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Methane production and digestion of different physical forms of rapeseed as fat supplements in dairy cows

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ABSTRACT

The purpose of this experiment was to study the effect of the physical form of rapeseed fat on methane (CH_4) mitigation properties, feed digestion, and rumen fermentation. Four lactating ruminal-, duodenal-, and ileal-cannulated Danish Holstein dairy cows (143 d in milk, milk yield of 34.3 kg) were submitted to a 4 × 4 Latin square design with 4 rations: 1 control with rapeseed meal (low-fat, CON) and 3 fat-supplemented rations with either rapeseed cake (RSC), whole cracked rapeseed (WCR), or rapeseed oil (RSO). Dietary fat concentrations were 3.5 in CON, 5.5 in RSC, 6.2 in WCR, and 6.5% in RSO. The amount of fat-free rapeseed was kept constant for all rations. The forage consisted of corn silage and grass silage and the forage to concentrate ratio was 50:50 on a dry matter basis. Diurnal samples of duodenal and ileal digesta and feces were compiled. The methane production was measured for 4 d in open-circuit respiration chambers. Additional fat reduced the CH_4 production per kilogram of dry matter intake and as a proportion of the gross energy intake by 11 and 14%, respectively. Neither the total tract nor the rumen digestibility of organic matter (OM) or neutral detergent fiber were significantly affected by the treatment. Relating the CH_4 production to the total-tract digested OM showed a tendency to decrease CH_4 per kilogram of digested OM for fat-supplemented rations versus CON. The acetate to propionate ratio was not affected for RSC and WCR but was increased for RSO compared with CON. The rumen ammonia concentration was not affected by the ration. The milk and energy-corrected milk yields were unaffected by the fat supplementation. In conclusion, rapeseed is an appropriate fat source to reduce the enteric CH_4 production without affecting neutral detergent fiber digestion or milk production. The physical form of fat did not influence the CH_4-reducing effect of rapeseed fat. However, differences in the volatile fatty acid pattern indicate that different mechanisms may be involved.
Key words: canola, fiber digestion, cattle

INTRODUCTION

Globally, agriculture accounts for 47% of total anthropogenic methane (CH_4) emissions, with enteric fermentation contributing 32% of the total non-CO_2 emissions from agriculture in 2005 (Smith et al., 2007). The CH_4 production per animal varies depending on the feed composition, feed quality, and production level from 2 to 12% of the gross energy (**GE**) intake (Johnson and Johnson, 1995) under extreme circumstances, but values between 3 and 7% (Martin et al., 2008) are more realistic in intensive dairy production.

Numerous studies have discussed nutritional possibilities to reduce the enteric CH_4 production (Boadi et al., 2004; Beauchemin et al., 2008), and fat supplementation is among the most promising tools to depress CH_4 production from ruminants (Martin et al., 2008). Furthermore, fat is fed to dairy cows to increase the energy density of the ration or to alter the product quality (Beauchemin et al., 2007). Several oils and oil seeds have been tested for their potential to reduce the CH_4 production, and effects of chain length and saturation have been reported. The degree of saturation is important, as the negative effect on bacterial growth increases with the degree of unsaturation, inhibiting both fibrolytic bacteria and methanogens (Giger-Reverdin et al., 2003). With reduced fiber digestibility and a shift in fermentation pattern, less hydrogen arises and, thus, less CH_4 (Boadi et al., 2004). Additionally, fat often replaces carbohydrates in the ration, thereby directly reducing rumen fermentation. Reduced fiber digestibility is associated with reduced DMI and milk production; therefore it has to be considered whether the overall reduction of CH_4 production from the animal due to the addition of fat is accompanied by a reduction per kilogram of product or per kilogram of feed digested.

Feeding whole seeds or cake, a by-product from the plant oil production, as well as pure oil, are tools to increase the dietary fat concentration, but the difference

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in physical form might influence the effect of fat in the rumen. Czerkawski et al. (1966) showed that the effect of FA on CH_4 production was stronger when the same amount was infused to the rumen once daily, compared with continuous infusion. Similarly, Machmüller et al. (2000) concluded that this could be of importance to achieve momentarily high fat concentrations in the rumen rather than a constant presence at a lower level. Oil in seeds is stored intracellularly, and the fat release depends on the digestion and breakdown of the cell wall, which leads to a slower release compared with feeding oil directly (Steele et al., 1971). This indicates that pure oil may increase the rumen FA concentration faster and reduce the CH_4 production more effectively compared with seeds or cake (Martin et al., 2008).

Oilseed rape (*Brassica napus*) is widely grown in many countries. The by-products, rapeseed meal and cake, remaining after oil extraction are common feed components in dairy cow rations. Rapeseed meal has a low crude fat concentration (about 4%) compared with rapeseed cake (10–20%) and whole seeds (approximately 50%). The aim of the current experiment was to study the effect of rapeseed fat and the physical form in which it was fed on enteric CH_4 production, rumen fermentation, and digestion.

MATERIALS AND METHODS

Animals and Rations

The experiment complied with the guidelines of the Danish Ministry of Justice with respect to animal experimentation and care of animals under study. Four lactating Danish Holstein dairy cows (1 primiparous and 3 multiparous) were assigned to 1 of 4 rations over 4 periods according to a balanced Latin square design; each period consisted of 4 wk. One cow was omitted from the last period due to disease.

The cows were 143 DIM (SD = 74 d), had a milk yield of 34.3 kg (SD = 8.6 kg), and a BW of 592 kg (SD = 81 kg) at the beginning of the experiment. All animals were fitted with a ruminal cannula (#1C, Bar Diamond Inc., Parma, ID), a duodenal cannula (open T-piece placed 60 cm caudal to pylorus), and an ileal cannula (open T-piece placed 20 cm cranial to the cecum). The cows were housed in a tie stall with rubber mats and sawdust as bedding and had free access to water. They were milked and fed twice daily at 0500 and 1700 h. Total mixed rations were prepared once a day and fed to the cows on an ad libitum basis after milking. The feed intake was recorded on a daily basis. The animals were weighed at the start of the experiment as well as just before and after the respiration chamber measurements (the last week of each period).

The rations were a control ration (**CON**) and 3 high-fat rations with fat supplemented as either rapeseed cake (**RSC**), whole cracked rapeseed (**WCR**), or rapeseed oil (**RSO**), respectively. The amount of fat-free rapeseed was equal for all rations, as the basic rapeseed meal content in the CON was reduced according to the fat-free rapeseed which was supplemented with either cake or seed in the treatment rations. Rapeseed cake, whole rapeseed, and rapeseed oil were obtained from Danraps (DLG Food Oil, Dronninglund, Denmark). The rapeseed used in this study was double-00 rape, equivalent to what is known as canola in North America.

The chemical composition of ingredients is shown in Table 1. All rations were fed as TMR with a forage to concentrate ratio of 50:50 (Table 2). The forage consisted of 54% corn silage and 46% prewilted perennial ryegrass silage (on DM basis). The corn silage was stored in a bunker silo and the grass silage in bales.

Measurements

The milk production and composition were measured once a week during morning and evening milkings. Weekly samples of the feed ingredients were stored (−20°C) and pooled during the whole experiment. Samples of TMR and refusals were taken daily in connection with the afternoon feeding, stored (−20°C), and pooled for each period from d 15 to 20.

Chromic oxide was used as a flow marker, and 10 g was administrated to the rumen via the ruminal cannula during each of the 2 daily feedings, except when the cows were in the respiration chambers.

Samples of duodenal chyme (600 mL), ileal chyme (300 mL), and feces (350 mL) were taken from d 15 to 19 at 1000, 1800 (d 15), 0200, 1200, 2000 (d 16), 0400, 1400, 2200 (d 17), 0600, 1600, 2400 (d 18), and 0800 h (d 19; 12 samples, representing every second hour of the day). Samples from the duodenum and ileum were taken in tube-formed plastic bags which were mounted to the cannulas with plastic knees. Duodenal, ileal, and fecal samples were added to the frozen pooled sample from previous samples at each sampling time. At the end of the period, representative subsamples from thawed material were taken and freeze-dried for chemical analysis. At the 12 sampling times, rumen liquid was sampled from the ventral ruminal sac with a collection tube (#RT, Bar Diamond Inc.). The rumen liquid pH was measured immediately, and two 8-mL samples were taken and frozen (−20°C) immediately for VFA and ammonia (NH_3) analysis at each sampling time.

Chemical Analysis

Ash was determined by combustion at 525°C for 6 h. Nitrogen was determined by the Dumas principle

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