Animal Feed Science and Technology 241 (2018) 121–132

Contents lists available at ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

Effect of concentrate feeding level on methane emissions, production performance and rumen fermentation of Jersey cows grazing ryegrass pasture during spring

J.D.V. van Wyngaard[a,*], R. Meeske[b], L.J. Erasmus[a]

[a] Department of Animal and Wildlife Sciences, University of Pretoria, Private Bag X20, Hatfield 0028, South Africa
[b] Department of Agriculture, Western Cape, Outeniqua Research Farm, P. O. Box 249, George 6530, South Africa

ARTICLE INFO

Keywords:
CH_4 measurement
Perennial ryegrass
Methane mitigation
Pasture-based
SF_6

ABSTRACT

Dietary supplementation has been well documented as an effective enteric methane (CH_4) mitigation strategy. However, limited studies have demonstrated the effect of concentrate level on enteric CH_4 emissions from grazing dairy cows, and to our knowledge none of these studies included a pasture-only diet or reported on rumen fermentation measures. Sixty multiparous (4.0 ± 1.51 SD) Jersey cows, of which six were rumen-cannulated, were used in a randomised complete block design, and the cannulated cows were used in a separate replicated 3 × 3 Latin square design, to investigate the effect of concentrate supplementation (0, 4, and 8 kg/cow per day; as fed) on enteric CH_4 emissions, milk production, dry matter intake (DMI), and rumen fermentation of dairy cows grazing perennial ryegrass pasture during spring, following a 14-d adaptation period. The sulphur hexafluoride tracer gas technique was used to measure enteric CH_4 emissions from 10 cows of each treatment group over a single 9-d measurement period. Parallel with the CH_4 measurement period, pasture DMI was determined using TiO_2 and indigestible neutral detergent fibre as external and internal markers, respectively, while milk yield, milk composition, cow condition, and pasture pre- and post-grazing measurements were also recorded. Total DMI (13.4 to 18.0 kg/d), milk yield (12.9 to 19.2 kg/d), energy corrected milk (14.6 to 20.7 kg/d), milk lactose content (46.2 to 48.1 g/kg) and gross energy intake (239 to 316 MJ/d) increased, while milk fat content (50.0 to 44.2 g/kg) decreased with increasing concentrate feeding level. Volatile fatty acid concentrations and ruminal pH were mostly unaffected by treatment, while dry matter disappearance decreased and NH_3-N concentration increased with increasing concentrate feeding level. Methane production (258 to 302 g/d) and CH_4 yield (20.6 to 16.9 g/kg of DMI) were similar for all cows, while pasture DMI (13.4 to 10.8 kg/d) and CH_4 intensity (20.4 to 15.9 g of CH_4/kg of milk yield) decreased linearly with increasing concentrate feeding level. Results indicate that concentrate supplementation on high quality pasture-only diets have the potential to effectively reduce CH_4 emissions per unit of milk yield from grazing cows during spring.

Abbreviations: BCS, body condition score; CH_4, methane; CP, crude protein; DIM, days in milk; DM, dry matter; DMI, dry matter intake; ECM, energy corrected milk; FCM, fat corrected milk; FO, faecal output; GE, gross energy; iNDF, indigestible neutral detergent fibre; ME, metabolisable energy; MUN, milk urea nitrogen; NDF, neutral detergent fibre; NIWA, National Institute of Water and Atmosphere; OMD, *in vitro* organic matter digestibility; SCC, somatic cell count; SF_6, sulphur hexafluoride; VFA, volatile fatty acid

* Corresponding author.
E-mail addresses: josefvw@elsenburg.com, jdvvanwyngaard@gmail.com (J.D.V. van Wyngaard).

https://doi.org/10.1016/j.anifeedsci.2018.04.025
Received 30 January 2018; Received in revised form 24 April 2018; Accepted 30 April 2018

1. Introduction

Over the past decade, enhanced management and genetics in dairy farming have resulted in increased milk production which led to, *inter alia*, improved feed efficiency and a more cost-effective product (Negussie et al., 2017). Conversely, dairy farming results in emissions of methane (CH_4) gas that is mainly produced by microbes in the rumen. Methane is a damaging greenhouse gas with 28 times the greenhouse potential of carbon dioxide over a 100 year period (Myhre et al., 2013) and signifies a loss of energy that could have been converted into animal products. The livestock sector is a major contributor to the buildup of CH_4 emissions in the atmosphere. The South African cattle industry produced 964 Gg of CH_4 emissions during 2010, of which 13.5% was represented by the dairy sector mainly in the form of enteric CH_4 emissions (Du Toit et al., 2013). The latter statistics were obtained by means of Tier 2 methodologies as described by the IPCC (2006). The need to implement a more refined method, such as Tier 3 methodologies, to further improve the accuracy of current national greenhouse gas inventories as well as the need to alleviate enteric CH_4 emissions has become a growing concern on an international level.

Several effective mitigation strategies for enteric CH_4 emissions have been extensively reviewed (Hristov et al., 2013; Knapp et al., 2014), which can be classified in the following categories: feeds and nutrition, rumen modifiers, and herd management and genetics. When selecting a mitigation strategy the combined effects of whole-farm profitability, on-farm practicality, and adoption potential should be considered (Hristov et al., 2013). Feeding high levels of concentrates as mitigation strategy meets the latter conditions. Tyrrell and Moe (1972) showed that CH_4 yield (g/kg of dry matter intake (DMI)) and intensity (g/kg of animal production) will decrease by increasing the proportion of concentrate in the diet if animal production remains the same or is increased. However, although concentrate feeding level has been evaluated extensively as a CH_4 mitigation strategy in confined dairy systems (Yan et al., 2010; Aguerre et al., 2011), pasture-based dairy systems received much less attention. The limited work undertaken has generally indicated that milk production and total DMI increased with increasing concentrate level, whereas the CH_4 emission response to treatment varied, with one study showing no treatment response (Young and Ferris, 2011). The level of concentrate evaluated in these limited studies ranged from 1 to 8 kg/cow per day and cows mainly grazed perennial ryegrass (*Lolium perenne*) dominant pasture during spring.

To our knowledge, no grazing study to date has examined the effect of concentrate level on enteric CH_4 emissions with the inclusion of a pasture-only treatment. Furthermore, although the potential of rumen parameters such as volatile fatty acids (VFA) and pH to act as proxies for enteric CH_4 emissions is variable (Negussie et al., 2017), CH_4 emissions studies that include these rumen fermentation measurements can be beneficial for future CH_4 proxy meta-analysis studies.

Thus, the aim of the study was to determine the effect of different concentrate levels (including a pasture-only treatment) on CH_4 emissions, production performance and rumen fermentation of Jersey cows grazing perennial ryegrass pasture during spring. We hypothesised that an increased concentrate level will increase milk production and total DMI while decreasing CH_4 yield and intensity. We further hypothesised that enteric CH_4 emissions will increase as total DMI increases. Results obtained from this study can be used to improve the accuracy of the greenhouse gas inventory of the pasture-based South African dairy sector, and may have application to grazing based dairy sectors in other countries.

2. Materials and methods

2.1. Location description

The study was conducted during spring of 2015 (September - November) at the Outeniqua Research Farm (33°58´S, 22°25´E; altitude 210 m above sea level) which forms part of the Western Cape Department of Agriculture (Elsenburg, South Africa). The study area has a temperate climate with a long-term (45 years) mean annual precipitation of 732 mm, distributed throughout the year, and a mean daily maximum and minimum temperature range of 18 °C to 25 °C, and 7 °C to 15 °C, respectively. Ethical clearance for animal care and use was obtained from the Western Cape Department of Agriculture (Elsenburg, South Africa) before commencement of the study (DECRA approval number: R114/115).

2.2. Animals, experimental design and treatments

Sixty multiparous Jersey cows (six rumen-cannulated) with mean pre-experimental milk yield of 20.1 (± 2.29 SD) kg/d, 142 (± 52 SD) days in milk (DIM), mean parity of 4.0 (± 1.51 SD), and mean body weight of 398 (± 33.2 SD) kg were selected from the Outeniqua dairy herd. Intact cows (54) formed part of a production study and were blocked (18 blocks) according to pre-experimental milk yield, DIM, and parity in one of three treatment groups. Each treatment group was then randomly assigned to one of three treatments that differed by level of concentrate feeding: 0, 4 and 8 kg/cow per day (as fed basis). Furthermore, the six rumen-cannulated cows (previously fitted with Bar Diamond #1C rumen cannulae; Bar Diamond Inc, Idaho, USA) formed part of a separate rumen study with a duplicated 3 × 3 Latin square design, which ran concurrent with the production study. Each of the rumen-cannulated cows was subjected to the three treatments over 20-d periods (14 d adaptation and 6 d data collection). Concentrate was fed individually to cows in pellet form split in two equal portions during milking. The ingredient composition of the concentrate offered was as follows (g/kg of dry matter; DM): 695 ground maize, 116 soybean oilcake, 34 sugarcane molasses, 20 limestone ($CaCO_3$), 3.7 monocalcium phosphate, 5.6 salt, 3.1 magnesium oxide and 1 trace mineral and vitamin premix (containing 4 mg of Cu/kg, 10 mg of Mn/kg, 20 mg of Zn/kg, 0.34 mg of I/kg, 0.2 mg of Co/kg, 0.06 mg of Se/kg, 6×10^6 IU of vitamin A/kg, 1×10^6 IU of vitamin D3/kg, and 8×10^3 IU of vitamin E/kg). Cows were allowed a 14-d dietary adaptation period, followed by a 52-d data