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Effects of grass-red clover silage digestibility and concentrate protein concentration on performance, carcass value, eating quality and economy of finishing Hereford bulls reared in cold conditions

Merja Manninen[1*], Markku Honkavaara[2], Lauri Jauhiainen[3], Arja Nykänen[4] and Anna-Maija Heikkilä[1]

[1]*MTT Agrifood Research Finland, Economic Research, FI-00410 Helsinki, Finland*
[2]*Finnish Meat Research Institute, FI-13110 Hämeenlinna, Finland*
[3]*MTT Agrifood Research Finland, Services Unit, FI-31600 Jokioinen, Finland*
[4]*MTT Agrifood Research Finland, Plant Production Research, FI-50100 Mikkeli, Finland*
**Present address: Evira, Finnish Food Safety Authority, Control department, FI-32200 Loimaa, Finland, email: merja.manninen@evira.fi*

The aim of the present experiment was to study the effects of (1) digestibility of grass-red clover silage (GCS) and (2) concentrate protein concentration on the performance, eating quality and economy of Hereford bulls during a six months pre-slaughter period, and reared in cold indoor facilities. Thirty-one bulls with an initial live weight (LW) of 289 kg were selected for a 2 × 2 factorial design experiment consisting of two primary growth GCSs harvested at different maturities (*in vitro* digestible organic matter (OM) in dry matter (DM), D value: Early-cut, E, 750 g kg^{-1} DM; Late-cut, L, 699 g kg^{-1} DM) and two concentrate crude protein concentrations (Medium, M, 170 g kg^{-1} DM; High, H, 210 g kg^{-1} DM). The concentrate comprised milled barley and pelleted commercial protein compound and was offered daily on average 3.2 kg DM, including 0.45 and 1.13 kg of rapeseed cake in M and H, respectively. Grass-red clover silage was offered *ad libitum*. The target cold carcass weight was 330 kg.The proportion of concentrate of the total daily DM intake averaged 0.337 during the entire experiment. Treatments had no effect on the daily intake of GCS, total intake of DM, DM intake kg^{-1} $LW^{0.75}$ and metabolizable energy averaging 6.0 and 9.4 kg DM, 97.4 g and 109.4 MJ, respectively. The digestibility of dietary OM and neutral detergent fibre was lower ($p < 0.05$, 0.733 vs. 0.769 and 0.625 vs. 0.665) on diet L than on diet E. The animals on diet E tended to consume daily on average 1.29 kg less ($p < 0.10$) DM kg^{-1} net weight gain than those on diet L. The time to achieve the target carcass weight was on average 18 days longer ($p < 0.01$) on diet L than on diet E. During the entire experiment the LW gain averaged 1795 and 1609 g d^{-1} ($p < 0.01$) on diets E and L, respectively. The concentrate protein concentration did not affect animal performance. Treatments had no significant effect on the kill-out proportion, EUROP carcass conformation and carcass fat classification which averaged 537 g kg^{-1}, 6.5 and 3.6, respectively. The eating quality of the tested loins was good. Treatments had only a minor effect on the yield of valuable cuts. It is concluded that the digestibility of silage is important since the early-cut silage improved the growth rate and shortened the finishing period of bulls significantly compared with those fed late-cut silage. The lower yield and, thus, higher unit cost of early-cut silage may, however, invalidate its superiority compared with the late-cut silage. There was no benefit from using concentrate of high protein concentration.

Key-words: Beef production, concentrate protein concentration, economy, eating quality, silage digestibility

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Introduction

Beef production from suckled beef-breed calves is increasing in Finland. The feeding of finishing cattle is largely based on grass silage. The nutritive value of this depends on the stage of growth at harvesting and the changes in the chemical composition during ensiling (e.g. Beever et al. 2000, Huhtanen et al. 2007). During the primary growth of grass, the daily decline in D value (digestible organic matter (OM) in dry matter (DM), g kg^{-1} DM) in Finnish conditions with timothy-meadow fescue grasses has typically been 5 g kg^{-1} DM (Rinne et al. 1999, Rinne et al. 2002) but lower values have been reported for the harvest of primary growth perennial ryegrass herbage (Keady et al. 2000). If the silage contains red clover, the decline is slower (Rinne and Nykänen 2000). According to Kuoppala et al. (2008), postponing the harvest of primary growth grass decreased silage DM intake (DMI) of dairy cows by 0.48 kg and the energy-corrected milk yield by 0.61 kg 10 g^{-1} decrease in silage D value. On the other hand, postponing the silage harvest increases the DM yield ha^{-1} and thus decreases the unit cost of silage DM. With growing cattle, several studies have confirmed that harvesting primary growth grass at an earlier stage of maturity improved the animal growth rate (e.g. Scollan et al. 2001, Nadeau et al. 2002, Steen et al. 2002, Keady et al. 2008). According to Steen (1988a), increasing the digestibility of grass silage by harvesting the grass at an earlier stage of growth may be the most effective method of increasing animal performance from silage.

In Finland, most producers use varying amounts of protein supplements with grain on grass silage-based diets. Protein supplementation for finishing cattle has been studied extensively, but the responses to supplementation have been inconsistent. The discrepancies may be due to the differences in animal live weight (LW) and the nutritive value of roughage as well as the amount and type of supplement offered. Additionally, the response to protein supplementation may depend on total diet crude protein concentration, stage of maturity of the beef animal and gender. At present, rapeseed is the most important protein supplement used for cattle in Finland and most of the commercial protein compounds available are based on rapeseed meal or rapeseed cake. In earlier studies with light (final LW between approximately 390 and 510 kg) dairy-breed bulls (Aronen 1990, Aronen et al. 1992), rapeseed meal supplementation increased the animal growth rate, particularly at the beginning of the finishing period, partly due to an increased silage and energy intake. In several studies, protein supplementation has not increased the growth rate (e.g. Steen 1996a, Huuskonen et al. 2008, Huuskonen 2009a), but there is evidence that finishing cattle may respond to supplementary protein in barley-based concentrates when the grass silage digestibility is moderate or low (Waterhouse et al. 1985) and in situations where the animals have very high growth potential (Steen 1996b). In some studies, excess protein supplementation has increased carcass fat classification (Steen and Moore 1988, 1989, Steen 1996a) but Berge et al. (1993) reported that steers which were given protein supplementation had leaner carcasses than steers not given protein supplementation. Meat tenderness is the most important property of beef meat for consumers and it has been studied widely (e.g. Berge et al. 1993, Manninen et al. 2010) but the effects of protein supplementation on high digestible grass silage-based diet on eating quality are scarce. Furthermore, overfeeding of protein may cause extra costs to beef producers and load to the animals' metabolism and environment.

No studies, made in Nordic conditions having timothy-meadow fescue grasses, are available on the effects of silage digestibility and protein supplementation with a low amount of concentrate on the performance of animals having a high growth potential. Therefore, the aim of the present experiment was to study the effects of grass-red clover silage (GCS) digestibility and concentrate protein concentration during a six months pre-slaughter period with Hereford (Hf) bulls, and reared in cold indoor facilities. However, the best economic performance is not necessarily reached with the feeding strategy that gives the best biological results. The effects of treatments on feed intake, diet digestibility, animal growth rate, feed conversion, carcass and eating quality, yield of valuable cuts and, finally, on the economy are discussed in this paper.

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Material and methods

Animals, experimental design and housing facilities

The experiment was carried out at Tohmajärvi Research Station, MTT Agrifood Research Finland, located in eastern Finland (62°20'N, 30°13'E) where the average vegetation growth period is 155 days. Thirty-two Hf bulls were taken for the experiment but one animal was removed from the experiment on 26 January due to acute lameness, possibly due to muscle injury. All data for this animal is deleted. Therefore, thirty-one Hf bulls (the dams were Hf cows) with an initial LW of 289 kg (standard deviation (SD) 37.7 kg) and age of 225 d (SD 22.6 d) on 18 November were selected for the experiment. The bulls were born at the Research Station between 13 March and 10 June (17 in March, nine in April, three in May and two in June). The birth weight averaged 42.0 kg (SD 4.81 kg). At pasture, dam milk and grass were the sole feeds for the bulls. From weaning on 17 September to the onset of the experiment on 19 November, the bulls were kept in an uninsulated barn and had free access to grass silage. During the last two weeks pre-experiment, milled barley, at most 2.0 kg DM d^{-1}, was given to facilitate adaptation to the experimental diet. The daily live weight gain (LWG) from birth to the onset of the experiment averaged 1097 g (SD 128.7 g).

In the present experiment, four treatments in a 2 × 2 factorially arranged design consisted of two primary growth digestibilities, GCSs (Early-cut, E; Late-cut, L) and two concentrate crude protein (CP) concentrations (Medium, M; High, H). Initial LW, age and sire were used to allocate the animals to four groups. Thereafter, the treatments were randomly assigned to groups. The animals were group-fed, four animals per pen and two pens per treatment. The two pens for each treatment were allotted in the barn so that pens having same treatment were not alongside.

During the experiment the animals were kept in an uninsulated barn in eight pens. Each pen was 37 m^2, including 26.5 m^2 of bedding area and 10.5 m^2 of passage. Straw and peat were used as bedding materials. The bulls had access to an asphalted outdoor exercise area of 53 m^2 for one to two hours two to three times weekly while bedding material was added. During the experiment the temperature in the barn was measured daily at 8:00 and 14:00 hours. The coldest temperature (-20.7 °C) was measured on 12 February at 8:00 hours and the highest temperature (+23.3 °C) on 7 May at 14:00 hours. The mean temperature during the experimental months was +2.0 °C.

Feeds and feeding

The aim was to have silages with D values of 700 and 650 g kg^{-1} DM, but the target was not met due to weather conditions. Wilted silages were harvested from two fields at the Research Station, 17–18 June (E) and 31 June–1 July (L), with a mower conditioner and a precision chopper. The herbage was ensiled in bunker silos using a formic acid-based additive (AIV 2 Plus: formic acid 760 g kg^{-1}, ammonium formate 55 g kg^{-1}, Kemira Oyj, Oulu, Finland) applied at 5 l t^{-1} fresh weight. The sward for silage was a second-year timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis* Huds.), red clover (*Trifolium pratense* L.) mixture sown in the proportions 650, 300 and 50 seeds m^{-2}, respectively. The sward was fertilized in spring using nitrogen (N) 33.5 kg ha^{-1}. The energy value of the GCS was evaluated prior to the experiment using *in vitro* OM digestibility (OMD, Friedel 1990).

The concentrate comprised milled barley and pelleted commercial protein compound (CPC), having a CP concentration of either 170 (M) or 210 (H) g kg^{-1} DM. The energy content in M and H was 12.88 and 12.55 MJ metabolizable energy (ME) kg^{-1} DM, respectively. Thus, the difference between M and H was 0.33 MJ ME kg^{-1} DM. Barley was milled using a 7 mm riddle. The CPC (the diameter of pills was 5 mm, Futura-Maituri 140 L, Raisio Feed Ltd, Raisio, Finland) included rapeseed cake (680 g kg^{-1}), wheat bran (105 g kg^{-1}), molassed sugarbeet pulp (70 g kg^{-1}), mixed molasses (50 g kg^{-1}), wheat middlings (42 g kg^{-1}), oat bran (30 g kg^{-1}), calcium carbonate (11 g kg^{-1}), sodium chloride (6 g kg^{-1}) and premix (6 g kg^{-1}). The amount of barley and CPC given was calculated on the basis of the pre-evaluated feed analysis of both feeds. The proportion of CPC in the concentrate was either 0.185 or 0.459 on an air-dry basis in diets M and H, respectively. During the experiment the animals received 280 g DM d^{-1} of mineral mixture (Luonnon Viher-Minera: Ca 84, P 34, Na 60 and Mg 70 g kg^{-1}, Suomen Rehu Oy, Vaasa, Finland). No vitamin mixture was given to the animals.

The concentrate was offered at 2.0, 3.0 and 4.0 kg DM d^{-1} during the periods P1 (56 d), P2 (57 d) and P3 (min 27 d, max 104 d, mean 74 d, SD 22.2 d, until slaughter), respectively. The animals were fed at 7:30 hours. Barley and CPC were spread on the feeding table evenly and, thereafter, the animals were tied up for maximum 2 h so that each animal could eat its own portion. Silage was offered *ad libitum* (at least 22 hours per day) during the entire experiment at an excess level of 1.05 of the daily intake. The amount of feeds offered and refused was recorded daily. Water was offered *ad libitum* via heated water-pipes and -cups.

Feed and faecal sampling and analysis

The swards were pre-sampled on 11, 18 and 23 June, i.e. once before the harvest of E and three times before the harvest of L. The D value and CP concentration of the sward were determined in order to monitor the change in sward digestibility. The pre-samples were cut by scissors from the swards from four 0.25 m^2 areas of the two fields, weighed, dried and analysed for DM content, as well as for D value and CP concentration by FOSS NIR Systems 5000 (Near Infra-Red Spectroscopy, FOSS, Eden Prairie, MN 55344, USA). At the time of harvest, similar samples were taken for botanical analyses to determine the red clover content of the swards. During the experiment, samples of GCS were taken for P1 and P2 and two samples for P3. One representative feed sample, pooled over twelve sub-samples, of barley, CPC and mineral mixture was taken at the onset of the experiment. The CPC and mineral mixture originated from one production batch and the barley from one harvest.

The total-tract apparent OM and protein as well as neutral detergent fibre (NDF) dietary digestibility were estimated using acid insoluble ash as an internal marker (European Commission 1971). Spot faecal samples were collected from each bull on two occasions, and on each occasion they were taken once daily for three consecutive days. Samples were taken on 3–5 February during P2 and 29 –31 March during P3. The samples were pooled on a pen basis (on a wet basis, equal amount per animal), thoroughly mixed, sub-sampled and stored at -20 °C. Totally 16 faecal samples were collected and analysed, i.e. one sample per pen per sampling period. Extra feed samples (four GCS samples, two barley samples and two CPC samples) were collected on the faecal collection days.

The GCS, barley, CPC and mineral mixture DM contents were determined by oven drying at 105 °C for 16 hours and GCS corrected for volatile losses according to Huida et al. (1986). Feed and faecal samples were analysed for ash (AOAC 1990, method No. 942.05), ether extract (AOAC 1990, method No. 920.39A) and crude fibre according to the EEC standard (92/89, ASN 3802) using the FiberCap 2021/2023 system (Foss Tecator AB, Höganäs, Sweden), total N of mineral mixture by the Dumas method using a Leco FP 428 nitrogen analyser (AOAC 1990, method No. 968.06, Leco Corp., St Joseph, MI 49085, USA) and total N of GCS, barley and CPC using a Foss Kjeltec 2300 Analyzer Unit (Foss Tecator AB, Höganäs, Sweden) and for NDF according to Van Soest et al. (1991). *In vitro* OMD was measured using a cellulase enzyme complex according to Friedel (1990). Fresh GCS samples were analysed for pH and water-soluble carbohydrates (WSC) by the method of Somogyi (1945), lactic acid (Haacker et al. 1983), volatile fatty acids (Huhtanen et al. 1998), ammonia N (McCullough 1967) and ethanol with an enzymatic kit (Cat No. 981680, KONE Instruments Corporation, Espoo, Finland) and soluble N by the Kjeldahl method using Cu as a digestion catalyst (AOAC 1990, method No. 984.13).

The ME value for GCS was calculated assuming a ME content of 16 MJ kg^{-1} digestible OM

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(DOM, MTT 2006). The D value was based on *in vitro* measurement. The AAT values were calculated using the measured D value and the CP concentration (MTT 2006). The intake index (IN) for GCS was calculated according to Huhtanen et al. (2002).

The energy value for barley was calculated using the determined chemical composition and average digestibility coefficients reported by MTT (2006). The energy value for CPC was calculated using the average chemical composition and average digestibility coefficients of each component (MTT 2006).

Live weight, slaughter procedures and eating quality

The animals were weighed on two consecutive days at the onset of the experiment and at the end of P1, P2 and P3 before feeding. Additionally, the animals were weighed once every 28 days.

The target cold carcass weight was 330 kg. The animals were selected for slaughter based on LW, LWG pre-slaughter and an assumed dressing proportion (0.550) which was assessed based on earlier studies (unpublished data) in Finland with Hf bulls. The animals were slaughtered in 11 slaughter batches, i.e. three batches in April (seven animals in all), four batches in May (ten animals in all) and four batches in June (14 animals in all). Feed was not offered on the morning of slaughter, but there was still silage available for all animals. The animals were slaughtered in the Atria Oyj slaughterhouse in Kuopio, 190 km away from the Research Station. The time interval from the departure to the slaughter was approximately six hours.

The carcasses were classified for conformation (12 classes: S, E, U, R+, R, R-, O+, O, O- and P+, P, P-) and fat cover (5 classes: 1, 2, 3, 4 and 5) using the EUROP quality classification scale (Commission of the European Communities 1991). The kill-out proportion was calculated as the proportion of cold carcass weight (hot carcass weight × 0.98; Ministry of Agriculture and Forestry 1995) to final LW and expressed as the proportion of kg cold carcass weight to kg final LW. The carcass temperature was chilled below 7 °C for 24 hours, after which the pH value of the loin was measured on the 11th rib of a half carcass. The right side of each carcass was then quartered at the 5th rib into a pistola hind quarter without the flank (Swatland 2000). The pistola was cut into valuable cuttings and tallow (subcutaneous fat). It is well known that the most valuable cuts come from the back and whole round of a half carcass. Thus, loin and tenderloin were cut from the back, whereas the whole round cuttings were outside round, inside round, corner round and roast beef. All cuttings and the tallow were weighed and their yields were expressed as percentages of the carcass cold weight (0.98 × carcass hot weight 50 min *post mortem*).

During cutting, a loin sample of 2 kg was taken from between the 5th and 8th ribs and vacuum packaged. After that, samples were sent to the Finnish Meat Research Institute (LTK) for further analyses. At LTK, the loin samples were aged for 17 days at 4 °C, making a total ageing time of 19 days, and thereafter frozen (-20 °C) for four months before sensory evaluation and shear force value measurement. After thawing, the organoleptic quality and shear force value of the loins were analysed. For the organoleptic evaluation, four 1.5 cm slices from each loin were heated to 68 °C in a rolling grill (Palux Rotimat, Germany) and evaluated by six trained sensory panellists for tenderness, juiciness and taste. These traits were scored on a 7-point scale (4=satisfactory, 5=good, 6=desirable and 7=most desirable). In addition, the panellists recorded off-flavours, if any, during the organoleptic evaluation.

For shear force value measurements loin samples were heated in a water bath of 85 °C until the core temperature of meat was 70 °C. After chilling for 24 hours (4 °C), loin samples of about 6 cm long (parallel to the myofibres), 1 cm high and 1 cm wide (square probe of 1 cm x 1 cm surface area) were placed in a Warner-Bratzler shear blade to be sheared perpendicularly to the muscle fibre longitudinal axis in Instron testing machine. Maximum force was recorded and results were expressed as kg cm^{-2} (Honkavaara et al. 2003).

Economic evaluation

The economic performance was determined by calculating the return on fixed inputs, or on inputs which were constant per day regardless of feeding strategy. In this examination, feeding cost and calf cost were considered as variable costs. The feeding cost varied because of diverse feed rations and feed prices. The treatment affected also the length of the finishing period and, thus, the calf cost per day. Market revenue and subsidies for beef production formed the gross return of the calculation. Since some premium payments are coupled to carcass weight, some to growing time (Niemi and Ahlsted 2008), the subsidies had to be included in the evaluation. The results are presented per day to allow for the varying length of the finishing period.

The unit prices and subsidy rates are shown in Table 1. The meat price expresses the price for meat in EUROP conformation R- and EUROP fat classification from 1 to 3. One step downwards or upwards in the conformation results in a 0.10 € kg^{-1} decrease or increase of the price, respectively. Fat classification 4 or 5 causes a 0.30 and 0.60 € kg^{-1} decrease of the price, respectively. The meat price is graded by carcass weight and calf price increases with LW (M. Ilola, Atria, Seinäjoki, Finland; personal communication). The subsidy rates represent the subsidy level in Central Finland (subsidy area C2).

Barley, CPC and mineral mixture were priced at the market prices for May 2009. A milling cost of 0.016 € kg^{-1} was added to the market price of barley (ProAgria 2009a). The price of silage was set according to its production cost, 1.123 € ha^{-1} when the subsidies paid ha^{-1} were subtracted from the total cost (ProAgria 2009a). Storage losses were estimated to be 15% (McDonald et al. 1991) and feeding losses 5% referring to the intended excess level of 1.05 in the feeding of silage.

A correlation between the harvesting time and yield of silage was considered while calculating the unit cost of E and L. Experiments undertaken in Central Finland in summer 2008 were used as a basic guideline in estimating the yield differences of varying cutting times (Vanhanen 2009). Using 100 kg N ha^{-1} as a reference fertilizing level, the later harvesting of silage produced a 24% higher DM yield ha^{-1} than the earlier harvest. As those experimental yields were fairly high compared to yields in farm conditions, the observed relative yield difference was transferred to two lower yield

Table 1. Input prices, meat prices and subsidy rates for beef production in 2009.

	Weight limits	Unit	Euro
Silage, early-cut		€ kg^{-1} DM	0.144
Silage, late-cut		€ kg^{-1} DM	0.116
Barley		€ kg^{-1} DM	0.134
Commercial protein compound		€ kg^{-1} DM	0.295
Mineral mixture		€ kg^{-1} DM	0.567
Calf	live weight 140 kg	€ $calf^{-1}$	365.00
Calf	live weight 141–300 kg	+ € kg^{-1}	2.20
Calf	live weight > 300 kg	+ € kg^{-1}	1.30
Meat	carcass weight 290–319 kg	€ kg^{-1}	2.83
Meat	carcass weight 320–349 kg	€ kg^{-1}	2.89
Meat	carcass weight ≥350 kg	€ kg^{-1}	2.91
Special beef premium		€ $bull^{-1}$	157.50
Slaughtered bull premium	carcass weight ≥ 330 kg	€ / slaughtered bull	30.30
National aid		€ / livestock unit [a] / year	422.00

[a] bull older than 6 months and younger than 2 years equals 0.6 livestock unit

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levels. A yield level of 8 700 kg DM ha^{-1}, which the best quarter of farmers are able to produce (ProAgria 2009b), was assumed in the basic solution. The other solution was based on an average yield, 6 000 kg DM ha^{-1} (ProAgria 2009b). The two levels were used to test the sensitivity of economic results with respect to silage price. Based on the results of Kuoppala et al. (2008), the effects of a change in the price difference between E and L were also analysed. Moreover, the sensitivity analysis concerned changes in the price of grain and meat and a reduction in subsidies.

Statistical analysis

Diet digestibility, daily intake, feed conversion (ratio of DM, ME, CP and AAT intake and kg net weight gain) and the ratio of DMI and kg^{-1} $LW^{0.75}$ were measured at the group level only and one-way analysis of variance was used to analyse the data. The rest of the variables were measured individually. Because treatments were assigned to groups, group was used as an error term when treatments were compared. The statistical model used in these analyses was:

$$y_{ijkl} = \mu + \varphi_l + \alpha_i + \beta_{ijl} + \varepsilon_{ijkl}$$

where y_{ijkl} is the observed value of the response variable for the k^{th} animal in the i^{th} treatment in the j^{th} group, μ is the overall mean, α_i is the effect of the i^{th} treatment, β_{ijl} is the effect of group, φ_l is the blocking effect for groups and g_{ijkl} is the residual error. Animals were divided to groups according to animals' age at the start of the study (youngest - oldest) and blocking effect takes into account this. The effect of α_i was divided into three parts: main effect of silage digestibility, main effect of concentrate protein concentration and their interaction. Statistical analyses were carried out using the SAS/GLM software (SAS 2004).

SAS/MIXED software was used only for economic variables. In the SAS/MIXED analyses the effect of group was used as a normally distributed random effect. MIXED analysis was rejected for the analysis of the non-economic variables, because the estimated variance for group effect was not positive for most variables.

Results

Feeds

The DM, CP and D values of the sward pre-samples were 191, 228 and 212 g kg^{-1}, 182, 162 and 137 g kg^{-1} DM and 763, 755 and 740 g kg^{-1} DM, respectively. The red clover content of the sward varied from 15 to 20% in DM with no difference between E and L. The D values for silages E and L averaged 750 and 699 g kg^{-1} DM, respectively. The contents of DM, ash, NDF, WSC as well as pH and ammonia and soluble N in total N were higher in L than in E (Table 2).

Diet digestibility and feed intake

The digestibility of diet OM was lower ($p < 0.05$, 0.733 vs. 0.769) and the digestibility of diet protein tended to be lower ($p < 0.10$, 0.667 vs. 0.697) on diet L than on diet E (Table 3). The digestibility of diet NDF was lower ($p < 0.05$, 0.625 vs. 0.665) on diet L than on diet E and tended to be lower ($p < 0.10$, 0.631 vs. 0.660) on diet M than on diet H.

During the entire experiment the daily intake of concentrate was almost identical on all diets as expected due to the fixed feeding regimens averaging 3.17 kg DM and including 0.452 and 1.129 kg of rapeseed cake in M and H, respectively (Table 4). No refusals of milled barley or pelleted CPC were observed due to the moderate amounts of both feeds offered, maximum 4.0 kg DM daily pre-slaughter (P3). Treatments had no effect on the daily intake of GCS, the total intake of DM, OM, DMI kg^{-1} $LW^{0.75}$ and ME averaging 6.0, 9.4 and 8.6 kg DM, 97.4 g and 109.4 MJ, respectively. The daily intake of CP was 65 g lower ($p < 0.05$) on diet L compared with diet E and 158 g lower ($p < 0.01$) on diet M compared with diet H. The daily

Table 2. Harvests of grass-red clover silages and mean chemical compositions and feed values of experimental feeds.

	Silage, Early-cut Mean	SD[a]	Silage, Late-cut Mean	SD	Barley	Commercial protein compound	Mineral mixture
Harvest date	17-18 June		31 June-1 July				
Growing time[b], (d)	42		55				
Degree days[b], (°C)	256		354				
Number of samples	4		4		1	1	1
Dry matter (DM, g kg^{-1})	251	44	307	22.4	879	881	968
In DM (g kg^{-1})							
Ash	76	2	85	3.8	29	88	550
Crude protein	162	19.9	151	7.4	143	289	67
Ether extract	nd[c]		nd		20	84	nd
Crude fibre	nd		nd		55	121	nd
Neutral detergent fibre	418	4.3	483	11.6	226	313	97
Lactic acid	73	4.8	45	10			
Acetic acid	28	2.5	18	3.4			
Butyric acid	0.4	0.388	0.38	0.573			
Ethanol	8	4.21	4.4	0.94			
Water-soluble carbohydrates	26	11.1	52	25.2			
pH	3.78	0.116	4.03	0.075			
In total nitrogen (g kg^{-1})							
Ammonia N	40	5.7	45	3.1			
Soluble N	511	69	547	43.9			
D value[d], g kg^{-1} DM	750	4.4	699	10.2			
Intake index	108	1.4	103	1.8			
Feed value, kg^{-1} DM							
Metabolizable energy, MJ	12	0.07	11.2	0.16	13.1	11.9	
AAT[e], g	91	1.1	86	0.5	107	137	

[a] Standard deviation.
[b] Calculated from the beginning of growing season on 6 May 2003.
[c] Not determined.
[d] Digestible organic matter in dry matter.
[e] Amino acids absorbed in the small intestine.

Table 3. Mean treatment effects on in vivo dietary digestibility coefficients.

Silage digestibility (S)	Early-cut		Late-cut			Significance[b]		
Concentrate protein concentration (P)	Medium	High	Medium	High	SEM[a]	S	P	S×P
Number of groups	2	2	2	2				
Organic matter	0.766	0.773	0.734	0.732	0.0067	*		
Protein	0.691	0.703	0.656	0.677	0.0104	o		
Neutral detergent fibre	0.642	0.688	0.619	0.632	0.0112	*	o	

[a] SEM = standard error of mean.
[b] o $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

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Table 4. Mean daily intakes on experimental diets.

Silage digestibility (S)	Early-cut		Late-cut			Significance[b]		
Concentrate protein concentration (P)	Medium	High	Medium	High	SEM[a]	S	P	S×P
Number of groups	2	2	2	2				
Dry matter, kg								
Grass-red clover silage	5.88	5.98	5.86	6.13	0.157			
Concentrate[c]	3.13	3.16	3.2	3.2	0.014	nt[d]	nt	nt
Mineral mixture	0.28	0.29	0.28	0.28	0.001	nt	nt	nt
Total	9.30	9.43	9.34	9.61	0.149			
Dry matter, g kg^{-1} LW$^{0.75}$	95.8	96.2	98.0	99.8	1.39			
Organic matter, kg	8.58	8.64	8.57	8.76	0.137			
Metabolizable energy, MJ	110.9	111.4	106.7	108.7	1.69			
Crude protein, g	1518	1666	1443	1611	19.8	*	**	
AAT[e], g	890	928	862	911	12.6		*	
Neutral detergent fibre, g	3250	3372	3637	3842	72.1	**		

[a]SEM = standard error of mean.

[b]o $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

[c]Concentrate: Including barley and commercial protein compound.

[d] Not tested.

[e]Amino acids absorbed in the small intestine.

intake of AAT was 43 g higher ($p < 0.05$) on diet H than on diet M. The daily intake of NDF was 429 g higher ($p < 0.01$) on diet L than on diet E.

The proportion of concentrate in the total daily DMI averaged 0.337 during the entire experiment. The proportion of CP and NDF in the total daily DMI on diets EM, EH, LM and LH were 0.163, 0.177, 0.155 and 0.168, and 0.350, 0.358, 0.389 and 0.400, respectively.

Animal growth and feed conversion

The health of the animals was good and no signs of diseases were observed. The concentrate protein concentration had no effects on animal performance (Table 5). The duration of the entire experiment was on average 18 days longer ($p < 0.01$) on diet L compared with diet E. The final LW was as planned equal for all animals, averaging 606 kg. During the entire experiment the LWG and the net weight gain were on average 187 ($p < 0.01$) and 116 g d^{-1} ($p < 0.05$) higher on diet E compared with diet L. The animals on diet E tended to consume daily on average 1.29 kg less DM ($p < 0.10$) kg^{-1} net weight gain than those on diet L. The daily consumption of CP, ME and AAT kg^{-1} net weight gain was on average 1614 g, 113.3 MJ and 930 g, respectively.

Carcass and meat evaluation

The treatments had no significant effect on the kill-out proportion, carcass conformation and carcass fat classification which averaged 537 g kg^{-1}, 6.5 and 3.6, respectively (Table 5), or on the juiciness and shear force value of the meat which averaged 4.5 and 4.3 kg cm^{-2}, respectively (Table 6). The taste of meat L tended to be better than that of meat E ($p <$ 0.10, 4.9 vs. 4.4). In pH and sensory evaluation of tenderness there were significant interactions ($p <$ 0.05) between silage digestibility and concentrate protein concentration. The tenderness was better and the pH lower in meat EM compared with meat EH with the opposite being true in meat L. Normal pH values of beef are from 5.50 to 5.90 a day after slaughter. On diet EM, three meat samples had a very low pH value (≤ 5.50). Correspondingly, on

Table 5. Age of animals, duration of the experiment, live weights, live and net weight gains, slaughter data and feed conversion.

Silage digestibility (S)	Early-cut		Late-cut			Significance[b]		
Concentrate protein concentration (P)	Medium	High	Medium	High	SEM[a]	S	P	S×P
Number of animals	8	8	7[c]	8				
Age, d								
Initial	229	215	232	225	6.5			
At end of experiment	407	395	430	420	7.5	o		
Duration of the experiment, d	179	179	198	195	1.8	**		
Live weight, kg								
Initial	288	288	287	288	0.4			
Final	604	610	601	606	3.8			
Live weight gain, g d^{-1}	1782	1809	1588	1630	22.1	**		
Net weight gain[d], g d^{-1}	1009	1048	902	923	20.2	*		
Slaughter data								
Carcass weight, kg	324	331	321	324	4.1			
Kill-out[e], g kg^{-1}	0.536	0.543	0.535	0.535	0.0038			
EUROP conformation[f]	6.5	6.6	6	6.6	0.34			
EUROP fat classification[g]	3.5	3.6	3.3	3.9	0.17			
Feed conversion, kg^{-1} net weight gain[h]								
Dry matter, kg	9.24	9.01	10.36	10.46	0.576	o		
Metabolizable energy, MJ	110.2	106.5	118.3	118.3	6.57			
Crude protein, g	1508	1592	1600	1754	95.8			
AAT[i], g	884	886	956	992	52.3			

[a] SEM = standard error of mean.

[b] o $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

[c] The SEM given should be multiplied by 1.0801 when making comparisons with other means except for feed conversion

[d] Kill-out proportion of 50 used for calculation of net weight gain.

[e] Ratio of cold carcass weight to final live weight.

[f] Conformation: O- = 4, O = 5, O+ = 6, R- = 7, R = 8, R+ = 9.

[g] Fat cover: 1 = leanest,…,5 = fattest.

[h] Two groups per treatment.

[i] AAT = Amino acids absorbed in the small intestine.

Table 6. Loin sensory evaluation, shear force value and pH.

Silage digestibility (S)	Early-cut		Late-cut			Significance[b]		
Concentrate protein concentration (P)	Medium	High	Medium	High	SEM[a]	S	P	S×P
Number of samples	8	8[c]	7[d]	8				
Sensory evaluation[e]								
Tenderness	5.6	5.1	5.2	5.9	0.13			*
Juiciness	4.5	4.3	4.7	4.8	0.23			
Taste	4.8	4.1	4.9	5.0	0.17	o		
Shear force value, kg cm^{-2}	4.4	4.6	4.2	4.1	0.23			
pH	5.52	5.59	5.57	5.54	0.011			*

[a] SEM = standard error of mean.

[b] o $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

[c] N = 7 for pH.

[d] The S.E.M. given should be multiplied by 1.0801 when making comparisons with other means.

[e] Sensory evaluation: Scale from 1 to 7.

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diets EH, LM and LH, two, one and one samples had a very low pH value. On diet EM, the minimum and maximum pH values were 5.40 and 5.62, respectively. The corresponding values on diets EH, LM and LH were 5.48 and 5.75, 5.42 and 5.73 and 5.38 and 5.62, respectively. Thus, all pH values were below 6.00.

On diet EM, two meat samples were recorded as being slightly dry and one dry with slight off-flavour. Two samples had liver flavour, one was tasteless and another dry on diet EH. On diet LM, one sample was slightly dry and one had liver flavour. Two samples had off-flavour and one was dry on diet LH.

The treatments had no significant effect on the amount (kg) and yield (%) of inside round, roast beef, loin, tenderloin and tallow in a carcass, averaging 11.5, 5.6, 10.3, 4.0 and 34.5 kg and 3.5, 1.7, 3.2, 1.2 and 10.6%, respectively (Table 7). The amount and yield of outside round tended to be higher ($p < 0.10$, 18.2 vs. 17.5 kg and 5.6 vs. 5.4%) on carcasses fed diet E than diet L. The amount of corner round was higher ($p < 0.05$, 10.6 vs. 10.1 kg) on carcasses fed diet E than diet L. The amount of valuable cuttings tended to be higher ($p < 0.10$, 100.9 vs. 98.6 kg) on carcasses fed diet E than diet L.

Economic performance

The results of the economic analysis (Table 8) indicated that the diet EH caused the highest feed cost per day ($p < 0.001$). A reason for this was the highest unit cost of feed since the daily DMI was unaffected by the diet (Table 4). Carcass weights, carcass conformation and carcass fat classification

Table 7. Valuable cuts of the animals.

Silage digestibility (S)	Early-cut		Late-cut			Significance[b]		
Concentrate protein concentration (P)	Medium	High	Medium	High	SEM[a]	S	P	S×P
Number of animals	8	8	7[c]	8				
Outside round, kg	18.1	18.3	17.4	17.7	0.24	o		
From yield, %	5.6	5.5	5.3	5.5	0.06	o		
Inside round, kg	11.8	11.6	11.1	11.4	0.40			
From yield, %	3.6	3.5	3.4	3.5	0.07			
Corner round, kg	10.7	10.5	10.1	10.2	0.09	*		
From yield, %	3.3	3.2	3.1	3.1	0.04	o		o
Roast beef, kg	5.5	5.9	5.5	5.4	0.21			
From yield, %	1.7	1.8	1.7	1.7	0.06			
Loin, kg	10.5	10.0	10.3	10.4	0.38			
From yield, %	3.2	3.0	3.2	3.2	0.06			
Tenderloin, kg	4.1	4.0	3.9	3.9	0.11			
From yield, %	1.3	1.2	1.2	1.2	0.02			
Tallow, kg	35.2	33.7	33.4	35.4	0.83			
From yield, %	10.9	10.1	10.2	10.9	0.40			
Yield from carcass weight, kg	101.5	100.2	97.2	100.0	0.88	o		
Yield from carcass weight, %	31.4	30.2	29.8	30.9	0.37			o

[a] SEM = standard error of mean.
[b] o $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
[c] The SEM given should be multiplied by 1.0801 when making comparisons with other means.

caused some variation in the meat price, but the differences between the diets were not statistically significant. However, the diet E resulted in slightly higher market revenue per day than the diet L (p < 0.10) because of a higher LWG per day and, thus, a shorter finishing period to reach the targeted carcass weight (Table 6). The premiums paid per animal decreased with the length of the finishing period and, therefore, the subsidies per day were slightly higher on diet E than on diet L (p < 0.10). Also the calf cost per day decreased, as expected, with the length of the finishing period, but not statistically significantly.

As the fluctuations in costs and returns cancelled each other out, the average return on the fixed inputs was nearly the same on all the diets. No statistically significant differences were found although the average return of diet LH was some lower than the returns of other diets. Sensitivity analysis revealed the stability of the results. Most of the analysed price changes did not change the ranking of the treatments; they just affected the level of the return on fixed inputs. Increase of 0.05 € kg^{-1} DM (L) and 0.06 € kg^{-1} DM (E) in the unit cost of silage would decrease the return on fixed inputs by 0.46 € d^{-1} (E) and 0.37 € d^{-1} (L). A smaller price difference (19%) between E and L would result in about 0.02 € d^{-1} higher (E) or lower (L) return on fixed inputs compared to the basic solution where the difference was 24%. A rise of 30% in the price of grain would cause a reduction in the return on fixed inputs ranging between 0.05 € d^{-1} (LM) and 0.10 € d^{-1} (EM). Only LM with the cheapest feed cost would result in a positive return to fixed inputs if the meat price fell off by 20%. Equal cutting of subsidies would not cause as dramatic drop in the return. The reduction would vary from 0.33 € d^{-1} (LH) to 0.36 € d^{-1} (EM and EH). An increase of 20% in the basic price of meat would raise the return considerably, more than double on E. Such a price change would also mean that E would give a better economic result than L (p < 0.10).

Discussion

Feeds

In the present study, a cold onset to the growing season delayed the decrease in the sward D value. In addition, the development of red clover is slower than that of grasses (Rinne and Nykänen 2000), which probably slightly affected the decrease in digestibility. In the present study, the daily decline

Table 8. Unit price of meat and feed, gross return, expenses and return on fixed inputs.

Silage digestibility (S)		Early-cut		Late-cut		SEM[a]	Significance[b]		
Concentrate protein concentration (P)		Medium	High	Medium	High		S	P	S*P
Number of groups		2	2	2	2				
Meat price	€ kg^{-1}	2.690	2.665	2.700	2.575	0.0678–0.0703			
Average feed price	€ kg^{-1} DM	0.173	0.180	0.159	0.166	0.0053	*	o	
Gross return									
Market revenue	€ d^{-1}	4.82	4.98	4.32	4.20	0.321–0.331	◦		
Subsidies	€ d^{-1}	1.82	1.81	1.69	1.67	0.125–0.127	◦		
Expenses									
Calf cost	€ d^{-1}	3.83	3.88	3.38	3.46	0.620–0.625			
Feed cost	€ d^{-1}	1.81	1.91	1.67	1.80	0.006	***	***	o
Return on fixed inputs	€ d^{-1}	1.00	1.00	0.96	0.61	0.229–0.233			

[a]SEM = standard error of mean.

[b] o p < 0.10; * p < 0.05; ** p < 0.01; *** p < 0.001.

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from pre sampling to early cut was on average 1.9 g kg^{-1} DM, and from early cut to late cut 3.6 g kg^{-1} DM. Because the swards were needed for grazing studies, the harvest had to be done at an earlier stage of maturity than planned, resulting in on average 50 g kg^{-1} DM higher D values in the silages than originally planned.

The fermentation quality was good in both silages, while the DM content in L was higher than in E. The E silage was slightly more fermented including less WSC than the L silage. In both silages, the CP concentration was fairly typical for primary growth silage, but the content of NDF was quite low, probably due to the early stage of maturity and the inclusion of red clover in the silage (MTT 2006). The wilted silages did not freeze and were therefore suitable for this type of feeding in cold conditions. The last group of animals was slaughtered on 23 June, but the quality of silage remained acceptable in May and June.

Effects of silage digestibility on animal performance

The digestibility of the silage did not affect the DMI of the silage, corresponding to the results reported by Nadeau et al. (2002) and Cummins et al. (2007). The similar intake of both silages may be due to the high digestibility and good fermentation quality of both silages and, partly, due to the higher DM content of L compared with E. However, several studies with growing cattle (Steen 1988b, Martinsson 1990, Steen 1992, Scollan et al. 2001, Steen et al. 2002, Keady et al. 2008) have confirmed an increased intake of silage in response to higher digestibility. Aronen et al. (1992) observed early-cut grass silage to improve the LWG of light (initial LW 123 kg) dairy-breed bulls during the first six months of growth but the bulls offered late-cut silage compensated the difference during the following six months pre-slaughter. This was mainly due to the larger grass silage intake of the early-cut bulls compared to the late-cut bulls. However, the difference between the harvest times of those silages was one week. Furthermore, Aronen et al. (1992) concluded that the bulls were not able to take full advantage of the high protein concentration (160 g kg^{-1} DM) of the early-cut silage. In the present study, the CP concentration of E and L averaged 162 and 151 g kg^{-1} DM. Thus, the difference in the CP concentration of silages was small compared with a big difference in D value.

As in the present study, in several studies with growing cattle and sheep, postponing the harvest of silage has reduced the digestibility of silage as a sole feed (Drennan and Keane 1987, Dawson et al. 2002, Keady et al. 2008) or the digestibility of diets (Steen 1988b, Martinsson 1990, Steen 1992, Scollan et al. 2001). Harvest date is the major factor effecting silage digestibility.

In the present study, the calculated ME intake was similar on all the diets and thus did not explain the difference in the growth rate. The growth rate can be considered as very high for all animals. Steen et al. (2002) concluded that high-digestibility (0.743 DOM in DM) silage had potential relative to high-concentrate diet. It can be assumed that the main reason for the very high growth rate in the present study was the effect of high silage digestibility leading to high energy intake and optimal conditions for microbial protein synthesis in the rumen. According to Schroeder and Titgemeyer (2008), energy supply affects the efficiency of protein utilization. The improved LWG on early-cut silage or on silage of high digestibility has earlier been confirmed in several studies (e.g. Scollan et al. 2001, Nadeau et al. 2002, Steen et al. 2002, Keady et al. 2008), but also opposing results exist (Steen 1988b, Cummins et al. 2007). In a review of literature, Steen (1988a) summarized that in 11 comparisons of unsupplemented silages, increasing digestibility increased daily LWG and carcass gain of finishing cattle by 45 and 33 g, respectively, per 10 g kg^{-1} increase in digestibility. In eight comparisons in which the silages were supplemented with concentrates (20 to 37% of total DMI), increasing digestibility increased daily LW and carcass gains by 37 and 28 g, respectively, per 10 g kg^{-1} increase in digestibility. In the present study, daily LWG and carcass gain were increased by 37 and 23 g per 10 g kg^{-1} increase in silage digestibility, well in agreement with Steen (1988a).

The silage digestibility had no effect on the kill-out proportion and the carcass fat and conformation scores were in accordance with earlier studies (Steen 1988b, Cummins et al. 2007). In some experiments, high digestible silage has increased carcass fatness (Drennan and Keane 1987, Steen et al. 2002, Keady et al. 2008). The varying responses to silage digestibility may be due to differences in silage digestibility, final LW, breed, breed maturity, gender and proportion of concentrate in the diet.

When Hf bulls were offered concentrate, either restricted or *ad libitum,* and grass silage (D value 700 g kg^{-1} DM) *ad libitum* for three months pre-slaughter, 35% of the carcasses had a fat score of 5, without treatment effects (Manninen et al. 2010). Those carcasses were approximately 30 kg heavier than the carcasses in the present study. The results of the present study and those observed by Manninen et al. (2010) agree with Steen and Kilpatrick (2000) who concluded that for cattle reared on high-forage diets, reducing slaughter weight is likely to be a more effective approach to reduce carcass fat content than reducing energy intake during the finishing period.

Effects of concentrate protein concentration on animal performance

The concentrate protein concentration did not affect the intake of silage and total DMI kg^{-1} metabolic LW, which was consistent with the results observed with heavy dairy-breed bulls (Huuskonen 2009a). Additionally, in earlier studies with suckled continental-cross bulls (Drennan et al. 1994) or heavy steers (Steen 1988b, Steen 1996a), silage intake was unaffected by protein supplement. On the contrary, rapeseed meal supplementation increased the silage (Aronen 1990, Aronen et al. 1992) intake of light dairy-breed bulls. The positive response of intake to protein supplement may be more evident in animals of lower LW than in the bulls in the present study, as also Aronen (1990) suggested.

The digestibility of dietary OM was unaffected by concentrate protein concentration, in accordance with Huuskonen et al. (2007, 2008) and Huuskonen (2009a). In numerous studies (e.g. Steen 1988b, Huuskonen et al. 2007, 2008, Huuskonen 2009a), protein supplement increased the digestibility of dietary protein, which was not observed in this study.

The growth response to protein supplementation depends generally on animal LW, silage digestibility, proportion of concentrate in the diet and breed. If the supply of energy is good, the microbial protein synthesis is generally sufficient to sustain a high LWG in animals of a LW over 250 kg (Huuskonen 2009b). Titgemeyer and Löest (2001) presented that, while amino acids were the limiting factor with lighter calves offered grass silage, energy availability was the limiting factor with heavier animals. Later, Schroeder and Titgemeyer (2008) concluded that energy supply affects the efficiency of protein utilization but the effects may be different, depending on which amino acid is the most limiting. In the present study, the supply of energy was sufficient with a diet with a moderate amount of concentrate and high-digestibility silage. Waterhouse et al. (1985) reported that Friesian steers were most likely to respond to supplementary protein in barley-based concentrate when the grass silage *in vitro* digestibility was below 0.65. In the present study, there was no benefit from the higher concentrate protein concentration, suggesting that the amino acid supply from feed protein and microbial protein synthesis in the rumen was sufficient on diet L for a high daily LWG. Correspondingly, in recent studies (Huuskonen et al. 2007, Huuskonen et al. 2008, Huuskonen 2009a) with heavy dairy-breed bulls, rapeseed meal supplementation did not improve the growth rate, as also observed with heavy steers (Steen 1988b, Steen 1996a) and suckled beef bulls (Drennan et al. 1994) fed fish meal/soybean meal supplementation.

According to Lowman and Lewis (1991), the performance of bulls is not very sensitive to a range of protein concentrations between 130 and 180 g CP kg^{-1} DM. In the present study, the diet CP concentrations were 163, 177, 155 and 167 g CP kg^{-1} DM on diets EM, EH, LM and LH, respectively. However, the diet CP concentrations do not take into account the quality of protein.

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The carcass traits were unaffected by the concentrate protein concentration being consistent with recent studies (Huuskonen et al. 2007, Huuskonen et al. 2008, Huuskonen 2009a). On the contrary, increased protein intake tended to increase the carcass fatness of steers and heifers (Steen and Robson 1995, Steen 1996a). Although not observed in this study, protein supplementation of high (D value about 710 g kg^{-1} DM) digestibility silage tended to reduce carcass fatness but had no effect with medium (D value about 650 g kg^{-1} DM) digestibility silage (Steen 1988b). It seems that the opportunities to affect carcass fatness by protein supplement may be limited since the carcass fatness on grass silage-based feeding is also dependent on the quality of the silage.

Eating quality

The results of the present study showed that the average sensory quality of the loins was assessed good or acceptable by the sensory panel. In fact, the analysed beef samples were evaluated as tender, quite juicy and quite tasty.

Beef from the bulls on diet LH had the best sensory quality and lowest shear force values, whereas EH beef had the lowest sensory quality and the highest shear force values. In this study, the measured average Warner-Bratzler shear force value of 4.3 kg cm^{-2} for the beef was lower than the average value of 5.5 kg cm^{-2} achieved in a previous study in Finland (Honkavaara et al. 2003). The difference in these shear force values can be explained by prolongation of ageing time, which was 19 days (followed by freezing) in the former and ageing time of eight days (without freezing) in the latter. The former were Hf bulls, whereas most of the latter were milk breed bulls. In both cases, carcasses were suspended from the achilles tendon overnight. The method for shear force value measurement was also the same in both studies. *Post mortem* hanging of carcasses also affects meat shear force value. Keady et al. (2008) improved meat shear force value by aitch bone hanging instead of achilles tendon suspension. According to Meisinger et al. (2006), liver-like off-flavours are specific to individual animals and pH and heme iron are not strongly related to off-flavour notes.

Economy

Price estimates have an important role in the economic comparison of feeding strategies. In this study, especially the price relation of E and L was an essential factor in the evaluation of different strategies.

Determination of the unit cost of silage requires information on both the first and the second cut of the sward. In this experiment, the re-growth was utilized as a pasture and the price setting had to be based on previous experiments. The quality of silage was not similar in the referred and in the present study but, as the quality effect was taken into consideration in the growth rates of the bulls, the subject of our interest was only the relative yield difference between E and L. For the determination of this difference, the earlier experiments were applicable.

Berthiaume et al. (1996) concluded that in a steer's diet it is technically possible to compensate for a lower forage digestibility by an addition of grain, but it is not necessarily economical. They based their statement on the average daily gain without including any price information in their analysis. Giving economic values to the inputs and outputs may change the result considerably as indicated in our study. Price relations are highly dependent on the economic environment where the beef producers operate and, therefore, the results of this study cannot be generalized. The study does, however, show that it is important to pay attention to the economic analysis, not only to growth rates, while seeking a profitable feeding strategy for finishing bulls.

All the tested feeding strategies gave nearly the same return for a beef producer. Moreover, the sensitivity analysis proved that this result is very stable; the price changes affect more the level of the return than the ranking of the treatments. Thus, the beef producer can adjust the harvesting time and make the feeding decisions according to farm-specific resources and production conditions. The most important thing is to know the feeding value of the silage and, thus, be able to give a proper amount of protein supplementation to reach the intended growth rates.

Conclusions

Health was good and production performance high in the uninsulated housing conditions used. The results confirmed the importance of silage digestibility in the feeding of finishing beef bulls since early-cut silage improved the growth rate and shortened the finishing period significantly compared with later-cut silage. Animal performance was unaffected by the concentrate protein concentration and, thus, use of concentrate of higher protein concentration was not beneficial. All carcass traits were unaffected by the treatments. The eating quality of the tested loins was good and treatments had only a minor effect on the yield of valuable cuts. The same economic performance was achieved with different feeding strategies, which allows the producers to adjust the feeding flexibly to the prevailing production conditions.

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