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Effects of forage source and extruded linseed supplementation on methane emissions from growing dairy cattle of differing body weights

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ABSTRACT

Changes in diet carbohydrate amount and type (i.e., starch vs. fiber) and dietary oil supplements can affect ruminant methane emissions. Our objectives were to measure methane emissions, whole-tract digestibility, and energy and nitrogen utilization from growing dairy cattle at 2 body weight (BW) ranges, fed diets containing either high maize silage (MS) or high grass silage (GS), without or with supplemental oil from extruded linseed (ELS). Four Holstein-Friesian heifers aged 13 mo (BW range from start to finish of 382 to 526 kg) were used in experiment 1, whereas 4 lighter heifers aged 12 mo (BW range from start to finish of 292 to 419 kg) were used in experiment 2. Diets were fed as total mixed rations with forage dry matter (DM) containing high MS or high GS and concentrates in proportions (forage:concentrate, DM basis) of either 75:25 (experiment 1) or 60:40 (experiment 2), respectively. Diets were supplemented without or with ELS (Lintec, BOCM Pauls Ltd., Wherstead, UK; 260 g of oil/kg of DM) at 6% of ration DM. Each experiment was a 4 × 4 Latin square design with 33-d periods, with measurements during d 29 to 33 while animals were housed in respiration chambers. Heifers fed MS at a heavier BW (experiment 1) emitted 20% less methane per unit of DM intake (yield) compared with GS (21.4 vs. 26.6, respectively). However, when repeated with heifers of a lower BW (experiment 2), methane yield did not differ between the 2 diets (26.6 g/kg of DM intake). Differences in heifer BW had no overall effect on methane emissions, except when expressed as grams per kilogram of digestible organic matter (OMD) intake (32.4 vs. 36.6, heavy vs. light heifers). Heavier heifers fed MS in experiment 1 had a greater DM intake (9.4 kg/d) and lower OMD (755 g/kg), but no difference in N utilization (31% of N intake) compared with heifers fed GS (7.9 kg/d and 799 g/kg, respectively). Tissue energy retention was nearly double for heifers fed MS compared with GS in experiment 1 (15 vs. 8% of energy intake, respectively). Heifers fed MS in experiment 2 had similar DM intake (7.2 kg/d) and retention of energy (5% of intake energy) and N (28% of N intake), compared with GS-fed heifers, but OMD was lower (741 vs. 765 g/kg, respectively). No effect of ELS was noted on any of the variables measured, irrespective of animal BW, and this was likely due to the relatively low amount of supplemental oil provided. Differences in heifer BW did not markedly influence dietary effects on methane emissions. Differences in methane yield were attributable to differences in dietary starch and fiber composition associated with forage type and source.
Key words: methane, dairy cattle, forage, oil supplementation

INTRODUCTION

The farming of ruminant livestock is a major source of greenhouse gas emissions, including methane, which has 25 times greater global warming potential than carbon dioxide (g/g basis; United Nations, 2009). Enteric methane not only contributes to greenhouse gas emissions, but also represents a substantial waste of feed energy for ruminant animals. Greater knowledge of factors that determine emissions could lead to reduced environmental effects and improvements in dietary energy utilization for ruminant-derived food production. Several methane-mitigation opportunities have been identified, including changes in diet carbohydrate amount and type as well as the use of dietary oil supplements to decrease methane emissions (Cottle et al., 2011; Grainger and Beauchemin 2011).

Maize silage- (**MS**) and grass silage (**GS**)-based diets are representative of typical rations fed to cattle in the United Kingdom. In particular, MS has been used increasingly in livestock diets as newer varieties with shorter growing seasons become available (O'Mara et al., 1998). Maize silage typically has high DM yields, providing biomass that is readily digestible and increases voluntary feed intake and animal performance

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(O'Mara et al., 1998; Beauchemin et al., 2008). Forage composition can vary considerably and depends on forage species and maturity at harvest. Maize silage has a digestible starch content of approximately 30%, whereas the major carbohydrate of GS is NDF (Brask et al., 2013). The contrasting carbohydrate profile of MS versus GS gives the expectation of differing methane emissions when they are fed to ruminants (Beauchemin et al., 2008). A greater starch intake can result in a lower rumen pH and enhanced propionate production, which is an alternative hydrogen sink to methane (Janssen, 2010) and is less favorable for fibrolytic bacteria (Owens et al., 2009). In contrast, increasing grass maturity increases NDF concentration and acetate is a major end product of NDF fermentation, with acetate production enhancing methane formation (Johnson and Johnson, 1995). Studies have reported decreased methane emission from ruminants when replacing GS with MS (Reynolds et al., 2010; Brask et al., 2013; van Gastelen et al., 2015), although some have reported no effect (Staerfl et al., 2012; Livingstone et al., 2015), and thus more research is needed.

In addition to alterations in dietary fiber and starch, the feeding of supplemental oil will typically reduce methane emissions by an amount dependent on the quantity fed (Beauchemin et al., 2008). However, the amount of oil supplemented in the diet can have detrimental effects on feed intake, digestibility, and fermentation of feeds, including animal performance, depending in part on the type and form of the oil fed (Patra, 2013). Oils in the diet replace fermentable substrates and PUFA provide an alternative to methane synthesis for hydrogen disposal as well as having direct inhibitory effects on the rumen microflora (Martin et al., 2010). It was found that for a 1% increase of oil supplementation, methane yield (g/kg of DMI) was reduced to a similar extent across various studies (0.79, Moate et al. 2011; 1.00, Grainger and Beauchemin, 2011; and 0.66, Patra, 2013). Renewed interest into the effects of linolenic acid (C18:3 n-3), including extruded linseed (Martin et al., 2008; Livingstone et al., 2015), on methane emissions has been noted. Linolenic acid has been found to decrease the number and activity of ruminal protozoa, cellulolytic bacteria (Nagaraja et al., 1997), and methanogens, either directly or indirectly affecting methanogenesis (Morgavi et al., 2010). However, the extent to which linolenic acid provided by linseed products and fed at practical levels of feeding decrease methane emissions are not certain (Livingstone et al., 2015).

The objectives of the present study were to determine the effects of feeding high-MS and high-GS diets, without or with supplemental oil from extruded linseed, on methane emissions, whole-tract digestibility, and energy and N balance in growing dairy cattle. Measurements were obtained using 2 groups of growing heifers with differing BW ranges. It was hypothesized that heifers fed a high-MS diet would have increased retention of energy and N, which would be associated with lower methane yields (g/kg of DMI), compared with heifers fed high-GS diets, and that ELS supplementation would reduce methane yield for both MS- and GS-based diets.

MATERIALS AND METHODS

Experimental Design

Both experiments were conducted at the University of Reading Centre for Dairy Research, between January and May 2011 for experiment 1 and December 2011 and April 2012 for experiment 2. Dietary treatments for both experiments were provided in a 4 × 4 Latin square design balanced for carry over effects with 33-d periods. From d 1 to 28 animals were group-housed and bedded on wood shavings with rubber mats and adapted to dietary treatments, with feed intakes measured using an electronic Calan Broadbent individual feeding system (American Calan, Northwood, NH). From d 29 to 33 animals were housed in individual respiration chambers where measurements of diet composition, intake, fecal and urine excretion, and energy and N excretion were undertaken, with oxygen consumption and methane and carbon dioxide excretion measured over the last 4 d. All animal procedures were conducted in accordance with the UK Animals (Scientific Procedures) Act, 1996.

Animals and Dietary Treatments

Four Holstein Friesian dairy heifers aged 13 mo with a BW range that spanned the experimental duration (from start to finish, respectively) of 382 to 526 kg, were used in experiment 1, and 4 lighter Holstein Friesian heifers, aged 12 mo, with a BW range from start to finish of the experimental duration of 292 to 419 kg were used for experiment 2. Body weight was measured weekly and when heifers entered and left the respiration chambers. Dietary treatments were fed once daily at 1000 h for intakes to achieve live weight gains (**LWG**) of 1 kg/d for experiment 1 and 0.75 kg/d for experiment 2 using estimates of diet ME concentrations and ME requirements for target LWG (Alderman and Cottrill, 1993). Target LWG for experiment 2 was lower to minimize feed refusals. In experiment 2, the diets were adjusted to incorporate approximately 1 kg of DM/d of commercial calf pellet [chemical composition (g/kg of DM) of ash = 85.1; oil = 46.5; ADF = 174;