J. Dairy Sci. 96:1769–1781
http://dx.doi.org/10.3168/jds.2012-6039

Response profiles of enteric methane emissions and lactational performance during habituation to dietary coconut oil in dairy cows

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ABSTRACT

Dietary coconut oil (CNO) can reduce dry matter intake (DMI), enteric methane (eCH_4) emissions , and milk fat yield of lactating cows. The goals of this research were to examine responses to different CNO concentrations during the habituation period (34-d) and to evaluate temporal patterns of DMI, eCH_4, and milk fat yield. Treatment diets contained (dry basis): 0.0% (CNO0), 1.3% (CNO1.3), 2.7% (CNO2.7), 3.3% (CNO3.3), or 4.0% CNO (CNO4). In experiment 1, 12 primi- or small secundiparous cows were housed in individual, environmentally controlled rooms and fed CNO0, CNO1.3, CNO2.7, or CNO4. Measurements included DMI, eCH_4, and milk yield and composition. Due to a precipitous drop in DMI (26%), cows fed CNO4 were replaced with cows fed CNO3.3 following d 10. Dietary CNO of 2.7% or more reduced eCH_4 emissions. Reduction was greater with increased CNO and during the first than the second half of the day. Simultaneously, decline in DMI of cows fed CNO2.7, CNO3.3, or CNO4 was increasingly precipitous with increased CNO concentration. Total-tract neutral detergent fiber (NDF) digestibility during wk 5 was reduced in cows fed CNO2.7 or CNO3.3, which in part explained concomitantly reduced eCH_4/DMI. In addition, milk fat yield was depressed at an increasing rate in cows fed CNO2.7, CNO3.3, and CNO4. In experiment 2, DMI was measured individually in 12 multiparous cows during habituation to CNO0, CNO1.3, CNO2.7, or CNO3.3 for 21 d before relocation to individual, environmentally controlled rooms. Dietary CNO2.7 or CNO3.3 reduced DMI by d 4 and total-tract NDF digestibility during wk 5. Relocation to individual rooms was associated with a 15% reduction in DMI, which was not affected by treatment. Results showed that 2.7% or more dietary CNO reduced eCH_4 and DMI, caused milk fat depression, and decreased NDF digestibility.

Key words: lactational response, enteric methane emission, dietary adaptation

INTRODUCTION

Feeding coconut oil (**CNO**) may be one approach to mitigate enteric methane (**eCH_4**) emissions from ruminants (Machmüller, 2006). Coconut oil contains about 75% medium-chain FA (**MCFA**; C_8 to C_{14}) that are otherwise rare in ruminant diets. These FA reduce eCH_4 emissions in ruminants (Blaxter and Czerkawski, 1966). However, characterization of eCH_4 emissions during habituation to dietary CNO has not been described in high-producing dairy cows.

Dietary CNO or MCFA treatments resulted in reduction of DMI and consequently lactational performance in dairy cows (Külling et al., 2002; Hollmann et al., 2012; Reveneau et al., 2012). Additionally, dietary CNO or MCFA depressed ruminal NDF digestibility (**NDFD**; Sutton et al., 1983; Reveneau et al., 2012). Recently, we speculated that at least 2 different mechanisms regulate DMI in cows fed CNO (Hollmann and Beede, 2012). Dry matter intake dropped and stayed depressed 1 to 2 d following the introduction of 4% or more (dry basis) dietary CNO. In contrast, DMI declined slowly (e.g., over 1 to 2 wk), when diets contained 2 to 3% CNO. Dietary FA with 12 or less C are mostly oxidized in ruminants (Blaxter and Czerkawski, 1966); thus, they could depress DMI through accumulation of ATP (Allen et al., 2009). Moreover, dietary C_{12}, the major FA in CNO, initiated a hormonal response that caused satiety in humans (Feltrin et al., 2004). Oxidation of fuels and hormonal responses to dietary CNO are presumed to be short-term regulators of DMI. In contrast, ruminal fill may build up over time with depressed ruminal NDFD and cause a slow reduction in DMI through ruminal fill limitations (Allen, 1996). The progression of the DMI response to the introduction of CNO at differing dietary concentrations requires further examination.

Ruminal fermentation of NDF generates more eCH_4 than digestion of NFC (Blaxter and Clapperton, 1965). Indeed, reduced ruminal NDFD is likely responsible,

Received August 7, 2012.
Accepted November 9, 2012.
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in part, for reduced eCH_4 emissions with CNO diets in ruminants. Yet, it is not feasible to directly assess ruminal NDFD during habituation to dietary treatment. First, NDFD presumably changes daily during the initial stage of CNO feeding, but detecting progression in NDFD is virtually impossible due to diurnal variations (e.g., in intake). Second, evacuation and sampling of ruminal contents would greatly disrupt the continued adaptation to treatment. Additionally, dietary CNO consistently causes milk fat depression (**MFD**; Hollmann et al., 2012; Reveneau et al., 2012), likely in response to impaired ruminal NDFD (Bauman and Griinari, 2001). Monitoring eCH_4 emissions and milk fat production during habituation to dietary treatment may provide insight into ruminal NDFD. Thus, the objective was to evaluate progression of eCH_4 emissions, DMI, and milk production during the habituation to introduction of various dietary concentrations of CNO. We hypothesized that (1) high CNO concentration (e.g., greater than 3%, dry basis) will reduce eCH_4 emissions and DMI short term, (2) moderate CNO concentrations will depress eCH_4 and DMI midterm (e.g., after 1 wk), and (3) eCH_4 emissions per unit of DMI and milk fat yield will decline at an increasing rate with increased dietary CNO concentrations.

MATERIALS AND METHODS

The current study examining the adaptation period to introduction of dietary CNO in lactating dairy cows was part of a larger experiment (Hollmann et al., 2012). The reader is referred to that paper for further description of experimental procedures. The All University Committee on Animal Use and Care at Michigan State University (East Lansing) approved all experimental procedures (approval number 07/07-130-00). Cows were observed and evaluated for potential health issues twice daily.

Treatments and Cows

All dietary concentrations are presented on a dry basis. Dry matter intakes and milk yields (**MY**) were recorded daily throughout the experiment. All cows had been fed a basal diet without supplemental fat or monensin-Na for 21 d before the experiments began at the Michigan State University Dairy Teaching and Research Center (**DTRC**).

Experiment 1. Dietary treatments had CNO concentrations of 0.0% (**CNO0**), 1.3% (**CNO1.3**), 2.7% (**CNO2.7**), 3.3% (**CNO3.3**), or 4.0% (**CNO4**) and were formulated to meet NRC (2001) recommendations. Dietary ingredients and nutrient compositions are given in Table 1. Briefly, CNO and soybean meal were substituted for portions of soy hulls to maintain similar CP and amino acids concentrations across treatments.

Eight primiparous and 4 small secundiparous Holstein cows [116 ± 30 DIM (mean ± SD) at the start of the experiment] were blocked by parity and MY and assigned randomly to CNO0, CNO1.3, CNO2.7, or CNO4. They were relocated and randomly assigned to individual, environmentally controlled rooms at the Animal Air Quality Research Facility on d −1. Cows were milked twice daily and fed at least 110% of their ad libitum DMI per 12-h period before each milking. Treatment diets were prepared daily as a TMR and fed for 34 d. Environmentally controlled rooms and management of cows were described elsewhere (Hollmann et al., 2012).

Cows were offered the preexperimental diet on d −1 (first day in rooms). Dietary treatments started d 1. Treatment CNO4 was discontinued after d 10 because of severe depression in DMI. Cows fed CNO4 (2 primiparous and 1 secundiparous cow) were removed from the experiment. They were replaced on d 12 with 3 different cows (2 primiparous and 1 secundiparous cow) that had been fed CNO0, CNO1.3, or CNO2.7 for 11 d at the DTRC. Replacement cows received CNO3.3. The average DIM for all 12 cows on d 12 was 126 (SD: ± 30). Primiparous cows weighed 569 (±36.7) kg and secundiparous cows weighed 633 (±50.1) kg after the morning milking on d 34.

Experiment 2. Twelve multiparous cows [129 ± 15 DIM (mean ± SD) at the start of the experiment] at the DTRC were blocked by MY and randomly assigned to CNO0, CNO1.3, CNO2.7, or CNO3.3. Cows were fed once daily ad libitum in a tiestall barn, milked twice per day in a parlor, and given access to an exercise lot for 1 h daily. They were relocated and kept in individual, environmentally controlled rooms at the Animal Air Quality Research Facilities from d 22 to 36 and managed as described for experiment 1.

Data and Sample Collections and Analyses

Experiment 1. Methane concentrations in incoming and out-flowing air streams were detected for each room during eight 5.5-min periods per day (variable: time of day) with a photoacoustic analyzer (Innova model 1412; LumaSense Technologies A/S, Ballerup, Denmark). A pressure transducer (Setra model 239; Setra Systems Inc., Boxborough, MA) measured air flow in and out of each room, and temperature and relative humidity of outlet air were recorded (CS500; Campbell Scientific Inc., Logan, UT; Li et al., 2011). Enteric CH_4 emissions were the difference between amount of CH_4 entering and exiting each individual room. Enteric CH_4 data were not available for d −1, 1, 19, and 32,