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The influence of fat and hemicellulose on methane production and energy utilization in lactating Jersey cattle[1]

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ABSTRACT

Feeding fat to lactating dairy cows may reduce methane production. Relative to cellulose, fermentation of hemicellulose is believed to result in less methane; however, these factors have not been studied simultaneously. Eight multiparous, lactating Jersey cows averaging (±SD) 98 ± 30.8 d in milk and body weight of 439.3 ± 56.7 kg were used in a twice-replicated 4 × 4 Latin square to determine the effects of fat and hemicellulose on energy utilization and methane production using a headbox-type indirect calorimetry method. To manipulate the concentration of fat, porcine tallow was included at either 0 or 2% of the diet dry matter. The concentration of hemicellulose was adjusted by manipulating the inclusion rate of corn silage, alfalfa hay, and soybean hulls resulting in either 11.3 or 12.7% hemicellulose (dry matter basis). The resulting factorial arrangement of treatments were low fat low hemicellulose (LFLH), low fat high hemicellulose (LFHH), high fat low hemicellulose (HFLH), and high fat high hemicellulose (HFHH). Neither fat nor hemicellulose affected dry matter intake, averaging 16.2 ± 1.18 kg/d across treatments. Likewise, treatments did not affect milk production, averaging 23.0 ± 1.72 kg/d, or energy-corrected milk, averaging 30.1 ± 2.41 kg/d. The inclusion of fat tended to reduce methane produced per kilogram of dry matter intake from 24.9 to 23.1 ± 1.59 L/kg, whereas hemicellulose had no effect. Increasing hemicellulose increased neutral detergent fiber (NDF) digestibility from 43.0 to 51.1 ± 2.35%. Similarly, increasing hemicellulose concentration increased total intake of digestible NDF from 6.62 to 8.42 ± 0.89 kg/d, whereas fat had no effect. Methane per unit of digested NDF tended to decrease from 64.8 to 49.2 ± 9.60 L/kg with increasing hemicellulose, whereas fat had no effect. An interaction between hemicellulose and fat content on net energy balance (milk plus tissue energy) was observed. Specifically, increasing hemicellulose in low-fat diets tended to increase net energy balance, but this was not observed in high-fat diets. These results confirm that methane production may be reduced with the inclusion of fat, whereas energy utilization of lactating dairy cows is improved by increasing hemicellulose in low-fat diets.
Key words: energy utilization, fat, hemicellulose, indirect calorimetry, methane

INTRODUCTION

Methane is a potent greenhouse gas that contributes to global warming (Benchaar et al., 2001). Methanogenesis, the formation of methane, is a vital biological pathway in ruminants because it is the main hydrogen sink in the rumen, yet it is also characterized as an energetic loss for cattle that ranges from 2 to 12% gross energy (**GE**) intake (Cabezas-Garcia et al., 2017). Because cattle produce more methane than any other livestock species, a need exists to develop effective methods to reduce methane production in lactating dairy cattle. A worldwide focus has been placed on developing mitigation strategies for both dairy and beef industries. In 2009, the US dairy industry, represented by the Innovation Center for US Dairy, committed to a voluntary goal to reduce greenhouse gas emissions by 25% by 2020 (Innovation Center for US Dairy, 2014).

One method to reduce methane production in dairy cattle is through manipulation of the ruminal microbial community via feed ingredients included in the diet. For example, the addition of fat is known to increase GE density of the diet, but also reduce methane production (Beauchemin et al., 2008). When consumed by cattle, fibrous by-products are also believed to result in less methane per unit of digested DM compared with other forages (Johnson and Johnson, 1995). Knapp et

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al. (2014) suggested this is because these feeds are high in hemicellulose and that the digestion of hemicellulose produces 37% less methane than that of digested cellulose (Moe and Tyrrell, 1979). The hemicellulose content of feeds can be estimated by the difference between NDF and ADF (Goering and Van Soest, 1970). Based on this method, estimates of the hemicellulose content of dry distillers grains and solubles (**DDGS**) is approximately 19% (NRC, 2001). Brewers grains contain approximately 25% hemicellulose, whereas corn gluten meal and citrus pulp contain approximately 3 and 2%, respectively. The hemicellulose content of forages such as alfalfa hay is approximately 9%, whereas grass hay and corn silage contain approximately 25 and 17% hemicellulose, respectively (NRC, 2001). Given that the hemicellulose content of feeds vary, it is likely that dietary manipulation may be an effective way to reduce methane production in dairy cattle. Recently Benchaar et al. (2013) and Foth et al. (2015) observed that dairy cattle produce 14 g/d or 7% less methane when they consume diets containing 30% DDGS compared with a traditional corn and soybean meal diet. Thus, a need exists to evaluate how methane production may be further reduced when cattle are consuming diets containing a high proportion of DDGS. The objective of our study was to determine the effects of feeding different concentrations of fat and hemicellulose on methane production and energy utilization in lactating Jersey cows consuming diets containing high concentrations of DDGS. We hypothesized that diets containing more fat and hemicellulose would result in a reduction of methane production and may also positively affect energy balance.

MATERIALS AND METHODS

Eight multiparous Jersey cows averaging 98 ± 30.8 DIM and 439.3 ± 56.7 kg of BW at the beginning of the experiment were used for this study. All cows were housed in a temperature-controlled barn at the Dairy Metabolism Facility at the Animal Science Complex at the University of Nebraska–Lincoln and milked at 0700 and 1800 h in individual tiestalls equipped with rubber mats. All animal care and experimental procedures were approved by the University of Nebraska–Lincoln Animal Care and Use Committee. At the conclusion of the last experimental period, all cows were less than 90 d pregnant; thus, no energetic adjustments were made for conceptus growth. This was because energy to fetus is very minimal less than 90 d pregnant.

The experimental design was a twice-replicated 4 × 4 Latin square. Cows were randomly assigned to 1 of the 4 dietary treatments, low fat low hemicellulose (**LFLH**), low fat high hemicellulose (**LFHH**), high fat low hemicellulose (**HFLH**), or high fat high hemicellulose (**HFHH**), according to Kononoff and Hanford (2006). Treatments were designed as a 2 × 2 factorial arrangement of treatments. Animals were blocked into each square by milk production (kg/d). Treatments alternated over 4 experimental periods and measurements were collected on each animal consuming each treatment within the same period. The study was conducted with a total of 4 experimental periods, each being 35 d in duration. Each period included 28 d for ab libitum diet adaptation, targeting about 5% refusals during that time, followed by 7 d of collection with 4 d of 95% ad libitum feeding to reduce the amount of refusals.

The 4 diets were formulated with treatments containing different concentrations of fat and hemicellulose (Table 1). Manipulation of hemicellulose was achieved by varying the concentrations of corn silage, alfalfa hay, and ground soybean hulls; ground corn also varied between treatments. The fat source used was porcine tallow, which was added to the diet at approximately 2% DM in 2 dietary treatments, whereas the other 2 dietary treatments had none. Dried distillers grains with solubles were added to all 4 dietary treatments at a consistent amount of 20.1% of diet DM. Complete diet compositions and nutrient analysis for all treatments are presented in Table 1. All dietary treatments contained corn silage, alfalfa hay, and a concentrate mixture that was combined as a TMR. The TMR was mixed in a Calan Data Ranger (American Calan, Inc., Northwood, NH) and fed once daily at 0900 h to the cows.

Individual feed ingredients were sampled (500 g) on the first day of each collection period and frozen at −20°C. A subsample was sent to Cumberland Valley Analytical Services Inc. (Hagerstown, MD) for complete nutrient analysis. The DM content of concentrates was determined by drying at 135°C (Method 930.15, AOAC International, 2000). The DM content of forages was determined by a 2-step process, where the first sample is partially dried at 65°C for 16 h (Goering and Van Soest, 1970) and then 105°C for 3 h. Additionally, nitrogen (Leco FP-528 N Combustion Analyzer, Leco Corp., St. Joseph, MI), NDF with sodium sulfite (Van Soest et al., 1991) and α amylase, ADF (method 973.18; AOAC International, 2000), acid detergent lignin (Goering and Van Soest, 1970), NFC [100 − (% NDF + % CP + % Fat + % Ash)], sugar (DuBois et al., 1956), starch (Hall, 2009), crude fat (2003.05; AOAC International, 2006), ash (943.05; AOAC International, 2000) and minerals (985.01; AOAC International, 2000) were determined. Total mixed rations were sampled (500 g) on each day