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Methane production, digestion, ruminal fermentation, nitrogen balance, and milk production of cows fed corn silage- or barley silage-based diets

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ABSTRACT

This study evaluated the effects of replacing barley silage (BS) with corn silage (CS) in dairy cow diets on enteric CH_4 emissions, ruminal fermentation characteristics, digestion, milk production, and N balance. Nine ruminally cannulated lactating cows were used in a replicated 3 × 3 Latin square design (32-d period) and fed (ad libitum) a total mixed ration (TMR; forage:concentrate ratio 60:40; dry matter basis) with the forage portion consisting of either barley silage (0% CS; 0% CS and 54.4% BS in the TMR), a 50:50 mixture of both silages (27% CS; 27.2% CS and 27.2% BS in the TMR), or corn silage (54% CS; 0% BS and 54.4% CS in the TMR). Increasing the CS proportion (i.e., at the expense of BS) also involved increasing the proportion of corn grain (at the expense of barley grain). Intake and digestibility of dry matter and milk production increased linearly as the proportion of CS increased in the diet. Increasing dietary CS proportion decreased linearly the acetate molar proportion and increased linearly that of propionate. Daily CH_4 emissions tended to respond quadratically to increasing proportions of CS in the diet (487, 540, and 523 g/d for 0, 27, and 54% CS, respectively). Methane production adjusted for dry matter or gross energy intake declined as the amount of CS increased in the diet; this effect was more pronounced when cows were fed the 54% CS diet than the 27% CS diet. Increasing the CS proportion in the diet improved N utilization, as reflected by decreases in ruminal ammonia concentration and urinary N excretion and higher use of dietary N for milk protein secretion. Total replacement of BS with CS in dairy cow diets offers a strategy to decrease CH_4 energy losses and control N losses without negatively affecting milk performance.

Key words: enteric methane, corn silage, barley silage, dairy cow

INTRODUCTION

In 2011, agricultural emissions in Canada were 54 Mt of CO_2 eq, representing 8% of total national greenhouse gases (**GHG**) emissions. Emissions from livestock accounted for 60% of agricultural emissions and, of that, CH_4 from enteric fermentation accounted for 55% of direct livestock emissions, with 20% associated with CH_4 from manure management (Environment Canada, 2013). Of the total gross energy consumed by the dairy cow, 4 to 7% is lost as CH_4 (Kebreab et al., 2008). Thus, reducing enteric CH_4 emissions is beneficial environmentally (i.e., CH_4 is a potent GHG), nutritionally (i.e., reducing energy losses), and economically (i.e., improved feed efficiency and increasing milk production).

It is well documented that feeding high-starch diets to ruminants decreases ruminal pH, which favors propionate production at the expense of acetate (Bannink et al., 2008; Beauchemin et al., 2009). Consequently, the availability of hydrogen is lowered, which can inhibit the growth or the activity of rumen methanogens (Van Kessel and Russell, 1996). Rumen protozoa are also often decreased in ruminants fed high-starch diets, which also reduces the transfer of hydrogen from protozoa to methanogens (Wolin and Miller, 1988; Hegarty, 1999).

Corn silage (**CS**) and barley silage (**BS**) are the main forage components of dairy cow diets in eastern and western Canada, respectively. Because CS contains more starch than BS (Beauchemin and McGinn, 2005; Addah et al., 2011), increasing CS proportion in the diet can make the ruminal environment less favorable to methanogens. Therefore, lower CH_4 energy losses are expected in cows fed CS-based diets as compared with cows fed BS-based diets. The objective of this study was to determine the effects of feeding CS- versus BS-based diets on CH_4 production, digestion, ruminal fermentation parameters (including protozoa populations), N balance, milk production, and milk composition.

MATERIALS AND METHODS

This study was conducted at the Dairy and Swine Research and Development Centre (Sherbrooke, Cana-

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Table 1. Chemical composition of barley silage and corn silage

Item (% of DM, unless otherwise noted)	Experimental silage	
	Barley silage	Corn silage
Chemical composition		
DM (%)	31.8	31.3
OM	93.9	96.9
CP	9.04	7.95
NDF	52.3	36.7
ADF	34.9	23.4
ADL	5.96	2.23
Starch	13.9	32.2
Ether extract	3.33	4.04
Gross energy (Mcal/kg of DM)	4.49	4.64
Ensiling characteristics		
pH	4.31	4.08
Lactic acid	10.77	9.96
Acetic acid	0.78	1.16
Propionic acid	ND[1]	ND
Butyric acid	ND	ND
Ammonia	0.135	0.075
Ethanol	0.25	0.48
Water-soluble carbohydrates	3.59	2.38

[1]ND = not detected.

da). Animal procedures were conducted under the approval of the Institutional Animal Care Committee of the Dairy and Swine Research and Development Center (Sherbrooke, Canada) and were in accordance with the guidelines of the Canadian Council on Animal Care (Ottawa, Canada; CCAC, 1993).

Cows, Experimental Design, and Diets

Nine multiparous lactating Holstein cows fitted with rumen cannulas (10 cm, Bar Diamond Inc., Parma, ID) were used in a replicated 3 × 3 Latin square design (32-d period). The cows averaged (mean ± SD) 114 ± 33 DIM at the start of the experiment with an average BW of 707 ± 49 kg and 47 ± 2.6 kg/d of milk. The dietary treatments were (1) 0% CS and 54.4% BS in the TMR (**0% CS**), (2) 27.2% CS and 27.2% BS in the TMR (**27% CS**), and (3) 54.4% CS and 0% BS in the TMR (**54% CS**). The chemical composition and the ensiling characteristics of the 2 silages are presented in Table 1. The forage:concentrate ratio of the TMR was 60:40 on a DM basis. Increasing the proportion of CS in the diet (i.e., at the expense of BS) was achieved by decreasing the proportions of barley grain, soybean meal, and inert fat and increasing proportions of corn grain, corn gluten feed, soybean hulls, and urea (Table 2). Each diet was provided for ad libitum intake (5% orts on an as-fed basis) and cows were housed in individual tiestalls and had free access to water during the experiment.

After 2 wk of adaptation to experimental diets, feed intake, in sacco ruminal degradability, rumen fermentation characteristics (including protozoa enumeration), apparent total-tract digestibility, N balance, milk performance (production and composition), and CH_4 production were measured. Only 2 air flow-controlled chambers were available for measuring CH_4 emissions in this study, which limited the number of animals that could be examined at the same time to 2 (i.e., 1 cow/chamber). Consequently, CH_4 determination and all measurements had to be staggered by 4 d within the 18-d sampling and data collection period to facilitate measurements. Cows were weighed at the beginning and the end of each experimental period on 2 consecutive days before the AM feeding and after the AM milking.

Intake, Apparent Total-Tract Digestibility, and N Balance

Apparent total-tract digestibility and N outputs were measured over 6 consecutive days as described in Hassanat et al. (2013). Diets were offered in equal amounts twice daily (0900 and 1930 h). Feed consumption was recorded daily by weighing feeds offered to and refused by the cows. Samples of the TMR, feed ingredients, and orts were collected daily and stored at −20°C. Samples were composited by cow within period, freeze-dried, ground to pass a 1-mm screen using a Wiley mill (standard model 4; Arthur M. Thomas, Philadelphia, PA), and analyzed for DM, OM, total N, NDF, ADF, starch, ether extract (**EE**), and gross energy (**GE**). Samples of BS and CS were also analyzed for ADL, lactic acid, VFA, ethanol, ammonia N, and water-soluble carbohydrates.