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Performance of growing dairy bulls offered diets based on silages made of whole-crop barley, whole-crop wheat, hairy vetch and grass

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The present experiment was conducted to study diet digestibility, feed intake, animal performance and carcass characteristics of growing dairy bulls offered diets based on whole-crop barley, a mixture of whole-crop barley and hairy vetch (*Vicia villosa* Roth.) or a mixture of whole-crop wheat and hairy vetch relative to moderate digestible grass silage-based diet. The feeding experiment with 24 Finnish Ayrshire and 8 Holstein-Friesian bulls included 4 forage feeding treatments: grass silage (G), whole-crop barley and hairy vetch mixture silage (BHV), whole-crop wheat and hairy vetch mixture silage (WHV) and whole-crop barley silage (B). In all treatments animals were offered silage ad libitum. The amount of concentrate supplementation was 36 g $(W^{0.75})^{-1}$ per animal per day for all treatments. The concentrate ration included rolled barley and rapeseed meal. Differences between the treatments were compared using an a priori test (Dunnett's test) so that comparison of the diets was based on the G diet. The animals were fed the experimental diets from day 240 to finish at day 505 of age. During the experiment the average concentrate proportions of G, BHV, WHV and B diets were 437, 424, 426 and 423 g dry matter (DM) $(\text{kg DM})^{-1}$, respectively. There were no significant differences in silage DM intake or in the total DM intake (DMI) (kg DM d^{-1}) between treatments. However, DMI kg^{-1} $W^{0.75}$ tended to be 3.5% higher ($p = 0.09$) in the B diet than in the G diet. Due to increasing energy intake, the gain of the bulls was higher with the G diet than with the WHV diet ($p < 0.05$). BHV and B diets did not differ from the G diet in gain. Treatments had no significant effect on the dressing proportion or carcass conformation. The carcass fat score of WHV bulls was 29% lower ($p < 0.05$) than that of the G bulls, but BHV and B diets did not differ from the G diet in carcass fatness. The feed conversion rate (DM intake kg^{-1} carcass gain) of the bulls was better ($p < 0.001$) and protein conversion (g AAT kg^{-1} carcass gain) tended to be better ($p = 0.07$) with the G diet than with the WHV diet. BHV and B diets did not differ from the G diet in any feed conversion parameters. It can be concluded that replacing moderate digestible grass silage with whole-crop wheat and hairy vetch mixture silage decreased the carcass gain of growing dairy bulls due to lower energy intake and poorer feed conversion. Instead, replacing moderate digestible grass silage with whole-crop barley or with whole-crop barley and hairy vetch mixture silage resulted in no differences in the performance or carcass characteristics parameters of growing dairy bulls.

Key-words: Beef production, dairy bulls, whole-crop silages, hairy vetch, Vicia villosa Roth, feed intake, growth rate

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Introduction

Grass silage is the main forage for growing cattle in Finland. However, increasingly other ensiled forages, such as different whole-crop silages, are being used due to their potentially lower costs. In addition, recent advances in plant breeding, agronomic practices and forage conservation technologies are expanding opportunities for these alternative crops (Walsh et al. 2008a) and nowadays small-grain cereals are widely grown for animal feed in temperate climates. An economic advantage of harvesting cereals as whole-crops is that farmers can use the same machines they use for making grass silage. However, direct cut harvest of the crop to decrease field losses at later maturity stages is recommended. Grains, on the other hand, need different types of machines and the investment costs involved may be high. Furthermore, drying and storage of grains can be costly processes for the farmer. Harvesting cereals at an earlier maturity stage compared to grain maturity increases the radiation to a developing undersown crop, and can be beneficial for weed control reasons (Wallsten 2008). In Finland, barley (*Hordeum vulgare*) is the dominant small-grain species utilized for whole-crop production (Ahvenjärvi et al. 2006), but oats (*Avena sativa*) and wheat (*Triticum aestivum*) are also used. In organic farming systems, annual legumes are often sown with cereals. The objective of mixed cultivation is to decrease the need for inorganic nitrogen fertilization and to improve the feeding value of harvested forage. Forage pea (*Pisum sativum* L.), common vetch (*Vicia sativa* L.) and hairy vetch (*Vicia villosa* Roth.) are current annual legumes in Finland.

The digestibility of whole-crop silages is highly dependent on the proportion of straw and is often lower than that of good-quality grass silage (Abdalla et al. 1999, Sinclair et al. 2003). However, the lower digestibility is largely compensated for by higher dry matter intake (DMI) such that energy intake is maintained (Abdalla et al. 1999, Sinclair et al. 2003). In a review of experiments where whole-crop wheat silage was included in grass silage-based diets for lactating dairy cows, Keady (2005) concluded that feed intake increased by 2–3 kg DM d^{-1} but that there were no beneficial effects on milk yield or yield of fat plus protein. An accompanying compilation of seven experiments with finishing beef cattle concluded that the inclusion of whole-crop wheat silage in grass silage-based diets increased forage intake by 1.4 kg DM d^{-1}, but did not alter animal performance (Keady 2005). However, there is lack of information on the effects of mixtures of whole-crop cereal and hairy vetch on the performance of growing dairy bulls relative to a grass silage-based diet. Therefore, the present experiment was conducted to study diet digestibility, feed intake, animal performance and carcass characteristics of growing dairy bulls offered diets based on silage made from (1) whole-crop barley, (2) mixture of whole-crop barley and hairy vetch, or (3) mixture of whole-crop wheat and hairy vetch relative to moderate digestible grass silage-based diet.

Material and methods

Animals, diets and experimental design

The feeding experiment with 24 Finnish Ayrshire and 8 Holstein-Friesian bulls was conducted in the experimental barn of the North Ostrobothnia Research Station of MTT Agrifood Research Finland (Ruukki, 64°44′N, 25°15′E). It started in November 2000 and ended in August 2001 (duration of experiment 265 d). The experimental procedures were evaluated and approved by the Animal Care and Use Committee of MTT Agrifood Research Finland. All animals were purchased from local dairy farms. Before the beginning of the present feeding experiment they were housed and fed individually in straw-bedded pens measuring 1.15 × 2.00 m until 120 days of age and fed milk, hay, silage and concentrates (barley and rapeseed meal (RSM)). From 120 until 240 days of age the animals were housed in tied stalls and fed grass silage (ad libitum) and concentrates (barley and RSM; limited to a maximum of 3 kg DM per head daily).

At the beginning of the present experiment the animals (initial live weight (LW) 319±28.5 (mean ± SD) kg and age 240±2.9 days) were divided into eight blocks of four animals by LW and breed so that there were six Ayrshire blocks and two Holstein-Friesian blocks. Age was not taken into account in the blocking because of the small variation in age. Within each block one randomly selected animal was chosen for each treatment. The bulls were placed in an insulated barn in adjacent tie-stalls. The width of the stalls was 70–90 cm for the first four months and 113 cm until the end of the experiment. The bulls were tied with a collar around the neck, and a 50 cm long chain was attached to a horizontal bar 40–55 cm above the floor. The floor surface was solid concrete under the forelegs and metal grids under the hind legs. No bedding was used on the floor.

The animals were fed three times per day (at 0800, 1200 and 1800 h). Refused feed was collected and measured at 0700 h daily. The bulls had free access to water from an open water bowl during the experiment. One animal was excluded from the study due to several occurrences of bloat and another due to hoof problems. There was no reason to suppose that the diets had caused these problems. The four feeding treatments were grass silage (G), whole-crop barley and hairy vetch mixture silage (BHV), whole-crop wheat and hairy vetch mixture silage (WHV) and whole-crop barley silage (B).

The grass silage used was the primary growth from a timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*) sward, cut using a mower conditioner, wilted for 6h, and then harvested using a precision-chop forage harvester. Grass silage was ensiled in bunker silos with a formic acid-based additive (AIV-2 Plus: 760 g formic acid kg^{-1}, 55 g ammoniumformate kg^{-1}; supplied by Kemira Ltd., Finland) applied at a rate of 5 l t^{-1} of fresh grass. All whole-crop silages used in the feeding experiment were harvested at the early dough stage (growth stage Z83 on Zadoks scale; Zadoks et al. 1974) of the cereal using a direct-cut flail harvester. Harvest dates of grass silage, BHV, WHV and B silages were June 25, August 2, August 27, and August 5, respectively. Also the BHV, WHV and B silages were ensiled in bunker silos with the same formic acid-based additive as for the grass silage applied at a rate of 5 l t^{-1} of fresh silage. The barley cultivar used in the BHV mixture was Artturi (seeding rate: 120 kg ha^{-1}) and the hairy vetch cultivar was Viola (seeding rate: 34 kg ha^{-1}). Respectively, the wheat cultivar used in the WHV mixture was Mahti (206 kg ha^{-1}) and the hairy vetch cultivar was Viola (34 kg ha^{-1}). The barley cultivar used in the B silage was Artturi (seeding rate: 200 kg ha^{-1}). According to botanical determinations (ten 25 cm × 50 cm forage samples were collected from both BHV and WHV fields) before harvesting, BHV contained barley (510 g DM (kg DM)$^{-1}$), hairy vetch (410) and other plants (80). Respectively, WHV contained wheat (410), hairy vetch (580) and other plants (10).

In all treatments the animals were offered silage ad libitum (proportionate refusals 5%). The amount of the concentrate supplementation was 36 g (W$^{0.75}$)$^{-1}$ per animal per day for all treatments, and the target for average daily concentrate level during the experiment was 400 g DM (kg DM)$^{-1}$. Silage and concentrate were fed separately. The concentrate ration for all treatments included rolled barley and RSM so that RSM supplementation was 440 g DM per animal daily. The daily concentrate ration also included 150 g of a mineral mixture (Tähkä Apekivennäinen: delivered by Feedmix Ltd., Koskenkorva, Finland). A vitamin mixture (Xylitol ADE-Vita: delivered by Suomen Rehu Ltd., Espoo, Finland) was given 50 g per animal weekly. The compositions of mineral and vitamin mixtures used are fully described by Huuskonen et al. (2007a) and Huuskonen (2009).

Procedures and sample analyses

Silage samples for chemical analyses were taken daily, pooled over periods of four weeks and stored at –20ºC. Thawed samples were analysed for DM, organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), starch, in vitro DM digestibility (DMD) and fermentation quality (pH, lactic

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and formic acids, volatile fatty acids, soluble and ammonia N content of total N). Barley and RSM sub-samples were collected weekly, pooled over periods of four weeks and analysed for DM, OM, CP and NDF. The chemical analyses of DM, ash, CP and NDF were made as described by Ahvenjärvi et al. (2000). Starch was determined as described by Bach Knudsen et al. (1987). Silage samples were analysed for in vitro DMD by the method described by Friedel (1990) and for fermentation quality by electrometric titration described by Moisio and Heikonen (1989).

Diet apparent digestibility was determined for all animals when the bulls were 503±28 kg LW, on average. Feed and faecal samples were collected twice a day (at 0700 and 1500 h) 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. Diet digestibility was determined using acid-insoluble ash (AIA) as an internal marker (van Keulen and Young 1977).

Calculations and carcass measurements

The ME contents of the feeds were calculated according to Finnish feed tables (MTT 2006). The ME value of the silages was calculated as 0.16 × D-value (MAFF 1981). The ME values of the concentrates were calculated as described by Schiemann et al. (1972) and MAFF (1984). The digestibility coefficients of concentrates were taken from Finnish feed tables (MTT 2006). The supply of amino acids absorbed from the small intestine (AAT) and 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, thereafter approximately every 28 days. Before slaughter they were weighed again on two consecutive days. The target for average carcass weight in the experiment was 300 kg. The live weight gain (LWG) was calculated as the difference between the means of initial and final weights. The estimated rate of carcass gain was calculated by assuming an initial carcass weight of 0.50 of initial LW which was used also in previous studies by Huuskonen et al. (2007b, 2008, 2009). After slaughter in a commercial meat plant carcasses were weighed hot. Cold carcass weight was estimated as 0.98 of hot carcass weight. Dressing proportions were calculated from the ratio of cold carcass weight to final live weight. Carcass conformation and carcass fat score were determined according to the EUROP classification (Commission 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 conformation scale was subdivided into 3 subclasses (O+, O, O-) to a transformed scale ranging from 1 to 15, 15 being the best conformation.

Statistical Methods

The experiment was set up according to a randomized complete block design with animal as an experimental unit. The results are shown as least squares means, because the records from two excluded animals were not replaced. The data were subjected to analysis of variance using the SAS mixed model procedure. The model used was

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

where μ is the overall mean, β_j is the random effect of block (j=1,…,8), e_{ij} is the random error term and α_i is the fixed effect of treatment. Differences between the treatments were compared using an a priori test (Dunnett's test) so that comparison of the diets was based on the G diet.

Results

Diets

Dry matter yields of BHV and WHV were 3 540 and 8 010 kg ha^{-1}. The difference in BHV and WHV yields was probably affected most by the severe lodging of BHV during growth period. The lodging probably reduced both the maximum obtainable yield and harvested yield. All silages were restrictively fermented and of good quality in terms of low pH and low concentrations of fermentation acids and ammonium-N (Table 1). Whole-crop silages had a slightly higher DM concentration than grass silage. The CP concentration of B silage was numerically lower than that of other silages. Grass silage had a 13–18% higher NDF concentration than whole-crop silages. Due to lower in vitro DMD, the energy content of the WHV silage was 7–8% lower than that of other silages. The addition of hairy vetch to the whole-crop barley (BHV) increased the CP concentration of silage by 25% compared with B silage. Hairy vetch sown with wheat instead of barley resulted in a silage with higher vetch and CP contents. The BHV mixture did not improve the digestibility of silage compared to B silage.

Table 1. Chemical composition and calculated feeding values of the experimental feeds (mean±SD[a]).

	Silages [b]				Barley	Rapeseed meal
	G	BHV	WHV	B		
N, number of samples	9	9	9	9	9	9
Dry matter (DM), g kg^{-1} feed	240±63.2	268±59.6	315±60.9	306±63.3	879±4.6	890±1.8
Organic matter, g kg^{-1} DM	931±15.9	928±18.8	913±17.6	935±16.5	978±3.5	928±1.3
Crude protein, g kg^{-1} DM	129±8.7	106±13.3	133±15.3	85±15.6	135±5.9	386±4.6
Neutral detergent fibre, g kg^{-1} DM	618±12.5	540±15.7	547±18.1	522±17.2	197±6.1	276±3.4
Starch, g kg^{-1} DM	8±0.1	136±9.7	124±10.3	242±12.9	569±3.5	26±0.3
in vitro digestibility, g kg^{-1} DM	651±12.9	685±13.1	578±13.2	677±14.3	-	-
Metabolizable energy, MJ kg^{-1} DM	10.3±0.2	10.2±0.2	9.5±0.2	10.2±0.2	13.3±0.1	11.2±0.1
AAT [c], g kg^{-1} DM	78±1.1	76±2.1	73±3.8	74±2.5	104±1.6	157±0.1
PBV [d], g kg^{-1} DM	-4±8.7	-22±9.6	7±8.9	-41±10.1	-48±3.5	146±0.9
Fermentation quality of silages						
pH	3.92±0.1	3.98±0.2	3.85±0.2	3.79±0.2	-	-
Volatile fatty acids, g kg^{-1} DM	15±2.9	12±6.8	17±7.5	12±6.6	-	-
Lactic+formic acid, g kg^{-1} DM	56±7.5	45±6.9	63±7.1	38±7.6	-	-
In total N, g kg^{-1}						
Ammonia N	64±14.8	71±9.0	83±8.6	82±12.7	-	-
Soluble N	491±71.9	593±56.1	594±33.1	641±62.6	-	-

[a] Standard deviation.

[b] G = Grass silage; BHV = Silage made from a mixture of whole-crop barley and hairy vetch; WHV = Silage made from a mixture of whole-crop wheat and hairy vetch; B = Whole-crop barley silage.

[c] Amino acids absorbed from small intestine.

[d] Protein balance in the rumen.

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Feed intake and diet digestibility

The average feed DM, ME, protein and fibre intakes during the experiment are presented in Table 2. During the experiment the average concentrate proportions of G, BHV, WHV and B diets were 437, 424, 426 and 423 g kg^{-1} DM, respectively. There were no significant differences in silage DM intake or in the total DMI (kg DM d^{-1}) between treatments. However, DMI kg^{-1} $W^{0.75}$ tended to be 3.5% higher in the B diet than in the G diet. In the WHV diet, energy intake (MJ d^{-1}) tended to be 4.9% lower than in the G diet, but the BHV and B diets did not differ from the G diet in energy intake. There were no differences in AAT intake between treatments, but CP intake was clearly lower in the BHV and B diets than in the G diet. There was no difference in CP intake between G and WHV diets. In all whole-crop silage diets the NDF intake was significantly lower than that in the G diet (Table 2).

The apparent diet DMD in BHV, WHV and B diets was 5.2, 7.0 and 8.7% lower, respectively, than that of the G diet (Table 2). Diet apparent OM digestibility (OMD) did not differ between G and BHV diets but in WHV and B diets apparent OMD was lower than that in the G diet (Table 2). The apparent CP digestibility was 13.5% lower in the B diet than in the G diet, but BHV and WHV diets did not differ from the G diet in CP digestibility.

Table 2. Daily feed intake and diet digestion.

	Treatment [a]				SEM [b]	*p*-values of contrasts [c]		
	G	BHV	WHV	B		1	2	3
N, number of animals	8	6	8	8				
Duration, d	265	265	265	265				
Dry matter (DM) intake, kg DM d^{-1}								
Silage	4.41	4.61	4.48	4.66	0.146	0.37	0.64	0.14
Concentrate	3.42	3.40	3.33	3.42	0.122	0.45	0.24	0.96
Total intake	7.83	8.01	7.81	8.08	0.243	0.72	0.96	0.27
Dry matter intake, g kg^{-1} $W^{0.75}$	81.9	84.0	83.3	84.8	1.42	0.29	0.39	0.09
Metabolizable energy intake, MJ d^{-1}	89.6	90.9	85.4	91.8	2.82	0.95	0.09	0.40
Crude protein intake, g d^{-1}	1030	946	1045	863	24.9	0.0009	0.51	<0.0001
AAT [d] intake, g d^{-1}	700	703	675	702	21.0	0.81	0.18	0.89
Neutral detergent fibre intake, g d^{-1}	3401	3163	3119	3108	94.8	0.02	0.009	0.007
Apparent diet digestibility [e]								
Dry matter	0.733	0.697	0.685	0.674	0.0152	0.09	0.02	0.004
Organic matter	0.750	0.723	0.715	0.698	0.0149	0.17	0.06	0.008
Crude protein	0.774	0.745	0.774	0.682	0.0142	0.14	0.98	<0.0001
Neutral detergent fibre	0.646	0.494	0.507	0.450	0.0253	0.0001	0.0001	<0.0001

[a] G = Grass silage; BHV = A mixture of whole-crop barley and hairy vetch; WHV = A mixture of whole-crop wheat and hairy vetch; B = Whole-crop barley.

[b] Standard error of means.

[c] Differences between the treatments were compared using an *a priori* test (Dunnett's test) so that comparison of the diets was based on the G diet. Contrasts: (1 = G vs. BHV), (2 = G vs. WHV), (3 = G vs. B).

[d] Amino acids absorbed from small intestine.

[e] Diet digestibility was determined when the bulls were 503±28 kg live weight, on average. The apparent digestibilities are for the diet and thus are not directly comparable to the *in vitro* digestibilities in Table 1.

In all whole crop diets, apparent NDF digestibility (NDFD) was clearly lower than that in the G diet.

Gain, carcass characteristics and feed conversion

The mean final LW of the bulls was 577 kg (Table 3). The final LW of the bulls fed WHV diet tended to be 4.3% lower compared with the bulls fed G diet. The average (all treatments) carcass weight was 299 kg and very close to the pre-planned carcass weight. The carcass weight was 5.6% lower in the WHV diet than in the G diet. The LWG and carcass gain of the bulls was higher with the G diet than with the WHV diet, but BHV and B diets did not differ from the G diet in gain. Treatments had no significant effect on the dressing proportion or carcass conformation (Table 3). The carcass fat score of WHV bulls was 29% lower than that of the G bulls, but the BHV and B diets did not differ from the G diet in carcass fatness.

The feed conversion rate (DM intake kg^{-1} carcass gain) of the bulls was better and protein conversion (g AAT intake kg^{-1} carcass gain) tended to be better with the G diet than with the WHV diet. However, there was no significant difference in the energy conversion rate (MJ intake kg^{-1} carcass gain) between G and WHV diets. BHV and B diets did not differ from the G diet in any feed conversion parameters (Table 3).

Table 3. Live weight, daily gain, feed conversion rate and slaughter data.

	Treatment [a]				SEM [b]	*p*-values of contrasts [c]		
	G	BHV	WHV	B		1	2	3
Initial live weight, kg	320	313	319	325	26.2	0.71	0.98	0.96
Final live weight, kg	588	578	564	579	12.9	0.27	0.10	0.55
Live weight gain, g d^{-1}	1123	1071	1036	1091	40.0	0.17	0.05	0.45
Carcass gain, g d^{-1}	601	603	535	593	26.2	0.80	0.02	0.74
Feed conversion								
DM intake kg^{-1} carcass gain	13.12	13.31	14.73	13.75	0.503	0.77	0.01	0.31
MJ intake kg^{-1} carcass gain	150	151	161	156	5.5	0.91	0.13	0.38
AAT [d] intake g kg^{-1} carcass gain	1172	1168	1271	1195	47.8	0.95	0.07	0.66
Slaughter data								
Carcass weight, kg	303	300	287	304	11.3	0.42	0.04	0.93
Dressing proportion, g kg^{-1}	515	519	508	524	4.7	0.48	0.20	0.13
EUROP conformation [e]	3.75	4.83	3.50	4.38	0.495	0.11	0.68	0.31
EUROP fat classification [f]	2.75	2.83	2.13	2.50	0.243	0.63	0.02	0.33

[a] G = Grass silage; BHV = Whole-crop barley and hairy vetch mixture; WHV = Whole-crop wheat and hairy vetch mixture; B = Whole-crop barley.

[b] Standard error of means.

[c] Differences between the treatments were compared using an *a priori* test (Dunnett's test) so that comparison of the diets was based on the G diet. Contrasts: (1 = G vs. BHV), (2 = G vs. WHV), (3 = G vs. B).

[d] Amino acids absorbed from small intestine.

[e] Conformation: (1=poor, 15=excellent).

[f] Fat cover: (1=low, 5 = very high).

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Discussion

Diet digestibility and feed intake

In accordance with earlier studies (e.g. Abdalla et al. 1999, Sinclair et al. 2003) and on the stage of grain development, the apparent digestibility of whole-crop cereal-based diets was lower than that of the G diet. In general, the digestibility of whole-crop cereals is highly dependent on the proportion of straw (Sinclair et al. 2003). Based on preliminary results with hairy vetch it can be assumed that the inclusion of hairy vetch in whole-crop silage does not substantially improve the digestibility of the mixture compared with pure cereal crop silage (Lehto 2000). In the present experiment the apparent NDFD of the G diet was clearly higher than that of the whole-crop diets. However, the differences in DMD and OMD between treatments were clearly smaller than the differences in NDFD. This indicates that the starch concentration of whole-crop silages, together with high starch digestibility (reported e.g. by Walsh et al. 2008b) could compensate for the reduced NDFD, which is also suggested by Wallsten (2008). In addition, in the present study grass silage was only of moderate in vitro digestibility which also explains the digestibility results above. If the in vitro digestibility of the grass silage had been greater, the differences in apparent DMD and OMD between treatment levels would presumably have been higher.

In the present experiment, DMI kg^{-1} $W^{0.75}$ tended to be higher in the B diet than in the G diet, but there were no significant differences in DMI between other treatments. In general, the DMI of silage can be affected by its DM content, fermentation characteristics, NDF concentration, OMD and NDFD (Huhtanen et al. 2007). While the first two factors can be controlled by wilting and use of appropriate additives at the time of ensiling, the others depend on the maturity stage at harvest and choice of cereal species (Wallsten 2008). According to current practices in Finland, whole-crop cereals are typically harvested at the dough stage with a DM concentration of 30 to 40% (Ahvenjärvi et al. 2006). Within such a range of DM content, active fermentation during the ensiling process is likely to occur, and therefore the preservation of whole-crop silages is based on fermentation using acid-based additives to restrict silage fermentation (Vanhatalo et al. 1999). In the present experiment, all silages were restrictively fermented and of good preservation quality, but due to the wet weather during the harvesting season, the DM content of whole-crop silages (especially BHV) was quite low compared to typical Finnish whole-crop silages and only slightly higher than the DM content of the G diet. This could be one reason for the absence of differences in DMI between BHV, WHV and G treatments.

Digestibility and concentration of the NDF fraction are typically positively and negatively correlated to DMI of the grass silage, respectively (Hetta et al. 2007). However, whole-crop cereal silages differ from grass silage in that the NDF concentration does not increase after heading, but remains constant or even decreases (Crovetto et al. 1998). This difference in maturity-related change between whole-crop cereal silages and grass silage make it difficult to predict the DMI of whole-crop cereal silages from models based on grass silage data (Wallsten et al. 2009). Previous authors have reported that the inclusion of whole-crop silage in grass-silage-based diets has increased forage intake of beef (O'Kiely and Moloney 2002) and dairy (Leaver and Hill 1995, Huhtanen et al. 2007) cattle. Two possible reasons for this are the usually higher DM content and lower NDF concentration of whole-crop silage than those of grass silage (Keady 2005, Ahvenjärvi et al. 2006, Wallsten and Martinsson 2009). However, including whole-crop silage does not always result in higher intake. For example, Ahvenjärvi et al. (2006) reported no increase in DMI when barley silage harvested at the early dough stage was exchanged for grass silage in the diets of dairy cows despite the higher DM content and lower NDF concentration of barley silage compared with grass silage. In the present study, the NDF concentration of the B silage was lowest among silages used, and this may explain the higher DMI (kg $W^{0.75}$) in the B diet. Due to higher NDF content of the grass silage, NDF intake was higher in the G diet than in whole-crop diets. Similarly, the differences in CP intake between treatments reflected differences in CP contents of feeds.

Gain, feed conversion and carcass characteristics

The absence of any differences between G, BHV and B treatments for LWG or carcass gain was a reflection of the similar ME intakes. In contrast, animal performance (in terms of LWG and carcass gain) for the WHV diet was lower than that for the G diet, primarily because of the lower ME intake with the WHV diet. This was due to a lower in vitro DMD measured with WHV silage. As opposed to energy intake, differences in CP intake between treatments had no effect on performance results in the present study. Similarly, calculations by Titgemeyer and Löest (2001) showed that, while supply of protein and amino acids are a limiting factor with lighter-weight calves offered grass silage, energy availability is the limiting factor with heavier steers.

To our knowledge there are no data available in the literature were whole-crop-hairy vetch mixtures harvested at a maturity similar to that in this experiment were compared to grass silage-based diets with growing bulls. Some previous studies have reported that the inclusion of whole-crop wheat silage in grass silage-based diets decreased (O'Kiely and Moloney 1999), had no effect (Keady et al. 2007) or increased (O'Kiely and Moloney 2002) the carcass gain of finishing beef cattle. In an Irish study, Walsh et al. (2008b) reported clearly lower animal performances when growing crossbred steers were fed a grass silage-based diet instead of a fermented whole-crop wheat-based diet. However, grass silage in the study by Walsh et al. (2008b) had a relatively low nutritive value due to the wet weather, late harvesting and relatively poor preservation. Keady (2005) concluded from a review of seven beef cattle studies that inclusion of whole-crop wheat silage in grass silage-based diets did not improve carcass gain of beef cattle. It can be concluded based on the present and on the these earlier experiments that the effects of replacing grass silage by whole-crop silages on the performance of growing cattle differ largely depending on the stage of harvest, cutting height, plant variety and growing conditions that affect the chemical composition and relative proportions of crop components, grain and straw.

The poorer feed conversion rate of animals offered the WHV treatment reflects the magnitude of the decline in carcass gain being proportionally much greater than the scale of decline in total DMI compared to the animals offered G treatment. On the contrary, Walsh et al. (2008b) found a better feed conversion rate with whole-crop wheat compared to grass silage but, as mentioned earlier, grass silage had a relatively low nutritive value then.

In accordance with earlier studies (e.g. Keady et al. 2007, Walsh et al. 2008b), carcass conformation was not affected when grass silage was replaced by whole-crop silages. However, in the WHV diet carcass fat classification decreased by 29% compared to the G diet. According to literature, reducing energy intake usually decreases carcass fat content (e.g. Fishell et al. 1985), which could explain the lower fat classification on the WHV diet. On the other hand, measures of fatness increase also with increasing carcass weight (Keane and Allen 1998) and in our trial, carcass weight was lower in the WHV diet than in the G diet, which probably also explained the differences in fatness. For cattle finished on grass silage and concentrates, Steen and Kilpatrick (2000) concluded that reducing slaughter weights is likely to be a more effective strategy to control carcass fat content than reducing energy intake.

It can be concluded that replacing moderate digestible grass silage with whole-crop wheat and hairy vetch mixture silage decreased the carcass gain and weight of growing dairy bulls due to lower energy intake and poorer feed conversion rate. Instead, replacing moderate digestible grass silage with whole-crop barley or with whole-crop barley and hairy vetch mixture silage resulted in no differences in the performance or carcass characteristics parameters of growing dairy bulls.

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