daily and composed to one sample per month, whereas silage samples for analysis of fermentation quality were taken weekly and composed to one sample per silo, with four and three silos for IPs 1 and 2, respectively. Barley samples were collected weekly and composed to one sample every second month for analysis of chemical composition.

Table I. Targeted and achieved liveweights at slaughter and slaughter age for four production systems with Charolais cross-bred male progeny.

	Bull ($n = 15$)		Steer					
			High ($n = 13$)		Medium ($n = 12$–13)		Low ($n = 11$–12)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Targeted liveweight at slaughter (kg)	680	–	640	–	680	–	720	–
Achieved liveweight at slaughter (kg)	675	14	639	13	670	14	713	24
Slaughter age (months)	15	1.1	20	0.8	25	2.2	30	0.5

Table II. Chemical composition of rolled barley and grass-clover silage fed during indoor period (IP) 1 and 2, and grass fed during grazing period (GP) 1 and 2 to Charolais cross-bred male progeny.

	Barley		Grass-clover silage				Grass			
	IP 1 and 2 ($n=9$)		IP 1 ($n=8$)		IP 2 ($n=9$)		GP 1 ($n=7$)		GP 2 ($n=7$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DM, g kg^{-1}	860	5	252[a]	35	314[b]	102	297	55	308	51
ME, MJ kg^{-1} DM	13.5	0.2	10.0	0.4	10.6	0.5	10.1	0.6	9.5	0.7
CP, g kg^{-1} DM	122	3	154	13	159	21	138	18	145	8
NDF, g kg^{-1} DM	158	15	564	30	530	29	579	25	555	30
Ash, g kg^{-1} DM	22	3	81	6	82	15	72	5	80	14

[a]$n=32$.
[b]$n=48$.
Note: SD, standard deviation; DM, dry matter; ME, metabolisable energy; CP, crude protein; and NDF, neutral detergent fibre.

Grazing periods (GPs)

The first GP lasted from 26 April to 14 August 2007 for the high steers and 26 April to 24 October 2007 for the medium and low steers. The second GP for the low steers lasted from 23 April to individual slaughter dates ranging from 2 September to 7 October 2008. Due to a shortage of grass, the animals were supplementary fed grass-clover silage during the two last weeks on pasture. During GP 1, the steers were rotated every second to third week between two paddocks consisting of in total 21 ha of pasture. During GP 2, they were continuously kept on 9 ha of pasture. The steers were offered water and a vitaminised mineral supplement *ad libitum* throughout the GPs.

A description and inventory of plant species in the unfertilised pasture was conducted before initiating the study. The moisture gradients of the pasture were 20% dry, 60% mesic and 20% wet areas in mainly open *Deschampsia cespitosa*/*Agrostis capillaris*/*Festuca ovina* meadows (70%). The grazings included areas of mixed deciduous tree pasture (20%) and small areas of sedges, rushes, reed and tall herb grasslands (all together 10%). Tree species consisted of *Betula* spp. and *Quercus robur* in dry and mesic areas and *Alnus glutinosa* in wet areas. Field layer in dry areas consisted of grass (*F. ovina*, *Deschampsia flexuosa*, *Nardus stricta*) and various herb species dominated by *Lathyrus linifolius*, *Galium verum*, *Galium boreale* and *Hieracium pilosella*. There were also *Veronica officinalis*, *Lotus corniculatus*, *Fragaria vesca*, *Saxifraga granulata*, *Plantago lanceolata*, *Hypericum maculatum*, *Leucanthemum vulgare*, *Thymus serpyllum*, *Lychnis viscaria*, *Antennaria dioica* and others. Mesic areas were dominated by the grasses *Festuca rubra* and *D. cespitosa* but also contained the grasses *A. capillaris* and *N. stricta* as well as the herbs *Ranunculus acris*, *Veronica chamaedrys*, *Ajuga pyramidalis*, *Succisa pratensis*, *Arnica montana*, *Scorzonera humilis* and others. Field layer in wet areas consisted of the grasses *D. cespitosa* and *Glyceria fluitans*, the rushes/sedges *Juncus effusus* and *Carex* species (*C. nigra*, *C. panicea*, *C. rostrata* and *C. vesicaria*) and a few herb species, mainly *Filipendula ulmaria* and *Ranunculus repens*, but also *Cardamine pratensis* and *Gerum rivale*.

At the end of each GP, the sward heights were visually judged to be short enough to ensure that no litter had been accumulated onto the sward (Swedish Board of Agriculture, 2007). Inspections of the pasture were conducted according to the national inspection protocol (Persson, 2005).

Sward height measurements and herbage sampling were performed each time steers changed paddocks during GP 1 and once a month during GP 2. A procedure was established by mapping out a path to follow passing through all parts of the paddocks. The path followed the shape of a W in each paddock, as recommended by Frame (1993). Sward height measurements were taken with a rising plate metre (0.3 × 0.3 m with a weight of 430 g) with 40–60 recordings in each paddock. Samples for chemical composition of the herbage were taken at every fifth sward height recordings. Samples were picked manually, trying to imitate the choice and bite of the animals, taking approximately 25 "bites" within a circle with a diameter of approximately 3 m. When a sampling spot contained pasture that seemed to be rejected by the animals, for example *Filipendula ulmaria*, the spot was left unsampled. Herbage samples were composed to one sample per month.

Chemical analysis

Silage, grain and pasture samples were analysed for DM, ash, crude protein (CP) and neutral detergent fibre (NDF). The DM concentrations of feeds were determined at 60° C and 105°C, respectively, for 24 h, whereas ash was determined at 550°C for 5 h.

The CP concentrations were analysed in a Tecator Kjeltec Auto sample system 1035 Analyzer (Tecator Inc., Höganäs, Sweden). Concentrations of NDF in silage and grass were determined according to Goering and Van Soest (1970) and NDF in grain was determined according to Van Soest et al. (1991). The metabolisable energy (ME) concentrations of silage and grass were calculated from *in vitro* organic matter digestibility (Lindgren, 1979) and the ME of grain was calculated according to Axelsson (1941). Concentrations of starch and crude fat were determined in grain (Åman & Hesselman, 1984; EU Council Directive, 1998). In addition, silage samples were analysed for pH and concentrations of NH_4-N (Tecator Kjeltec Auto sample system 1035 Analyzer, Tecator Inc., Höganäs, Sweden), organic acids and ethanol (Andersson & Hedlund, 1983).

Carcass measurements

The cattle were slaughtered in a commercial abattoir when each individual reached the target weight for the respective treatment. The weight of the kidney knob and channel fat (KKCF) was recorded. The carcasses were divided along the vertebral column and cold carcass weights were estimated as 0.98 × hot carcass weights. Conformation and fatness were graded according to The EU Carcass Classification Schemes EUROP modified to the Swedish system in which 15 classes are used (SJVFS 127 1998, EU Council Directive, 2005). The EUROP classes were transformed to numerical figures for conformation score (1 = P–, poorest, and 15 = E+, best) and fatness (1 = 1–, leanest, and 15 = 5+, fattest). After cooling for one day in +2 to +4°C, the fore and hind quarters were separated between the 10th and 11th ribs where marbling was determined visually on right hind quarters in *musculus (m.) longissimus dorsi* on a 10-scored scale with steps of 0.5 from 1 (lean) to 5 (well marbled). The right hind quarter from each cattle was weighed, as well as its seven high-valued retail cuts; strip loin (*m. longissimus dorsi*), fillet (*m. psoas major*), topside (*m. semimembranosus*), outside round (*m. biceps femoris*), eye of round (*m. semitendinosus*), top rump (*m. quadriceps femoris*) and rump steak (*m. gluteus medius*). Furthermore, trim fat, bones and two commercially defined cuts, Grades 2 and 3 meat assortments assumed to contain 10 and 23% fat, respectively, from the hind quarter were weighed. Trim fat was defined as subcutaneous and intermuscular fat deposits separable with a knife in a standardised cutting up procedure. Bones were weighed together with closely bound connective tissue capsules and without extra cleaning of the bones. Dressing proportion out of cold carcass weight, g KKCF kg^{-1} carcass weight, as well as proportion of retail cuts, trim fat, bones and meat assortments of the hind quarter were calculated.

Statistical analysis

Two different statistical models were used, as the dietary intake and feed efficiency (FE) data were recorded on a pen level, whereas liveweight gain and carcass characteristics were recorded for the individual animal nested within pen.

Dietary intake and FE data were analysed with the GLM procedure of SAS (2003) using the model:

$$y_{ij} = \mu + \alpha_i + e_{ij}.$$

Liveweight gain and carcass characteristics were analysed with the Mixed procedure of SAS (2003) using the model:

$$y_{ijk} = \mu + \alpha_i + b_{ij} + e_{ijk},$$

where α_i is the fixed effect of production system, b_{ij} is the random effect of pen, whereas e_{ij} and e_{ijk} are the error terms.

Dietary intake data were analysed separately for each IP and summarised over the two IPs. Liveweight gain data were analysed for each indoor and GP, and averaged over the period from weaning to slaughter. Means of production systems were compared pairwise by using $LSD_{0.05}$-tests and denoted as significant at $P < 0.05$ and as a tendency for significance at $0.05 < P < 0.10$. Analyses were undertaken both for the four production systems separately and as contrasts were the bulls were compared to the three steer systems together. Results from the latter analysis are presented in tables only.

Results

Feeds

The main parts of chemical composition of the feeds are presented in Table II and Figure 1. The pH values of the grass-clover silage were on average 4.6 (SD 0.5) and 4.3 (SD 0.2) during IPs 1 and 2, respectively, whereas the concentrations of NH_4-N were 17 (SD 11) and 16 (SD 8) g kg^{-1} DM during the two IPs. On average, the grass-clover silage contained 41 (SD 30) and 65 (SD 30) g lactic acid, 27 (SD 20) and 36 (SD 20) g acetic acid, <4 (SD 4) and <2 (SD 3) g butyric acid, and 5 (SD 1) and 10 (SD 1) g ethanol kg^{-1} DM during IPs 1 and 2, respectively. The barley contained 627 (SD 13) g starch and 31 (SD 2) g crude fat kg^{-1} DM on average over the two IPs.

The pasture stocking rates were 832 and 774 kg liveweight ha^{-1} and the sward heights were 4.7 (SD 2.2) and 4.6 (SD 2.1) cm averaged over GPs 1 and

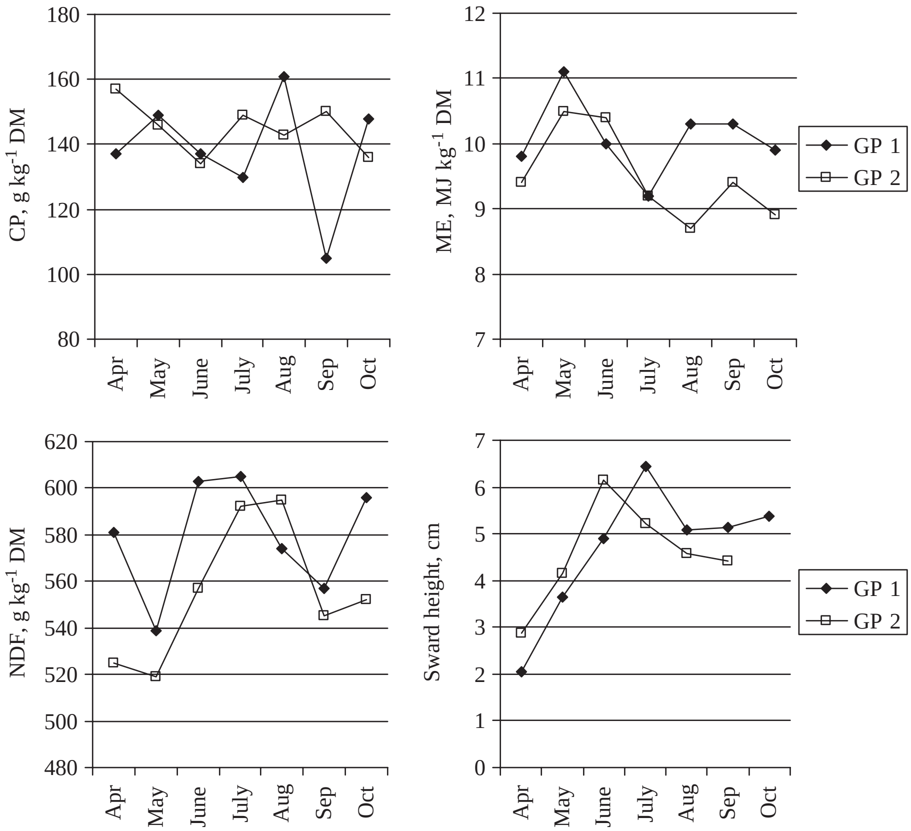

Figure 1. Herbage concentrations of crude protein (CP), metabolisable energy (ME) and neutral detergent fibre (NDF) as well as sward heights in *Deschampsia cespitosa*-dominated semi-natural grassland grazed from April until October by Charolais cross-bred steers in grazing periods (GP) 1 and 2, where data from GP 1 are average over exited and entered rotationally grazed paddocks and data from GP 2 are sampled from one paddock continuously grazed

2, respectively. Calculating backwards from animal liveweights, weight gains and stocking rate, the utilised biomass of the pasture was 1.6 ton DM ha^{-1}. At the end of the two GPs, the average sward heights were 5.4 and 4.4 cm, respectively (Figure 1). The final sward heights were visually classified as being short enough to prevent litter accumulation and, hence, the management was satisfactory from a nature conservation point of view.

Dietary intake, liveweight gain and feed efficiency (FE)

From weaning to first turn-out to pasture, i.e. IP 1, gender differences were shown between the bulls and the high steers, which were fed the same feed ration. During the period, the daily total dietary intake was 5% higher in the bulls than in the high steers ($P=0.003$; Table III). Simultaneously, liveweight gains were 35% higher in the bulls ($P<0.001$), resulting in 25% higher liveweight gains MJ^{-1} ME ($P<0.001$; Table III). Averaged over the IPs from weaning to slaughter, the FE was 26% higher in the bulls ($P=0.003$).

Among the steer groups during IP 1 there were similar FE in the two groups high and medium steers. The higher dietary intake in the high steers compared to the medium steers in combination with their 53% higher liveweight gains ($P=0.001$) gave this result. The low steers had 74% lower liveweight gain than the medium steers ($P<0.001$), resulting in the lowest FE among the three groups ($P<0.001$; Table III). Also during IP 2, the dietary intakes were highest in the high steers and lowest in the low steers (Table III). The high steers had 82% and 107% higher liveweight gains than the medium and low steers, respectively ($P<0.001$). However, the medium steers had lower FE than the two other groups ($P<0.01$; Table III).

During the first grazing weeks steers in all treatments lost a considerable amount of liveweight (Figure 2). During GP 1, the high steers did not gain weight at all, but decreased in liveweights (Table III; Figure 2). At the same time, liveweight gains in the low steers were 50% higher than in the medium steers ($P=0.002$). In total from weaning to slaughter the high steers obtained all their liveweight gains from indoor feeding, whereas 21 and 47% of the gains were obtained from pasture for the medium and low steers, respectively.

Table III. Daily feed intake, daily liveweight gain and feed efficiency of Charolais cross-bred bulls kept on high indoor feed intensity slaughtered at 15 months of age and of Charolais cross-bred steers in three production systems including grazing on semi-natural grasslands in summers with high, medium or low indoor feed intensity slaughtered at 20, 25 and 30 months of age, respectively; least square means, pooled standard error of the means (SE) and significance of the effects of production system analysed both for the four systems separately and for bulls compared to all three steer systems together.

	Bull	Steer				Four separate systems		Bulls vs. all steers	
		High	Medium	Low	All	Level of SE	Level of signficance	SE	Level of significance
Indoor period 1[a]									
Days, no.	182	182	182	182	182	0		0	
Initial LW, kg	299	288	285	287	287	10	NS	7	NS
Silage intake, kg of DM	3.87[b]	3.77[b]	6.48[c]	4.72[d]	4.99	0.06	***	0.49	NS
Total dietary intake, kg of DM	8.50[c]	8.09[d]	6.48[b]	4.72[e]	6.43	0.10	***	0.60	*
Total dietary intake,% of LW	1.90[d]	2.00[c]	1.80[b]	1.42[e]	1.74	0.02	***	0.10	NS
Intake of NDF, kg	2.91[d]	2.80[bd]	3.68[c]	2.68[b]	3.06	0.04	***	0.19	NS
LW gain, kg	1.79[c]	1.33[d]	0.87[b]	0.50[e]	0.93	0.04	***	0.07	***
Feed efficiency, g gain MJ^{-1} ME	17.2[c]	13.8[d]	13.5[d]	10.4[b]	12.6	0.40	***	0.72	**
Grazing period 1									
Days, no.	–	112	182	182	154	6	***		
Initial LW, kg	–	529[c]	442[d]	383[b]	463	11	***		
LW gain, kg	–	–0.16[b]	0.46[d]	0.69[c]	0.29	0.05	***		
Indoor period 2[f]									
Days, no.	–	87	180	182	144	12	***		
Initial LW, kg	–	511	527	508	515	11	NS		
Silage intake, kg of DM	–	5.44[b]	10.00[c]	9.20[d]	8.21	0.07	***		
Total dietary intake, kg of DM	–	11.00[c]	10.00[d]	9.20[b]	10.07	0.09	***		
Total dietary intake,% of LW	–	1.95[c]	1.66[d]	1.58[b]	1.73	0.02	***		
Intake of NDF, kg	–	3.60[b]	5.23[c]	4.81[d]	4.55	0.04	***		
LW gain, kg	–	1.51[c]	0.83[d]	0.73[d]	1.07	0.05	***		
Feed efficiency, g gain MJ^{-1} ME	–	8.3[c]	5.0[d]	7.5[c]	6.9	0.5	**		
Grazing period 2									
Days, no.[g]	–	–	–	155	155	5			
Initial LW, kg[g]	–	–	–	641	641	8			
LW gain, kg[g]	–	–	–	0.45	0.45	0.05			
From weaning to slaughter									
Days, no.	220[e]	381[b]	544[d]	701[c]	532	11	***	37	***
LW gain, kg	1.72[c]	0.93[d]	0.72[b]	0.60[e]	0.76	0.04	***	0.03	***

[a-d]Means within a row with different superscripts differ significantly ($P<0.05$) according to a $LSD_{0.05}$-test when analysing data for the four production systems separately.
[e]Refers to the period 25 October to 25 April for all groups although bulls stayed indoors until slaughter which occurred on average 38 days later.
[f]From 15 August for high steers and from 24 October for medium and low steers.
[g]Averages for this treatment, not least square means.
*, **, *** significant at $P<0.05$, 0.01, 0.001, NS, non-significant at $P>0.10$
Note: n=15 for bulls, 13 for high steers, 12–13 for medium steers, 11–12 for low steers for days, initial LW and LW gain and 3 for all other parameters. Pooled standard error of the means, SE; LW, liveweight; DM, dry matter; NDF, neutral detergent fibre; ME, metabolisable energy.

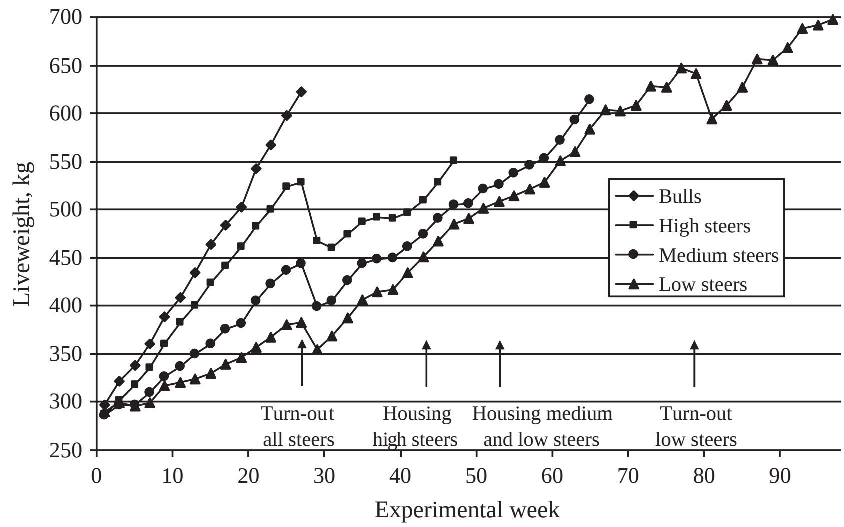

Figure 2. Average liveweights from weaning at 7.4 months of age to first slaughter occasions in groups of Charolais cross-bred bulls kept indoors at high-feed intensity and slaughtered at 15 months of age ($n = 15$) and Charolais cross-bred steers kept on semi-natural grasslands during grazing periods with high ($n = 13$), medium ($n = 12$–13) and low ($n = 11$–12) indoor feed intensity with slaughter at 20, 25 and 30 months of age, respectively

Summarised over the two IPs, the total feed consumptions were 28% lower in the high steers and 34% lower in the low steers compared to the medium steers (Table IV). Simultaneously, the liveweight gains from weaning to slaughter were 29% higher in the high steers than in the medium steers who on their part were 20% higher than in the low steers (Table III).

Carcass characteristics

The bulls and the low steers were slaughtered at 675 and 705 kg liveweight, respectively. However, the 4 percentage-units higher dressings in the bulls resulted in similar carcass weights for the two groups (Table V). Conformation scores were on average three classes lower in the steers (score R-) than in the bulls (score U-; $P < 0.001$). At the same time, the high and medium steers had higher fatness scores than the bulls (score 3 vs. 2+; $P < 0.01$), whereas the low steers were intermediate (Table V). Weights of KKCF in proportion of carcass weight were highest in the high and medium steers, whereas marbling was most pronounced in the medium and low steers (Table V). The bulls had lower KKCF weights than the high and medium steers ($P < 0.001$) and lower marbling score than the medium and low steers ($P < 0.03$; Table V).

Compared to the steers, a greater proportion of the hind quarters of the bulls consisted of high-valued retail cuts ($P < 0.001$), whereas proportions of trim fat (compared to high and medium steers only; $P < 0.001$), meat assortment with 10% fat ($P < 0.001$), and bones ($P < 0.01$) were lower (Table V). However, in the bulls the hind quarters made up lower proportions of the carcass weights than in the steers (48% vs. 51%, $P < 0.001$). Compositions of the hind quarters in the steer groups were rather similar, but the low

Table IV. Total feed consumption of Charolais cross-bred bulls kept on high indoor feed intensity slaughtered at 15 months of age and of Charolais cross-bred steers in three production systems including grazing on semi-natural grasslands in summers with high, medium or low indoor feed intensity slaughtered at 20, 25 and 30 months of age, respectively; least square means, standard error of the means and significance of the effects of production system analysed both for the four systems separately and for bulls compared to all three steer systems together.

	Bull	Steer				Four separate systems		Bulls *vs.* all steers	
		High	Medium	Low	All	Level of SE	Level of significance	SE	Level of significance
Grass-clover silage, kg of DM	1015[a]	1331[b]	3838[c]	2533[d]	2567	42	***	443	*
Rolled barley, kg of DM	1278[d]	1450[c]	0[b]	0[b]	483	31	***	297	*T*

[a–d]Means within a row with different superscripts differ significantly ($P < 0.05$) according to a $LSD_{0.05}$-test when analysing data for the four production systems separately.

*, *** Significant at $P < 0.05$, 0.001; *T*, a tendency for significance at $0.05 < P < 0.10$.

Note: $n = 3$. SE, standard error of the means; DM, dry matter.

Table V. Carcass characteristics of Charolais cross-bred bulls kept on high indoor feed intensity slaughtered at 15 months of age and of Charolais cross-bred steers in three production systems including grazing semi-natural grasslands in summers with high, medium or low indoor feed intensity slaughtered at 20, 25 and 30 months of age, respectively; least square means, pooled standard error of the means and significance of the effect of production system analysed both for the four systems separately and for bulls compared to all three steer systems together.

	Bull	Steer				Four separate systems		Bulls vs. all steers	
		High	Medium	Low	All	Level of SE	Level of significance	SE	Level of significance
Slaughter									
Liveweight, kg	675^{a}	639^{b}	670^{a}	713^{c}	676	6.2	***	6.9	NS
Carcass weight, kg	393.6^{c}	344.2^{b}	355.5^{a}	386.2^{c}	360.1	3.7	***	4.8	***
Dressing,%	58.3^{c}	53.9^{a}	53.1^{a}	54.2^{a}	53.7	0.5	***	0.4	***
Conformation^{d}	10.0^{c}	7.1^{a}	7.1^{a}	6.8^{a}	7.0	0.3	***	0.3	***
Fatness^{e}	6.1^{b}	7.8^{c}	8.0^{c}	6.4^{a}	7.4	0.4	**	0.3	**
KKCF, g kg^{-1} carcass weight	34^{b}	47^{c}	45^{ac}	38^{ab}	44	2	**	2	**
Marbling^{f}	1.1^{b}	1.3^{ab}	1.6^{c}	1.5^{ac}	1.5	0.1	*	0.1	*
Cutting up									
HQ, kg	98^{c}	89^{a}	91^{a}	99^{c}	93	1.1	***	1.1	*
Retail cuts,^{g}% of HQ	42.2^{c}	33.0^{a}	32.5^{a}	31.6^{a}	32.4	0.7	***	0.5	***
Grade 2 meat ass.,^{h}% of HQ	24.3^{a}	30.0^{c}	29.6^{c}	29.9^{c}	29.8	0.9	***	0.7	***
Grade 3 meat ass.,^{i}% of HQ	11.1^{ac}	8.7^{b}	10.1^{ab}	12.3^{c}	10.2	0.6	**	0.5	NS
Trim fat,% of HQ	3.9^{a}	7.0^{c}	7.1^{c}	4.9^{a}	6.4	0.6	***	0.5	***
Bone,% of HQ	18.6^{a}	21.5^{c}	20.7^{c}	21.3^{c}	21.2	0.5	***	0.4	***

[a–c]Means within a row with different superscripts differ significantly ($P<0.05$) according to a $LSD_{0.05}$-test when analysing data for the four production systems separately.
[d]EUROP system: 6 = O+, 7 = R–, 8 = R, 9 = R+, 10 = U–.
[e]EUROP system: 6 = 2+, 7 = 3–, 8 = 3.
[f]Visually determined in *musculus longissimus dorsi* between 10th and 11th ribs on a scale 1 = lean and 5 = well marbled.
[g]High-value retail cuts; strip loin, fillet, topside, outside round, eye of round, top rump and rump steak.
[h]Commercial cut estimated to contain 10% fat.
[i]Commercial cut estimated to contain 23% fat.
*, **, *** Significant at $P<0.05$, 0.01, 0.001; NS, non-significant at $P>0.10$.
Note: $n=15$ for bulls, 13 for high steers, 12 for medium steers, 11 for low steers. SE, pooled standard error of the means; KKCF, kidney knob and channel fat; HQ, right hind quarter; meat ass., meat assortment.

steers had higher proportions of meat assortment with 23% fat ($P<0.03$) and lower proportions of trim fat ($P<0.03$) than the high and medium steers.

Discussion

The aim of this limited study was to identify production systems where marketable carcasses could be produced from a specific type of cattle at the same time as the farmer receive environmental payment for managing semi-natural grasslands, hereby increasing the profitability of the beef production. The effects of entire specific systems where therefore in focus and not single parameters such as carcass weight or gender. Nevertheless, some comparisons of single parameters may be undertaken all the same.

High steers, for example, which had the same feed ration as the bulls from weaning to the first turn-out to pasture, can be compared to each other. The steers had 5% lower ME intakes and 20% lower FE than the bulls during this period, which is in compliance with previous studies where steers had 19% lower FE than bulls (Steen, 1995). During the same period, the high steers on 55% grain daily consumed 4.32 kg DM grain and their intake of grass-clover silage was reduced with 2.71 kg DM, compared to the medium steers fed silage only. This resulted in a 59% substitution increase (Table III). Similar substitution rates of concentrate DM for silage DM has been recorded previously (Keane et al., 2006). An increased indoor feed intensity also resulted in higher ME intakes where high steers had 47% higher ME intakes than medium steers and the medium steers had 27% higher ME intakes than low steers during IP 1. Consequently, and in accordance with previous studies, the average daily liveweight gains and FE increased along with a higher feed intensity (Keane & Drennan, 2009).

In all three steer production systems studied, animal liveweights decreased after turn-out to pasture (Figure 2). A daily decrease of 1 to 1.5 kg liveweight during the first weeks at pasture is common in cattle grazing semi-natural grasslands due to losses in intestinal fill, associated with changes in diet digestibility and intakes (Tayler et al., 1957; Spörndly et al., 2000; Hessle et al., 2007). The decrease was more pronounced the higher the previous indoor feed intensity had been, probably due to a larger rumen and intestinal fill and also a lower herbage intake on pasture by steers previously fed at a higher indoor-feed intensity (Hinks et al., 1999). In the present study, one cannot exclude that the regrouping of animals at turn-out to pasture reinforced the liveweight losses in the early GP (Gupta et al., 2008), especially as one of the steers was very nervous and its temperament might have rub off on the others.

Steers with low indoor feed intensity had 59 kg lower liveweights at turn-out to pasture for GP 1 compared to the medium steers, but showed compensatory growth and weighed only 19 kg less at housing (Figure 2). In agreement with earlier studies (Wright et al., 1989; Hinks et al., 1999), steers of previously low indoor feed intensity regained more than half of their lost live weight gain during their recovery period on pasture. This occurred even though the pasture was unfertilised and consisted of natural plant species and herbage of mediocre nutritive concentrations lower than those of the grass-clover silage (Figure 1, Wright et al., 1989; Hinks et al., 1999). The high steer system aimed to maximize total average live weight gain from weaning to slaughter even though grazing semi-natural grasslands was presupposed in order to receive the environmental payment for the pastures. Due to the intense indoor feeding, a low weight gain during the separate GP was predicted although a positive gain would have been desirable.

For steers with *ad libitum* indoor feeding, i.e. the high and medium steers, liveweight gains were lower during the GPs than during the IPs (Table III). Often energy concentration in herbage on semi-natural grasslands is low, which is particularly true for *D. cespitosa* (Andersson, 1999; Olsson, 2008), the grass species dominating the pastureland in this study. Consequently, in the present study, concentration of ME was about 7% lower in the pasture herbage than in the grass-clover silages fed during the IPs although the NDF concentrations were more similar (Table II). However, this difference in energy concentration alone cannot explain the lower liveweight gains during the GPs compared to the IPs. Assuming the medium steers having daily pasture feed intakes intermediate to the figures for the two IPs, 1.73% of their liveweight, the liveweight gains should be more than 900 g day^{-1} which is double to what was achieved in the study (Table III). Also, in a Finnish study of grazing on coastal meadows (Niemelä et al., 2008), low digestibility of vegetation did not have any injurious effect on the live weight gain of beef cattle. However, these animals were suckler calves and got the majority of their nutrients from the dams.

Quantity and not quality of herbage mass was probably the most limiting factor of weight gain in the present study. The average sward heights on the pastures were 4.8 and 4.6 cm during GPs 1 and 2, respectively. In an earlier study of beef production on semi-natural grasslands, low sward heights, below 6 cm, was shown to restrict weight gain of cattle (Spörndly et al., 2000). Similar results were also indicated in an earlier study of beef heifers grazing the same pastures as in the present study (Hessle et al., 2007). Therefore, the liveweight gains on pasture were most likely restricted by the herbage mass and not the nutrient concentrations. However, decreasing the stocking rate to increase the sward height would not improve the production system as a whole since a short sward height at the end of the GP is required to obtain the environmental payment for semi-natural grasslands (Swedish Board of Agriculture, 2007). In fact, the low steer system in this study could have resulted in too high a final sward height after GP 2, as stocking rate decreased from early September in time with the slaughtering of individual steers. However, the final sward height after GP 2 was similar to the final sward height after GP 1, 4.4 cm, and the visual inspection judged the sward to be short enough to qualify for the environmental payment for both GPs (Persson, 2005). Hence, the optimal sward height on semi-natural grasslands becomes a trade-off between beef production and nature conservation aspects.

Conformation score and proportion of high-valued retail cuts were lower in all the steer groups than in the bulls, whereas the fat measurements such as fatness score, KKCF, marbling and trim fat generally were higher in the steers than in the bulls. Carcasses with less lean meat and more fat in steers than in bulls, when fed on similar feed rations and slaughtered at similar liveweights, has been consistent in several studies (e.g. Robelin, 1986; Li et al., 2006). The difference, caused by steers having greater adipocyte cells, is most pronounced in the subcutaneous deposits compared to intermuscular, perinephric and omental deposits (Robelin, 1986). This is in agreement with the present results where fatness scores, mainly based on subcutaneous deposits, were lower in the bulls than in all the three steer groups, whereas KKCF, marbling scores and trim fat proportions were lower in the bulls compared to two of the steer groups only (Table V).

In the present study, bulls and low steers had similar carcass weights although the average daily liveweight gains of the steers were only one-third of the weight gains of the bulls. The lower weight gains per se should in theory have resulted in leaner carcasses at these similar carcass weights (Keane et al., 2006). Apparently, gender influenced the fat proportions of the carcasses more than level of liveweight gain did. However, among the steer groups liveweight gain seemed to influence the fat proportions of the carcasses more than carcass weights did. The low steers had the least fat deposits, expressed both as fatness and marbling scores and as KKCF and trim fat proportions (Table V), despite the fact that they had the highest carcass weights. The low fat proportion was probably due to the low liveweight gain during the period before slaughter (450 g day^{-1}) compared to the indoor finished cattle.

Lipogenic activity is highest in peritoneal fat deposits, intermediate in subcutaneous deposits and lowest in intramuscular fat deposits (Mendizabal et al., 1999). This means fat is firstly stored in KKCF and last as intramuscular fat. This may be indicated in the high steers who after a GP with negative liveweight gains were put on a short finishing period resulting in fat being stored as KKCF and subcutaneous deposits in levels similar to the medium steers. However, the marbling scores in the high steers were still lower than in the medium steers in spite of the finishing period.

The greater muscle proportions in bulls compared to steers give more valuable carcasses, expressed as kg saleable meat. However, well-marbled meat in steers, such as in the medium and low steers in this study, results in a higher and less variable meat quality with more tender and juicer meat (Maher et al., 2004; Li et al., 2006). This may result in steers having more valuable carcasses than muscular bulls. In the present study as many as 62% of the steers reached carcass weights (275–400 kg), conformation scores (at least *R*–) and fatness scores (2+ to 3+) qualifying them for the best payment levels. This should be compared to 47% of the bulls, resulting in a 9% higher price per kg for the steers. The problem with the Continental type bulls is their late maturity which conflicts with the demand of the market for a certain carcass weight at slaughter. Therefore, slaughter weight often is a compromise between biological efficiency and the demand of the market resulting in the slaughter occurring before an optimal degree of fatness has been reached.

In production systems comparable to the high or medium steers in the present study, there are possibilities to obtain environmental payment for the management of semi-natural grasslands during one summer post-weaning. Use of grasslands with general values and the stocking rate used in the study of 1.5 animals ha^{-1}, means a possibility of receiving environmental payment corresponding to 7–8% of the economical value of the carcasses. Lowering the indoor feed intensity to the level of the low steers in this study gives opportunities to double the income from environmental payment per steer by letting it become older and, hence, graze another summer. If steers in the low system are combined with grasslands entitled to payment for specific values, the environmental payment corresponds to as much as 30% of the value of the carcasses. Also, due to a higher dietary intake on pasture (Wright et al., 1989), steers in the low system would probably be able to manage more than the double area of semi-natural grasslands compared to high and medium steers. Furthermore, a considerable proportion of the Swedish beef steers would benefit by being turned out to pasture for one additional summer. The average steer slaughtered in Sweden is not fully mature but is too light with insufficient conformation scores (Taurus, 2010).

Not only are the revenues higher in the low systems, the costs of production can also be lower. Indoor feed consumption in the low steer system is just two-thirds of the feed consumption of the medium steer (Table IV). This can compensate for the higher labour and building costs in the low steer system. Under Danish conditions (Nielsen et al., 2004), low indoor feed intensity was the most profitable system in organic steer production. In this case, however, the authors recommended permanent pastures the first summer only, and thereafter grazing the animals on leys. In Ireland, it was concluded (Keane & Drennan, 2009) that at the current concentrate and beef prices a high indoor feed intensity was not economically justified. In these two studies about half of liveweight gains were obtained from pasture (Nielsen et al., 2004; Keane & Drennan, 2009).

Contrary to indoor feeds, herbage from semi-natural grasslands usually has a negative cost when environmental payment is included in the production calculus (Kumm, 2009). As environmental payment is obtained per hectare grassland (Swedish Board of Agriculture, 2007), land with low biomass could be more attractive to farmers as every animal is able to manage a greater area. Estimation of utilised herbage mass at the experimental site originating from the animal liveweight gain and stocking rate (1.5 animals ha^{-1}) results in a relatively high biomass, 1.6. ton ha^{-1} for this area. Since the requirement for obtaining the environmental payment is a well-grazed area, animals on low productive grazing earn a bigger payment per head. The herbage mass from semi-natural grasslands can differ as much as six fold (Heinsoo et al., 2010) and, hence, also the environmental payment possible to obtain per animal.

For a farmer managing semi-natural grasslands, the profitability can be further promoted by using the production system as an added value when selling the meat. For consumers in general, price is not the sole issue taken into consideration (Grunert, 1997). Beside paying for a fresh appearance, pleasant taste and perceived high quality, many consumers are willing to pay extra for added values such as preservation of semi-natural grasslands (Plateryd, 2004). The present study indicates that the added values of high quality and preservation of semi-natural grasslands can be combined in the same beef production system.

Conclusion

The limited material studied here shows that steers had a lower FE than young bulls and their carcasses were composed of less muscle but more fat. Beef breed steers on low feed intensity during the IPs and managing semi-natural grasslands during two GPs post-weaning seems, according to this limited study, to be a promising alternative compared to traditional young bulls and steers on more intensive indoor feeding. The suggested production system may result in a high proportion of liveweight gain obtained from pasture, possibilities to receive large quantities of environmental financial payment and still produce market-oriented carcasses.

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