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Effects of replacement of late-harvested grass silage and barley with early-harvested silage on ruminal digestion efficiency in lactating dairy cows

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ABSTRACT

The objective of this experiment was to quantify the effects of graded replacement of late-harvested grass silage and barley with early-harvested silage on nutrient digestion and rumen fermentation. Four experimental diets were fed to 4 multiparous rumen-cannulated Nordic Red cows in 4 × 4 Latin square design with 21-d periods. Dietary treatments consisted of late-cut grass silage (LS) and rolled barley, which was gradually replaced with early-cut grass silage [ES; 0, 33, 67, and 100% of the forage component (ES + LS) of the diet]. With increased proportion of ES in the diet, the proportion of barley decreased from 47.2 to 26.6% on a dry matter basis. Early- and late-cut silages were harvested at 2-wk intervals (predicted concentrations of metabolizable energy 11.0 and 9.7 MJ/kg of dry matter). The 4 diets were formulated to support the same milk production. Nutrient flows were quantified using omasal sampling technique applying the triple-marker method (Cr, Yb, and indigestible neutral detergent fiber) and ^{15}N as a microbial marker. Feed intake decreased with graded replacement of LS and barley with ES, but milk production was not influenced by diet. Digestibility of nutrients improved with graded addition of ES in the diet with the greatest difference observed in digestibility of neutral detergent fiber (NDF) and potentially digestible NDF (pdNDF). The results suggested that improved cell wall digestibility with graded level of ES in the diet was partly related to higher intrinsic digestibility of ES than LS, and partly due to negative associative effects with an increased proportion of LS and barley in the diet. Efficiency of microbial N synthesis was not influenced by the diet, but ruminal protein degradability increased with ES in the diet. Rumen fermentation pattern was not affected by the diet despite large difference in the profile of dietary carbohydrates. Rumen pool size of NDF and pdNDF, and ruminal turnover time of NDF decreased with graded addition of ES in the diet, whereas digestion rate of pdNDF improved. The results of this study indicate that increased CH_4 yield in a parallel production study with graded addition of ES in the diet were more related to greater ruminal and total digestibility of organic matter than to the changes in rumen fermentation pattern.
Key words: silage digestibility, concentrate, nutrient digestion, rumen fermentation

INTRODUCTION

Nutritional strategies to mitigate CH_4 emissions have been intensively sought to identify alternative hydrogen sinks in the rumen. With high-grain diets that are common in feedlot situations with beef cattle, typical CH_4 loss may drop to approximately 3% of gross energy (Johnson and Johnson, 1995), which is much lower than 6 to 7% of gross energy with typical dairy cow diets (e.g., Yan et al., 2000). This suggests that feeding more grain in diets for dairy cows could be an effective strategy to reduce emissions. However, recent data have indicated that the effect of proportion of dietary concentrate supplementation is relatively small within the range of typical dairy cow diets (Ramin and Huhtanen, 2013).

In northern latitudes of Europe, grass silage is the main dietary ingredient and carbohydrate source for dairy cows (Huhtanen et al. 2013). It is well known that early harvested grass silage of high quality can support higher milk yields with lower input of purchased concentrate feed than a silage harvested at a more mature stage (Ferris et al., 2001; Kuoppala et al., 2008; Randby et al., 2012). Additionally, cereal grains can be used directly as human food or more efficiently by monogastric animals, but on the other hand substitution of starch with fiber might contribute to increased CH_4 production by promoting acetate rather than propionate fermentation in the rumen (Moss et

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al., 2000). A companion production study published previously demonstrated that milk production and CH_4 intensity (g of CH_4/kg of ECM) were not influenced, but a greater CH_4 yield (g of CH_4/kg of DMI) was observed when medium-quality late harvested grass silage and rolled barley were replaced by high-quality early harvested grass silage (Cabezas-Garcia et al., 2017). Several digestive mechanisms may contribute to the effects on CH_4 production when different carbohydrate sources are fed to dairy cows, and any nutritional strategy should ideally also strive to reduce potential environmental emissions.

The aim of this experiment was to explain the mechanisms explaining differences in CH_4 emissions when replacing late-harvested grass silage and barley with early-harvested grass silage in the diets to lactating dairy cows. The approach of investigating the effect of grass cut early or late and at the same time reducing concentrate level with early cutting is novel, and will provide insight into the real mechanisms whereby changes in diet composition alter rumen function and nutrient use.

MATERIALS AND METHODS

All animals were registered and cared for according to guidelines approved by the Swedish University of Agricultural Sciences Animal Care and Use Committee and the National Animal Research Authority, and the experiment was carried out in accordance with the laws and regulations controlling experiments performed with live animals in Sweden. The present experiment was conducted in parallel with a production study, which evaluated production responses and CH_4 emissions in 16 lactating cows fed the same experimental diets (Cabezas-Garcia et al., 2017).

Cows, Diets, and Experimental Design

Four multiparous Nordic Red cows, averaging (mean ± SD) 676 ± 79 kg of BW, 90 ± 19.1 DIM, and producing 31 ± 6.3 kg of milk/d at the beginning of the study were used in a balanced 4 × 4 Latin-square design. The experimental periods lasted for 21 d, and were divided into 14 d of adaptation, and 7 d of data recording and sampling. All cows were fitted with 10-cm ruminal cannulas (Bar Diamond Inc., Parma, ID). The cows were housed in tie stalls bedded with sawdust. They had free access to water and salt blocks during the whole experiment, and were offered feed twice daily at 0600 and 1800 h. Orts were recorded once daily and feeding rate adjusted to yield orts of approximately 10% of the intake except during the 4 d of sampling from the omasum, when it was restricted to 95% of ad libitum intake to minimize between- and within-day variations in intake due to intensive sampling. Total DMI and milk production were recorded daily. Milking was performed twice daily at 0700 and 1600 h.

Two grass silages were harvested at 2-wk interval (June 10 and 24, 2013) using a disc mower conditioner (GMT 3605 FlexP, JF-Stoll A/S, Sønderborg, Denmark) and a precision-chop forage wagon (ES 5000 MetaQ Protec, JF-Stoll A/S). The herbage was harvested as a primary growth of a third-year ley dominated by timothy grass (*Phleum pratense*) with some red clover (*Trifolium pratense*) in Umeå, Sweden (63°45′ N, 20°17′). The crops were wilted to an approximate DM concentration of 300 g/kg and ensiled in bunker silos using a commercial acid-based additive (ProMyr XR 630, Perstop, Sweden) provided at a rate of 3.5 L/t.

The experimental diets were formulated to meet the ME and MP requirements for production of 35 kg/d of ECM within the constraints of intake potential (see Cabezas-Garcia et al., 2017). The dietary treatments in the study comprised gradually replacing late-cut silage (**LS**) and rolled barley with 3 incremental levels of early-cut silage (**ES**). A mixture of LS and barley were gradually replaced with ES (0, 33, 67, and 100% of the forage component of diet) to obtain 4 diets defined as follows: late-cut (**L**), late-early (**LE**), early-late (**EL**), and early-cut (**E**) silage. With increasing proportion of ES in the diet, proportion of barley decreased from 47.2 to 26.6% on a DM basis. The changes in the proportion of total forage, barley, and proportions of LS and ES within the forage component were all linear. Heat-treated solvent-extracted canola meal containing low levels of glucosinolates and erucic acid (ExPro-00SF from AarhusKarlshamn Ltd., Malmö, Sweden) was used as a protein supplement. Because the cows in the production study (Cabezas-Garcia et al., 2017) received a compound feed (Solid 220; Lantmännen Lantbruk AB, Malmö, Sweden) while visiting the GreenFeed system (GreenFeed system, C-Lock Inc., Rapid City, SD) for recording CH_4 emissions, the rumen-cannulated cows were offered 1 kg of DM/d of the same compound feed to have a similar diet composition in both studies. The diets were fed as TMR. The DM concentration of the grass silages was determined twice a week and once a week for the concentrate ingredients for adjustment of diet composition. The formulation of the experimental diets is shown in Table 1.

Sampling Procedures

Total DMI and milk yield were recorded daily, but only data from d 14 to 21 were used for statistical analysis. Milk yield was recorded twice daily with gravimetric milk recorders (SAC, S.A. Christensen and