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Effect of nitrogen fertilization rate and regrowth interval of grass herbage on methane emission of zero-grazing lactating dairy cows

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ABSTRACT

Dairy cattle farming in temperate regions often relies on grass herbage (GH)-based diets but the effect of several grass management options on enteric CH_4 emission has not been fully investigated yet. We investigated the combined effect of N fertilization rate and length of regrowth period of GH (predominantly ryegrass) on CH_4 emission from lactating dairy cows. In a randomized block design, 28 lactating Holstein-Friesian dairy cows received a basal diet of GH and compound feed [85:15; dry matter (DM) basis]. Treatments consisted of GH cut after 3 or 5 weeks of regrowth, after receiving either a low (20 kg of N/ha) or a high (90 kg of N/ha) fertilization rate after initial cut. Feed intake, digestibility, milk production and composition, N and energy balance, and CH_4 emission were measured during a 5-d period in climate respiration chambers after an adaptation to the diet for 12 d. Cows were restricted-fed during measurements and mean DM intake was 15.0 ± 0.16 kg/d. Herbage crude protein content varied between 76 and 161 g/kg of DM, and sugar content between 186 and 303 g/kg of DM. Fat- and protein-corrected milk (FPCM) and feed digestibility increased with increased N fertilization rates and a shorter regrowth interval. Increasing the N fertilization rate increased daily CH_4 emission per cow (+10%) and per unit of DM intake (+9%), tended to increase the fraction of gross energy intake emitted as CH_4 (+7%), and (partly because of the low crude protein content for the low fertilized GH) only numerically reduced CH_4 per unit of FPCM. The longer regrowth interval increased CH_4 emission per unit of FPCM (+14%) compared with the shorter regrowth interval, but did not affect CH_4 emission expressed in any other unit. With increasing N fertilization CH_4 emission decreased per unit of digestible neutral detergent fiber intake (−13%) but not per unit of digestible organic matter intake. There was no interaction of the effect of N fertilization rate and regrowth interval on CH_4 emission, but effects of N fertilization were generally most distinct with GH of 5 wk regrowth. The present results suggest that altering grass quality through an increase of N fertilization and a shorter regrowth interval can reduce CH_4 emission in zero-grazing dairy cows, depending on the unit in which it is expressed. The larger amount of CH_4 produced per day and cow with the more intensively managed GH is compensated by a higher feed digestibility and FPCM yield.

Key words: fresh grass, methane, grass maturity, energy balance, nitrogen balance

INTRODUCTION

Dairy systems in temperate regions largely rely on grass-based diets. Although pasture grazing is the most economical source of nutrients for dairy cows (Taweel et al., 2006; Peyraud and Delagarde, 2013), feeding grass herbage from pasture in an enclosed system (i.e., zero-grazing) has increasingly gained acceptance to allow for a greater feed intake and a better control of nutrient supply (Dohme-Meier et al., 2014). Ingested grass is fermented by ruminal microorganisms to yield energy for the host animal and CH_4 as a by-product. Because of the global warming potential (IPCC, 2006) and the potential of a loss of energy to the host animal with eructated CH_4 (Moe and Tyrrell, 1979), a socio-economic interest exists to reduce CH_4 emission from dairy cattle.

Grassland management is a valuable CH_4 mitigation strategy (Hristov et al., 2013a,b) and improving feeding value of grass to improve animal productivity will reduce CH_4 emission per unit of milk produced. Grass quality can be improved by applying more N fertilizers and by harvesting grass at an earlier (vegetative) stage. A model-simulation study (Bannink et al., 2010) predicted large effects of altered N fertilization on grass herbage composition and simulated CH_4 production. On average, CH_4 yield per unit of fat- and protein-corrected milk (**FPCM**) was predicted to

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be 16% smaller, and CH_4 loss as proportion of gross energy intake (**GEI**) 9% smaller when N fertilization rates increased from 150 to 450 kg/ha per year. Similar reductions in simulated CH_4 yield per unit of FPCM or GEI were predicted for early versus late cut grass silage as well as for high versus low N fertilization rate.

In vivo data on effects of grass herbage quality on CH_4 emission are limited. Hammond et al. (2009) found that DMI explains the largest part of variation in CH_4 emission, but chemical composition of grass herbage accounts for only 13% of the variation when CH_4 emission was expressed per unit of DMI. Wims et al. (2010) reported increased CH_4 emissions of up to 21% per kilogram of milk yield and 16% per kilogram of DMI for dairy cows grazing ryegrass swards of high versus low herbage mass (2,200 vs. 1,000 kg of DM/ha), although in 1 out of 2 experimental measurement periods only. A later maturity stage (reproductive vs. vegetative) increased daily CH_4 production per cow by 34% and per unit of GEI by 14% in beef cattle grazing timothy (Pinares-Patiño et al., 2003). However, with zero-grazing sheep no differences due to ryegrass maturity were observed (Molano and Clark, 2008). When CH_4 emission is expressed per unit of digestible OM intake (**DOMI**) using digestibility coefficients reported in those studies, emission was roughly 20% smaller with high- versus low-digestible grass in the respective studies. Hart et al. (2009) reported a non-significant 9%-lower CH_4 emission per unit of digestible DMI in beef cattle fed high-digestible compared with low-digestible ryegrass herbage.

To date, combined effects of N fertilization and maturity stage of grass herbage on CH_4 yield per unit of feed intake or per unit of digested feed have not been described for lactating dairy cattle. The aim of the present study was to evaluate the effect of N fertilization rate and regrowth interval of grass herbage on enteric CH_4 production, feed intake, feed digestibility, milk production, energy and N balance, and rumen fermentation in lactating cows.

MATERIALS AND METHODS

Experimental Design

Experimental procedures and surgical cannulation of cows were approved by the Institutional Animal Care and Use Committee of Wageningen University (Wageningen, the Netherlands) and carried out under the Dutch Law on Animal Experimentation. The animal experiment was conducted over 6 wk in summer 2012 (June 4 to July 16) at Carus Research Facilities of Wageningen University, Wageningen, the Netherlands. The experiment followed a staggered approach because the 4 climate respiration chambers (**CRC**) available offered space for testing a maximum of 4 cows simultaneously. The experiment was thus designed as a completely randomized block design with 28 lactating dairy cows allocated to 7 blocks, based on parity, lactation stage, FPCM production, and whether cows were rumen cannulated or not. Within each block, 4 similar cows were randomly assigned to 1 of 4 experimental treatments (Table 1).

Grass Herbage

The grass herbage originated from a mixed sward established in 2010 and composed of diploid perennial ryegrass (*Lolium perenne*) cultivars of intermediate- and late-heading type (36% each) and timothy (*Phleum pratense*; 28%) (BG Superplus, Barenbrug, Oosterhout, the Netherlands) sown on 3 grassland fields on sandy soil. Grass swards received an initial 80 kg of N/ha of animal manure (2.86 g of N/kg of manure) and 30 kg of N/ha of artificial fertilizer (calcium ammonium nitrate; Rijnvallei, Wageningen, the Netherlands) 2 wk before the start of the initial cut (May 2012 onward). After the initial cut, fields were divided into 60 plots of varying plot size and, according to a 2 × 2 randomized design, were fertilized per plot at a low (20 kg of N/ha; **N20**) or high (90 kg of N/ha; **N90**) rate with calcium ammonium nitrate, and herbage was cut after 3 wk (**R3**) or 5 wk (**R5**) of regrowth. Each of the 3 fields comprised plots for all 4 treatments to prevent confounding between field used and treatment. Each plot size was designed such to accommodate sufficient grass DM yield for 3 consecutive feeding days. It was assumed that within these 3 feeding days differences in grass characteristics of harvested grass remained negligible. The initial cut and N application was staggered per individual plot with a 3-d interval to coincide with the scheduled harvest date of the respective plot. Thus, plots of 5 wk of regrowth were given a corresponding head start relative to plots of 3 wk of regrowth to be able to supply all treatments at the same time at the start of a feeding period. Average daily temperature and precipitation during the entire growing season (May to July 2012) were 15.3°C and 2.6 mm.

Animals, Feeding, and Housing

Twenty-eight dairy cows (4 primiparous and 24 multiparous cows) in mid to late lactation (193 ± 137 DIM; mean ± SD) with an average FPCM production of 34 ± 5.9 kg/d were used in the experiment. Twelve cows were previously fitted with a permanent rumen cannula