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Enteric methane production, rumen volatile fatty acid concentrations, and milk fatty acid composition in lactating Holstein-Friesian cows fed grass silage- or corn silage-based diets

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ABSTRACT

The objective of this study was to determine the effects of replacing grass silage (GS) with corn silage (CS) in dairy cow diets on enteric methane (CH_4) production, rumen volatile fatty acid (FA) concentrations, and milk FA composition. A completely randomized block design experiment was conducted with 32 multiparous lactating Holstein-Friesian cows. Four dietary treatments were used, all having a roughage-to-concentrate ratio of 80:20 based on dry matter (DM). The roughage consisted of either 100% GS, 67% GS and 33% CS, 33% GS and 67% CS, or 100% CS (all DM basis). Feed intake was restricted (95% of ad libitum DM intake) to avoid confounding effects of DM intake on CH_4 production. Nutrient intake, apparent digestibility, milk production and composition, nitrogen (N) and energy balance, and CH_4 production were measured during a 5-d period in climate respiration chambers after adaptation to the diet for 12 d. Increasing CS proportion linearly decreased neutral detergent fiber and crude protein intake and linearly increased starch intake. Milk production and milk fat content (on average 23.4 kg/d and 4.68%, respectively) were not affected by increasing CS inclusion, whereas milk protein content increased quadratically. Rumen variables were unaffected by increasing CS inclusion, except the molar proportion of butyrate, which increased linearly. Methane production (expressed as grams per day, grams per kilogram of fat- and protein- corrected milk, and as a percent of gross energy intake) decreased quadratically with increasing CS inclusion, and decreased linearly when expressed as grams of CH_4 per kilogram of DM intake. In comparison with 100% GS, CH_4 production was 11 and 8% reduced for the 100% CS diet when expressed per unit of DM intake and per unit fat- and protein-corrected milk, respectively. Nitrogen efficiency increased linearly with increased inclusion of CS. The concentration of *trans* C18:1 FA, C18:1 *cis*-12, and total CLA increased quadratically, and *iso* C16:0, C18:1 *cis*-13, and C18:2n-6 increased linearly, whereas the concentration of C15:0, *iso* C15:0, C17:0, and C18:3n-3 decreased linearly with increasing inclusion of CS. No differences were found in short- and medium-straight, even-chain FA concentrations, with the exception of C4:0 which increased linearly with increased inclusion of CS. Replacing GS with CS in a common forage-based diet for dairy cattle offers an effective strategy to decrease enteric CH_4 production without negatively affecting dairy cow performance, although a critical level of starch in the diet seems to be needed.
Key words: dairy cow, enteric methane production, grass silage, corn silage

INTRODUCTION

Developing strategies to reduce enteric methane (CH_4) emissions from ruminants has received increasing interest recently, as it reduces the ecological footprint of milk production and potentially improves feed efficiency. Dietary manipulation seems to be the most direct and effective approach for reducing CH_4 production from ruminants (Beauchemin et al., 2009) because CH_4 production depends greatly on the level of feed intake and dietary composition, in particular the type of carbohydrates (Beauchemin et al., 2008; Ellis et al., 2008). Including various inhibitors or electron receptors in ruminant diets can reduce CH_4 production up to 50%, but in view of effectiveness and safety issues (e.g., issues with nitrates include potential toxicity from intermediate products), reductions of 10 to 30% are more likely in commercial practice (Hristov et al., 2013). Roughage represents the major component in dairy cow diets and, therefore, it is interesting to investigate the reduction of CH_4 production using roughage-based diets.

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Replacing fiber-rich roughage with starch-rich roughage has potential to reduce CH_4 emissions (Brask et al., 2013; Hassanat et al., 2013). Fermentation of starch favors the ruminal production of propionate at the expense of acetate and decreases rumen pH, which reduces hydrogen availability and activity of rumen methanogens (Van Kessel and Russell, 1996; Hook et al., 2011). The scientific evidence for this particular dietary replacement strategy is limited and does not always reflect diets used in practice. Staerfl et al. (2012) investigated this strategy, but the corn silage (**CS**) used had a net energy content some 10% lower than that of the grass silage (**GS**), which is uncommon in many countries. Brask et al. (2013) also investigated the effect of this dietary strategy, but the CS used had a starch content of only 150 g/kg of DM, which is low and uncommon compared with the reported starch content of CS at comparable DM contents (Sutton et al., 2000; Mc Geough et al., 2010a); therefore, the difference in starch content between the CS- (141 g/kg of DM) and the GS-diet (43 g/kg of DM) was not large.

When manipulating dairy cow diet for CH_4 reduction, one should be aware that the composition of milk can also change. Several studies observed that changes in dietary proportion of GS and CS can alter milk FA composition (Ferlay et al., 2006; Nielsen et al., 2006; Kliem et al., 2008). These studies were mainly interested in altering milk FA from a human health perspective, because milk and dairy products are an important source of fat and specific FA in the human diet (van Valenberg et al., 2013). In terms of dietary CH_4 mitigation strategies, differences in milk FA are interesting because they reflect the variations in the amount and composition of carbohydrate between GS and CS (Nielsen et al., 2006), which influences both rumen environment and biohydrogenation of unsaturated FA (Kliem et al., 2008). Consequently, milk FA composition has been suggested as a method to predict enteric CH_4 output in lactating dairy cattle (Dijkstra et al., 2011).

Roughages are nutritionally and economically important (Hassanat et al., 2013). Therefore, it is imperative to investigate dietary strategies using roughage-based diets to mitigate CH_4 production and to determine its effect on milk FA composition. Although GS and CS represent the major conserved roughages and are commonly used in dairy production (Wilkinson et al., 1996), to the best of our knowledge no study has investigated the effect of replacing GS with CS on enteric CH_4 production, rumen VFA concentrations, and milk production and composition, including milk FA composition together. Thus, the objectives of our study were (1) to gain more scientific evidence for the CH_4 mitigation strategy of replacing fiber-rich GS with starch-rich CS, (2) to examine the changes in ruminal VFA concentration and pH when replacing GS with CS, and (3) to determine the effects of replacing GS with CS on milk production and milk FA composition.

MATERIALS AND METHODS

Experimental Design

The experiment was conducted from October to December 2012 in accordance with Dutch law and approved by the Animal Care and Use Committee of Wageningen University. The experiment followed a completely randomized block design with 4 dietary treatments and 32 multiparous lactating Holstein-Friesian cows with an average milk production of 34.0 ± 5.71 kg/d and 192 ± 87 DIM at the start of the experiment. Cows were blocked in groups of 4 according to lactation stage, parity, milk production, and presence of a rumen cannula (12 cows), and within each block cows were randomly assigned to 1 of 4 dietary treatments; treatment periods, 8 in total, lasted 17 d.

Diets and Feeding

All dietary treatments had a roughage-to-concentrate ratio of 80:20 based on DM content. The composition of the compound feed was the same for all 4 treatments, whereas the roughage was GS, CS, or a mixture of both. The ingredient and chemical composition of the 4 diets are presented in Table 1. Dietary treatments were (ingredient as percentage of the total amount of roughage in the diet; DM basis): (1) 100% GS (**GS100**); (2) 67% GS and 33% CS (**GS67**); (3) 33% GS and 67% CS (**GS33**); and (4) 100% CS (**GS0**).

Cows were fed individually and feed refusals collected to determine DMI throughout the experiment. The cows received their feed twice daily in equal portions before milking, with compound feed supplied on top of the roughage. The cows were fed ad libitum during the first 7 d of the adaptation period in the tiestalls. From d 8 to 17 [i.e., last 5 d of the adaptation period and the 5-d period in the climate respiration chambers (**CRC**)], feed intake was restricted to 95% of the ad libitum DMI of the cow within a block consuming the lowest amount of feed during d 5 to 8, as described previously by van Zijderveld et al. (2011a).

Samples of GS, CS, and compound feed were obtained when fresh feed was prepared (i.e., twice a week). These samples were subsequently pooled per period and subsampled for analyses. Orts, when present during the 5-d period in the CRC, were collected and pooled per cow