A comparison of first-, second- and third-cut timothy silages in the diets of finishing beef bulls

Arto Huuskonen and Maiju Pesonen

Natural Resources Institute Finland (Luke), Green Technology, Tutkimusasemantie 15, FI-92400 Ruukki, Finland

e-mail: arto.huuskonen@luke.fi

The objective of the present experiment was to study the effects of the third-cut grass silage compared with the first- and second-cut silages on intake, performance and carcass characteristics of finishing bulls. A feeding experiment comprised 45 Simmental bulls which were fed a total mixed ration *ad libitum*. The three dietary treatments included either first-, second- or third-cut grass silage (550 g kg^{-1} dry matter), rolled barley (435 g kg^{-1} dry matter) and a mineral-vitamin mixture (15 g kg^{-1} dry matter). Dry matter and energy intakes and growth rates of the bulls increased when either first- or third-cut silages were used instead of the second-cut silage. This was probably due to differences in digestibility, which was the lowest in the second-cut silage. There were no differences in intake or growth between the first- and third-cut silage-based rations. No significant differences in carcass traits among the feeding treatments were observed.

Key words: beef production, bulls, carcass characteristics, feed intake, grass silage, growth

Introduction

Grass silage is the basic component of diets for growing cattle in Northern Europe. The nutritive value of grass silage depends of the stage of growth at harvesting and the changes in the chemical composition during ensiling (Huhtanen et al. 2007). In general, early-cut grass produces highly digestible primary growth for silage, but the digestibility of the second cut tends to be lower (Rinne 2000, Kuoppala 2010). A three-cut strategy, which provides better utilisation of the entire growing season than a two-cut strategy (Hyrkäs et al. 2015), is becoming more common also in northern Finland. Hyrkäs et al. (2015) reported that over the whole growing season under Finnish conditions, three cuts provided higher average digestibility than two cuts. Also Thorvaldsson et al. (2007) stated that grass harvested at the third cut can have high digestibility as a consequence of low amounts of fibre in northern climate zones, due to low average temperatures and low radiation during the late-summer period. Thus, the feeding value of the autumn-cut grass silage should be high.

However, in some recent studies third-cut silage has resulted in lower milk production than expected based on feed analysis (Sairanen and Juutinen 2013, Sairanen et al. 2016). Sairanen et al. (2016) concluded that the high energy content of the autumn-cut silage was not realised as milk production and low total feed dry matter (DM) intake was the main reason for the relatively low milk yield with third-cut silage. Furthermore, Sairanen et al. (2016) speculated that weather conditions are variable during autumn and for this reason the herbage could contain variable microbial flora or be affected by diseases that result in decreased intake of the silage. These types of quality parameters do not necessarily affect chemical analysis and cause variation in experimental results.

For growing cattle the importance of grass silage digestibility is demonstrated, for example, by Steen et al. (1998) and Huuskonen et al. (2013). In the meta-analysis of Huuskonen et al. (2013) a 1 g kg^{-1} DM increase in digestible organic matter (DOM) in DM (D-value) increased silage DM intake (DMI) by 7.2 g d^{-1}. Further, Huuskonen et al. (2013) observed that the effects of forage quality characteristic on DMI are quite similar in growing cattle and lactating dairy cows. Subsequently, Huuskonen and Huhtanen (2015) concluded that voluntary feed intake in cattle has a great impact on growth performance and energy intake is the most important variable affecting live weight gain (LWG) of growing cattle. However, there is a lack of published information on performance of finishing bulls when autumn-cut grass silage harvested under northern climatic conditions is used in feeding. Therefore, the objective of the present experiment was to study the effects of the third-cut grass silage compared with the first- and second-cut silages on intake, performance and carcass characteristics of finishing bulls. Based on earlier milk production experiments (Sairanen and Juutinen 2013, Sairanen et al. 2016) it was hypothesised that DMI and LWG of the autumn-cut silage-fed bulls would be lower than expected based on feed analysis.

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Materials and methods

Animals and housing

A feeding experiment was conducted in the experimental barn of Natural Resources Institute Finland (Luke) in Ruukki, Finland starting in February 2016 and ending in July 2016. Animals were managed according to the Finnish legislation regarding the use of animals in scientific experimentation. The experiment comprised in total 45 pure-bred Simmental (Si) bulls. The animals, with an initial LW of 475 (±36.8) kg, were purchased from five commercial herds and were from eight different sires. At the start of the experiment the bulls were on average 328 (±13.9) days old.

During the feeding experiment, the bulls were housed in an uninsulated barn in pens (10.0 × 5.0 m; 5 bulls in each pen), providing 10.0 m^2 of space per bull. 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; see validation studies: DeVries et al. 2003, Mendes et al. 2011) 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/pen) during the experiment.

Feeds, feeding and experimental design

Experimental grass silages were produced at the experimental farm of Natural Resources Institute Finland (Luke) in Ruukki (64°44'N, 25°15'E) and harvested from the first-year timothy (*Phleum pratense* cv. Tuure) stands at early heading stage of timothy on 25 June, 11 August and 3 October 2015; first cut, second cut and third cut, respectively. Commercial N–P–K fertilizers were applied at rates of 75–4–40 kg ha^{-1} for the first cut, 70–0–40 kg ha^{-1} for the second cut and 22–0–12 kg ha^{-1} for the third cut. The stands were cut by a mower conditioner (Elho 280 Hydro Balance, Oy Elho Production Ab, Pännäinen, Finland) and harvested with an integrated round baler wrapper (McHale Fusion 3, McHale, Ballinrobe, Co. Mayo, Ireland) approximately 24 hours after cutting. All silages were treated with a formic acid-based additive (AIV ÄSSÄ; Taminco Finland Ltd., Oulu, Finland; 590 g formic acid kg^{-1}, 200 g propionic acid kg^{-1}, 40 g ammonium formate kg^{-1} and 25 g benzoic acid kg^{-1}) applied at a rate of 5.8 kg t^{-1} of fresh forage.

At the beginning of the feeding experiment the bulls were randomly allotted to pens which were then randomly allotted to three feeding treatments (three pens and 15 bulls per treatment). The compositions of the three feeding treatments (GS1, GS2 and GS3) were:

GS1: first-cut grass silage (550 g kg^{-1} DM), rolled barley (435 g kg^{-1} DM) and mineral-vitamin mixture (15 g kg^{-1} DM).

GS2: second-cut grass silage (550 g kg^{-1} DM), rolled barley (435 g kg^{-1} DM) and mineral-vitamin mixture (15 g kg^{-1} DM).

GS3: third-cut grass silage (550 g kg^{-1} DM), rolled barley (435 g kg^{-1} DM) and mineral-vitamin mixture (15 g kg^{-1} DM).

Mineral and vitamin composition of the mineral-vitamin mixture (Kasvuape E-Hiven, A-Rehu Ltd., Seinäjoki, Finland) is fully described by Huuskonen et al. (2017). The bulls were fed a total mixed ration *ad libitum* (proportionate refusals of 5%). Total mixed rations were carried out by a mixer wagon (Trioliet, BW Oldenzaal, the Netherlands) once a day.

Feed sampling and analysis

During the feeding experiment silage sub-samples were taken twice a week, pooled over periods of approximately 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 extracts), silage fermentation quality [pH, water-soluble carbohydrates (WSC), lactic and formic acids, volatile fatty acids (VFA), soluble and ammonia N content of total N], and D-value. Barley sub-samples were collected weekly, pooled over periods of approximately eight weeks and analysed for DM, ash, CP, NDF and crude fat.

Fresh silage samples were analysed 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. Samples for chemical analyses were dried at 60 °C for 16 h and milled using a sample mill (Sakomylly KT-3100, Koneteollisuus Ltd., Helsinki, Finland) using a 1 mm sieve. Oven DM concentration of silages 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. 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 determined by a Soxcap-Soxtec-analyser (AOAC Official Method 920.39) (AOAC 1990). 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 comprised of Finnish *in vivo* digestibility trials (Huhtanen et al. 2006).

The metabolisable energy (ME) concentration of the silages was calculated as 0.016 × D-value (MAFF 1984). The ME concentration of barley grain was calculated based on concentrations of digestible crude fibre, CP, crude fat and nitrogen-free extract as described by Luke (2017). Crude fibre concentrations and digestibility coefficients were taken from the Finnish Feed Tables (Luke 2017). 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 2017) 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).

Slaughter procedures, ultrasound measurements and carcass traits

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 target for the average carcass weight was 400–410 kg, which is currently the average carcass weight for slaughtered Simmental bulls in Finland (Pesonen and Huuskonen 2015). The 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 0.52 × initial LW based on earlier studies (unpublished data).

Ultrasound measurements were made one day before slaughter. Ultrasound subcutaneous fat (mm) at the 1st lumbar vertebrae, ultrasound depth (mm) and area (cm^2) of *longissimus dorsi* muscle at the 1st lumbar vertebrae and ultrasound intramuscular fat (IMF) (%) were performed 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 machine was calibrated before each scanning event, using a calibration phantom for the ASP-18 probe (Classic Medical Inc., Tequesta, FL, USA). Guidelines for use of the equipment were described by Gresham (1996). The images were transferred with the ODT software system (Open Data Transfer; Esaote Pie Medical, Genoa, Italy) to a PC, followed by subsequent processing in the laboratory. The image analyses were carried out as described by Aass et al. (2009).

The bulls were selected for slaughter based on LW, and slaughtered in the Atria Ltd. commercial slaughterhouse in Kauhajoki, Finland in three batches. All three feeding treatments were represented in all 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 normality of residuals was checked using graphical methods: box plots and scatter plots of residuals and fitted values. 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

$$y_{ijkl} = \mu + \delta_j + \alpha_i + \theta_{ijl} + \beta x_{ijk} + e_{ijkl}$$

where μ is the intercept and e_{ijkl} is the residual error term associated with k^{th} animal. α_i, is the effect of i^{th} diet (GS1, GS2, GS3), while δ_j is the effect of the slaughtering batch (j=1, 2, 3) and θ_{ijl} is the effect of pen. The effect of pen was used as an error term when differences between treatments were compared because treatments were allocated to animals penned together. Initial LW was used as a covariate (βx_{ijk}) in the model for intake, gain and feed conversion parameters. When the dressing proportion, carcass conformation, carcass fat score and ultrasound measurements were tested, carcass weight was used as a covariate. Tukey's *t*-test was applied for multiple comparison among the treatment means considering $p<0.05$ as significant.

Results

Chemical composition and feeding values of the experimental feeds and total mixed rations are presented in Table 1. Due to the weather conditions during harvesting, the DM concentrations of the second-cut and third-cut silages were 47 and 41% higher compared to the first-cut silage, respectively. According to the feed analyses, the third-cut silage had 5–7% higher ME concentration and 22–26% higher CP concentration compared to the first- and second-cut silages. The NDF concentrations of the first- and second-cut silages were 33 and 20% higher compared to the third-cut silage, respectively. Further, the third-cut silage had 16 and 10% higher SDMI index compared to the first- and second-cut silages, respectively.

Table 1. Chemical composition and feeding values (mean ± standard deviation) of the ingredients and total mixed rations (calculated) used in the feeding experiment. Number of samples: silages 5, barley grain 3

	Feeds				Total mixed rations		
	Grass silage first cut	Grass silage second cut	Grass silage third cut	Barley	GS1[1]	GS2[2]	GS3[3]
Dry matter (DM), g kg^{-1}	222±25.2	326±19.7	314±28.6	872±6.4	334	453	441
Organic matter (OM), g kg^{-1} DM	945±3.9	932±3.4	917±8.2	971±0.9	958	949	940
Crude protein, g kg^{-1} DM	152±17.0	147±15.4	186±19.9	115±11.7	135	132	154
Neutral detergent fibre (NDF), g kg^{-1} DM	592±22.1	533±8.7	446±15.2	211±10.4	420	388	340
Crude fat, g kg^{-1} DM	35±0.8	34±1.0	37±1.1	22±0.9	29	29	30
Metabolisable energy, MJ kg^{-1} DM	11.2±0.40	11.0±0.16	11.8±0.18	12.9±0.04	12.0	11.8	12.3
MP[4], g kg^{-1} DM	85±4.4	82±2.3	92±2.8	95±1.5	90	88	93
Protein balance in the rumen, g kg^{-1} DM	26±9.5	24±9.2	49±7.1	–27±8.6	2	1	15
Digestible OM in DM, g kg^{-1} DM	701±12.9	685±11.4	740±9.9	821±3.3	755	746	776
Silage DM intake index[5]	99±3.0	105±2.9	115±2.5				
Fermentation quality of silages							
pH	3.90±0.134	4.26±0.131	4.56±0.064				
Volatile fatty acids, g kg^{-1} DM	15±1.3	8±1.1	8±2.7				
Lactic + formic acid, g kg^{-1} DM	49±3.3	37±5.1	32±4.3				
Water soluble carbohydrates, g kg^{-1} DM	65±13.9	115±11.8	148±10.5				
In total N, g kg^{-1}							
NH_4N	66±3.5	56±2.6	53±5.7				
Soluble N	543±35.3	485±27.5	427±25.6				

[1] GS1 = first-cut grass silage (550 g kg^{-1} DM), rolled barley (435 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM); [2] GS2 = second-cut grass silage (550 g kg^{-1} DM), rolled barley (435 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM); [3] GS3 = third-cut grass silage (550 g kg^{-1} DM), rolled barley (435 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM); [4] MP = metabolisable protein; [5] The relative intake potential of silage dry matter (SDMI index); calculated as described by Huhtanen et al. (2007)

The fermentation characteristics of all three silages were good, as indicated by the low concentrations of ammonia N in total N and total fermentation acids (Table 1). All silages were restrictively fermented with a high residual WSC concentration and low lactic acid concentration. However, the second- and third-cut silages had clearly higher WSC concentrations compared to the first-cut silage. The barley grain had typical chemical composition and feeding values, corresponding to the average values in the Finnish Feed Tables (Luke, 2017). Due to differences in composition of the experimental silages, the GS3 ration contained slightly more ME and CP and less NDF compared to GS1 and GS2 rations (Table 1). In all rations the PBV value fulfilled the Finnish recommendation for growing cattle (PBV of the diet above –10 g kg^{-1} DM for animals above 200 kg LW).

The feeding experiment lasted 128 days and the slaughter age of the bulls was 456 days on average (Table 2). The GS2 bulls were slightly older at slaughter compared to the GS1 bulls. There were significant treatment differences in feed intake.

Table 2. Intake, growth, feed conversion and carcass traits of the bulls fed different rations

	Diets				
	GS1[1]	GS2[2]	GS3[3]	SEM[4]	*p*-value[5]
Number of observations	15	15	15		
Duration of the experiment, d	124[a]	131[b]	128[ab]	3.3	0.04
Initial live weight (LW), kg	482	470	472	9.7	0.64
Final LW, kg	731	721	738	5.9	0.10
Slaughter age, d	449[a]	463[b]	457[ab]	5.0	0.051
Intake					
Total intake, kg dry matter (DM) d^{-1}	11.47[a]	10.38[b]	11.57[a]	0.299	0.006
DM intake, g kg^{-1} metabolic LW	93.5[a]	86.1[b]	94.8[a]	2.23	0.01
Metabolisable energy (ME), MJ d^{-1}	138[a]	123[b]	142[a]	3.6	<0.001
Metabolisable protein, g d^{-1}	1032[a]	913[b]	1082[a]	26.8	<0.001
Crude protein (CP), g d^{-1}	1586[a]	1363[b]	1794[c]	41.8	<0.001
Neutral detergent fibre, g d^{-1}	4715[a]	3999[b]	3936[b]	119.8	<0.001
Live weight gain (LWG), g d^{-1}	2097[a]	1883[b]	2082[a]	52.5	0.005
Carcass gain, g d^{-1}	1299[a]	1169[b]	1304[a]	36.2	0.01
Feed conversion					
kg DM kg^{-1} LWG	5.47	5.51	5.56	0.189	0.94
kg DM kg^{-1} carcass gain	8.83	8.88	8.87	0.334	0.96
MJ ME kg^{-1} LWG	65.8	65.3	68.2	2.26	0.54
MJ ME kg^{-1} carcass gain	106.2	105.2	108.9	3.98	0.71
g CP kg^{-1} LWG	756[a]	724[a]	862[b]	25.3	0.001
g CP kg^{-1} carcass gain	1221[a]	1166[a]	1376[b]	44.5	0.006
Carcass characteristics					
Carcass weight, kg	406	400	413	4.7	0.15
Dressing proportion, g kg^{-1}	554	559	556	3.4	0.40
Conformation, EUROP	9.7	10.4	10.6	0.26	0.054
Fat score, EUROP	2.4	2.2	2.3	0.12	0.51
Ultrasound measurements					
Subcutaneous rump fat, mm	6.0	5.6	5.9	0.35	0.82
Intramuscular fat, %	3.2	3.3	3.3	0.19	0.79
Depth of *longissimus dorsi* muscle, mm	7.4	7.5	7.9	0.17	0.14
Area of *longissimus dorsi* muscle, cm^2	97.4	96.9	102.9	2.51	0.06

[1] GS1 = first-cut grass silage (550 g kg^{-1} DM), rolled barley (435 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM); [2] GS2 = second-cut grass silage (550 g kg^{-1} DM), rolled barley (435 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM); [3] GS3 = third-cut grass silage (550 g kg^{-1} DM), rolled barley (435 g kg^{-1} DM), mineral-vitamin mixture (15 g kg^{-1} DM); [4] SEM = standard error of mean; [5] Between treatment comparisons (Tukey, $p<0.05$): estimated means with the different letters were significantly different ($p<0.05$).

Daily DMI was approximately 11% and DMI in relation to metabolic LW approximately 10% higher when GS1 and GS3 were used instead of GS2. There were no differences in feed intake between GS1 and GS3 treatments.

Energy intake of the GS1 and GS3 bulls was 12 and 15% and MP intake 13 and 19% higher, respectively, compared to the GS2 bulls. There were no differences in ME or MP intake between GS1 and GS3. Due to differences in CP composition of the experimental silages, GS3 bulls received clearly more CP compared to the GS1 and GS2 bulls (Table 2). Furthermore, NDF intake of the GS1 bulls was approximately 18% higher compared to the GS2 and GS3 bulls.

The average LWG and carcass gain of the bulls was 2021 and 1257 g d^{-1}, respectively. Both LWG and carcass gain of the GS1 and GS3 bulls was approximately 11% higher compared to the GS2 bulls. There were no differences in growth parameters between GS1 and GS3 treatments. Dietary treatments had no significant effects on DM or energy conversion rates (Table 2). However, CP conversion was better in GS1 and GS2 bulls compared to the GS3 bulls.

The carcass weight, dressing proportion, carcass conformation score and carcass fat score of the bulls were, on average, 406 kg, 556 g kg^{-1}, 10.2 and 2.3, respectively, and there were no significant differences among the feeding treatments. However, the carcass conformation score of the GS3 bulls tended to be 9% higher ($p<0.10$) compared to the GS1 bulls. There were no significant differences in ultrasound measurements among the feeding treatments (Table 2) but the area of *longissimus dorsi* muscle tended to be larger ($p<0.10$) in GS3 than in GS2 bulls.

Discussion

Due to the rainy weather conditions during the first cut, the DM concentration of the first-cut silage was clearly lower compared to the second- and third-cut silages. This difference affected also the SDMI index as the meta-analysis by Huhtanen et al. (2007) implied that SDMI is independently affected by silage DM concentration. Kuoppala (2010) concluded that regrowth of grass differs from primary growth with respect to tiller and chemical composition, digestibility and intake potential. Generally, regrowth contains more ash and CP and less NDF compared with the primary growth but the variation in chemical composition is large within and between the cuts, mainly due to the differences in harvesting time and environmental factors (Kuoppala 2010). In the present experiment, the third-cut silage had higher analysed digestibility and SDMI index compared to the first- and second-cut silages. Based on this, the intake and production responses of GS3 should have been higher compared to GS1 and GS2. This was also realised when comparing GS2 and GS3. Nevertheless, there was no difference in DM or energy intake between GS1 and GS3 so SDMI index was not able to predict the differences in DMI in this case. However, in previous large-scale meta-analyses SDMI index has generally predicted well the factors affecting silage DMI in both dairy cows (Huhtanen et al. 2002, 2007) and growing cattle (Huuskonen et al. 2013).

Contrary to the earlier milk production experiments (Sairanen and Juutinen 2013, Sairanen et al. 2016) DMI was not decreased in the present study when the third-cut silage was used in the feeding instead of the first- and second-cut silages. The observed daily DMI was clearly higher when the GS1 and GS3 were used instead of the GS2. This may partly be due to digestibility, which was the lowest in the second-cut silage. Feed digestibility is one of the most important factors affecting silage intake (Huhtanen et al. 2007). Earlier, several studies with growing cattle (Steen 1992, Scollan et al. 2001, Steen et al. 2002, Keady et al. 2008) have confirmed an increased intake of silage in response to higher digestibility.

One possible reason for the decreased DMI in GS2 could be the impaired microbiological quality of herbage. Earlier, Kuoppala (2010) discussed that the microbiological quality of regrowth grass may differ from that of primary growth because regrowth contains more dead plant material. In Finland, the weather is typically warmer later in the summer when the second cut is generally harvested, compared to the first cut in early summer or third cut in autumn. Therefore, the second cut may have contained more dead plant material than first and third cuts. However, the occurrence of leaf spot infections was not evaluated in the present study.

Higher daily DMI of the GS1 and GS3 bulls compared to the GS2 bulls was reflected also as larger daily ME and nutrient intake. Observed difference in ME intake is probably a crucial explanation for the improved LWG and carcass gain of the GS1 and GS3 bulls compared to the GS2 bulls. Based on the meta-analysis of feeding experiments, Huuskonen and Huhtanen (2015) found that energy intake was clearly the most important variable affecting LWG of growing cattle, whereas the results showed only marginal effects of protein supply on growth.

The average LWG and carcass gain of the bulls were high in the present experiment. It can be assumed that the main reason for the high growth rate was the effect of high silage digestibility leading to high energy intake. Earlier, also Manninen et al. (2011) reported high carcass gains (1029 and 913 g d^{-1}) when finishing Hereford bulls were fed highly digestible silage (D values 750 and 699 g kg^{-1} DM, respectively) and barley-based concentrate supplementation. The improved growth rate on highly digestible silage has previously been confirmed in several studies (e.g. Scollan et al. 2001, Steen et al. 2002, Keady et al. 2008). Steen (1988a) summarised eight comparisons in which grass silages were supplemented with concentrates (20 to 37% of total DMI) and observed that increasing silage digestibility increased daily LWG and carcass gain by 37 and 28 g, respectively, per 10 g kg^{-1} increase in digestibility.

Protein conversion rate was better in GS1 and GS2 bulls compared to the GS3 bulls because also in GS1 and GS2 rations the PBV value fulfilled the protein recommendation for growing cattle. Therefore, the bulls could not utilise the additional protein obtained through feeding the third-cut silage. A recent meta-analysis (Huuskonen et al. 2014) and feeding experiments (Huuskonen 2013, Pesonen et al. 2014) indicate that the currently recommended PBV (PBV of the diet above –10 g kg^{-1} DM for animals above 200 kg LW, Luke 2017) could even be reduced without adverse effects on growth performance and carcass traits.

In the present study, feeding treatments had no significant effects on carcass traits. Previous reports have shown no effects of silage digestibility on dressing proportion, carcass conformation and fat scores (Steen 1988b, Cummins et al. 2007, Manninen et al. 2011). However, increasing energy intake has often increased carcass conformation (Aronen et al. 1994, Caplis et al. 2005, Pesonen et al. 2013, Huuskonen and Huhtanen 2015) and carcass fatness (Huuskonen et al. 2007, Pesonen et al. 2013, Huuskonen and Huhtanen 2015, Manni et al. 2016) of growing and finishing cattle but these effects could not be demonstrated in the present experiment.

In conclusion, daily DM and energy intakes, as well as growth rates of the finishing bulls, increased when either first- or third-cut timothy silages were used in total mixed ration instead of the second-cut silage. This was probably due to digestibility, which was the lowest in the second-cut silage. There were no differences in feed intake or growth between the first-cut and the third-cut silage-based rations, although based on feed analysis the third-cut silage had a clearly higher digestibility and DM intake index compared to the first-cut silage. Thus, as hypothesised, intake and growth of the autumn-cut silage-fed bulls was lower than expected based on the feed analysis. In the future, it could be justifiable to carry out a comparable feeding trial in which the autumn-cut silage would be fed as a sole feed or with a clearly lower concentrate allowance compared to the present experiment. Then the significance of silage quality would be highlighted and the production potential of the autumn cut grass silage could be estimated better.

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