J. Dairy Sci. 93:2612–2619
doi:10.3168/jds.2009-2888

Supplementation with whole cottonseed causes long-term reduction of methane emissions from lactating dairy cows offered a forage and cereal grain diet

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ABSTRACT

The objective of our work was to supplement a forage and cereal diet of lactating dairy cows with whole cottonseed (WCS) for 12 wk and to determine whether the expected reduction in CH_4 would persist. A secondary objective was to determine the effect of supplementing the diet with WCS on milk yield and rumen function over the 12-wk feeding period. Fifty lactating cows were randomly allocated to 1 of 2 diets (control or WCS). The 2 separate groups were each offered, on average, 4.2 kg of DM/cow per day of alfalfa hay (a.m.) and 6.6 kg of DM/cow per day of ryegrass silage (p.m.) on the ground in bare paddocks each day for 12 wk. Cows in each group were also individually offered dietary supplements for 12 wk in a feed trough at milking times of 5.4 kg of DM/cow per day of cracked wheat grain and 0.5 kg of DM/cow per day of cottonseed meal (control) or 2.8 kg of DM/cow per day of cracked wheat grain and 2.61 kg of DM/cow per day of WCS. The 2 diets were formulated to be similar in their concentrations of CP and ME, but the WCS diet was designed to have a higher fat concentration. Samples of rumen fluid were collected per fistula from the rumen approximately 4 h after grain feeding in the morning. Samples were taken from 8 cows (4 cows/diet) on 2 consecutive days in wk 2 of the covariate and wk 3, 6, 10, and 12 of treatment and analyzed for volatile fatty acids, ammonia-N, methanogens, and protozoa. The reduction in CH_4 emissions (g/d) because of WCS supplementation increased from 13% in wk 3 to 23% in wk 12 of treatment. Similarly, the reduction in CH_4 emissions (g/kg of DMI) increased from 5.1% in wk 3 to 14.5% in wk 12 of treatment. It was calculated that the average reduction in CH_4 emissions over the 12-wk period was 2.9% less CH_4 per 1% added fat, increasing from 1.5% in wk 3 to 4.4% less CH_4 in wk 12. There was no effect of WCS supplementation on rumen ammonia-N, rumen volatile fatty acids, rumen methanogens, and rumen protozoa. On average over the 12-wk period, supplementation with WCS decreased the yield of milk (10%), fat (11%), protein (14%), lactose (11%), and fat plus protein (12%) and BW gain (31%). The WCS supplementation had no effect on milk fat concentration but resulted in a decrease in concentration of protein (5%) and lactose (11%). The major finding from this study is that addition of WCS to the diet of lactating dairy cows resulted in a persistent reduction in CH_4 emissions (g of CH_4/kg of DMI) over a 12-wk period and that these reductions in CH_4 are consistent with previous work that has studied the addition of oilseeds to ruminant diets.
Key words: dietary oil, methane emission, lactating dairy cow, sulfur hexafluoride tracer technique

INTRODUCTION

Agriculture was responsible for about 10 to 12% of total global anthropogenic emissions of greenhouse gases in 2005. Globally, emissions of methane (CH_4) and nitrous oxide (N_2O) increased by approximately 17% from 1990 to 2005. Enteric CH_4 fermentation accounted for about 32% of total non-CO_2 emissions from agriculture in 2005 (Smith et al., 2007).

Adding oils or oilseeds to the diet has been shown to be an effective means of mitigating CH_4 emissions of dairy cows (Martin et al., 2008; Beauchemin et al., 2009a). However, in recent reviews of adding lipids to the diet of ruminants, Beauchemin et al. (2009b) and Martin et al. (2010) pointed out that many of the studies have been short-term and that there is a need to demonstrate the long-term effect of oil-based feeding strategies.

Over the summer period in winter-rainfall dairying areas in Victoria, Australia, dryland pasture is generally of low availability and is also low in protein and energy content. Consequently, supplementary feeds often com-

Received November 8, 2009.
Accepted February 6, 2010.
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prise a large component of the diet, and sometimes the whole diet, and need to provide much of the energy and protein required by the animals. Oilseeds such as whole cottonseed (**WCS**) are high in energy and protein (14 MJ/kg of DM and 22% CP) and also contain about 22% oil. In a previous study, addition of 3 kg of WCS daily per cow over 5 wk to a diet of ryegrass silage, alfalfa hay, and cracked cereal grain reduced CH_4 emissions by 12% and increased milk yield by about 15% (Grainger et al., 2008). In the present work, rather than adding extra DM (energy) in the form of WCS to a basal diet of ryegrass silage, alfalfa hay, and cracked cereal grain, the 2 diets were formulated to be balanced for ME and CP. This was achieved by substituting cottonseed meal and extra cracked cereal grain in the control diet for WCS in the treatment diet. Consequently, the major difference between the 2 diets was the extra fat provided by the WCS.

The objective of our work was to extend the period of feeding WCS to dairy cows from 5 to 12 wk and determine whether the reduction in CH_4 would persist. A secondary objective was to determine the effect of supplementing the diet with WCS on milk yield and rumen function over a 12-wk feeding period.

MATERIALS AND METHODS

Animals, Experimental Design, and Diets

Fifty lactating cows, including 12 primiparous cows, from the experimental herd at the Department of Primary Industries–Victoria, Ellinbank Research Center (Ellinbank, Australia; 38°14′ S, 145°56′ E), 177 ± 10 DIM and with initial BW of 541 ± 56 kg, were allocated to 1 of 2 diets (control or WCS) so that the groups were balanced for means and variances of age, milk yield (measured during a covariate period 2 wk before treatments commenced), and calving date, as described by Baird (1994). Four of the cows in each group were ruminally fistulated. The experiment was conducted in accordance with the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes (www.nhmrc.gov.au).

The 2 separate groups were each offered, on average, 4.2 kg of DM/cow per day of alfalfa hay (a.m.) and 6.6 kg of DM/cow per day of ryegrass silage (p.m.) on the ground in bare paddocks each day for 12 wk over summer and fall during 2008. The low levels of hay and silage offered per cow resulted in no recorded refusals of hay or silage for either group. Cows in each group were also individually offered dietary supplements for 12 wk in a feed trough at milking times. The control group was offered 6.0 kg of DM/cow per day of a mixture of cracked wheat grain (92%) and cottonseed meal (8%), and the treatment group was offered 5.4 kg of DM/cow per day of a mixture of cracked wheat grain (52%) and WCS (48%; Table 1). The 2 supplement mixtures (wheat grain and cottonseed meal or wheat grain and WCS) were separately weighed for each cow and then thoroughly combined and offered to each cow as a mixture at milking times. Any refusals of the grain mixture were individually weighed, DM was measured, and the amount of each component was calculated based on the proportion of the wet weight of the individual components initially offered. The WCS was untreated and consisted of small seeds surrounded by lint. The 2 diets were formulated to be similar in their concentrations of CP and ME, but the WCS diet was designed to have a higher fat concentration (Table 2). Because of a shortage of cottonseed meal for the control diet, 0.9 kg of DM/cow per day of canola meal was used as a substitute for 0.5 kg of DM/d of the cottonseed meal in wk 11 of the treatment period to maintain the CP and ME contents of the control diet.

Table 1. Measured DMI of control and whole cottonseed (WCS) groups averaged over wk 1 to 12 of feeding of WCS[1]

Item, kg of DM/cow per day	Control	WCS
Ryegrass silage	6.6 (0.6)	6.6 (0.6)
Alfalfa hay	4.2 (0.2)	4.2 (0.2)
Grain mixture[2]	5.99 (0.12)	4.91 (0.82)
Total DMI	16.8 (0.6)	15.7 (0.6)

[1]Data are means (SD). Standard deviation for silage and hay refers to variation in amounts offered per day to each group.

[2]Grain mixture for control diet comprised cracked wheat (92%) and cottonseed meal (8%). Canola meal was substituted for cottonseed meal in wk 11 of treatment because of a shortage of cottonseed meal. The WCS diet comprised cracked wheat (52%) and WCS (48%).

Cows were weighed fortnightly during the experiment and milked twice daily through a common parlor at about 0600 and 1500 h. Milk yield was measured daily for each cow using a DeLaval Alpro milk metering system (DeLaval International, Tumba, Sweden). One day per week a separate a.m. and p.m. milk sample was taken from each cow using in-line milk meters. Samples were analyzed for concentrations of fat, CP, and lactose using a near-infrared milk analyzer (model 2000, Bentley Instruments, Chaska, MN). Milk solids was defined as fat + protein.

Feed Analyses

Representative samples of feeds offered were collected each week, oven-dried and ground through a 0.5-mm sieve, and analyzed by a commercial laboratory (SGS Australia Pty Ltd., Toowoomba, Queensland). Some details of the methods used are given below. Fat content was analyzed by Soxhlet extraction using petro-