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ORIGINAL PAPERS

THE EFFECT OF GRASS SILAGE QUALITY AND SUPPLEMENTARY CONCENTRATE LEVELS ON FEED INTAKE AND FATTENING PERFORMANCE OF CROSSBRED STEERS*

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Abstract

Grass silage is the basic component of diets for winter or year-round feeding of beef cattle in Central and Northern Europe, but its quality can vary considerably. The aim of this study was to determine whether the quality of silage influences the fattening performance of crossbred steers and whether higher intake of supplementary concentrate improves performance in steers fed silage of lower quality. The experiment was conducted on 52 crossbred steers with the initial body weight of 300 kg, produced by crossing Polish Holstein-Friesian dairy cows with Charolais, Limousin and Hereford bulls. The animals had *ad libitum* access to one of two types of grass silages (of higher and lower quality), and silage intake was recorded individually. Supplementary concentrate consisted of crimped triticale grain (785 g kg^{-1}), rapeseed meal (190 g kg^{-1}) and a mineral-vitamin premix for beef cattle (25 g kg^{-1}). Concentrate was administered at two levels of 1.9 and 2.4 kg dry matter per day. The animals were housed in a free-stall system and feed intake was recorded individually. The fattening period lasted 65 days. Live weight gains were higher ($P < 0.0001$) in the group of steers fed high feed value grass silage than in the group administered low feed value grass silage. Steers fed silage supplemented with a higher level of

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concentrate were characterized by higher live weight gains ($P < 0.0001$) than those receiving silage with a lower level of concentrate. Average daily gains were similar in steers fed lower-quality silage with a higher level of concentrate and in those offered higher-quality silage with a lower level of concentrate (0.972 and 0.975 kg, respectively). It can be concluded that a comparable level of fattening performance can be achieved in steers fed low feed value silage supplemented with a higher amount of concentrate and in animals receiving high feed value silage supplemented with a lower amount of concentrate.

Keywords: silage quality, concentrate levels, beef cattle, grass silage, steers.

INTRODUCTION

Grass silage is the basic component of diets for winter or year-round feeding of beef cattle in Central and Northern Europe, but its quality can vary considerably (Purwin et al. 2006). The nutritional value of grass silage and its suitability as a component for inclusion in the diet of ruminants depend on the quality of fodder and additives used in the ensiling process as well as the processes that take place during silage fermentation, storage and unloading from the silo (Purwin et al. 2006). Silage quality exerts a multifactorial impact on intake, which accounts for the simultaneous effects of all fermentation products (Purwin et al. 2010). The quality of silage fed to livestock affects its intake, total feed intake and consequently fattening efficiency (Steen et al. 1998). Silage quality influences fattening performance regardless of the breed type (Cummins et al. 2007). Feed intake and productivity in ruminants fed only silage are closely correlated with silage quality (Kirkland et al. 2005), but they are far less significant in cattle whose diets are supplemented with concentrate (Keady et al. 2008), which suggests that appropriate inclusion rates of concentrate can have a compensatory effect on diets composed of low-quality silage. Due to the high cost of silage additives in Poland, the most popular method of improving silage quality involves wilting of herbage to approximately 40% DM (Sobiech et al. 2015). However, there is a risk that the wilted material will be soaked by rain, making it unsuitable for ensiling. Soaking the previously wilted herbage with rain water can deteriorate fermentation conditions by decreasing the concentrations of water-soluble carbohydrates (WSC) and increasing the moisture content of the ensiled material.

Therefore, the aim of this study was to determine the extent to which the quality parameters of silage influence the fattening performance of crossbred steers and whether higher daily intake of supplementary concentrate improves productivity in steers fed silage of lower quality. This evaluation was carried out on the basis of feed intake, growth rate and feed conversion in steers.

MATERIALS AND METHODS

Two types of grass silages were produced in the Agricultural Experimentation Station in Bałcyny (53°35′N, 19°51′E), north-eastern Poland, from the first and second cut of identical grass mixtures (*Lolium perenne, Phleum pretense, Festuca rubra, Poa pratensis*) grown on arable land in the second year of use. Mineral fertilizers were applied at the following doses: nitrogen – 160 kg ha^{-1} (3/6 of the dose in spring, 2/6 after the first cut, and 1/6 after the second cut), phosphorus – 70 kg ha^{-1} (in spring), potassium – 160 kg ha^{-1} (in spring). The crop was mown using a drum mower conditioner. Wilted green material was harvested with a precision chop forage harvester (John Deere 7050), and it was compacted in horizontal silos by a tractor (laden weight of 7770 kg) in layers of 0.5 m. Each silo was covered with polythene sheets and weighted down. Silages were produced without additives.

Higher-quality silage was produced from the primary growth of grass harvested in the earing stage and left to wilt for 36 hours under good weather conditions. Lower-quality silage was produced from 7-week-old secondary growth which was wilted for 24 hours and was soaked by rain.

The experiment (performance measurements) was conducted on 52 crossbred steers during a fattening period of 65 days. The experimental animals were produced in terminal crossbreeding by crossing Charolais, Limousin and Hereford beef bulls and Polish Holstein-Friesian dairy cows. The animals were purchased, and they underwent chemical dehorning at 8 weeks of age. Beginning in the second week of life, during the milk-feeding period, calves received concentrate and hay *ad libitum*. Milk feeding was stopped when their body weights reached 125 kg, after which the calves were fed haylage *ad libitum* and 2 kg of concentrate daily.

The adaptation period was started at 6 months of age. Steers were placed in a fattening laboratory and they were divided by the analogue method into four groups with equal distribution of breeds. The animals in each group were fed the same silage and the same concentrate in adequate amounts depending on the feeding pattern. Performance measurements began when the body weights of calves reached 300 kg and when experimental silages were administered. Four dietary treatments were applied. Each diet was composed of higher-quality silage (HQS) or lower-quality silage (LQS) supplemented with a higher (HC) or lower (LC) level of concentrate (HQS-HC, HQS-LC, LQS-HC and LQS-LC, respectively). The animals were housed in a free-stall system with free access to water and salt licks. The animals had *ad libitum* access to grass silages. Silages were administered twice daily in feed bunks (at 9 a.m. and 3 p.m.). Silage intake was recorded individually using the Roughage Intake Control System (Insentec, Holland). There were five animals per feed bin. Concentrate was fed separately and upon request, in rations not exceeding 1 kg, in feeding stations where intake was recorded. Steers were fattened at two levels of feeding intensity. Silages were supplemented with concentrate at a lower or higher level (1.9 and 2.4 kg DM per day, respectively). Concentrate feeding stations were equipped with weighing floors to monitor body weight during each visit. The concentrate consisted of crimped triticale grain (785 g kg^{-1}), rapeseed meal (190 g kg^{-1}) and a mineral-vitamin premix for beef cattle (25 g kg^{-1}). The mineral–vitamin premix contained in 1 kg: Fe – 500 g, Ca – 235 g, Na – 79 g, Mg – 28 g, P – 48 g, Mn – 2000 mg, Zn 3 750 mg, Cu – 375 mg, Co – 12.5 mg, I – 50 mg, Se – 12.50 mg, vitamins: A – 250 000 IU, D3 – 50000 IU, DL-alpha tocopherol – 909 mg, E – 1000 mg. Average daily gain (ADG) and daily dry matter intake (DMI) were calculated for each animal. The feed conversion ratio (FCR) was calculated as daily DMI divided by ADG (Nogalski et al. 2013). PDI intake per day and per ADG were calculate on the basis of PDIE.

Silages samples (500 g) were collected from feed bins twice a week and were stored at -20°C. Samples were pooled over 30-day periods. The nutrient content of feeds was determined according to the AOAC (2005) procedure. The content of water-soluble carbohydrates (WSC) was determined by the anthrone method (Thomas 1977). The content of neutral-detergent fiber (aNDF), acid-detergent fiber (ADF) and acid-detergent lignin (ADL) was determined by the method proposed by Van Soest et al. (1991) using the ANKOM[220] fiber analyzer (ANKOM Technology Corp., Macedon, NY). Protein nitrogen content was determined with the use of trichloroacetic acid (Licitra et al. 1996). Acid detergent insoluble nitrogen (ADIN) was determined based on the method proposed by Licitra et al. (1996) and buffer soluble nitrogen (BSN) – by the method described by Hedqvist, Udén (2006). The ammonium nitrogen content of silage was determined by micro-diffusion (modification of the method proposed by Conway 1954) and acidity was measured with the HI 8314 pH-meter (Hanna Instruments, USA). The concentrations of carboxylic acids in silages were determined by high-performance liquid chromatography (HPLC) with the MetaCarb 67H P/N 5244 (Varian, Palo Alto CA, USA) column and 0.0025 M sulfuric acid as the mobile phase, according to manufacturer's protocol. Biogenic amines in silages were identified by HPLC with a UV-VIS detector (546 nm) and the ET 125/4 Nucleosil 120–5 (Macherey-Nagel, Düren, Germany) C18 column, according to the method described by Joosten, Olieman (1986). *In vitro* DM digestibility (IVDMD) was determined in a Daisy II incubator (ANKOM Technology Corp.) with rumen fluid, followed by extraction in neutral detergent solution according to the method proposed by Kowalski et al. (2014). The nutritional value of diets were determined using the WINWAR program (Kowalski, Kański 1993)

The statistical analysis was performed with use of the STATISTICA v. 10.00 program (StatSoft, Inc., 2011). The results of two-way ANOVA, followed by the Tukey's post-hoc test (HSD), were regarded statistically significant at $P \leq 0.05$. ANOVA was performed on the assumption of normality (Shapiro-Wilk test) and homogeneity of variances (Levene's test). Silage parameters were processed with Student's *t*-test. All data were presented as means ± standard error of the mean.

RESULTS

First-cut grass silage of higher quality (HQS) was characterized by a significantly higher content of DM ($P < 0.05$), WSC, BSN ($P < 0.01$) and IVDMD ($P < 0.01$) but lower acidity ($P < 0.01$), a lower content of fiber fractions (NDF, ADF, ADL), ADIN ($P < 0.01$), biogenic amines ($P < 0.01$) – tyramine ($P < 0.05$), putrescine and cadaverine ($P < 0.01$), a lower proportion of ammonium nitrogen in total nitrogen ($P < 0.05$) and a lower forage fill value ($P < 0.01$) as compared with second-cut silage of lower quality (LQS). HQS was also characterized by significantly higher ($P < 0.01$) net energy and PDIE values, whereas PDIN values were similar in both silage types. PDIE values were lower than PDIN values (Table 1).

The feed intake analysis revealed that the quality of grass silage affected net energy intake ($P < 0.001$) and PDI intake ($P < 0.01$) but it had no significant effect on the intake of: total DM, silage DM and crude protein (CP) – Table 2. Only certain trends were observed despite the fact that lower-quality silage contained significantly higher concentrations of biogenic amines and ammonium nitrogen.

In steers fed a higher level of concentrate, intake was higher by approximately 0.62 kg DM concentrate per day than in steers fed a lower level of concentrate (2.36 kg vs. 1.74 kg). A tendency toward higher intake of DM and CP, and a tendency toward lower intake of silage were observed in animals receiving a higher level of concentrate. In animals fed higher-quality silage, roughage intake was reduced numerically by 0.42 kg DM per day, and in steers fed lower-quality silage – by 0.14 kg DM per day. A higher amount of concentrate did not lead to a significant increase in total feed intake.

The quality of silage affected live weight gains and ADG ($P < 0.001$), FCR ($P < 0.01$), concentrate intake per kg of weight gain ($P<0.001$), and the utilization efficiency of CP ($P < 0.05$) and NE ($P < 0.05$) – Table 2. The level of concentrate influenced live weight gains ($P < 0.001$), ADG ($P < 0.001$) and FCR ($P < 0.01$), and the efficiency of silage and concentrate DM ($P < 0.001$), CP ($P < 0.01$), NE ($P < 0.05$) and PDI ($P < 0.05$) utilization for ADG. No silage quality x concentrate level interactions were observed for any of the analyzed parameters.

Significant differences in live weight were found between the groups. The lowest final live weight was noted in the LQS-LC group, and the highest – in the HQS-HC group. No differences in final live weight were observed between HQS-LC and LQS-HC groups. Feeding intensity influenced the growth rate of steers. A higher level of concentrate supplementation increased ADG by 0.185 kg in animals fed higher-quality silage and by 0.151 kg in steers receiving lower-quality silage. Higher-quality silage contributed to higher ADG values in groups fed identical amounts of concentrate – the difference in ADG values between HQS-LC and LQS-LC was determined at 0.154 kg ($P < 0.01$), and between HQS-HC and LQS-HC – at 0.188 kg ($P < 0.01$). As expected, ADG was highest in HQS-HC and lowest in LQS-LC (decrease of 29.2%).

Table 1

Chemical composition and nutritional value of feeds (mean±SEM)

Specification	Higher-quality silage	Lower-quality silage	Concentrate
n	11	11	11
Dry matter (g kg^{-1})	410^{b} ± 17.9	328^{a} ± 24.7	882 ± 8.2
pH	4.53^{A} ± 0.07	4.87^{B} ± 0.05	-
Chemical composition of dry matter (g kg^{-1} DM)			
organic matter	874 ± 12.9	875 ± 16.3	925 ± 8.3
crude protein	154 ± 3.0	150 ± 3.7	159 ± 2.1
ether extract	28 ± 1.6	29 ± 1.8	31 ± 1.2
neutral detergent fiber	539^{A} ± 11.9	591^{B} ± 10.4	-
acid detergent fiber	336^{A} ± 11.5	412^{B} ± 10.5	-
acid detergent lignin	42^{A} ± 2.9	67^{B} ± 4.3	-
water-soluble carbohydrates	95^{B} ± 10.6	25^{A} ± 5.3	-
Nitrogen compounds (g kg^{-1}total N)			
protein N	531 ± 3.0	565 ± 5.3	-
ammonium N	64^{a} ± 0.8	109^{b} ± 2.0	-
acid detergent-insoluble-N	73^{A} ± 0.7	120^{B} ± 0.9	-
buffer-soluble-N	342^{B} ± 2.0	270^{A} ± 2.5	-
Carboxylic acids (g kg^{-1} DM)			
lactic acid	56 ± 8.2	50 ± 16.7	-
acetic + propionic acid	14 ± 2.4	22 ± 7.0	-
butyric acid	6 ± 1.1	7 ± 3.4	-
sum of determined carboxylic acids	76 ± 1.8	78 ± 10.2	-
Biogenic amines (mg kg^{-1} DM)			
tyramine	142^{a} ± 20.4	295^{b} ± 54.6	-
putrescine	275^{A} ± 4.2	623^{B} ± 2.7	-
cadaverine	144^{A} ± 25.8	439^{B} ± 73.6	-
sum of determined biogenic amines	570^{A} ± 79.5	1367^{B} ± 217.1	-
IVDMD* (%)	74^{B} ± 1.0	55^{A} ± 2.4	-
Feed value			
forage fill value (CFU kg^{-1} DM)**	0.88^{A} ± 0.04	1.10^{B} ± 0.07	-
net energy (UFV kg^{-1} DM)***	0.83^{A} ± 0.002	0.61^{B} ± 0.01	1.09 ± 0.02
PDIN (g kg^{-1} DM)****	90 ± 2.0	87 ± 2.5	103 ± 0.7
PDIE (g kg^{-1} DM)*****	72^{A} ± 2.3	57^{B} ± 0.8	105 ± 0.5

* in vitro dry matter digestibility, ** cattle fill unit, *** feed unit energy for cattle, **** protein digested in the small intestine when rumen degraded dietary N is limiting, ***** protein digested in the small intestine when rumen energy available is limiting, SEM – standard error of the mean, differences significant at *a,b* $P < 0.05$; *A,B* $P < 0.01$.

Table 2

Effect of dietary treatment on feed intake and animal performance (mean values ± SEM)

Silage quality (Q)	Higher-quality silage		Lower-quality silage		Significance†	
Grain feed level (L)	lower	higher	lower	higher	Q	L
Initial live weight (kg)	300 ± 0.4	300 ± 0.1	300 ± 0.5	300 ± 0.4		
Final live weight (kg)	363 ± 2.0	376 ± 2.1	354 ± 2.4	363 ± 2.3	***	***
Silage intake (kg DM day^{-1})	4.66 ± 0.19	4.24 ± 0.18	4.18 ± 0.29	4.04 ± 0.19		
Total feed intake (kg DM day^{-1})	6.40 ± 0.19	6.60 ± 0.19	5.91 ± 0.29	6.41 ± 0.19		
CP intake (g day^{-1})	965 ± 29.3	997 ± 28.7	888 ± 43.8	938 ± 29.0		
Net Energy intake (UFV day^{-1})	6.0 ± 0.16	6.3 ± 0.16	4.4 ± 0.18	5.0 ± 0.12	***	
PDI intake (g day^{-1})	520 ± 13.8	555 ± 13.6	419 ± 16.5	477 ± 11.2	**	
Live-weight gain (kg)	63 ± 1.9	75 ± 2.1	53 ± 2.3	63 ± 2.2	***	***
ADG (kg day^{-1})	0.975 ± 0.03	1.160 ± 0.03	0.821 ± 0.03	0.972 ± 0.03	***	***
FCR (kg kg^{-1})	6.60 ± 0.20	5.72 ± 0.16	7.32 ± 0.44	6.64 ± 0.19	**	**
Silage intake/ADG (kg DM kg^{-1})	4.8 ± 0.18	3.7 ± 0.14	5.2 ± 0.40	4.2 ± 0.15		***
Concentrate intake/ADG (kg DM kg^{-1})	1.8 ± 0.06	2.1 ± 0.06	2.2 ± 0.08	2.5 ± 0.09	***	***
CP intake/ADG (g kg^{-1})	997 ± 31.1	863 ± 24.9	1098 ± 66.5	974 ± 28.6	*	**
Net energy intake/ADG (UFV kg^{-1})	6.1 ± 0.17	5.4 ± 0.14	5.4 ± 0.29	5.1 ± 0.14	*	*
PDI intake/ADG (g kg^{-1})	537 ± 15.5	481 ± 12.8	519 ± 27.2	496 ± 13.7		*

† There were no grain feed level x silage feed value interactions. SEM – standard error of the mean, * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

DISCUSSION

In comparison with other studies, the silages used in this experiment were characterized by low concentrations of fermentation acids, excluding butyric acid, and relatively high concentrations of total nitrogen (KEADY et al. 2008). Both silages had a similar content of crude protein, protein nitrogen and organic matter. The observed differences in carbohydrate fractions and IVDMD could indicate that silages varied in their ruminal digestibility. Differences in the pH, biogenic amine content and the ratio of ammonium nitrogen to total nitrogen in the analyzed silages could point to differences in silage palatability (PURWIN et al. 2010). The chemical composition of the experimental silages produced from the first and second cut of the same grasses indicates that weather conditions during growth, harvest and wilting have a significant influence on the quality of silage (PURWIN et. al. 2014). Soaking with rainwater affected the concentrations of ammonium, biogenic amines and acetic acid. Those fermentation products are negatively correlated with voluntary intake of silage (PURWIN et al. 2006). Moreover, high ADIN values and low BSN values in lower-quality silage could be attributed to thermal processes that take place in mown plant material and during ensiling (FIJAŁKOWSKA et al. 2015).

In our study, the quality of fermentation had no significant effect on silage intake and total intake, which could be attributed to a relatively high supplementation level (STEEN et al. 2002). Animals fed a higher level of concentrate were characterized by higher total dry matter intake and lower intake of roughage, and the substitution effect tended to be lower in groups receiving lower feed value silage compared with higher feed value silage. The substitution rate in groups HQS and LQS was 0.68 and 0.22, respectively. The noted trends are in agreement with the findings of DAWSON et al. (2002), who reported that every kg of concentrate fed to young cattle decreased intake by approximately 0.61 kg DM and 0.39 kg DM with regard to grass silage of superior and inferior quality, respectively. The effect of supplementation depends on roughage digestibility. The addition of concentrates to low-digestibility silage stimulates ruminal microflora and decreases food residence time in the rumen, which can increase the intake of dry matter supplied with silage of inferior quality (PURWIN et al. 2009). In other studies, the intake of higher-quality silage decreased with an increase in total dry matter intake (CAPLIS et al. 2005, HUUSKONEN et al. 2007).

The daily intake of silage, total feed intake and CP intake did not differ between dietary treatments. However, significant differences in NE and PDI intake were noted. In the HQS-HC group, NE and PDI intake met the NE and PDI requirements (INRA 2007) of medium-early maturing young bulls with daily gains of around 1200 g. In the HQS-LC group, NE intake could guarantee similar daily gains but the level of PDI intake appeared to be the limiting factor. In the LQS-LC group, a deficit in NE and PDI intake relative to the requirements of steers with daily gains of around 1000 g was observed: 14% UFV and 20% PDI, respectively. An increase in concentrate levels let to an increase in NE intake corresponding to the requirements of steers with daily gains of around 1000 g, but a 10% deficit in PDI intake was still observed. Live weight gains were identical in HQS-LC and LQS-HC groups, but concentrate conversion was 26.7% lower in the HQS-LC treatment than in the LQS-HC treatment. The opposite trend was noted in NE and PDI intake per kg of live weight gain, which is consistent with the findings of other authors who demonstrated that the effect of concentrate supplementation is inversely proportional to grass silage digestibility (Steen et al. 2002, Huuskonen et al. 2007).

The FCR ratio ranged from 5.72 in HQS-HC to 7.32 in LQS-LC, and it was significantly improved in the group of steers fed higher-quality silage with a higher level of concentrate. Concentrate utilization was higher in steers receiving higher-quality silage regardless of the level of concentrate supplementation compared with LQS-LC and LQS-HC groups. At the same time, animals fed a higher level of concentrate were characterized by improved FCR but lower concentrate conversion per kg of weight gain, irrespective of silage quality. The composition of the carbohydrate fraction, which significantly influences forage digestibility (Dawson et al. 2002) could affect weight gains and FCR. Significantly higher levels of ADIN and lower concentrations of BSN appear to be the major factors that contribute to the decreased efficiency of nitrogen utilization.

In our study, no silage quality x concentrate level interactions were observed for any of the analyzed parameters, whereas contrary results were reported by Keady et al. (2008) who found interactions between those factors for final live weight and live weight gains. The above differences could be attributed to the fact that silage quality in our study was determined by a number of attributes, including the first or second cut, growth stage and the DM content of the ensiled material.

Due to the higher content of ADIN and the lower content of BSN, nitrogen utilization efficiency was much lower in steers fed silage of inferior quality. High feed efficiency, including in groups fed lower-quality silage, can be attributed to the presence of rapeseed meal in the concentrate. In cattle fed grass silage and flattened barley grain, apparent CP digestibility increases with the addition of rapeseed meal (Huuskonen 2009). In a study by Huuskonen (2009), the addition of rapeseed meal to diets based on high-quality grass silage supplemented with flattened barley grain also improved production results in the initial phase of fattening (195-284 days of age; average concentrate level of approximately 400 g kg^{-1} DM).

CONCLUSIONS

In our study, differences in the analyzed properties of grass silage did not influence the silage intake or total daily DM intake in steers. However, differences in silage quality may affect energy intake and, consequently, crude protein utilization, FCR and weight gains, as well as the concentrate conversion rate per kg of live weight gain.

The level of supplementary concentrate in steer diets influenced weight gains, FCR and the efficiency of concentrate utilization. Regardless of silage quality, a higher level of concentrate increased weight gains and silage utilization, but decreased concentrate utilization efficiency per kg of live weight gains.

It can be concluded that a comparable level of fattening performance can be achieved in steers fed low feed value silage supplemented with a higher amount of concentrate and in animals receiving high feed value silage supplemented with a lower amount of concentrate.

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