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Intake, gain and carcass traits of Hereford and Simmental bulls offered total mixed rations based on red clover and whole-crop barley silages

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Total mixed rations (TMR) based on red clover silage (RS), whole-crop barley silage (BS) and mixture of RS and BS were fed to thirty Hereford (HF) and thirty Simmental (SI) bulls. The proportion (g kg^{-1} dry matter (DM)) of the silages in the TMRs were as follows: (1) RS (600); (2) BS (600); (3) RS (300) and BS (300). Concentrate proportion was 400 g kg^{-1} DM. Breed × feeding interactions were observed for intake parameters. Replacing RS by BS tended to increase DM and nutrient intake more in the SI compared to the HF breed. For growth performance a significant quadratic effect was observed for the dietary treatments; both the live weight gain and carcass gain were the highest when RS was partially replaced by BS. There were no differences in carcass weight, dressing proportion or carcass conformation among the dietary treatments. However, replacing RS by BS increased carcass fatness. The SI bulls had higher growth rate and they produced better conformed carcasses and less fat compared to the HF bulls.

Key words: beef production, feeding, growth performance, *Hordeum vulgare*, *Trifolium pratense*

Introduction

In the Nordic countries most of the forages fed to growing and finishing cattle are based on ensiled mixtures of different grasses and red clover (*Trifolium pratense*). Although timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*) are the two most common species used in forage grass production in Finland (Termonen et al. 2020), forage legumes, particularly clovers, may play an increasingly significant role in the future. Phelan et al. (2015) stated that the primary agronomic benefits of forage legumes are their contribution to the nitrogen (N) economy of agricultural land due to their ability to fix atmospheric N_2 by the symbiotic *Rhizobium* bacteria in their root nodules and their ability to increase herbage production, herbage feed value and ultimately ruminant production of meat and milk, particularly in areas of low fertilizer N input. Therefore, forage legumes are a vital part of low input and organic beef production systems.

In boreal leys red clover is typically cultivated as a mixture with grasses. However, there are some challenges associated with mixed cultivation of clover and grasses (Rinne et al. 2023). Firstly, the proportion of red clover can be highly variable over the years due to winter damage (Rinne et al. 2023). In addition, the proportion of red clover is also generally lower in the primary growth after winter than in the regrowth (Rinne and Nykänen 2000). Furthermore, the red clover content may be highly variable even within the field (Nykänen et al. 2008). These factors result in an unpredictable proportion of red clover in the harvested forage, which makes efficient ration formulation for livestock difficult. One solution could be to cultivate red clover as a pure stand and mix it at the total mixed ration (TMR) preparation stage to be able to create optimized rations for different animal groups. If red clover is produced as pure stands instead of mixtures with grasses, compromises in N fertilization, plant protection and harvest time are not required, and this may favour the longevity of red clover.

Pure red clover stands typically contain crude protein (CP) between 190–235 g kg^{-1} dry matter (DM) depending on the harvesting stage (Luke 2024). The relatively high CP content may be helpful in providing a N source for rumen microbes but if N is provided in excess, it results in poor N use efficiency in growing and finishing cattle (Huuskonen et al. 2014), and consequently increased N emissions to the environment. Therefore, supplementing pure red clover silage with a low CP content silage would probably be the best option when feeding growing and finishing cattle with red clover-based silage. One option could be small grain cereal based whole-crop silages which also provide an opportunity to improve forage production efficiency for ruminants under the Nordic conditions (Rustas 2009, Huuskonen et al. 2016, Manni et al. 2021). In Finland, barley (*Hordeum vulgare*) has been the dominant small grain cereal species utilized for whole crop silage production, but oats (*Avena sativa*), wheat (*Triticum aestivum*) and triticale (*X Triticosecale*) are also used (Huuskonen et al. 2017a, 2020).

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Both red clover and whole-crop silages have had positive effects as a forage source for both dairy and beef cattle, such as increasing feed intake as a component in grass silage-based rations (Huhtanen et. al. 2007, Keady et al. 2013). In a meta-analysis of dairy cow feeding experiments the maximum silage DM intake (DMI) was obtained when the proportion of the whole crop silage was 0.48 of total silage DM (Huhtanen et. al. 2007). Bertilsson and Murphy (2003), Dewhurst et al. (2003) and Kuoppala et al. (2009) have observed that higher silage DMI was found for dairy cows consuming mixed forage diets compared to cows that received only one forage. However, to our best knowledge, there is a lack of published information on the intake, growth performance and carcass quality of growing and finishing bulls when red clover silage (RS) is partly or completely replaced by whole-crop barley silage (BS).

In the present experiment, we wanted to compare the use of RS and BS in a typical Finnish feeding method of growing and finishing bulls, using a concentrate level of 400 g kg^{-1} DM. The feeding experiment was carried out with two beef breeds, Hereford (HF) and Simmental (SI), which were chosen because they are common beef breeds used in Finland. In addition, we wanted to test possible breed × feeding interactions, when two different breed types, early maturing British and late maturing Continental, were used. The objective of the study was to evaluate the effects of partially or completely replacing RS by BS on intake, growth performance and carcass traits of growing and finishing HF and SI bulls. It was hypothesized that partially replacing RS by BS in the diet could increase DMI and growth performance of the bulls compared to animals that receive only one forage. In addition, it was hypothesized that there are no interactions between breed and feeding treatments on animal performance.

Material and methods

Animals and housing

A feeding experiment was carried out in the experimental barn of Natural Resources Institute Finland (Luke) in Ruukki starting in January 2022 and ending in August 2022. The feeding experiment was conducted using thirty purebred SI and thirty purebred HF bulls which were purchased and transported from commercial herds. The HF bulls were from six and the SI bulls from five different sires. The spring born bull calves spent their first summer at pasture with their dams. After weaning the calves were moved to the experimental barn of Luke on average at seven months of age, two months before the start of the feeding experiment. During this pre-experimental period the calves were adapted to the housing conditions and the grass silage plus barley grain-based feeding. The calves remained healthy throughout the pre-experimental period. At the start of the feeding experiment HF and SI bulls were on average 269 (±21.1) and 264 (±19.2) days old and weighed 371 (±39.7) and 436 (±57.9) kg, respectively. They were managed according to the Finnish legislation regarding the use of animals in scientific experimentation. This study design was reviewed and approved by Animal Welfare body (Government decree 564/2013 22§) of Natural Resources Institute Finland. Project authorization was not needed as the experiments did not cause the animals a level of pain, suffering, distress or lasting harm equivalent to, or higher than, that caused by the introduction of a needle (2010/63/EU).

The bulls were housed in an uninsulated barn in pens (10.0 m × 5.0 m) in groups of 5 bulls in each pen, providing 10.0 m^2 per bull. The rear half of the pen area was a peat-bedded lying area, and the fore half was a feeding area with a solid concrete floor. A Vytelle feed intake system (model 4000E; Vytelle Ltd., Airdrie, AB, Canada) was used to record individual daily feed intakes so that each pen contained two feeder nodes. The bulls had free access to water during the whole feeding experiment.

Feeding and experimental design

At the beginning of the feeding experiment, both SI and HF bulls were randomly allotted to pens which were randomly allotted to the feeding treatments so that each feeding treatment included two SI pens and two HF pens (10 SI bulls and 10 HF bulls per feeding treatment). The three experimental diets included RS or BS as sole forage or a mixture of RS and BS (1:1 on DM basis, RBS) (Table 1). The silage proportion (600 g kg^{-1} DM) and the proportions of rolled barley (385 g kg^{-1} DM) and mineral-vitamin mixture (15 g kg^{-1} DM) were the same in each diet (Table 1). The bulls were fed TMR *ad libitum* (proportionate refusals of 5%). Rations were mixed in a mixer wagon (Trioliet, BW Oldenzaal, the Netherlands) once a day. Two SI bulls from RS diet and one HF bull from RBS diet were excluded from the study due to hoof problems. There was no reason to suppose that the experimental diets had caused these problems. The other 57 bulls remained healthy throughout the study.

Table 1. The proportion (g kg^{-1} dry matter) of the feeds in the experimental diets

Treatment	RS	RBS	BS
Red clover silage	600	300	
Barley silage		300	600
Rolled barley grain	385	385	385
Mineral-vitamin mixture	15	15	15

Both experimental silages were produced at the experimental farm of Luke in Ruukki (64°44’N, 25°15’E). Red clover variety was Selma (Boreal Plant Breeding Ltd., Jokioinen, Finland) and the stand was one year old. It was cut by using a mower conditioner (Elho 280 Hydro Balance, Oy Elho Production Ab, Pännäinen, Finland), wilted for approximately 24 hours after cutting, and harvested using a precision-chop forage harvester (New Holland FX 60, CNH Industrial N.V., Amsterdam, the Netherlands). Spring-sown barley (cv. Wolmari, four-rowed, Boreal Plant Breeding Ltd., Jokioinen, Finland) was used as whole crop silage. It was harvested at the soft dough stage (growth stage Z85; Zadoks et al. 1974) of the cereal using a direct-cut flail harvester (Claas Jaguar 970, Claas Group, Harsewinkel, Germany) and at a stubble height of about 10 cm. Both silages were ensiled in bunker silos and treated with a formic acid-based additive (AIV ÄSSÄ Na, Eastman, Oulu, Finland) applied at a rate of 5.8 kg t^{-1} of fresh forage.

Spring-sown barley (cv. Brage) was used as a cereal grain in the present experiment. It was harvested with a conventional combine harvester, dried to the targeted DM concentration of 870–880 g kg^{-1} and stored in a vertical silo. The grain was rolled within 7 days prior to feeding. The composition of the mineral-vitamin mixture used in the present feeding experiment (Kasvuape E-Hiven; A-Rehu Ltd., Seinäjoki, Finland) is fully described by Huuskonen et al. (2017b).

Feed sampling and analysis

During the feeding experiment silage sub-samples were taken twice a week, pooled over periods of four weeks and stored at –20 °C prior to analyses. Thawed samples were analyzed for DM, ash, CP, neutral detergent fibre (NDF) assayed with a heat stable amylase and expressed exclusive of residual ash, indigestible NDF (iNDF), silage fermentation quality [pH, water-soluble carbohydrates (WSC), lactic and formic acids, ethanol, volatile fatty acids, soluble and ammonia N content of total N], and digestible organic matter (DOM) in DM (DOMD, D-value). Barley grain sub-samples were collected weekly, pooled over periods of eight weeks and analyzed for DM, ash, CP and NDF. The DM, ash, CP, NDF and DOMD were determined by standard methods as described by Huuskonen et al. (2020a,b). Fresh silage samples were analyzed for fermentation characteristics by electrometric titration as described by Moisio and Heikonen (1989).

The metabolizable energy (ME) concentration of RS was calculated as ME (MJ kg^{-1} DM) = 16.0 × DOMD (kg kg^{-1} DM) (MAFF 1984). For BS, a coefficient of 15.5 instead of 16.0 was used (MAFF 1984). The ME concentration of barley grain and mineral-vitamin mixture was calculated based on the tabulated digestibility coefficients and analyzed chemical composition, except that for crude fibre and crude fat concentrations tabulated values were used (Luke 2024). In the Scandinavian feed protein evaluation system (Madsen et al. 1995), the protein value of the diet is expressed as amino absorbed from the small intestine (metabolizable protein, MP) and the protein balance value in the rumen (PBV), which describes the balance between the dietary supply of rumen-degradable protein (RDP) and the microbial requirements for RDP. In the present study MP and PBV values of the feeds were calculated using the Finnish version (Tuori et al. 1998, Luke 2024) of the Scandinavian feed protein evaluation system. The relative intake potential of silage DM (SDMI index) was calculated as described by Huhtanen et al. (2007).

Live weight and carcass measurements

The bulls were weighed on two consecutive days at the beginning of the experiment and thereafter approximately every 28 days. Before slaughter they were weighed on two consecutive days. The target for the average carcass weight was 370 kg and 430 kg for HF and SI bulls, respectively. The bulls were selected for slaughter based on LW and assumed dressing proportions of 530 and 550 g kg^{-1} for HF and SI bulls, respectively, which were assessed based on earlier studies (Pesonen 2020) in Finland with beef breed bulls. The LW gain (LWG) was calculated as the difference between the means of the initial and final LW 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 at the beginning of the experiment divided by the number of growing days. The carcass weight at the start of the experiment was assumed to be 0.50 and 0.52 × initial LW for HF and SI bulls, respectively, because previous trials have found a similar difference in dressing proportions between these breeds (Huuskonen and Pesonen 2017, Huuskonen et al. 2018).

Ultrasound measurements were taken one day before slaughter. Ultrasound subcutaneous fat (mm) at the first lumbar vertebrae, ultrasound depth (cm) and area (cm^2) of *longissimus dorsi* muscle at the first lumbar vertebrae and ultrasound intramuscular fat (IMF) (%) were performed as described by Huuskonen and Pesonen (2017) with a Pie 200 SLC scanner (FPS 8; DFR 2–4 inches) equipped with the QUIP (Quality Ultrasound Indexing Program) software (Version 2.6) and a ASP-18 transducer (3.5 MHz) without a stand-off pad.

The bulls were slaughtered at the Atria Ltd. commercial slaughterhouse in Kauhajoki, Finland in two batches. All three dietary treatments were represented in both batches. After slaughter 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 graded for conformation and fat score in accordance with the EU beef carcass classification scheme on a continuous 15-point scale (Conroy et al. 2010).

Statistical methods

The results are shown as least squares means. The data were subjected to analysis of variance using the SAS GLM procedure (version 9.4, SAS Institute Inc., Cary, NC, USA). The statistical model used was

$$y_{ijklm} = \mu + \delta_k + \alpha_i + \gamma_j + (\alpha\times\gamma)_{ij} + \theta_{ijm} + \beta x_{ijkl} + e_{ijklm}$$

where μ is the intercept and e_{ijklm} is the residual error term associated with l^{th} animal. α_i, γ_j and $(\alpha\times\gamma)_{ij}$ are the effects of i^{th} diet (RS, RBS, BS) and j^{th} breed (SI, HF) and their interaction, respectively, while δ_k is the effect of the slaughtering batch (k=1,2) and θ_{ijm} is the effect of pen. The effect of pen was used as an error term when differences between treatments (diet, breed and their interaction) were compared because treatments were allocated to animals penned together. Initial LW was used as a covariate (βx_{ijkl}) in the model.

Differences between the treatments were tested using orthogonal contrasts: (1) breed (SI vs. HF); (2) linear effect of BS inclusion; (3) quadratic effect of BS inclusion; (4) linear interaction between breed and BS inclusion, and (5) quadratic interaction between breed and BS inclusion.

Results

Feeds

Chemical composition and feeding values of the experimental feeds used in the present experiment are available in Table 2. Due to the rainy weather conditions during RS harvesting, the DM content of RS was 34% lower compared BS. According to feed analyses, the RS had 24% higher CP concentration and 12% higher iNDF content compared to BS. The BS had 3% higher ME concentration as well as 20% higher SDMI index compared to RS. The fermentation characteristics of both RS and BS were good as indicated by the low pH value and the low concentrations of ammonia N in total N and total fermentation acids (Table 2). The barley grain had typical chemical compositions and feeding values, corresponding to the average values in the Finnish Feed Tables (Luke 2024). Due to differences in composition of the experimental silages, replacing RS partially or completely by BS reduced the CP and PBV content but increased DM and ME content of TMR.

Table 2. Chemical composition and feeding value (mean ± standard deviation) of the experimental feeds and calculated chemical compositions and feeding values of the total mixed rations used in the feeding experiment

	Feeds				Total mixed rations		
	Red clover silage	Barley silage	Rolled barley	Mineral-vitamin mixture	RS[1]	RBS[2]	BS[3]
Number of feed samples	8	8	8	2			
Dry matter (DM), g kg^{-1}	243±24.9	368±28.5	885±2.1	986±0.9	351	412	498
Organic matter (OM), g kg^{-1} DM	918±9.7	929±7.5	978±0.3	65±0.5	942	945	948
Crude protein, g kg^{-1} DM	135±23.5	109±12.4	117±5.4	9±0.2	128	120	112
Neutral detergent fibre (NDF), g kg^{-1} DM	505±23.1	498±23.1	213±28.4	24±0.4	388	386	384
Indigestible NDF, g kg^{-1} DM	137±13.3	122±11.0	ND[4]	ND			
Metabolizable energy, MJ kg^{-1} DM	9.4±0.21	9.7±0.29	13.1±0.19	5.0±0.1	10.9	11.0	11.1
Metabolizable protein, g kg^{-1} DM	76±3.9	76±2.4	96±1.0	5±0.2	84	84	84
Protein balance in the rumen, g kg^{-1} DM	23±19.6	–5±11.2	–28±5.5	1±0.1	3	–6	–14
Digestible OM in DM, g kg^{-1} DM	585±12.2	626±18.1	ND	ND			
Silage DM intake index	97±4.7	116±3.5					
Fermentation quality of silages							
pH	3.99±0.199	4.40±0.643					
Volatile fatty acids, g kg^{-1} DM	20±4.2	11±6.1					
Lactic + formic acid, g kg^{-1} DM	72±20.3	26±14.8					
Water soluble carbohydrates, g kg^{-1} DM	28±26.4	68±11.3					
NH_4N in total N, g kg^{-1}	38±17.4	39±17.4					

[1]Red clover silage (600 g kg^{-1} DM), rolled barley (385 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM). [2]Red clover silage (300 g kg^{-1} DM), whole-crop barley silage (300 g kg^{-1} DM), rolled barley (385 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM). [3]Whole-crop barley silage (600 g kg^{-1} DM), rolled barley (385 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM). [4] Not determined.

Intake, growth performance and feed conversion

The feeding experiment lasted 223 days and the slaughter age of the bulls was 490 days, on average across all treatment combinations (Table 3). No significant breed × feeding interactions for the slaughter age or final LW were observed. There was no difference in slaughter age among the dietary treatments, but the SI bulls were 15 d younger at slaughter compared to the HF bulls (p <0.05). The final LW of the SI bulls was 12% higher (p <0.001) compared to the HF bulls, but there were no differences among dietary treatments in the final LW.

For DM, ME, CP and MP intake a significant breed × feeding interaction (ME, MP) or a tendency for interaction (DM, CP) were observed (Table 3). Replacing RS by BS increased DM, ME and MP intakes of the bulls, both linear and quadratic effects being significant, but the increasing effect was higher in the SI bulls compared to the HF bulls.

No significant breed × feeding interactions for the LWG or carcass gain were observed. The LWG and carcass gain of the SI bulls were 13 and 18% higher, respectively, compared to the HF bulls (p <0.001). A significant quadratic effect (p <0.05) was observed for the dietary treatments because both the LWG and carcass gain were the highest when RS was partially replaced by BS (Table 3).

No significant breed × feeding interactions for the DM, ME or CP conversion rates were observed. Breed had no effects on DM,ME or CP conversion rates. When comparing dietary treatments both linear and quadratic effects of BS inclusion were significant. The DM, ME and CP conversion rates were clearly the weakest when RS was completely replaced by BS. Instead, the differences in feed conversion were not so clear between RS and RBS (Table 3).

Carcass characteristics

No significant breed × feeding interactions for the carcass weight, dressing proportion or carcass conformation were observed (Table 3). Furthermore, there were no significant differences in carcass weight, dressing proportion or carcass conformation score among the dietary treatments. The SI bulls had 17% higher carcass weight, 4% higher dressing proportion and 31% better conformed carcasses compared to the HF bulls (p <0.001).

Table 3. Intake, growth performance and carcass traits of the Hereford and Simmental bulls fed different total mixed rations

Breed	Hereford			Simmental			SEM[4]	Orthogonal contrasts (*p*-values)[5]				
Feeding	RS[1]	RBS[2]	BS[3]	RS	RBS	BS		1	2	3	4	5
Number of observations	10	9	10	8	10	10						
Initial live weight, kg	367	370	377	434	437	437	18.1	<0.001	0.682	0.967	0.839	0.904
Duration of the experiment, d	232	234	220	216	212	227	8.9	0.140	0.942	0.966	0.170	0.224
Final live weight, kg	704	733	693	796	805	793	16.5	<0.001	0.625	0.092	0.773	0.356
Slaughter age, d	498	503	491	478	478	491	9.5	0.038	0.756	0.926	0.276	0.345
Intake												
Dry matter (DM) intake, kg d^{-1}	10.7	10.7	11.7	11.9	12.4	14.3	0.36	<0.001	<0.001	0.037	0.051	0.731
DM intake, g kg^{-1} metabolic LW	96	94	106	97	100	116	3.1	0.026	<0.001	0.008	0.095	0.958
Metabolizable energy (ME), MJ d^{-1}	116	117	129	130	136	157	3.9	<0.001	<0.001	0.043	0.047	0.735
Crude protein (CP), kg d^{-1}	1.35	1.27	1.31	1.50	1.47	1.59	0.040	<0.001	0.455	0.054	0.081	0.782
Metabolizable protein, kg d^{-1}	0.90	0.90	0.98	1.00	1.04	1.20	0.030	<0.001	<0.001	0.043	0.048	0.736
Live weight gain, g d^{-1}	1456	1555	1456	1694	1759	1576	69.4	<0.001	0.358	0.049	0.362	0.816
Carcass gain, g d^{-1}	798	851	765	965	987	891	39.2	<0.001	0.144	0.048	0.571	0.868
Feed conversion												
kg DM kg^{-1} carcass gain	13.5	12.7	15.5	12.5	12.7	16.2	0.061	0.788	<0.001	<0.001	0.153	0.845
MJ ME kg^{-1} carcass gain	147	139	171	136	139	178	6.7	0.798	<0.001	<0.001	0.155	0.847
kg CP kg^{-1} carcass gain	1.70	1.51	1.74	1.57	1.51	1.80	0.071	0.660	0.042	0.001	0.131	0.795
Carcass characteristics												
Carcass weight, kg	368	384	355	433	434	429	10.4	<0.001	0.359	0.137	0.637	0.236
Dressing proportion, g kg^{-1}	523	523	512	544	538	540	4.7	<0.001	0.104	0.826	0.423	0.194
Conformation, EUROP	7.6	7.6	7.7	10.4	10.2	9.3	0.35	<0.001	0.138	0.634	0.075	0.418
Fat score, EUROP	6.0	7.8	8.9	4.3	5.3	5.2	0.43	<0.001	<0.001	0.194	0.018	0.720
Subcutaneous rump fat, mm	6.6	7.9	8.4	4.1	5.5	5.2	0.51	<0.001	0.003	0.123	0.514	0.595
Intramuscular fat, %	3.5	3.8	4.2	2.2	3.1	3.0	0.19	<0.001	<0.001	0.253	0.849	0.087
Depth of *longissimus dorsi* muscle, cm	6.8	6.7	6.9	7.5	7.6	7.7	0.17	<0.001	0.473	0.510	0.828	0.452
Area of *longissimus dorsi* muscle, cm^2	90	92	92	106	107	108	2.9	<0.001	0.404	0.822	0.909	0.821

[1]Red clover silage (600 g kg^{-1} DM), rolled barley (385 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM). [2]Red clover silage (300 g kg^{-1} DM), whole-crop barley silage (300 g kg^{-1} DM), rolled barley (385 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM). [3]Whole-crop barley silage (600 g kg^{-1} DM), rolled barley (385 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM). [4] Standard error of the mean. [5] Orthogonal contrasts: (1) Hereford vs. Simmental, (2) linear effect of whole-crop silage inclusion, (3) quadratic effect of whole-crop silage inclusion, (4) linear interaction between breed and whole-crop silage inclusion, and (5) quadratic interaction between breed and whole-crop silage inclusion.

For carcass fat score a significant ($p < 0.05$) breed × feeding interaction was observed. The carcass fat score of the HF bulls was 53% higher compared to the SI bulls ($p < 0.001$) and replacing RS by BS increased carcass fat score linearly ($p < 0.001$). However, the effect of dietary treatments on carcass fat score was greater in the HF bulls than in the SI bulls.

No significant breed × feeding interactions for the ultrasound measurements were observed (Table 3). Replacing RS by BS increased both subcutaneous rump fat and intramuscular fat but there were no differences in depth or area of *longissimus dorsi* muscle among the dietary treatments. The HF bulls had 55% higher subcutaneous rump fat thickness and 39% higher intramuscular fat percent compared to the SI bulls (p <0.001). In contrast, the SI bulls had higher depth and area of *longissimus dorsi* muscle compared to the HF bulls (p <0.001).

Discussion

Effects of breed

Typically, the DM intake of SI cattle is greater than other beef breeds (e.g. Bartoň et al. 2007, Romanzin et al. 2022). However, contrary to our hypothesis, there were some interactions between breed and dietary treatments in the present study. The DMI of the SI and HF bulls increased 20% and 9%, respectively, when RS was completely replaced by BS so replacing RS with BS tended to increase the DMI more in the SI than in the HF breed. The reason for this effect is not clear but DMI of these breeds might differ due to their evolutionary backgrounds. The SI breed has a higher maintenance requirement than HF (Ferrell and Jenkins 1985). Selective breeding has been used to improve the performance potential of late maturing SI bulls during the past decades (Hönig et al. 2020) and higher growth increases ME demand (Lawrence and Fowler 1997). Kelly et al. (2021) showed that genetically heavier cattle and those with faster growth rate have higher ME intake and a faster feeding rate which could result in higher DMI. Therefore, it is possible that the SI bulls were able to eat more BS with a higher SDMI index compared to RS than the HF bulls. Consistent with the present results, Pesonen and Huuskonen (2015) reported that SI bulls had 11% higher daily carcass gain compared to HF bulls in a data set collected from Finnish slaughterhouses.

Also, Gregory et al. (1994), Laborde et al. (2001) and Alberti et al. (2008) reported that the Continental breeds were superior in growth performance compared to British breeds. The lower dressing proportion of the HF bulls can be partly explained by lower carcass weight compared to the SI bulls because it is reported that the dressing proportion is increased by increasing carcass weight (Kempster et al. 1988). Nevertheless, Wheeler et al. (2005) stated that the carcasses from British breeds tended to have lower dressing percentage than Continental breeds at common fat thickness and fat trim percent endpoints.

Earlier, Pesonen and Huuskonen (2015) reported that the conformation score of the SI bulls was 21% higher compared to the HF bulls which is in line with the present results. Previously, Bartoň et al. (2006), Alberti et al. (2008) and Holló et al. (2012) also concluded that the EUROP conformation score is generally higher for Continental breeds compared to British breeds. Increased fat yields and higher fat deposition of early maturing British breeds relative to late maturing Continental breeds at constant times on feed have been reported previously for example by Pesonen (2020).

Effects of dietary treatments

According to feed analyses, BS had 20% higher SDMI index compared to RS and roughly the same difference was observed in the measured DMI when RS was completely replaced with BS. The treatment differences in the SDMI index and observed DMI are explained by the lower digestibility and DM content of RS compared to BS. Due to the wet weather conditions during harvesting, the DM concentration of RS was clearly lower compared to BS. Many studies have reported positive association between silage DM content and observed DMI (Steen et al. 1998, Wright et al. 2000, Huhtanen et al. 2007). Huhtanen et al. (2007) implied that silage DMI is independently affected by its DM concentration. In growing cattle Steen et al. (1998) observed that the maximum grass silage intake was achieved at a DM concentration of 320 g kg^{-1} while in dairy cows Huhtanen et al. (2007) reported that the maximum grass silage DMI was predicted at a DM concentration of 419 g kg^{-1}. The DM content of BS measured in the present study (368 g kg^{-1}) was clearly closer to the previously presented maximum intake values than that of RS (243 g kg^{-1}). Treatment differences in DMI can also be partly explained by a lower amount of total fermentation acids in BS compared to RS because the products of silage in-silo fermentation generally depress DMI (Wright et al. 2000, Huhtanen et al. 2007, Huuskonen et al. 2013). The fibre contents of silages were close to each other in the present experiment, so they probably do not explain the differences in DMI between dietary treatments.

The highest growth rates and the best feed and CP conversion rates were achieved when RS was partially replaced by BS. Generally, energy intake is the most important nutritional variable affecting LWG of growing and finishing cattle (Huuskonen and Huhtanen 2015). However, in the present experiment the highest DM and energy intakes and the lowest growth rates were measured with BS feeding. The reason for this is not clear. Theoretically, one reason could be related to the protein content of the diets. The CP concentration of whole-crop silages is commonly lower than that of moderately digestible grass silages (O'Kiely 2011, Huuskonen 2013, Huuskonen et al. 2017a) as observed also in the present study when compared to RS. The Finnish feeding recommendation for growing cattle above 200 kg LW is that diet PBV should be above -10 g kg^{-1} DM which ensures sufficient N supply for the needs of rumen microbes (Luke 2024). This was fulfilled in RS and RBS rations but not in BS ration, in which the PBV value was slightly lower than recommended. Compared to other dietary treatments, the growth performance results of the SI bulls on the BS ration were relatively weaker than those of the HF bulls. There is some evidence that protein requirements are relatively higher for bulls of late maturing breeds like SI, Charolais and Limousin compared to early maturing breeds like HF and Aberdeen Angus (Geay 1984). Therefore, it could be possible that the lowest PBV availability with BS diet restricted the growth of SI bulls even though their DM and ME intakes were the highest with BS diet. On the other hand, based on the meta-analysis of the growing and finishing cattle feeding experiments, Huuskonen et al. (2014) concluded that recommended PBV could be even lower than the current -10 g kg^{-1} DM without harmful effects on growth performance. Therefore, it is unlikely that differences in the PBV values of the diets would explain the observed differences in growth rates between the treatments.

According to our knowledge, no earlier comparisons between RS and BS in growing cattle feeding exist. However, replacing grass silage with BS has had conflicting results. The replacement of grass silage by BS has decreased (Huuskonen 2013), had no effect (Huuskonen and Joki-Tokola 2010) or increased (Huuskonen et al. 2020a) gain of growing and finishing cattle. Huuskonen (2013) observed poorer feed conversion ratio for BS-based diet compared grass silage-based diet whereas Huuskonen and Joki-Tokola (2010) and Huuskonen et al. (2020a) reported no difference in feed conversion between BS and grass silage-based diets. Nevertheless, the direct comparisons of experiments are challenging since the nutritive values and growth responses of whole-crop silages differ largely depending on the stage of plant maturity at harvest, cutting height, plant variety, growing and harvesting conditions as well as harvesting and storage techniques, which all affect the chemical composition, preservation quality and relative proportions of grain and straw (Wallsten 2008, Rustas 2009, Wallsten et al. 2009, Huuskonen et al. 2016).

According to literature, increasing energy intake typically increases carcass fat content (e.g. Patil et al. 1993, Schaake et al. 1993), which could explain the higher fat classification when RS was replaced by BS in the present study. It is also possible that the differences in carcass fatness are partly explained by used plant species. In several previous studies, replacing grass silage with silage containing red clover or alsike clover (*Trifolium hybridum*) has reduced carcass fatness in finishing cattle (Pesonen et al. 2014, Berthiaume et al. 2015, Huuskonen et al. 2017b). Respectively, replacing RS by BS increased carcass fat score, rump fat thickness and intramuscular fat percent in the present experiment. This could be related to the enzyme polyphenol oxidase (PPO) (Lee et al. 2009a). Red clover PPO has been associated with a reduction in the extent of proteolysis and lipolysis both in silo (Albrecht and Muck 1991, Lee et al. 2008) and in the rumen (Merry et al. 2006, Lee et al. 2007). This protection may be related to the formation of quinones produced by the PPO-catalyzed oxidation of vacuolar diphenols (Lee et al. 2009b). The reduction in the extent of proteolysis results in lower rumen degradation of red clover protein compared to most grass-based forages. Increasing the rumen-stable protein content of the diet would lead to improved N utilization and less nitrogenous waste. On the other hand, PPO has been reported to link proteins into more complex cross-linked polymers which make them resistant to microbial degradation (Lee et al. 2009a). The less degradation in the rumen will lead to more protein availability and absorption in the small intestine. Owens et al. (1995) concluded that there might be poor efficiency when excess protein or microbial protein is converted to fat as protein has less value for fat cell accumulation than carbohydrates or protein that is degraded within the rumen. There is some indication from previous studies that higher protein availability will produce less and low protein availability will produce more subcutaneous and intramuscular fat (Gibb et al. 2008, Bharanidharan et al. 2021, Jeon et al. 2021). Nevertheless, only increasing the CP content of the diet seems not to reduce carcass fatness. Based on a meta-analysis, Huuskonen et al. (2014) observed that increasing dietary CP concentration increased carcass fat score of growing and finishing cattle. However, although significant, the effect on fat score was quantitatively minimal (Huuskonen et al. 2014).

Conclusions

The later maturing SI bulls had higher growth rate and they produced better conformed carcasses and less fat compared to the earlier maturing HF bulls. Contrary to our hypothesis, breed × feeding interactions were observed for intake parameters. Replacing RS by BS tended to increase DM and nutrient intake more in the SI compared to the HF breed. Both RS and BS were suitable feeds for growing and finishing bulls. There were no differences in the carcass characteristics except for fatness that increased when RS was replaced with BS. However, mixed forage diets resulted in better performance of the bulls compared to the diets that included only one forage. Replacing RS partially by BS improved the growth performance and feed conversion of the bulls. Therefore, a partial replacement of RS by BS seems to be a recommended feeding strategy for growing and finishing beef bulls.

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