J. Dairy Sci. 99:1–9
http://dx.doi.org/10.3168/jds.2016-11509

Effects of concentrate crude protein content on nutrient digestibility, energy utilization, and methane emissions in lactating dairy cows fed fresh-cut perennial grass

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ABSTRACT

Although many studies have investigated mitigation strategies for methane (CH_4) output from dairy cows fed a wide variety of diets, research on the effects of concentrate crude protein (CP) content on CH_4 emissions from dairy cows offered fresh grass is limited. The present study was designed to evaluate the effects of cow genotype and concentrate CP level on nutrient digestibility, energy utilization, and CH_4 emissions in dairy cows offered fresh-grass diets. Twelve multiparous lactating dairy cows (6 Holstein and 6 Holstein × Swedish Red) were blocked into 3 groups for each breed and assigned to a low-, medium-, or high-CP concentrate diet [14.1, 16.1, and 18.1% CP on a dry matter (DM) basis, respectively], in a 3-period changeover study (25 d per period). Total diets contained (DM basis) 32.8% concentrates and 67.2% perennial ryegrass, which was harvested daily. All measurements were undertaken during the final 6 d of each period: digestibility measurements for 6 d and calorimetric measurements in respiration chambers for 3 d. Feed intake and milk production data were reported in a previous paper. We observed no significant interaction between concentrate CP level and cow genotype on any parameter. Concentrate CP level had no significant effect on any energy utilization parameter, except for urinary energy output, which was positively related to concentrate CP level. Similarly, concentrate CP content had no effect on CH_4 emission (g/d), CH_4 per kg feed intake, or nutrient digestibility. Cross breeding of Holstein cows significantly reduced gross energy, digestible energy, and metabolizable energy intake, heat production, and milk energy output. However, cow genotype had no significant effect on energy utilization efficiency or CH_4 parameters. Furthermore, the present study yielded a value for gross energy lost as CH_4 (5.6%) on fresh grass-based diets that was lower than the widely accepted value of 6.5%. The present findings indicate that reducing concentrate CP content from 18.1 to 14.1% may not be a successful way of alleviating CH_4 emissions from lactating dairy cows offered good-quality fresh grass, but grazing cows could be offered a low-CP concentrate without compromising energy utilization efficiency. Further research is needed to investigate whether larger differences in dietary CP content may yield positive results.
Key words: dairy cow, energy utilization, methane, fresh grass

INTRODUCTION

The agricultural industry is a major contributor of atmospheric methane (CH_4) and is responsible for 13.5% of total greenhouse gas emissions globally (IPCC, 2007). A large proportion of these emissions (80%) come from livestock production systems (FAO, 2006). In Northern Ireland, agriculture is responsible for the emission of 6.49 Mt of CO_2 equivalents annually or 29% of total annual greenhouse gas emissions (Salisbury et al., 2015). Methane emissions not only raise environmental concerns but also form a sizable loss of feed energy intake from dairy and beef cows, from 2 to 12% (Johnson and Johnson, 1995). Alleviating CH_4 emissions may increase the ME available and improve energy utilization efficiency in ruminant systems. Rates of CH_4 emission are influenced by a range of diet and animal factors, such as feed intake, diet quality, and nutrient utilization efficiency (Johnson and Johnson, 1995; Kebreab et al., 2006; Muñoz et al., 2015). Many mitigation strategies have been investigated for dairy

Received May 25, 2016.
Accepted July 27, 2016.
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cows offered ensiled forage, but information for grazing cows is lacking.

Pasture-based dairy systems are widely used in Ireland and in other countries with similar climatic conditions; 89% of agricultural land is allocated for grazing swards (Hart et al., 2009). A promising mitigation strategy reported in several studies (Aguerre et al., 2011; Haque et al., 2014) appears to be the increase of dietary starch content, either by increasing concentrate input (which increases feed costs) or by replacing high-protein feed components (e.g., soybean meal, rapeseed extract) with high-starch components (e.g., corn, wheat). However, replacing the CP content of concentrate with starch in pasture-based diets—a successful strategy for alleviating N excretion—has not been investigated. In a meta-analysis of indirect calorimetry data from dairy cows offered perennial ryegrass silage–based diets, Yan and Mayne (2007) found a negative relationship between CH_4/kilogram of DMI and dietary CP concentration. This effect was likely not solely dependent on dietary CP concentrations, but a result of changes in other dietary factors (e.g., fiber and starch concentrations). Indeed, Stergiadis et al. (2016) found increasing grass CP and water-soluble carbohydrate concentrations increased CH_4/kilogram of DMI in dry cows offered diets of only fresh perennial ryegrass at maintenance feeding levels. Therefore, the effects of dietary CP contents on CH_4 emissions and energy utilization merit investigation in studies with dairy cows offered fresh-forage diets.

Animal genetic factors have been found to play a significant role in energy utilization efficiency and CH_4 emissions from ruminants (Pinares-Patiño et al., 2009; Clark, 2013). It is well documented that improving productivity can lead to a reduction in CH_4 emissions per unit of produce (Chagunda et al., 2009; Wall et al., 2010; Cottle et al., 2011) while making mitigation strategies appealing to producers. Beecher et al. (2014) and Palladino et al. (2010) showed that Holstein-Friesian cows on perennial ryegrass silage diets offered at maintenance levels and grazing perennial ryegrass, respectively, may exhibit differences in production efficiency compared with Jersey and Jersey × Holstein-Friesian cows. However, comparisons of CH_4 emissions between Holstein and other breeds under grazing or zero-grazing conditions have been limited, with the literature focusing on ensiled forage (Xue et al., 2011; Arndt et al., 2015).

The present study was designed to address these knowledge gaps by evaluating the effects of reducing concentrate CP content (with little influence on starch and fiber content), cow genotype, and their interaction on nutrient digestibility, energy utilization efficiency, and CH_4 emissions in lactating dairy cows offered fresh perennial ryegrass diets, so that practices are widely applicable to pasture-based systems.

MATERIALS AND METHODS

All scientific procedures described were carried out under experimental license from the Department of Health, Social Services and Public Safety of Northern Ireland in accordance with the Animal (Scientific Procedures) Act (Home Office, 1986).

Experimental Design

The current study presents observations from a calorimetry experiment performed at Agri-Food and Biosciences Institute (Hillsborough, Northern Ireland, UK), using 12 multiparous lactating (6 Holstein and 6 Holstein × Swedish Red 50:50 crossbred) cows on diets of fresh-cut perennial ryegrass and concentrate feeds during the 2014 grazing season. Details of the animals, experiment design, and diets are reported in a companion paper (Hynes et al., 2016). A brief description of the design and measurement procedures follows.

Animals were offered 3 dietary treatments with different concentrate CP contents (2 cows in each genotype/diet) in a changeover study with 3 periods of 25 d. All measurements were taken during the final 6 d of each period: 3 d in digestibility units and 3 d in indirect open-circuit respiration calorimeter chambers, with continuation of digestibility measurements in the respiration chambers. Diets were composed of zero-grazed perennial ryegrass and concentrate feeds of differing CP content: low-CP concentrate (14.1% DM), medium-CP concentrate (16.1% DM), and high-CP concentrate (18.1% DM) fed at 32.8% DMI combined with perennial ryegrass fed at 67.2% DMI. The low- and high-CP concentrates were formulated to possess the same dietary components and similar chemical composition except for CP level, and the medium-CP concentrate was produced by mixing the low- and high-CP concentrates in equal proportions. This resulted in 3 concentrate feeds that were comparable in terms of ME, fermentable ME, and fiber content. Concentrates were offered at milking (50% at 0700 h and 50% at 1500 h), and fresh herbage was offered ad libitum at 1000 h each morning. The zero-grazed herbage was harvested from a single sward each morning using a Haldrup 1500 (Plot Combine, Haldrup, UK) and boxed loosely to avoid nutrient degradation. The temperature of the perennial ryegrass was monitored for the duration of the study. Herbage regrowth intervals (initially 22 d of regrowth with incremental increases up to 30 d from June to September) and fertilization practices (within 3 d of