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Effects of barley grain compared to commercial concentrate or rapeseed meal supplementation on performance of growing dairy bulls offered grass silage-based diet

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The objectives of the study with dairy bulls offered grass silage-based diet were to determine the effects on animal performance of (1) concentrate type (barley vs. commercial concentrate) and (2) supplementation of rapeseed meal (RSM) in barley-based concentrate, with data being compared from preweaning to slaughter. The experiment comprised a total of 37 Finnish Ayrshire and 23 Holstein-Friesian bulls. Experimental concentrate treatments were 1) rolled barley (B), 2) rolled barley + rapeseed meal (BRSM) and 3) commercial concentrate (CC). During the preweaning (from 0.5 to 2.5 months) there were no differences in intake, gain or feed conversion. During the postweaning (from 2.5 to 6.0 months) the energy intake and gain of the B bulls were 12–13% lower than those of the BRSM bulls ($p < 0.05$) and 16% lower than those of the CC bulls ($p < 0.01$). However, there were no treatment differences in the energy intake or gain of the bulls during the finishing period (from 6.0 to 18.0 months of age) or on average during the experiment. Furthermore, carcass traits of the bulls did not differ between treatments. It is concluded that production traits were unaffected by concentrate type or RSM supplementation when data is compared from preweaning to slaughter.

Key words: Beef production, concentrate supplementation, dairy bulls, supplementary protein

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Introduction

Unlike in many other countries, beef production in Finland is based mainly on raising dairy-breed bulls born on dairy farms. The decrease in the number of dairy cows has diminished the supply of calves for beef production from dairy herds. Consequently, slaughterhouse pricing favours heavy carcasses and the average carcass weights of animals have clearly increased during recent years. For example, the average carcass weight of bulls increased from 275 kg (1996) to 335 kg (2008) in twelve years (Karhula and Kässi 2010).

In Finland, the feeding of dairy bulls is mainly based on grass silage and grain, typically on barley and/or oats. Nowadays, some beef producers supplement grass silage-based rations with commercial concentrates of lower starch concentration and higher protein and fibre concentration rather than straight grain. Especially young calves are typically fed using commercial starter concentrates. However, the price of these concentrates is high compared with that of grain or forage. Based on literature reports the effect of energy supplement type on the intake and performance of growing cattle is complicated and partly unclear (McGee 2005). Mayne et al. (1995) concluded that starch or fibre supplements had no significant difference on the mean substitution rate in growing cattle when considered across a range of silage compositions, but there were interactions between supplement type and silage type. Steen (1993) reported that silage intake was higher for fibre than starch-based concentrate for growing cattle. However, the silage intake of growing and finishing cattle was shown not to be differentially affected by starch, fibre or sugar-based concentrates (Moloney et al. 1993) or by fibre or starch-based concentrates (O'Kiely and Moloney, 1994). In more recent studies it has been observed that the intake, performance and carcass characteristics of Continental crossbred steers (McGee et al. 2006) or finishing Hereford bulls (Manninen et al. 2010) were unaffected by concentrate energy source. Manninen et al. (2010) concluded that production and carcass traits were unaffected by concentrate type, i.e. concentrates of differing energy sources, since the energy and protein contents were similar in both concentrates.

In Finland, rapeseed meal (RSM) is the most important protein feed used in concentrates for cattle. Huuskonen et al. (2007, 2008) reported that RSM did not affect animal performance of finishing dairy bulls (from 6.0 to 18.0 months of age), and concluded that there is no reason to use protein supplement for finishing dairy bulls when they are fed with good quality grass silage and barley-based concentrate. However, inclusion of RSM in the diet was found to have a positive effect on the performance of young bulls and bull calves in some feeding experiments (Aronen et al. 1992, Aronen and Vanhatalo 1992). The growth and feed efficiency over the whole growth period, including preweaning, postweaning and finishing periods, are critical also from the economic viewpoint. The amount of commercial concentrate and RSM strongly affects the production costs, since the prices of commercial concentrate and RSM are high compared to grain and thus it is important to asses how long the possible growth advantage will be maintained after weaning when dairy bulls are raised to carcass weights over 300 kg.

To my knowledge, there is a paucity of published information on the relative performance of growing and finishing dairy bulls offered grass silage-based diets supplemented by just barley, barley plus RSM or commercial concentrates with performance data being compared from preweaning to slaughter. Therefore the objectives of the present experiment with growing dairy bulls raised to a carcass weight of 340 kg were to determine the effects on diet digestibility, feed intake, gain and carcass characteristics of (1) concentrate type (barley grain vs. commercial concentrate) and (2) supplementation of RSM in barley-based concentrate.

Materials and methods

Animals and housing

The feeding experiment was conducted in the experimental barn of the North Ostrobothnia Research Station of MTT Agrifood Research Finland (Ruukki, 64°44'N, 25°15'E) and included two trials. The first trial started in November 2007, ended in May 2009 and carried out 540 days in total. The second trial started in January 2009, ended in July 2010 and carried out 546 days in total. The experimental procedures were evaluated and approved by the Animal Care and Use Committee of MTT Agrifood Research Finland. The first trial comprised 18 Finnish Ayrshire bulls and 12 Holstein-Friesian bulls. The second trial comprised 19 Finnish Ayrshire bulls and 11 Holstein-Friesian bulls.

All animals, initial live weight (LW) 53±2.5 kg and age 15±6.3 days, on average, were purchased from local dairy farms. During the preweaning (from 0.5 to 2.5 months of age) and postweaning (from 2.5 to 6.0 months of age) periods the animals were housed in an insulated barn on peat bedding in six pens (3.0 × 3.5 m, 5 calves in each) providing 2.1 m^2/calf. The air temperature in the insulated barn varied between 11 and 20 °C in winter (October–April) and between 15 and 23 °C in summer (May–September).

For determination of diet digestibility all animals were placed in an insulated barn in adjacent tie-stalls from 6.0 to 7.0 months of age. The width of the stalls was 70–90 cm and the bulls were tied with a collar around the neck attached by a 50 cm chain to a horizontal bar 40–55 cm above the floor. The floor surface was solid concrete under the forelegs and metal grid under the hind legs. No bedding was used on the floor. Each bull had its own water bowl.

From 7.0 to 18.0 months of age the bulls were placed in an uninsulated barn in adjacent pens (4 × 8 m, 6.4 m^2/bull, 5 bulls in each pen). The barn was covered with a roof and had solid wooden walls on all sides except for the front side that was left open. The rear half of the pen area was a straw-bedded lying area and the front was a feeding area with a solid concrete floor. A feeding trough was situated on the front side of the pen, and there was 0.8 m of feeding space/bull at the feeding trough. There were heated water bowls between the pens offering water for bulls.

Feeding and experimental design

The three concentrate feeding treatments used in the experiment were: 1) barley grain (B), 2) barley grain + rapeseed meal (BRSM) and 3) commercial concentrate (CC). The calves were randomly (balanced for breed) allotted to pens (5 calves/pen) which were then randomly allotted to three experimental treatments.

During the preweaning period the calves received a milk replacer (MR) [at a dilution of 11.9% dry matter (DM)] supplied by Valio Ltd. (Helsinki, Finland). The MR included (g kg^{-1} DM) skim milk powder (558), whey powder (245), lard (152), wheat starch (23), rapeseed oil (9), lecithin (4), $CaCl_2$ (4), NaCl (3) and vitamin-mineral premix (2). In both trials and all treatments the MR was served by a computer-controlled feeder (two pens/feeder; Stand Alone 2 Plus, Förster, Engen, Germany; programme: Kalbmanager 4.2). The feeding temperature of the MR was 37 ºC. The calves were allocated to treatments at 15 days of age, and from days 15 to 57 the highest possible MR allowance of the calves was 8.5 l. All calves were weaned gradually from days 57 to 70 with the MR allowance being cut by reducing the number of MR portions per day. During the preweaning period the animals received water, concentrate, grass silage and hay *ad libitum* **(**proportionate refusals as 5%)**.** Concentrate offered for three concentrate treatments were 1) rolled barley, 2) mixture of rolled barley **(**800 g kg^{-1} DM) and RSM (200 g kg^{-1} DM**)** and 3) commercial concentrate (Primo I) produced by Suomen Rehu Ltd. (Hyvinkää, Finland). Forage and concentrates were offered separately from a box feeder during the pre- and postweaning periods.

The amounts of the included ingredients of the commercial concentrates varied slightly between trials. The commercial concentrate (Primo I) used during the pre- and postweaning periods comprised (g kg^{-1} DM, shown as mean values over the trials**)** rapeseed cake (150), barley (150), wheat bran (127), oats (100), wheat (80), molassed sugar-beet pulp (80), naked oats (60), rapeseed meal (50), soybean meal (50), molasses (50), wheat feed meal (30), barley malt feed (30), $CaCO_3$ (16), brewery yeast (Progut®, patent: FI109759) (10), vegetable oil mix (5), vitamin, mineral and trace element premix (4), salt (4), Na_2CO_3 (2) and MgO (2). During the postweaning period the animals received grass silage, hay and water *ad libitum*, but the amount of concentrate was restricted to 3 kg (air dry)/animal/d. Concentrate feeding treatments and feeds were the same as during the preweaning period.

During the finishing period (including the determination of diet digestibility) the bulls were fed total mixed ration (TMR) *ad libitum*. The target concentrate proportion for all treatments was 500 g kg^{-1} DM. The TMR for treatment B included grass silage (500 g kg^{-1} DM) and barley grain (500), for treatment BRSM grass silage (500), barley grain (450) and RSM (50), and for treatment CC grass silage (500) and commercial concentrate (500). The commercial concentrate used during the finishing period was Primo II (Suomen Rehu Ltd) which comprised (g kg^{-1} DM, shown as mean values over the trials) barley (264), oats (220), wheat bran (127), mash feed meal (100), rapeseed meal (89), barley malt feed (80), molasses (55), $CaCo_3$ (20), oat husk meal (20), brewery yeast (Progut®, patent: FI109759) (8), salt (7), vegetable oil mix (6), vitamin, mineral and trace element premix (2), and MgO (2). The animals were fed three times per day (at 0800, 1200 and 1800 hours). Refused feed was collected and measured at 0700 hours daily. The daily ration for B and BRSM bulls included also 150 g of a mineral mixture (KasvuApeKivennäinen delivered by A-Rehu Ltd., Seinäjoki, Finland). A vitamin mixture (Xylitol ADE-Vita delivered by Suomen Rehu Ltd., Hyvinkää, Finland) was given at 50 g per animal weekly. The commercial concentrate included sufficient vitamins and minerals and therefore separate mineral or vitamin mixtures were not used in the CC treatment.

The grass silages in both trials were primary growth from a timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*) sward and ensiled in bunker silos with a formic acid-based additive (AIV-2 Plus: 760 g formic acid kg^{-1}, 55 g ammonium formate kg^{-1}, supplied by Kemira Ltd., Oulu, Finland) applied at a rate of 5 litres t^{-1} of fresh grass.

Procedures and sample analyses

Silage sub-samples for chemical analyses were taken twice a week, pooled over periods of four weeks and stored at –20ºC. Thawed samples were analysed for DM, ash, crude protein (CP), crude fat (CF), neutral detergent fibre (NDF), indigestible NDF (INDF), starch, silage fermentation quality (pH, water-soluble carbohydrates (WSC), lactic and formic acids, volatile fatty acids, soluble and ammonia N content of N) and digestible organic matter (DOM) in DM (D value). Concentrate, MR and hay sub-samples were collected weekly, pooled over periods of eight weeks and analysed for DM, ash, CP, CF, NDF, INDF and starch (hay also for D value). The analyses of DM, ash, CP, CF, NDF, INDF and starch were made as described by Huuskonen (2009) and Huuskonen & Joki-Tokola (2010). The silage was analysed for fermentation quality by electrometric titration as described by Moisio and Heikonen (1989) and for D value by the method described by Nousiainen et al. (2003).

Feed and faecal samples were collected twice a day (at 0700 and 1500 hours) during the collection period (5 d) and stored frozen prior to analyses. The samples were analyzed for DM, ash, CP and NDF as described above. The diet digestibility was determined using acid-insoluble ash (AIA) as an internal marker (Van Keulen and Young 1977).

Calculations

The metabolizable energy (ME) contents of the feeds were calculated according to the Finnish feed tables (MTT 2006). The ME value of the silage was calculated as 0.016 × D value (MTT 2006). The ME value of the hay was calculated as 0.0169 × D value – 1.05 (MTT 2006). The ME values of the concentrates were calculated based on concentrations of digestible crude fibre, CP, crude fat and nitrogen-free extract described by MAFF (1984). The digestibility coefficients of the concentrates were taken from the Finnish feed tables (MTT 2006). The supply of amino acids absorbed from the small intestine (AAT) and the protein balance in the rumen (PBV) were calculated according to the Finnish feed tables (MTT 2006).

The animals were weighed on two consecutive days at the beginning of the experiment and thereafter every 14 days during the preweaning period. During the postweaning and finishing periods the animals were weighed approximately every 28 days. Before slaughter they were weighed on two consecutive days. The target for average carcass weight in the experiment was 340 kg. The LWG was calculated as the difference between the means of initial and final live weights divided by the number of growing days. The estimated rate of carcass gain was calculated as the difference between the final carcass weight and the carcass weight in the beginning of the experiment divided by the number of growing days. Carcass weight in the beginning of the experiment was assumed to be 0.40 × initial LW as the same value is used by Atria Ltd. (a Finnish slaughterhouse) in daily extension work (Herva et al. 2009). The LWG and feed dry matter intakes of the bulls are presented separately for preweaning, postweaning and finishing periods.

Carcass measurements

After slaughter in a commercial meat plant the carcasses were weighed hot. The cold carcass weight was estimated as 0.98 of the hot carcass weight. Dressing proportions were calculated from the ratio of cold carcass weight to final LW. The carcasses were classified for conformation and fatness using the EUROP quality classification (Comission of the European Communities, 1982). For conformation, development of carcass profiles, in particular the essential parts (round, back, shoulder), was taken into consideration according to the EUROP classification (E: excellent, U: very good, R: good, O: fair, P: poor), and for fat cover degree the amount of fat on the outside of the carcass and in the thoracic cavity was taken into account using a classification range from 1 to 5 (1: low, 2: slight, 3: average, 4: high, 5: very high). Each level of the conformation scale was subdivided into three sub-classes (O+, O, O-) to produce a transformed scale ranging from 1 to 15, with 15 being the best conformation.

Statistical methods

The results were calculated across the two trials and are shown as least squares means. Normality of residuals was checked using graphical methods: box-plot and scatter plot of residuals and fitted values. The pen (a group of five animals) was used as an experimental unit for testing feed intake and feed conversion data. There were 4 pens/treatment (20 animal/treatment). The average group feed dry matter intake (DMI) and feed conversion data were subjected to analysis of variance using the SAS general linear models procedure. The statistical model (1) used was

$$y_{jkl} = \mu + \beta_k + \alpha_j + (\beta \times \alpha)_{jk} + e_{jkl} \qquad (1)$$

where μ is the overall mean, e_{jkl} is the random error term and y_{jkl} is the mean of five animals penned together (4 pens/treatment; l=1,…,4). α and β are the effects of treatment and trial.

The gain and carcass characteristics variables were measured individually and were subjected to analysis of variance using the SAS MIXED model procedure. The following statistical model (2) was used to analyse the gain and carcass characteristics data

$$Y_{ijkl} = \mu + \beta_j + \alpha_i + (\beta \times \alpha)_{ij} + \chi_{ijk} + e_{ijkl} \quad (2)$$

where μ is the overall mean and e_{ijkl} is the random error term. α and β are the effects of treatment and trial. χ_{ijk} is the effect of group within treatment-by-trial combination and it was used as an error term when differences between treatments were tested.

For diet apparent digestibility coefficients animal was used as an experimental unit. During the digestibility determinations the animals were placed in the insulated barn in adjacent tie-stalls, and the digestibility data were subjected to analysis of variance using the SAS MIXED model procedure. The statistical model (3) used was

$$y_{jkl} = \mu + \beta_k + \alpha_j + (\beta \times \alpha)_{jk} + e_{jkl} \quad (3)$$

where μ is the overall mean and e_{jkl} is the random error term. β_k and α_j are the fixed effects of treatment and trial.

Differences between the treatments were tested by making two orthogonal contrasts: B vs. BRSM and B vs. CC. The first contrast described the effects of RSM supplementation and the second contrast the effects of concentrate type.

Results

Feeds

Because the grass silages used in the feeding experiment came from two different harvests, the chemical compositions and feeding values are also given separately for the two silages in Table 1. However, the compositions of the silages differed only slightly from each other. The silages used were of good nutritional quality as indicated by the D value as well as the AAT and CP contents (Table 1). The fermentation characteristics of the silages were also good as indicated by the pH value and the low concentration of ammonia N and total acids. The silages used were restricted fermented with high residual WSC concentration and low lactic acid concentration. Because the chemical compositions and feeding values of the hay and concentrates were very uniform throughout the experiment, only mean values over the trials are given for hay, barley, commercial concentrate, RSM and MR in Table 1. The calculated ME value of the barley was 6% higher than that of the CC used during the pre- and postweaning periods and 10% higher than that of the CC used during the finishing period. However, the commercial concentrate contained 17 (finishing) and 49% (pre- and postweaning) more CP than the barley grain. Furthermore, CC contained clearly more crude fat and NDF and less starch than the barley grain (Table 1).

The average chemical compositions of the total mixed rations used during the finishing period are presented in Table 2. Because of the higher energy content of the barley grain the CC ration contained 5% less ME than the B and BRSM rations. The B ration contained 7% less CP than the BRSM and CC rations. The CC ration contained 14% more NDF and 41% less starch than the B and BRSM rations. Furthermore, the B ration contained 29 and 39% less crude fat than the BRSM and CC rations, respectively.

Table 1. Chemical composition and nutritional values of feeds (mean±S.D.[a]).

	Silage trial 1	Silage trial 2	Hay	Milk replacer	Barley	Rapeseed meal	Commercial concentrate (pre- and postweaning periods)	Commercial concentrate (finishing period)
N [b]	14	14	12	4	14	14	6	10
Dry matter (DM), g kg^{-1} feed	324±95.3	260±90.8	888±5.7	965±2.2	874±3.8	881±1.7	875±2.0	870±2.2
Organic matter, g kg^{-1} DM	922±7.2	936±6.3	947±3.2	919±1.9	971±4.6	914±2.8	927±2.1	926±2.5
Crude protein, g kg^{-1} DM	173±15.6	161±14.2	62±4.9	206±2.1	124±6.4	351±2.5	185±3.6	145±4.2
Neutral detergent fibre (NDF), g kg^{-1} DM	536±14.6	550±18.8	685±10.5	16±0.5	204±11.1	318±1.4	242±3.4	306±4.3
Indigestible NDF, g kg^{-1} DM	60±6.1	51±5.4	ND [c]	2±0.1	43±2.3	133±2.1	46±1.9	91±2.1
Crude fat, g kg^{-1} DM	39±0.8	43±0.9	21±0.6	170±5.6	22±1.3	40±0.7	53±0.9	47±1.0
Starch, g kg^{-1} DM	12±0.1	7±0.2	ND	48±0.2	525±5.6	22±0.2	327±4.9	360±5.5
D value [d], g kg^{-1} DM	675±30.8	695±30.3	550±10.6	-	-	-	-	-
Metabolizable energy, MJ kg^{-1} DM	10.8±0.5	11.1±0.5	8.8±0.2	19.9±0.1	13.1±0.2	11.7±0.1	12.4±0.1	11.9±0.1
AAT [e], g kg^{-1} DM	85±3.8	86±3.2	74±0.2	180±0.2	104±0.1	151±0.1	111±0.1	102±0.1
PBV [f], g kg^{-1} DM	27±9.6	14±11.7	-63±0.3	-	-38±0.9	111±1.1	29±0.5	3±0.8
Fermentation quality of silage								
pH	4.3±0.3	4.0±0.3						
Volatile fatty acids, g kg^{-1} DM	6±3.7	18±9.5						
Lactic + formic acid, g kg^{-1} DM	35±10.3	53±18.7						
Water-soluble carbohydrates, g kg^{-1} DM	87±50.0	46±60.3						
In total N, g kg^{-1}								
NH_4N	49±23.7	56±16.1						
Soluble N	459±169.2	504±124.8						

[a] Standard deviation.

[b] Number of feed samples. Silage: values of two trials are given separately. Other feeds: only mean values over the trials are given because the chemical compositions and feeding values were very uniform throughout the experiment.

[c] Not determined.

[d] Digestible organic matter in dry matter.

[e] Amino acids absorbed from small intestine.

[f] Protein balance in the rumen.

Table 2. Chemical compositions and nutritional values of total mixed rations used in finishing period (from six months of age to slaughter).

	Silage + barley	Silage + barley + rapeseed meal	Silage + commercial concentrate
Dry matter (DM), g kg^{-1}	473	484	472
Organic matter, g kg^{-1} DM	947	945	924
Crude protein, g kg^{-1} DM	149	159	159
Neutral detergent fibre (NDF), g kg^{-1} DM	370	367	421
Indigestible NDF, g kg^{-1} DM	52	56	76
Crude fat, g kg^{-1} DM	31	40	43
Starch, g kg^{-1} DM	269	256	186
Metabolizable energy, MJ kg^{-1} DM	11.9	11.9	11.3
AAT [a], g kg^{-1} DM	95	97	94
PBV [b], g kg^{-1} DM	-6	0	15

[a] Amino acids absorbed from small intestine.

[b] Protein balance in the rumen.

Diet digestibility and feed intake

Diet apparent DM digestibility (DMD) and organic matter digestibility (OMD) were both 10% higher with B diet than with CC diet ($p < 0.001$), but there were no differences between B and BRSM diets in DMD or OMD (Table 3). Diet CP digestibility was 11% lower with B than that with BRSM diet ($p < 0.001$), but there were no differences between B and CC diets in CP digestibility. Furthermore, diet NDF digestibility (NDFD) was 12% higher with B than with CC diet ($p < 0.001$). In NDFD there was no difference between B and BRSM treatments.

During the preweaning period there were no significant treatment differences in feed, energy or protein intake (Table 4). However, roughage intake tended to be higher with BRSM than that with B diet ($p = 0.08$) and CP intake tended to be higher in both BRSM ($p = 0.07$) and CC ($p = 0.08$) diets than that in B diet. In addition, NDF intake tended to be 25% higher in BRSM diet than in B diet ($p = 0.07$). Unlike the preweaning period, there were many treatment differences in intake parameters during the postweaning period (Table 4). The DM ($p < 0.05$), ME ($p < 0.05$) CP ($p < 0.001$), AAT ($p < 0.01$) and NDF ($p < 0.01$) intakes were respectively 14, 12, 34, 19 and 21% higher for the BRSM animals than for the B animals. Further, the DM ($p < 0.01$), ME ($p < 0.01$) CP ($p < 0.001$), AAT ($p < 0.01$) and NDF ($p < 0.001$) intakes were

Table 3. Effects of concentrate type on apparent diet digestibility of growing dairy bulls.

	Concentrate type [a]				Statistical significance *(p* value) [c]				
	B	BRSM	CC	SEM [b]	F	T	F × T	C1	C2
Digestibility coefficients									
dry matter	0.775	0.779	0.725	0.0038	<0.0001	<0.0001	0.002	0.224	<0.0001
organic matter	0.786	0.794	0.740	0.0038	<0.0001	<0.0001	0.0006	0.335	<0.0001
crude protein	0.722	0.799	0.708	0.0043	<0.0001	<0.0001	0.007	0.043	0.653
neutral detergent fibre	0.679	0.686	0.608	0.0069	<0.0001	<0.0001	0.329	0.269	0.013

[a] B = barley grain as concentrate supplement; BRSM = barley grain + rapeseed meal as concentrate supplement; CC = commercial concentrate mixture as concentrate supplement.

[b] Standard error of mean.

[c] F = feeding treatment, T = trial, F × T = feeding treatment and trial interaction. Differences between feedings were tested by making two orthogonal contrasts: C1 = B vs. BRSM and C2 = B vs. CC.

Table 4. Effects of concentrate type on daily feed intakes of growing dairy bulls during preweaning (from 0.5 to 2.5 months), postweaning (from 2.5 to 6.0 months) and finishing (from 6.0 to 18.0 months) periods and on the average during the experiment.

	Concentrate type [a]				Statistical significance (*p* value) [c]				
	B	BRSM	CC	SEM [b]	F	T	F × T	C1	C2
Preweaning period									
Dry matter (DM) intake (DMI), kg DM d^{-1}									
Milk replacer	0.82	0.82	0.83	0.013	0.869	0.126	0.512	0.953	0.682
Concentrate	0.29	0.38	0.38	0.043	0.288	0.994	0.998	0.177	0.181
Roughage	0.20	0.24	0.19	0.014	0.083	0.001	0.166	0.084	0.586
Total DMI	1.31	1.44	1.40	0.063	0.385	0.112	0.701	0.192	0.361
Metabolizable energy (ME) intake, MJ d^{-1}	18.64	20.15	19.85	0.823	0.440	0.076	0.747	0.241	0.340
Crude protein intake, g d^{-1}	259	294	292	11.3	0.125	0.140	0.706	0.073	0.084
AAT [d] intake, g d^{-1}	222	238	235	7.9	0.367	0.155	0.701	0.194	0.291
Neutral detergent fibre (NDF) intake, g d^{-1}	184	230	214	14.7	0.162	0.011	0.414	0.070	0.195
Postweaning period									
DMI, kg DM d^{-1}									
Concentrate	2.36	2.50	2.54	0.047	0.066	0.062	0.679	0.071	0.030
Roughage	1.63	2.06	2.14	0.089	0.014	0.041	0.440	0.015	0.007
Total DMI	3.99	4.56	4.68	0.118	0.013	0.347	0.439	0.015	0.006
ME intake, MJ d^{-1}	49.56	55.60	57.67	1.413	0.016	0.425	0.406	0.023	0.007
Crude protein intake, g d^{-1}	601	805	848	20.1	0.0003	0.139	0.533	<0.001	<0.001
AAT intake, g d^{-1}	393	468	474	11.2	0.004	0.394	0.467	0.003	0.002
NDF intake, g d^{-1}	1311	1591	1753	51.0	0.003	0.239	0.490	0.008	<0.001
Finishing period									
Total DMI, kg DM d^{-1}	9.20	9.23	9.78	0.200	0.131	0.778	0.547	0.957	0.081
ME intake, MJ d^{-1}	109.99	109.78	113.61	2.334	0.472	0.410	0.475	0.951	0.314
Crude protein intake, g d^{-1}	1274	1377	1487	31.1	0.009	0.018	0.556	0.059	0.003
AAT intake, g d^{-1}	862	886	912	18.7	0.252	0.907	0.501	0.408	0.111
PBV [e], g d^{-1}	-160	-94	221	3.9	<0.0001	0.0004	<0.0001	<0.001	<0.001
NDF intake, g d^{-1}	3329	3376	4242	80.0	0.0003	0.507	0.524	0.692	<0.001

[a] B = barley grain as concentrate supplement; BRSM = barley grain + rapeseed meal as concentrate supplement;
CC = commercial concentrate mixture as concentrate supplement.

[b] Standard error of mean.

[c] F = feeding treatment, T = trial, F × T = feeding treatment and trial interaction. Differences between feedings were tested by making two orthogonal contrasts: C1 = B vs. BRSM and C2 = B vs. CC.

[d] Amino acids absorbed from small intestine.

[e] Protein balance in the rumen.

respectively 17, 16, 41, 21 and 34% higher for the CC animals than for the B animals.

During the finishing period the DMI tended to be 6% higher for the CC bulls than for the B bulls ($p = 0.08$), but there was no difference in DMI between B and BRSM bulls (Table 4). However, there were no treatment differences in the ME and AAT intakes between treatments. Instead, the CP ($p < 0.01$), PBV ($p < 0.001$) and NDF ($p < 0.001$) intakes were clearly higher for the CC animals than for the B animals during the finishing period. For the BRSM bulls the PBV intake was ($p < 0.001$) and the CP intake tended to be ($p = 0.06$) higher than for the B bulls.

Growth rate, feed conversion and slaughter parameters

During the preweaning period there were no treatment differences in LWG or feed conversion parameters (MJ or CP conversion) (Table 5). Instead, during the postweaning period the LWG of the B bulls was 13% lower than the LWG of the BRSM bulls ($p < 0.05$) and 16% lower than that of the CC bulls ($p < 0.01$). The improved gain of the BRSM and CC bulls during the postweaning period also emerges from the live weights of the animals (Table 5). The energy conversion rate (MJ kg^{-1} LWG) did not differ between treatments during the postweaning period, but the CP conversion rate (g kg^{-1} LWG) was better with B bulls than with BRSM and CC bulls ($p < 0.01$). There were no treatment differences in LWG of the bulls during the finishing period or on average during the experiment, but CP conversion rate was better with B bulls than with BRSM and CC bulls. Energy conversion rate did not differ significantly between treatments during the finishing period or on average during the experiment.

The average (all treatments) carcass weight of the animals was 345 kg and very close to the preplanned. There were no treatment differences in carcass gain or carcass weight of the bulls (Table 6). Furthermore, the dressing proportion, carcass conformation or carcass fat score of the bulls did not differ between treatments. The CP conversion during the whole experiment (g kg^{-1} carcass gain) was better for the B bulls than for the BRSM ($p < 0.05$) and CC ($p < 0.01$) bulls. However, there were no treatment differences in DM (Kg DM kg^{-1} carcass gain) or ME (MJ kg^{-1} carcass gain) conversions during the experiment (Table 6).

Discussion

Diet apparent DMD, OMD and NDFD were higher with the B diet than with the CC diet which was possibly due to differences in the sources of both carbohydrates and protein between these two diets. Besides grain, the commercial pelleted concentrate also included various by-product fractions, e.g. wheat bran and oat husk meal. Therefore the CC included more cell wall fractions than the barley grain and the NDFD of these by-product fractions is generally lower than the NDFD of barley grain (MTT 2006). Also Huuskonen et al. (2009) found that the commercial concentrate with more cell wall fractions decreased the OMD and NDFD of the diet compared to rolled barley grain in grass silage-based diets for growing dairy heifers. Similarly to what was reported by Huuskonen et al. (2008) and Huuskonen (2009), RSM supplementation had no effect on diet apparent OMD or NDFD when barley was partly replaced by RSM. In accordance with earlier studies (Aronen et al. 1992, Huuskonen et al. 2007, 2008, Huuskonen 2009), the apparent CP digestibility increased with protein supplementation. Some of the increased apparent digestibility of the CP in the RSM-supplemented diets may have reflected the better digestibility of RSM protein compared to barley grain protein (MTT 2006). Most of this increase was, probably, only apparent, related to the decreased proportion of faecal metabolic nitrogen recovered in faeces when the CP content increased. This hypothesis is supported by Minson (1982).

During the preweaning period there were no notable differences in intake parameters between the treatments. This is a logical result because the MR allowance of the calves was 8.5 l d^{-1} and MR was the most important energy and protein source

Table 5. Effects of concentrate type on live weight, daily live weight gain and feed conversion of growing dairy bulls during preweaning (from 0.5 to 2.5 months), postweaning (from 2.5 to 6.0 months) and finishing (from 6.0 to 18.0 months) periods and on the average during the experiment.

	Concentrate type [a]				Statistical significance (*p* value) [c]				
	B	BRSM	CC	SEM [b]	F	T	F × T	C1	C2
Live weight, kg									
initial, at age of 0.5 months	50	55	55	1.2	0.034	0.842	0.190	0.027	0.019
at the end of preweaning	86	94	92	2.7	0.200	0.562	0.866	0.095	0.186
at the end of postweaning	216	241	242	3.8	0.004	0.411	0.607	0.003	0.003
at the age of 12.0 months	428	441	451	6.1	0.098	0.043	0.374	0.170	0.039
final, at the age of 18.0 months	650	660	673	9.2	0.267	0.152	0.311	0.445	0.119
Live weight gain (LWG), g d^{-1}									
preweaning period	653	717	686	45.1	0.624	0.812	0.790	0.352	0.622
postweaning period	1198	1355	1384	32.4	0.014	0.123	0.594	0.014	0.007
finishing period	1142	1116	1126	20.66	0.677	0.597	0.715	0.400	0.599
average during the experiment	1105	1115	1138	17.7	0.438	0.358	0.445	0.693	0.227
Feed conversion									
MJ kg^{-1} LWG									
preweaning period	30.45	30.40	30.24	1.430	0.994	0.225	0.957	0.982	0.922
postweaning period	41.96	41.57	41.99	1.064	0.952	0.035	0.833	0.803	0.982
finishing period	96.51	99.71	101.21	2.341	0.406	0.878	0.632	0.371	0.205
average during the experiment	80.39	81.33	81.81	1.323	0.752	0.737	0.540	0.635	0.476
Crude protein g kg^{-1} LWG									
preweaning period	423	443	445	18.5	0.736	0.411	0.969	0.530	0.498
postweaning period	509	602	617	15.7	0.006	0.016	0.634	0.006	0.003
finishing period	1119	1252	1324	29.9	0.008	0.012	0.626	0.020	0.003
average during the experiment	940	1044	1089	17.2	0.002	0.004	0.417	0.005	<0.001

[a] B = barley grain as concentrate supplement; BRSM = barley grain + rapeseed meal as concentrate supplement;
CC = commercial concentrate mixture as concentrate supplement.

[b] Standard error of mean.

[c] F = feeding treatment, T = trial, F × T = feeding treatment and trial interaction. Differences between feedings were tested by making two orthogonal contrasts: C1 = B vs. BRSM and C2 = B vs. CC.

Table 6. Effects of concentrate type on carcass characteristics and feed conversion of growing dairy bulls.

	Concentrate type [a]			SEM [b]	Statistical significance (*p* value) [c]				
	B	BRSM	CC		F	T	F × T	C1	C2
Slaughter data									
carcass gain, g d^{-1}	585	595	609	12.9	0.466	0.687	0.737	0.604	0.237
carcass weight, kg	338	345	351	6.8	0.357	0.992	0.648	0.471	0.168
dressing proportion, g kg^{-1}	520	523	524	3.8	0.766	0.020	0.863	0.656	0.488
carcass EUROP conformation score [d]	4.75	4.43	4.85	0.267	0.544	0.699	0.837	0.433	0.792
carcass EUROP fat score [e]	2.65	2.47	2.52	0.150	0.690	0.096	0.210	0.420	0.565
Feed conversion during the experiment									
Kg DM kg^{-1} carcass gain	12.59	12.69	13.02	0.263	0.519	0.654	0.786	0.794	0.291
MJ kg^{-1} carcass gain	151.67	152.55	153.00	3.372	0.961	0.217	0.748	0.860	0.791
Crude protein g kg^{-1} carcass gain	1772	1956	2035	43.0	0.013	0.064	0.614	0.023	0.005

[a] B = barley grain as concentrate supplement; BRSM = barley grain + rapeseed meal as concentrate supplement; CC = commercial concentrate mixture as concentrate supplement.

[b] Standard error of mean.

[c] F = feeding treatment, T = trial, F × T = feeding treatment and trial interaction. Differences between feedings were tested by making two orthogonal contrasts: C1 = B vs. BRSM and C2 = B vs. CC.

[d] Conformation: (1 = poorest, 15 = excellent).

[e] Fat cover: (1 = leanest, 5 = fattest).

for the calves during the preweaning period. The absence of any differences between treatments for LWG or feed conversion during the same period was a reflection of the similar ME and protein intakes (Table 4). The average intake, LWG and feed conversion parameters of the calves were on the same level as in earlier studies with dairy bull calves fed MR-grass silage-grain-based diets in a similar housing environment (e.g. Huuskonen et al. 2005, 2011, Huuskonen and Khalili 2008).

During the postweaning period both the BRSM and CC animals ate more both roughage and concentrate than the B animals. This difference in total intake together with differences in the chemical contents of the concentrates led to the increasing energy and protein intakes and, finally, to the increasing LWG of the BRSM and CC bulls compared to the B bulls during the postweaning period. There are many potential reasons which could cause intake differences between treatments. One possible reason is the superior palatability of the CC compared to the barley grain. The CC was pelleted unlike the barley grain which might have affected the intake of concentrate. According to Spörndly and Åsberg (2006) and Manninen et al. (2010), pellets which include small amounts of molasses have good palatability. However, this explanation does not explain the intake and gain differences between the B and BRSM diets in which the concentrates were not pelleted. Some experiments have shown a positive response of LWG and the hay (Aronen 1990) or grass silage (Aronen 1990, Aronen et al. 1992) intake of young dairy bulls to RSM supplementation. The positive effect of RSM on LWG was often explained by the increased feed intake and thereby higher energy and protein intake. It is also possible that the B diet without protein supplementation was likely to provide inadequate supplies of protein or some amino acids for a growing bull in the early phase of growth.

Although the CP intake of the BRSM and CC bulls was higher than that of the B bulls during the finishing period, the treatments had no effects on the LWG or carcass gain. This is a logical result, because there were no differences in the energy intakes between treatments during the finishing period. Similarly, RSM had no effect on the performance of finishing dairy bulls (from 6 to 18 months) with grass silage-barley-based feedings (Huuskonen et al. 2007, 2008, Huuskonen 2009). As in the present experiment, also in studies by Huhtanen et al. (1989) and Aronen (1990) the positive effect of protein supplementation was restricted to only the early phase of the growth (i.e., LW below 300 kg). Similarly, calculations by Titgemeyer and Löest (2001) showed that while amino acids were the limiting factor with lighter weight calves offered grass silage, energy availability was the limiting factor with heavier steers. In addition, often much of the advantage of protein supplementation of young cattle was lost during the finishing period due to compensatory growth (McGee 2005).

As in the present experiment, McGee et al. (2006) and Manninen et al. (2010) reported that the dressing proportion, carcass conformation and carcass fat score were unaffected by the concentrate energy source. Similarly, in accordance with many earlier studies (Huhtanen et al. 1989, Aronen 1990, Huuskonen et al. 2007, 2008, Huuskonen 2009), protein supplementation had no effects on the dressing proportion, carcass conformation score or carcass fat score of growing dairy bulls.

In conclusion, there were no notable differences in intake and gain parameters between the treatments during the preweaning period but during the postweaning period commercial concentrate and RSM supplementation clearly increased the dry matter and energy intakes as well as the gain of the calves compared with barley grain. However, during the finishing and entire period, the treatments had no effect on the LWG or carcass gain. Furthermore, the dressing proportion, carcass conformation or carcass fat score of the bulls did not differ between treatments. Thus, concentrate with a higher protein concentration than barley grain is not needed for growing and finishing dairy bulls when they are fed high or medium digestibility and restrictively fermented grass silage and barley-based concentrate. Because the prices of commercial concentrates are generally higher in relation to barley and other grains, it is not economical to use commercial concentrates for feeding growing dairy bulls. Still, this experiment indicates that it is not necessary to use commercial starter concentrates for dairy calves during the pre- and postweaning periods because much of the advantage of starter feeds compared with rolled barley was lost during the finishing period.

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