Effects of replacing different proportions of barley grain by rye grain on performance of growing and finishing dairy bulls

Arto Huuskonen[1] and Maiju Pesonen[2]

[1]Natural Resources Institute Finland (Luke), Production systems, Halolantie 31A, FI-71750 Maaninka, Finland
[2]Natural Resources Institute Finland (Luke), Production systems, Survontie 9A, FI-40500 Jyväskylä, Finland
email: arto.huuskonen@luke.fi

The objective was to study the effects of partial replacement of barley grain by rye grain on dry matter (DM) intake, growth performance and carcass traits of growing and finishing bulls. The experiment was conducted using 80 dairy bulls which were fed total mixed rations *ad libitum*. The rations included grass silage (500 g kg^{-1} DM) and concentrate (500 g kg^{-1} DM). Four different experimental concentrate mixtures included rye at 0, 150, 300 and 450 g kg^{-1} DM. The average daily DM and metabolisable energy intakes of the bulls were 10.9 kg d^{-1} and 127 MJ d^{-1}, respectively. There were no differences in DM, energy or nutrient intakes among the treatments. The average live weight gain and carcass gain of the bulls were 1543 and 832 g d^{-1}, respectively, and rye inclusion had no effects on growth. There were no significant differences in feed conversion or carcass characteristics among the treatments. It can be concluded that rye grain is a suitable energy supplement with good quality silage for growing dairy bulls.

Key words: beef production, bulls, feed intake, growth, rye

Introduction

Beef production in Finland is based mainly on raising dairy bulls fed grass silage based diets. To meet the energy requirements, concentrate feeds typically based on cereal grains are commonly included in rations. Cereals are the primary source of dietary starch in growing cattle and make up a substantial proportion of feed ingredients used. In Northern Europe, diets for cattle are mainly based on grass silage and barley (*Hordeum vulgare*), oats (*Avena sativa*) or wheat (*Triticum aestivum*) supplements. In some cases also rye (*Secale cereale*) could be a cost-effective concentrate supplement in cattle rations. Rye is highly valued particularly in Eastern and Northern Europe in producing traditional dark bread. Especially in Poland rye is used also for animal feeding, mainly for pigs and cattle (Pieszka et al. 2015). Grajewski et al. (2012) reported that rye had the highest resistance to mould and the lowest level of toxins among cereals grown for grain when examining the risk of contamination with *Fusarium* fungi. However, there is scepticism concerning high rye proportions in the diet mainly due to the high concentration of alkylresorcinols compared with other grains (Kozubek and Tyman 1999, Kulawinek and Kozubek 2008, Ziegler et al. 2015). In addition ergot has been linked, for example, with reduced feed intake, depressed growth rate, diarrhoea and lameness (Spiece 1986) and therefore, maximum level of ergot in feeds (1 mg kg^{-1} with a moisture content of 12%) is defined (Verstraete 2013).

Surprisingly, there are only few old reports in the scientific literature where the effects on rye inclusion on feed intake, gain and carcass traits of growing and finishing cattle has been examined. Spiece (1986) reviewed some old beef cattle research reports from the 1970's in his dissertation concerning feeding rye to lactating dairy cattle and concluded that the results of rye studies are conflicting. Antoniou (1980) stated that the possible feed intake and growth depression effects due to rye inclusion are less evident in older than in young animals. In dairy cows, Pieszka et al. (2015) reported that feeding with concentrates containing 250 or 400 g rye kg^{-1} dry matter (DM) did not reduce feed intake or milk yield during the first 100 days of lactation compared to the control group fed without rye. Because there are very few studies using rye in growing cattle, the objective of the present experiment was to study the effects of partial replacement of barley grain by rye grain on feed intake, gain and carcass traits of growing and finishing dairy bulls.

Materials and methods

Animals and housing

A feeding experiment was carried out in the experimental cattle unit of Natural Resources Institute Finland (Luke) in Ruukki, Finland starting in January 2017 and ending in August 2017. Animals were managed according to the Finnish legislation regarding the use of animals in scientific experimentation. The experiment was conducted using 80 dairy bulls (48 Holstein and 32 Nordic Red). All animals were purchased from local dairy farms at on average age of 21 d. From three weeks to six months of age the animals were housed in an insulated barn and received milk replacer (until the age of 75 days), grass silage and a commercial pelleted calf starter. The bulls were moved to the experimental cattle unit of Luke on six months of age, two months before the start of the feeding experiment. During this pre-experimental period the bulls were adapted to experimental feeds and housing conditions. At the beginning of the pre-experimental period both Holstein and Nordic Red bulls were randomly allotted to pens (three Holstein and two Nordic Red bulls per pen) which were then randomly allotted to four feeding treatments (four pens and 20 bulls per treatment). At the start of the feeding experiment the bulls were on average 250 (±10.4) days old and weighed 320 (±34.9) kg.

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

Feeds, feeding and experimental design

The bulls were fed total mixed rations *ad libitum* (proportionate refusals of 5%). Total mixed rations were carried out by a mixer wagon (Trioliet, BW Oldenzaal, the Netherlands). All four rations were produced every day and feed was offered two times a day.

The experimental diets included grass silage (500 g kg^{-1} DM) and concentrate (500 g kg^{-1} DM). Four different concentrate mixtures (C1, C2, C3 and C4) included rye grain 0, 150, 300 and 450 g kg^{-1} DM, respectively. Ingredients, chemical compositions and nutritional values of the concentrate mixtures are presented in Table 1. The C1 was a typical Finnish commercial concentrate mixture for growing and finishing cattle including mainly barley, wheat bran and oats. In the three other concentrate mixtures barley was partly replaced by rye. Rye used in the present experiment did not contain ergot or mycotoxins. All four concentrate mixtures were isoenergetic and isonitrogenous. Grass silage DM content was determined every second day to ensure correct mixture ratios of the experimental diets.

Grass silage used in the present experiment was produced at the experimental farm of Luke in Ruukki (64°44'N, 25°15'E) and harvested from timothy (*Phleum pratense*) stands (on 20 June and 26 July 2016, primary growth and regrowth, respectively). The primary growth of timothy was fed during the first half and regrowth during the second half of the experiment. The stands were cut by mower conditioner (Elho 280 Hydro Balance, Oy Elho Production Ab, Pännäinen, Finland), harvested using a precision-chop forage harvester (Lely Storm 130P, NHK Group, Hämeenlinna, Finland) approximately 24 hours after cutting, treated with a formic acid-based additive (AIV ÄSSÄ, Eastman Chemical Company, Oulu, Finland) applied at a rate of 5.8 kg t^{-1} of fresh forage and stored in bunker silos.

Feed sampling and analysis

During the feeding experiment grass silage sub-samples were taken three times a week, pooled over periods of four weeks and stored at −20 °C prior to analyses. Thawed samples were analysed for DM, ash, crude protein (CP), neutral detergent fibre (NDF) exclusive of residual ash, crude fat (analysed as ether extract), starch, silage fermentation quality (pH, water-soluble carbohydrates (WSC), lactic and formic acids, volatile fatty acids, soluble and ammonia N content of total N), and digestible organic matter (DOM) in DM (D-value). Concentrate sub-samples were collected weekly, pooled over periods of eight weeks and analysed for DM, ash, CP, NDF, crude fat and starch.

Table 1. Ingredients, chemical composition and feeding values of the four concentrate feeds (C1, C2, C3 and C4) and grass silages (GS1 = primary growth, GS2 = regrowth) used in the feeding experiment

	C1	C2	C3	C4	GS1	GS2
Ingredients, g kg^{-1} dry matter (DM)						
Barley	491	356	210	54	-	-
Rye	-	150	300	450	-	-
Wheat bran	144	144	144	144	-	-
Oats	130	119	120	130	-	-
Rapeseed meal	70	69	67	65	-	-
Molassed sugar-beet pulp	66	66	66	66	-	-
Wheat feed meal	65	65	65	65	-	-
Calcium carbonate	16	16	16	16	-	-
Vegetable oil mix	8	5	2	-	-	-
Sodium chloride	7	7	7	7	-	-
Magnesium oxide	2	2	2	2	-	-
Vitamin, mineral and trace element premix	1	1	1	1	-	-
Chemical composition and feeding values						
Number of feed samples	4	4	4	4	4	4
DM, g kg^{-1}	879	875	878	878	228	260
Organic matter, g kg^{-1} DM	939	939	940	944	948	948
Crude protein, g kg^{-1} DM	142	148	142	140	142	134
Ether extracts, g kg^{-1} DM	37	36	31	30	40	42
Neutral detergent fibre, g kg^{-1} DM	253	260	258	275	569	550
Starch, g kg^{-1} DM	369	373	391	404	9	9
Metabolisable energy, MJ kg^{-1} DM	12.4	12.4	12.4	12.4	11.0	11.1
Metabolisable protein, g kg^{-1} DM	96	96	96	96	82	82
Protein balance in the rumen, g kg^{-1} DM	5	5	5	5	20	12
Digestible organic matter in DM, g kg^{-1} DM	-	-	-	-	687	694
Silage DM intake index	-	-	-	-	103	102

Fermentation quality of grass silage (primary growth and regrowth on average): pH 3.78; volatile fatty acids 14 g kg^{-1} DM; lactic + formic acid 52 g kg^{-1} DM; water soluble carbohydrates 64 g kg^{-1} DM; ammonium-N 44 g kg^{-1} N; soluble N 464 g kg^{-1} N

The DM content was determined by drying at 105 °C for 20 h (+ 2 h at 50 °C at first). Samples for chemical analyses were dried at 105 °C for 16 h and milled using sample mill (Sakomylly KT-3100, Koneteollisuus Ltd., Helsinki, Finland) using a 1 mm sieve. Oven DM concentration of silage samples was corrected for the loss of volatiles according to Huida et al. (1986). The ash concentration was determined by ashing at 600 °C for 2 h (AOAC method 942.05; AOAC 1990). Nitrogen content was determined by the Dumas method (AOAC method 968.06; AOAC 1990) using a Leco FP 428 nitrogen analyser (Leco, St Joseph, MI, USA). Crude protein content was calculated as 6.25 × N content. Concentration of NDF was determined according to Van Soest et al. (1991) using Na-sulphite, without amylase for forages and presented ash-free. Crude fat was analysed according to the official method 920.39 (AOAC 1990) and starch according to Salo and Salmi (1968). The silages were analysed for D-value as described by Huhtanen et al. (2006). The pepsin-cellulase solubility values were converted to *in vivo* digestibility using correction equations (different equations for primary growth and regrowth) based on a data set comprising of Finnish *in vivo* digestibility trials (Huhtanen et al. 2006). Fresh silage samples were analysed for fermentation characteristics by electrometric titration as described by Moisio and Heikonen (1989).

The metabolisable energy (ME) concentration of the silage samples was calculated as 0.016 × D-value (MAFF 1984). The ME concentration of concentrates was calculated based on concentrations of digestible crude fibre, CP, crude fat and nitrogen-free extract described by Luke (2018). Crude fibre concentrations and digestibility co-

efficients were taken from the Finnish Feed Tables (Luke 2018). The values of metabolisable protein (MP) and the protein balance in the rumen (PBV) were calculated according to the Finnish feed protein evaluation system (Luke 2018) in which MP describes the amount of amino acids absorbed from the small intestine and PBV describes the balance between the dietary supply of rumen-degradable protein (RDP) and the microbial requirements for RDP. The relative intake potential of silage DM (SDMI index) was calculated as described by Huhtanen et al. (2007).

Weighing, slaughter procedures and carcass quality measurements

The bulls were weighed on two consecutive days at the beginning of the experiment and before slaughter. The target for the average carcass weight was 350–360 kg. 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 × initial LW based on earlier studies (unpublished data).

The bulls were selected for slaughter based on LW and slaughtered in the Atria Ltd. commercial slaughterhouse in Kauhajoki, Finland in two batches. All four feeding 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 classified for conformation and fatness using the EUROP quality classification (EC 2006). For conformation, the development of the 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). Each level of the conformation scale was subdivided into three sub-classes to produce a transformed scale ranging from 1 to 15, with 15 being the best conformation. 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).

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 for feed intake, growth performance and carcass traits was:

$$y_{ijk} = \mu + \alpha_i + \theta_{ik} + \beta x_{ij} + e_{ijk}$$

where μ is the intercept, α_i, is the effect of diet (C1, C2, C3, C4), while θ_{ik} is the effect of pen and e_{ijk} is the residual error term. The effect of pen was used as an error term when differences between feeding treatments were compared because treatments were allocated to animals penned together. Initial LW was used as a covariate (βx_{ij}) in the model for intake, gain and feed conversion parameters. When the dressing proportion, carcass conformation and carcass fat score were tested, carcass weight was used as a covariate. The effect of the rye inclusion was further divided into linear and quadratic effects using orthogonal polynomial contrasts.

Results

According to feed analyses the grass silage used in the present experiment was good both nutritionally and in terms of preservation (Table 1). It was restrictively fermented with high residual WSC concentration and relatively low lactic acid concentration.

The feeding experiment lasted on average 234 days (Table 2). Two bulls (one C1 and one C3 bull) were excluded from the study due to pneumonia and two bulls (both C3) due to accidents. There was no reason to suppose that the diets had caused these problems. The other 76 bulls remained healthy throughout the study.

The average daily DM, ME and CP intakes of the bulls were 10.9 kg d^{-1}, 127 MJ d^{-1} and 1522 g d^{-1}, respectively, during the total experimental period (Table 2). There were no significant differences in DM, ME or nutrient intakes between the feeding treatments. However, CP intake tended to decrease linearly (p=0.061) with increasing rye proportion in the diet. The average LWG and carcass gain of the bulls were 1543 and 832 g d^{-1}, respectively, and replacing barley by rye had no effects on growth performance. Furthermore, there were no significant differences in feed, ME or CP conversion rates among the feeding treatments.

Table 2. Intake, growth performance and feed conversion of the bulls

	Diet[1]					p-values	
	C1	C2	C3	C4	SEM[2]	L[3]	Q[4]
Number of bulls	19	20	17	20			
Duration of the experiment, d	239	233	231	233	3.6	0.221	0.195
Intake							
Dry matter (DM), kg d^{-1}	11.1	10.9	10.9	10.5	0.29	0.152	0.592
DM, g kg^{-1} metabolic live weight	104	103	105	99	2.8	0.309	0.279
Metabolisable energy (ME), MJ d^{-1}	130	128	128	123	3.4	0.149	0.598
Crude protein (CP), g d^{-1}	1552	1559	1520	1457	40.0	0.061	0.356
Metabolisable protein, g d^{-1}	985	973	970	933	25.5	0.146	0.602
Neutral detergent fibre, g d^{-1}	4470	4454	4474	4351	118.9	0.509	0.634
Starch, g d^{-1}	2092	2102	2204	2164	56.2	0.190	0.642
Live weight gain (LWG) , g d^{-1}	1544	1549	1511	1545	35.6	0.773	0.651
Carcass gain, g d^{-1}	835	835	825	828	23.0	0.824	0.950
Feed conversion rate							
kg DM kg^{-1} LWG	7.2	7.0	7.2	6.8	0.25	0.543	0.402
MJ kg^{-1} LWG	84	83	85	80	3.0	0.537	0.406
g CP kg^{-1} LWG	1005	1006	1006	943	35.2	0.346	0.263
kg DM kg^{-1} carcass gain	13.3	13.1	13.2	12.7	0.53	0.690	0.659
MJ kg^{-1} carcass gain	156	153	155	148	6.2	0.685	0.663
g CP kg^{-1} carcass gain	1859	1868	1843	1759	72.9	0.483	0.486

[1] C1, C2, C3 and C4 diets included rye 0, 75, 150 and 225 g kg^{-1} DM, respectively; [2] standard error of the mean; [3] linear effect of rye supplementation; [4] quadratic effect of rye supplementation

The slaughter age, carcass weight and dressing proportion were on average 484 d, 354 kg and 521 g kg^{-1}, respectively, and no treatment differences were observed (Table 3). Finally, rye inclusion had no significant effects on carcass conformation or carcass fat score.

Table 3. Live weights and carcass characteristics of the bulls

	Diet[1]					p-values	
	C1	C2	C3	C4	SEM[2]	L[3]	Q[4]
Number of bulls	19	20	17	20			
Live weight, kg							
Initial	321	321	315	322	8.7	0.984	0.686
Final	690	682	664	682	7.8	0.193	0.085
Slaughter age, d	490	481	482	483	3.6	0.202	0.135
Carcass characteristics							
Carcass weight, kg	360	355	348	354	5.1	0.272	0.281
Dressing proportion, g kg^{-1}	521	520	524	519	3.7	0.889	0.508
Conformation, EUROP[5]	5.2	5.0	5.1	5.0	0.10	0.266	0.847
Fat score, EUROP[6]	2.3	2.2	2.3	2.1	0.12	0.344	0.767

[1] C1, C2, C3 and C4 diets included rye 0, 75, 150 and 225 g kg^{-1} DM, respectively; [2] standard error of the mean; [3] linear effect of rye supplementation; [4] quadratic effect of rye supplementation; [5] Conformation: 1=poorest, 15=excellent; [6] Fat score: 1=leanest, 5=fattest

Discussion

In recent Finnish experimental data sets for dairy bulls fed grass silage and grain based diets and housed in similar environments (Huuskonen et al. 2016, 2017a, 2017b), the average DM intake of the bulls was roughly at the same level as in the present experiment. In an earlier meta-analysis Huuskonen et al. (2013) found that DM intake of growing and finishing cattle can be predicted from body weight and diet composition with a reasonable accuracy. Body weight, dietary NDF concentration, SDMI index and dietary concentration of volatile fatty acids were included in the final model (Huuskonen et al. 2013). Based on the equation of Huuskonen et al. (2013) and the dietary compositions of the present rations, the predicted total DM intakes for C1–C4 rations in the present experiment would have been 10–14% lower (9.4–9.6 kg DM d^{-1}) than the measured intakes (10.5–11.1 kg DM d^{-1}).

In the present study, feeding dairy bulls with concentrates containing 150–450 g rye kg^{-1} DM did not result in a decrease in DM intake compared to control group fed without rye. Consistent with the present experiment, Schneider et al. (1990) observed that replacement of barley by rye in the concentrate for bulls did not reduce feed intake. In dairy cows, Pieszka et al. (2015) found no reduction in feed intake when feeding with concentrates containing rye at 250 or 400 g kg^{-1} DM compared to the control group fed without rye. On the contrary, Sharma et al. (1981) reported that DM intake was reduced when lactating dairy cows were fed 250, 500 or 750 g kg^{-1} DM rye in their grain mixture compared to barley.

Because all concentrate mixtures were isoenergetic and there were no differences in feed intake among treatments there was also no difference in energy intakes. Therefore, it is logical that there were no differences either in gain parameters among treatments. Based on the meta-analysis of growing cattle feeding experiments, Huuskonen and Huhtanen (2015) concluded that energy intake was clearly the most important variable affecting LWG of growing and finishing cattle, whereas the results showed only marginal effects of protein supply on gain.

Earlier scientific information on the effects of rye on growth performance of growing and finishing cattle is very limited. Spiece (1986) pulled together old research reports and stated that feeding recommendations indicate that rye should not exceed 50% of the grain in the ration for cattle. However, Spiece (1986) also concluded that some studies indicate that rye may be included up to 80% in the grain ration for growing steers without reduction in intake or growth. Sharma et al. (1981) used sixty Holstein calves to evaluate the nutritive value of rye grain in calf starter diets. Calves were assigned randomly to one of five starters containing 0, 300, 600 and 800 g kg^{-1} DM dry rolled or 800 g kg^{-1} DM roasted rye for an 18 week growth trial. Average daily gain and feed intake were similar during the first six weeks, however calves receiving 600 g kg^{-1} DM dry rolled rye consumed less feed and gained slower than the barley control and 800 g kg^{-1} DM roasted rye fed groups in the next 12 weeks (Sharma et al. 1981).

Recent datasets from Finnish slaughterhouses indicate that the average slaughter age, carcass weight, conformation score and fat score for dairy bulls are 590 d, 330 kg, 4.5 and 2.4, respectively (Huuskonen 2014). Hence, the bulls in the present experiment were younger and heavier and conformed better than dairy bulls on average in Finnish beef cattle population. Previous scientific results related to the effects of rye inclusion on carcass characteristics on finishing cattle are very limited. However, also Schneider et al. (1990) reported no significant difference in dressing proportion, carcass conformation or carcass fat score of finishing bull when they received rye, barley, wheat or maize grain.

Overall, the present experiment indicate that the addition of 150–450 g kg^{-1} DM of rye grain to concentrate mixtures for growing and finishing dairy bulls does not influence DM intake or gain compared to barley based concentrate. No differences in carcass characteristics of the bulls were observed among the feeding treatments. Therefore, it can be concluded that rye grain is a suitable energy supplement with good quality silage for growing and finishing dairy bulls. The rationality of the use of rye will depend on its price in relation to alternative concentrate feeds.

Acknowledgements

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