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Effects of carbohydrate type or bicarbonate addition to grass silage-based diets on enteric methane emissions and milk fatty acid composition in dairy cows

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ABSTRACT

The aim of the study was to compare the effect of fiber- or starch-rich diets based on grass silage, supplemented or not with bicarbonate, on CH_4 emissions and milk fatty acid (FA) profile in dairy cows. The experiment was conducted as a 4 × 4 Latin square design with a 2 × 2 factorial arrangement: carbohydrate type [starch- or fiber-rich diets with dietary starch level of 23.1 and 5.9% on a dry matter basis, respectively], without or with bicarbonate addition [0 and 1% of the dry matter intake, respectively]. Four multiparous lactating Holstein cows were fed 4 diets with 42% grass silage, 8% hay, and 50% concentrate in 4 consecutive 4-wk periods: (1) starch-rich diet, (2) starch-rich diet with bicarbonate, (3) fiber-rich diet, and (4) fiber-rich diet with bicarbonate. Intake and milk production were measured daily and milk composition was measured weekly; CH_4 emission and total-tract digestibility were measured simultaneously (5 d, wk 4) when animals were in open-circuit respiration chambers. Sensors continuously monitored rumen pH (3 d, wk 4), and fermentation parameters were analyzed from rumen fluid samples taken before feeding (1 d, wk 3). Cows fed starch-rich diets had less CH_4 emissions (on average, −18% in g/d; −15% in g/kg of dry matter intake; −19% in g/kg of milk) compared with fiber-rich diets. Carbohydrate type did not affect digestion of nutrients, except starch, which increased with starch-rich diets. The decrease in rumen protozoa number (−36%) and the shift in rumen fermentation toward propionate at the expense of butyrate for cows fed the starch-rich diets may be the main factor in reducing CH_4 emissions. Milk of cows fed starch-rich diets had lower concentrations in *trans*-11 C18:1, sum of *cis*-C18, *cis*-9,*trans*-11 conjugated linoleic acid (CLA), and sum of CLA, along with greater concentration of some minor isomers of CLA and saturated FA in comparison to the fiber-rich diet. Bicarbonate addition did not influence CH_4 emissions or nutrient digestibility regardless of the carbohydrate type in the diet. Rumen pH increased with bicarbonate addition, whereas other rumen parameters and milk FA composition were almost comparable between diets. Feeding dairy cows a starch-rich diet based on grass silage helps to limit the negative environmental effect of ruminants, but does not lead to greater milk nutritional value because milk saturated FA content is increased.
Key words: bicarbonate, carbohydrate type, dairy cow, methane emission, milk fatty acid

INTRODUCTION

Livestock farming is a great contributor to total greenhouse gas emissions via CH_4 production by cattle. Dairy cow CH_4 emissions account for 46% of the total greenhouse gas emissions in dairy supply chains, when expressed as CO_2-equivalents (Gerber et al., 2013), and also lead to significant energy losses ranging between 2 to 12% of the gross energy (**GE**) intake by animals (Johnson and Johnson, 1995). Livestock competitiveness needs to reduce enteric CH_4 emissions without altering animal performance to improve feed efficiency and to reduce the carbon footprint of the dairy cattle sector.

Among the different dietary strategies tested worldwide, increasing the proportion of concentrate to above 30 to 40% in the diet is known to mitigate CH_4 emissions in ruminants (Martin et al., 2010). Limited information is available on the effect of carbohydrate type in the diet on methanogenesis, though Hindrichsen et al. (2005) studied the effects of concentrates (50% of the diet) providing different carbohydrates type on enteric CH_4 emissions in dairy cows. These authors reported similar CH_4 emissions (g/d and g/kg of DMI) with fiber-rich concentrate (containing soybean hulls) as compared with starch-rich concentrate (containing wheat).

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Moe and Tyrrell (1979) reported that CH_4 production in dairy cows is reduced further as the carbohydrate digestion rate is high. In addition, diets rich in readily fermentable carbohydrates such as starch are known to modify the rumen environment greatly through a decrease in pH and, consequently, to increase the risk of SARA (Krause and Oetzel, 2006). To limit these rumen disorders associated with high-starch diets, fiber can replace starch in carbohydrate diets because it is fermented more slowly, or sodium bicarbonate can be added to diets as a digestive regulator to reduce the risk of SARA (Solorzano et al., 1989). To the best of our knowledge, the effect of buffer addition to the diet of dairy cows on methanogenesis has been studied by very few authors. Hellwing et al. (2012) reported no effect of bicarbonate addition (9.5 g/kg of DM) to a grass-clover silage-based diet rich in molasses on CH_4 emissions (g/d and g/kg of DMI) in dairy cows when compared with a diet rich in wheat.

In addition to CH_4 mitigation, high-starch diets may decrease milk fat content and modify milk fatty acid (**FA**) composition in dairy cows (Cabrita et al., 2007; Shingfield et al., 2008). Such diets may influence rumen biohydrogenation (**RBH**) of PUFA (Bauman and Griinari, 2003), resulting in a shift from the *trans*-11 C18:1 to the *trans*-10 C18:1 pathway. High-starch diets also modify the activity or number of bacteria implicated in the synthesis of odd- and branched-chain FA (Vlaeminck et al., 2006; Pirondini et al., 2015). Nevertheless, to the best of our knowledge, no authors have studied the effect of carbohydrate type on milk FA composition in dairy cows fed grass silage-based diets.

The aim with the study was to test the effects of (1) the carbohydrate type in diets [fiber-rich diets (**F**) or starch-rich diets (**S**)], (2) the addition of bicarbonate to diets, and (3) the interaction between the carbohydrate type and bicarbonate addition on digestive process, more particularly on CH_4 emissions, and on milk FA composition in lactating dairy cows fed grass silage-based diets.

MATERIALS AND METHODS

The experiment was conducted at the animal experimental facilities of INRA Theix (Saint-Genès-Champanelle, France) from February to June 2015. Procedures involving animals were performed in accordance with the French Ministry of Agriculture guidelines for animal research and the applicable European Union guidelines and regulations on animal experiments. The Auvergne Regional Ethics Committee on Animal Experimentation C2EA-02 approved the experiment with the reference number 821–2015060811534198.

Cows, Diets, and Experimental Design

Four multiparous lactating Holstein cows (mean ± SD, average BW of 639 ± 62 kg, DIM of 61 ± 12.5, lactation rank of 2.8 ± 0.4, and milk yield of 31.5 ± 4.6 kg/d at the start of the experiment) were used in the experiment which was conducted as a 4 × 4 Latin square design with a 2 × 2 factorial arrangement. Each experimental period lasted 4 wk (28 d). From d 1 to 20, cows were housed together in a free-stall barn and received the experimental ad libitum concentrates and forages. From d 21 to 26, cows were moved to individual open-circuit respiration chambers for measurement of CH_4 emissions and total-tract digestibility, and were fed 95% of individual voluntary feed intake (determined during d 1 to 20) to ensure complete consumption of the feed. Changes from one diet to another were achieved with 6-d transition at the beginning of each 28-d period. From d 27 to 28, cows returned to the freestall barn and were fed the same diet than from d 1 to 26.

The 4 dietary treatments aimed at evaluating the main effects of the type of carbohydrates (fiber vs. starch), addition of bicarbonate, and their interaction and were (1) high-fiber diet (F), (2) high-fiber diet with bicarbonate addition (**F+b**), (3) high-starch diet (S), and (4) high-starch diet with bicarbonate addition (**S+b**). Diets contained a 50:50 forage-to-concentrate ratio, on a DM basis, 45% grass silage (natural grassland, first cut), 5% hay (natural grassland, first cut), and 50% pelleted concentrates and were formulated to meet individual energy and protein requirements for lactation and maintenance (INRA, 2007). In the F+b and S+b diets, bicarbonate was weighed and mixed every day with the concentrate and given all together with the grass silage at the level of 1% of the DMI. The chemical composition of the different dietary ingredients and diets are reported in Table 1. Diets were iso-energy and iso-protein and were adjusted daily to maintain the forage-to-concentrate ratio as close as possible to the 50:50 ratio targeted. Hay was given once daily (0730 h); the grass silage and concentrates were mixed together by hand as a partial mixed ration (**PMR**) and were given twice a day (66% at 0900 h and 34% at 1600 h). Cows had free access to water throughout the experiment.

Measurements, Sampling, and Chemical Analyses

Feed Intake and Composition. Feed intake was weighted and recorded on 4 d in wk 1, 2, and 3 and on 5 d in wk 4 of each experimental period to estimate DMI as the difference between DM offered and refused. The DM content of feed was determined (103°C for 24 h)