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FEED INTAKE AND LIVE WEIGHT GAIN OF HEREFORD BULLS OFFERED DIETS BASED ON WHOLE-CROP BARLEY AND WHOLE-CROP WHEAT SILAGES RELATIVE TO MODERATELY DIGESTIBLE GRASS SILAGE WITH OR WITHOUT PROTEIN SUPPLEMENTATION*

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Abstract

The present experiment was conducted to study the performance of Hereford bulls offered diets based on whole-crop barley (WCB) and whole-crop wheat (WCW) silages relative to a moderately digestible grass silage (GS)-based diet with or without rapeseed meal (RSM) supplementation. The experiment comprised 30 bulls and a 3×2 factorial design was used. The bulls were offered silages *ad libitum*. In all forage diets (WCB, WCW, GS) the concentrate used was either rolled barley alone or rolled barley plus RSM. The amount of the concentrate supplementation was 37 g/metabolic live weight/animal/day for all treatments. The crude protein (CP) content of barley was 126 g/kg dry matter (DM) and the CP content of the concentrate increased 23% with RSM supplementation. Average live weight gains (LWG) for the GS, WCB and WCW feedings were 1411, 1331 and 1181 g/d, respectively. Differences in diet digestibility and energy intake probably explain the differences in LWG among the forage types. RSM supplementation increased both silage and total DM intake in the WCB and WCW feedings but not in the GS feeding. Furthermore, RSM supplementation increased LWG 7 and 17% in the WCB and WCW feedings, respectively, but only 2% in the GS feeding.

Key words: beef production, bulls, growth, rapeseed meal, whole-crop silages

Most of the forage for growing cattle in Finland is based on silage mixtures of different grasses and red clover (*Trifolium pratense*) (Huuskonen, 2013). However,

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other ensiled forages, such as different whole-crop silages, are increasingly being used due to their potentially lower costs compared to grass silages (Pesonen et al., 2014; Huuskonen et al., 2016). In addition, recent advances in plant breeding, agronomic practices and forage conservation technologies are expanding opportunities for these alternative crops (Wallsten, 2008; Rustas, 2009; Keady et al., 2013) and nowadays small-grain cereals are widely used as whole-crop silages for animal feed in temperate climates. In Finland, barley (*Hordeum vulgare*) is the dominant small-grain species utilized for whole-crop production, but oats (*Avena sativa*) and wheat (*Triticum aestivum*) are also used.

The digestibility of whole-crop silages is highly dependent on the proportion of straw and is often lower than that of high-quality grass silage, but the lower digestibility is largely compensated for by higher dry matter (DM) intake (DMI) (Huhtanen et al., 2007). In a review of seven comparisons involving finishing beef cattle, Keady (2005) concluded that the inclusion of whole-crop wheat silage in grass silage-based diets increased forage intake by 1.4 kg DM/d, but did not alter animal performance. Walsh et al. (2008) noted that replacing poorly preserved and low feed-value grass silage with whole-crop wheat silage increased the performance of finishing beef cattle. However, there is limited information available on the effects of whole-crop barley silages on the performance of growing cattle relative to grass silage or whole-crop wheat silage-based diets.

Rapeseed meal (RSM) is the most important supplementary protein feed for cattle in Finland. Huuskonen et al. (2014 a) concluded that because of limited production responses, high prices of protein supplements and increases in the nitrogen and phosphorus emissions, there is generally no benefit from using protein supplementation for growing cattle fed grass silage-based diets. However, whole-crop silages typically contain less protein than grass silage (Huuskonen and Joki-Tokola, 2010; Huuskonen, 2013), and therefore Finnish protein feeding recommendations for growing cattle are not usually fulfilled if whole-crop silage-based rations are fed without protein supplementations. In Finnish Feed Tables (Luke, 2017), the protein intake for animals over 200 kg live weight (LW) is considered adequate if the protein balance in the rumen (PBV) of the total diet is not lower than −10 g/kg (DM). The PBV value describes the balance between the dietary supply of rumen-degradable protein (RDP) and the microbial requirements for RDP. According to literature, nitrogen is routinely overfed to ruminants which, in combination with the continuous trend to concentrate animals in intensive units, leads to nutrient surpluses at farm and system levels (e.g. Ondersteijn et al., 2002). Therefore it is important to know if protein supplements can be reduced or excluded also from the whole-crop-based diets without compromising animal performance.

The present experiment was conducted to study feed intake, LW gain (LWG) and diet digestibility of growing Hereford bulls offered diets based on whole-crop barley (WCB) and whole-crop wheat (WCW) silages relative to moderately digestible grass silage (GS)-based diet with or without RSM supplementation.

Material and methods

Animals, management and experimental design

A feeding experiment was conducted in the experimental barn of Natural Resources Institute Finland (Luke) in Ruukki, Finland. Animals were managed according to Finnish legislation regarding the use of animals in scientific experimentation. The experiment comprised a total of 30 Hereford bulls. All the animals were spring-born calves that spent their first summer at pasture with their dams. In October the bulls were weaned and transferred to an insulated barn. During the pre-experimental period of 110 days the animals received grass silage and concentrates (barley grain, RSM and mineral-vitamin mixture). At the beginning of the present feeding experiment the bulls weighed 438±57.8 kg, on average.

During the feeding experiment the bulls were placed in an insulated barn in adjacent tie-stalls. 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. Each bull had its own water bowl.

A 3×2 factorial design was used to study the effects of (1) forage type, (2) inclusion of RSM and (3) their interactions. At the beginning of the experiment the bulls were divided into five blocks of six animals by LW. Within the block, the bulls were randomly allotted to one of the following six treatments:

1) Grass silage plus rolled barley without RSM supplementation (GS RSM−).
2) Grass silage plus rolled barley with RSM supplementation (GS RSM+).
3) Whole-crop barley silage plus rolled barley without RSM supplementation (WCB RSM−).
4) Whole-crop barley silage plus rolled barley with RSM supplementation (WCB RSM+).
5) Whole-crop wheat silage plus rolled barley without RSM supplementation (WCW RSM−).
6) Whole-crop wheat silage plus rolled barley with RSM supplementation (WCW RSM+).

Feeds and feeding

All experimental silages were produced at the experimental farm of Natural Resources Institute Finland (Luke) in Ruukki (64°44'N, 25°15'E). The GS used was the regrowth from a timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*) sward, cut using a mower conditioner, wilted for 24 h, and then harvested using a precision-chop forage harvester. Spring-sown barley (cv. Artturi, four-rowed) and spring-sown wheat (cv. Mahti) were used as whole-crop silages. Both whole-crop silages 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 at a stubble height of about 10 cm. The harvest dates of WCB, WCW and GS were August 31, September 8 and September 19, respectively.

For botanical determinations ten 25 cm × 50 cm forage samples were collected from all silage fields before harvesting. On DM basis, GS contained timothy (435 g/kg), meadow fescue (540 g/kg) and other plants (25 g/kg). Respectively, WCB contained barley (965 g/kg) and other plants (35 g/kg) and WCW contained wheat (955 g/kg) and other plants (45 g/kg). All silages were treated with a formic acid-based additive (AIV-2 Plus; Eastman Chemical Company, Oulu, Finland: 760 g formic acid/kg, 55 g ammonium formate/kg) applied at a rate of 5 liters/t of fresh forage and ensiled in bunker silos.

The feeding experiment lasted 168 days and during the experiment the bulls were offered silages *ad libitum* (proportionate refusals as 5%). The bulls were fed three times per day (at 0800, 1200 and 1800 hours). Refused feed was collected and measured at 0700 daily. In all three forage diets the concentrate used was either rolled barley alone or rolled barley plus RSM. The amount of the concentrate supplementation was 37 g/kg metabolic LW/animal/day for all treatments, and the target for average concentrate level during the experiment was 400 g/kg DM. The crude protein (CP) content of rolled barley was 126 g/kg DM and RSM was given so that the CP content of the concentrate was raised to 155 g/kg DM. Thereby, the CP content of the concentrate increased 23% with RSM supplementation. The daily ration for the bulls included also 150 g of a mineral-vitamin mixture.

Feed and fecal sampling and analyses

During the feeding experiment silage sub-samples were taken twice a week, pooled over periods of four weeks and stored at –20ºC prior to analyses. Thawed samples were analyzed for DM, ash, crude protein (CP), neutral detergent fiber (NDF), starch, silage fermentation quality [pH, lactic and formic acids, volatile fatty acids (VFA), soluble and ammonia N content of total N] and digestible organic matter (DOM) in DM (D-value). Barley and RSM sub-samples were collected weekly, pooled over periods of eight weeks and analyzed for DM, ash, CP, NDF and starch.

Fresh silage samples were analyzed for fermentation quality by electrometric titration as described by Moisio and Heikonen (1989). The DM concentration was determined by drying at 105°C for 20 h and organic matter (OM) concentration by ashing at 600°C for 2 h. Oven DM concentration of the silages was corrected for the loss of volatiles according to Huida et al. (1986). After drying, the samples were milled using a sample mill (Sakomylly KT-3100, Koneteollisuus Oy, Helsinki, Finland) and 1 mm sieve. The CP content of feeds was determined using a Dumas-type N analyzer (Leco FP-428; Leco Corporation, St Joseph, MI, USA) (AOAC Official Method 968.06) (AOAC, 1990). Concentration of NDF was determined as described by Huuskonen et al. (2016) and starch as described by Huuskonen et al. (2014 b). The silages were analyzed for D-value as described by Huhtanen et al. (2006). The pepsin-cellulase solubility values were converted to *in vivo* digestibility using correction equations based on a data set comprised of Finnish *in vivo* digestibility trials (Huhtanen et al., 2006).

Apparent diet digestibility was determined for all animals when the bulls were 517 kg LW, on average. Fecal grab samples (2×200 g) were obtained from each animal via rectal palpation twice a day (at 0700 and 1500 hours) during the five-day collection period. Fecal samples were stored at −20°C and at the end of the sampling period samples were thawed and pooled per individual bull on an equal-weight basis.

Also feed samples were collected daily during the collection period. The feed and fecal samples were analyzed for DM, ash and CP 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) concentration of the grass silage was calculated from the concentration of DOM using the equation ME (MJ/kg DM) = 16.0 (MJ/kg DM) × DOM (kg/kg DM) (MAFF, 1984). For whole-crop silages a coefficient of 15.5 instead of 16.0 was used (MAFF, 1984). The ME concentrations of the concentrate feeds were calculated based on concentrations of digestible crude fiber, CP, crude fat and nitrogen-free extract described by MAFF (1984). The digestibility coefficients of the concentrates were taken from the Finnish Feed Tables (Luke, 2017). The metabolizable protein (MP) and PBV values were calculated according to the Finnish feed protein evaluation system (Luke, 2017).

The bulls were weighed on two consecutive days at the beginning of the experiment and thereafter single weighings were done approximately every 28 days. Before slaughter the bulls were weighed on two consecutive days. The LWG was calculated as the difference between the means of the initial and final LW divided by the number of growing days. Intakes of concentrates and silage were recorded daily. Overall, total DM intake (concentrate and silage) and feed efficiency (kg DM/kg LWG and MJ/kg LWG) were also calculated.

Statistical methods

The data were subjected to analysis of variance using the SAS GLM procedure (version 9.4, SAS Institute Inc., Cary, NC).

The model used was:

$$y_{ijkl} = \mu + \gamma_k + \alpha_i + \beta_j + (\alpha \times \beta)_{ij} + e_{ijkl},$$

where: μ is the intercept and e_{ijkl} is the random error term associated with l^{th} bull. α_i and β_j are the fixed effects of i^{th} forage type (GS, WCB, WCW) and j^{th} protein supplementation (RSM−, RSM+), respectively, while γ_k is the random effect of the block (k=1,...,5). Differences between the treatments were tested using orthogonal contrasts: (1) RSM+ vs. RSM−, (2) GS vs. WCB, (3) GS vs. WCW, (4) WCB vs. WCW, and (5) interaction between forage type and RSM supplementation. P-values less than 0.05 are reported as statistically significant. In addition, when a P-value around 0.10 is obtained it is discussed in the text.

Results

Chemical composition and feeding values of the experimental feeds are presented in Table 1. The DM content of WCB and WCW silages was 37 and 29% higher, respectively, compared to GS. The grass silage had a higher CP concentration (173 g/kg

DM) than WCB (84 g/kg DM) and WCW (64 g/kg DM) silages. Further, GS had a 3 and 13% higher ME content compared to WCB and WCW silages, respectively, and also a higher PBV value (Table 1). Whole-crop barley silage had a lower NDF and higher starch content compared to WCW. Barley grain and RSM used in the experiment had typical chemical compositions and feed values, corresponding to the average values in the Finnish Feed Tables (Luke, 2017).

Table 1. Chemical composition and feeding values of the feeds used in the feeding experiment

	Grass silage	Barley silage	Wheat silage	Barley grain	Rapeseed meal
Number of samples	6	6	6	3	3
Dry matter (DM) (g/kg feed)	253	347	326	860	890
Organic matter (OM) (g/kg DM)	918	948	946	982	921
Crude protein (g/kg DM)	173	84	64	126	386
Neutral detergent fiber (g/kg DM)	591	494	563	199	284
Starch (g/kg DM)	8	312	88	672	10
Metabolizable energy (MJ/kg DM)	10.5	10.2	9.3	13.3	11.6
Metabolizable protein (g/kg DM)	82	76	68	98	170
Protein balance in the rumen (g/kg DM)	51	–30	–38	–20	159
Digestible OM in DM (g/kg DM)	655	655	602		
Fermentation quality of the silages					
pH	3.97	4.26	4.07		
volatile fatty acids (g/kg DM)	21	7	15		
lactic + formic acid (g/kg DM)	51	23	25		
in total N (g/kg)					
NH_4N	62	70	82		
soluble N	442	518	594		

In the GS-based diets, the PBV value fulfilled the Finnish recommendation for growing cattle (PBV of the diet above −10 g/kg DM for animals above 200 kg LW) being 22 and 29 g/kg DM for GS RSM− and GS RSM+ diets, respectively. In the whole-crop silage-based diets the PBV values were lower than recommended being −26, −18, −30 and −22 g/kg DM for WCB RSM−, WCB RSM+, WCW RSM− and WCW RSM+ diets, respectively.

There was an interaction between forage type and RSM supplementation for silage (P=0.05) and total DMI (P=0.06) (Table 2). Rapeseed meal supplementation increased both silage and total DMI in the whole-crop-based feeding treatments but not in the GS feeding. Silage intake increased 22 and 15% in the WCB and WCW feedings, respectively, as a result of RSM supplementation. Replacing GS by WCW decreased both silage and total DMI of the bulls (P<0.05) but this effect was evident only in the RSM− treatments (Table 2). Furthermore, replacing GS by WCB tended (P=0.09) to decrease total DMI of the bulls in the RSM− feeding. There was no difference in silage or total DMI between WCB and WCW treatments.

Table 2. Effects of forage type and rapeseed meal (RSM) supplementation on daily feed intake, apparent diet digestibility, growth performance and feed conversion of growing bulls

Forage type	GS		WCB		WCW		SEM	Polynomial contrasts (P-values)				
RSM supplementation	–	+	–	+	–	+		1	2	3	4	5
n	5	5	5	5	5	5						
Duration of the experiment (d)	168	168	168	168	168	168	-	-	-	-	-	-
Intake parameters												
silage (kg dry matter (DM)/d)	5.88	5.64	4.86	5.91	4.79	5.49	0.267	0.03	0.16	0.03	0.37	0.05
barley grain (kg DM/d)	4.00	3.76	3.89	3.49	3.80	3.50	0.193	0.06	0.33	0.24	0.85	0.58
rapeseed meal (kg DM/d)	0.00	0.44	0.00	0.44	0.00	0.45	0.001	<0.001	0.30	0.85	0.23	0.48
total (kg DM/d)	9.88	9.84	8.75	9.84	8.59	9.44	0.338	0.03	0.09	0.02	0.41	0.06
metabolizable energy (MJ/d)	114.9	114.4	101.1	111.6	95.3	103.0	3.79	0.07	0.03	<0.001	0.07	0.06
crude protein (g/d)	1513	1614	904	1115	784	961	35.1	<0.001	<0.001	<0.001	<0.001	0.06
metabolizable protein (g/d)	874	907	751	867	699	792	28.1	0.002	0.007	<0.001	0.03	0.06
protein balance in the rumen (g/d)	220	283	-224	-177	-258	-208	11.0	<0.001	<0.001	<0.001	0.006	0.63
Initial live weight (kg)	436	456	434	429	432	434	28.4	0.80	0.61	0.65	0.96	0.90
Final live weight (kg)	670	696	650	660	615	648	26.2	0.28	0.29	0.06	0.37	0.61
Live weight gain (g/d)	1394	1428	1286	1376	1087	1274	75.7	0.10	0.29	0.005	0.06	0.55
Feed conversion												
kg DM/kg live weight gain	6.96	6.47	8.18	6.77	8.52	7.25	0.514	0.02	0.14	0.03	0.44	0.69
MJ/kg live weight gain	78	74	93	77	96	83	6.1	0.04	0.17	0.03	0.44	0.68
Apparent digestibility coefficients												
dry matter	0.754	0.741	0.699	0.668	0.610	0.625	0.013	0.37	<0.001	<0.001	<0.001	0.25
organic matter	0.771	0.756	0.716	0.687	0.628	0.646	0.014	0.44	<0.001	<0.001	<0.001	0.26
crude protein	0.719	0.754	0.632	0.673	0.546	0.664	0.016	<0.001	<0.001	<0.001	0.007	0.03

Forages: GS = grass silage, WCB = whole-crop barley silage, WCW = whole-crop wheat silage. SEM – Standard error of mean. Polynomial contrasts: 1= RSM+ vs. RSM−, 2 = GS vs. WCB, 3 = GS vs. WCW, 4 = WCB vs. WCW, 5 = interaction between forage type and RSM supplementation.

There tended to be an interaction between forage type and RSM supplementation for ME, CP and MP intake (P=0.06). The inclusion of RSM tended (P=0.07) to increase ME intake in the whole-crop silage-based feedings but not in the GS feeding. In addition, the RSM inclusion tended to increase CP and MP intakes more in the whole-crop silage-based feedings compared to the GS feeding (Table 2). Replacing GS by whole-crop silages decreased ME, CP, MP and PBV intakes of the bulls (Table 2). Further, CP, MP and PBV intakes were higher and ME intake tended (P=0.07) to be higher in the WCB- compared to the WCW-based feeding.

Replacing GS by whole-crop silages decreased DM, OM and CP digestibilities (P<0.001) (Table 2). In addition, the digestibility coefficients were higher in the WCB-based feeding compared to the WCW-based feeding. The CP digestibility was higher in the RSM+ diets compared to the RSM− diets, but RSM supplementation had no effect on the DM and OM digestibilities.

Average daily LWG for the GS, WCB and WCW feedings were 1411, 1331 and 1181 g/d, respectively. Replacing GS with WCW decreased LWG of the bulls (P<0.01) but there was no significant difference in LWG between GS and WCB treatments (Table 2). The LWG tended to be higher (P=0.06) in the WCB-based feeding compared to that of WCW. Rapeseed meal supplementation tended to increase (P=0.10) daily LWG 7 and 17% in WCB and WCW feeding, respectively, but only 2% in GS feeding. This implies an interaction between forage type and RSM supplementation for LWG, which was, however, not evident statistically.

There were no significant interactions between forage type and RSM supplementation for feed conversion rates. The RSM inclusion improved both DM and energy conversion rates (P<0.05) (Table 2). Replacing GS by WCW impaired DM and energy conversion (P<0.05) but there was no significant difference between GS and WCB treatments. Still, no significant difference between WCB and WCW was observed in feed conversion.

Discussion

Although both WCW and WCB silages were harvested at the early dough stage, WCW had a higher NDF and lower starch content compared to WCB, which affected differences in energy content and probably also performance parameters. The same phenomenon (variability in the carbohydrate concentration at the same growth stage) has been found earlier in several experiments that have been carried out in the Nordic countries (e.g. Kristensen, 1992; Nadeau, 2007; Jaakkola et al., 2009; Wallsten et al., 2009). Also Givens et al. (1993) recognized that the growth stage alone is not a good guide to the composition of whole-crop cereals because the assessment of growth stage is a subjective technique and also other factors such as plant cultivar and cutting height have an influence.

Consistent with earlier studies (Abdalla et al., 1999; Sinclair et al., 2003; Huuskonen, 2013) the apparent digestibility of the whole-crop-based diets was lower than that of the GS diet. The digestibility of whole-crop cereals is highly dependent on the proportion of straw and varies considerably between studies (Sinclair et al., 2003). In general, it is rather challenging to make fair comparisons between feeds from different plant species, because there is variation in nutritional quality between plant species as well as between plant cultivars.

In accordance with Huuskonen (2009, 2011, 2013), the apparent CP digestibility increased with protein supplementation. Most of this increase was probably only apparent, i.e. related to the decreased proportion of fecal metabolic nitrogen recovered in feces, when the CP content increased and the true digestibility of dietary CP is generally almost complete (Huhtanen et al., 2006).

Similar to many earlier studies in grass silage-barley-based diets (Huuskonen, 2009, 2011; Pesonen et al., 2013), protein supplementation had no effects on diet DM or OM digestibility (OMD). Most of the experiments in which protein supplementation resulted in positive effects on OMD or fiber digestion have been conducted with extensively or poorly fermented silages. With grass silage-based diets, inclusion of a protein feed has been found to improve OMD when poor fermentation quality silages have been used (Gill and England, 1984; England and Gill, 1985). With well-preserved silages, the inclusion of a protein feed in the diet had only a small effect (Aronen et al., 1992; Steen, 1992) or no effect at all (Steen, 1988, 1989; Aronen, 1990). In the present experiment all silages were treated with a formic acid-based additive and the fermentation characteristics of silages were good, as indicated by the low pH value and the low concentrations of ammonia N and total fermentation acids. Therefore, it was logical that no effect of RSM supplementation on OMD was observed.

The lower apparent digestibility of WCW compared to the GS and WCB diets probably explains the differences in LWG among the forage types. The higher energy content and OMD of the GS and WCB diets compared with WCW was reflected also as larger daily ME intake of the bulls. The difference in ME intake is probably a crucial explanation for the improved growth rate of the GS and WCB bulls compared to the WCW bulls. For example, a recent meta-analysis by Huuskonen and Huhtanen (2015) demonstrated that energy intake is clearly the most important variable affecting LWG of growing cattle.

As expected, RSM supplementation increased feed and nutrient intake and improved gain in the whole-crop-based feedings in which the PBV values were lower than recommended. Also a meta-analysis of the data from feeding trials in growing cattle (Huuskonen et al., 2013) indicated that increasing the concentration of CP in the concentrate by replacing energy supplements with protein supplements had a positive effect on DMI. However, intake response to protein supplementation reported by Huuskonen et al. (2013) was minimal with a maximum predicted response less than 2%; that is much smaller than the corresponding response in lactating cows (Huhtanen et al., 2008) or the responses in the whole-crop feedings in the present experiment.

Intake responses to protein supplementation in ruminants have been discussed to be associated with improved OMD related to: (1) overcoming deficiency of rumen degradable N, (2) higher intrinsic rate and potential extent of fiber digestion of protein supplements, (3) better rumen conditions for fiber digestion due to reduced dietary starch content and (4) stimulation of cellulolytic bacteria by amino acids (AA) and peptides derived from supplementary protein (Huuskonen et al., 2013). However, RSM supplementation did not affect OMD in the present experiment, which does not support any of these mechanisms. Increasing intake responses to supplementary protein observed in the present experiment with whole-crop silage-based diets support the concept that other factors, such as improved AA to ME balance at the tissue level, can also be involved. Huuskonen et al. (2013) suggested that a possible explanation could be an increased and/or more balanced supply of AA with protein supplementation, which improves performance, and DMI is increased as a result of increased energy demand. Such a "pull effect" could explain intake responses in the present experiment as supplementary protein increased LWG in the WCB- and WCW-based diets.

A limitation of the present study is the absence of carcass data. It is possible that there would have been some differences, especially among the forage diets, in dressing proportion and thus, some advantages observed in LWG would be negated expressed as carcass gain. However, in earlier Finnish feeding experiments no differences in dressing proportion between grass silage and whole-crop silage feedings or among different whole-crop silage feedings were observed (Huuskonen and Joki-Tokola, 2010; Huuskonen, 2013; Huuskonen et al., 2016).

Conclusions

Replacing moderately digestible grass silage with whole-crop wheat silage decreased LWG of growing bulls due to lower energy intake and poorer feed conversion rate. Corresponding differences were not observed when replacing grass silage with whole-crop barley. However, if higher nutritive value grass silage had been used, the results could have been different. Nevertheless, the fairly high growth rates measured in the present study indicate that moderately digestible grass silage could be totally replaced by whole-crop barley silage in the diet of growing bulls. If production costs of whole-crop cereals are lower than those of grass silage and including them in crop rotation brings benefits, using them may increase overall farm profitability. Rapeseed meal supplementation increased feed intake and improved feed conversion and growth performance of the bulls in whole-crop-based diets. This indicates that there is need for protein supplementation in the diet of growing bulls when the diet PBV values were lower than −20 g/kg DM.

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