Animal Feed Science and Technology 176 (2012) 107–116

Contents lists available at SciVerse ScienceDirect

Animal Feed Science and Technology

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

Methane emissions from sheep fed fresh brassicas (*Brassica* spp.) compared to perennial ryegrass (*Lolium perenne*)

X.Z. Sun[a,*], G.C. Waghorn[b], S.O. Hoskin[a], S.J. Harrison[a], S. Muetzel[a], D. Pacheco[a]

[a] *Grasslands Research Centre, AgResearch Limited, Private Bag 11008, Palmerston North, New Zealand*
[b] *DairyNZ Limited, Private Bag 3221, Hamilton, New Zealand*

ARTICLE INFO

Keywords:
Methane
Brassicas
Swede
Turnip
Kale
Rape
Perennial ryegrass
Sheep

ABSTRACT

Four forage brassicas, kale (*Brassica oleracea* L. *cv.* Kestrel), turnip (*B. campestris* L. *cv.* Appin), rape (*B. napus* L. *cv.* Titan) and swede (*B. napus* L. *cv.* Dominion) were compared with perennial ryegrass (*Lolium perenne* L. *cv.* mixture of Delish and Banquet) to examine their potential to mitigate CH_4 emissions from sheep. Sixty healthy, one-year-old Romney cryptorchids (liveweight 36 ± 1.0 kg) were randomly allocated to 5 groups of 12. The sheep were initially adapted to their diets for 2 wks on paddocks and 1 wk in indoor pens, then fed at 1.5 times their metabolisable energy (ME) maintenance requirement during measurements. Apparent total tract digestibility (n = 5) and ME (n = 5) of brassicas and ryegrass, and rumen fermentation parameters (n = 10) were measured, and CH_4 emissions (n = 9) were determined using open circuit respiration chambers. Correlations between nitrate, sulphur, sulphate, glucosinolates and S-methyl cysteine sulphoxide (SMCO) contents of forages and CH_4 emissions were determined. Methane emissions/unit feed dry matter intake (g CH_4/kg) from sheep were kale 19.8, rape 16.4, swedes 16.9, turnips 20.6 and ryegrass 22.0. Compared with ryegrass, rape and swedes reduced CH_4 yield by 23% and 25%, respectively. Total tract digestibilities were higher for brassicas than for ryegrass: 25% higher for DM, organic matter (OM) and crude protein, and 12–16% higher for neutral detergent fibre (aNDF) and acid detergent fibre (ADF). The ME values (MJ/kg DM) were kale 12.7, rape 13.2, swedes 14.1, turnips 12.1 and ryegrass 9.4. Digestibility (P<0.05) and ME (P<0.001) of the forages were correlated to CH_4 yield. The correlation coefficients were −0.570 for OM digestibility, −0.505 for NDF digestibility, −0.469 for ADF digestibility and −0.699 for ME. Although the ratio of acetate to propionate in the rumen of sheep fed brassicas was lower than that measured from those fed ryegrass, this ratio was not correlated to CH_4 emissions. There were large variations in nitrate, sulphur, sulphate, glucosinolates and SMCO amongst the forage brassicas and ryegrass, but these parameters could not explain reduced CH_4 emissions. Feeding brassica forages to sheep reduced emissions/unit DM intake and digestible OM with the reduction being particularly large for forage rape and swedes. Thus these forages may be a viable option for CH_4 mitigation from pastoral based sheep production systems. However the mechanisms underlying the reduction need further investigation.

This paper is part of the special issue entitled: Plant Bioactive Compounds in Ruminant Agriculture – Impacts and Opportunities, Guest Edited by A.Z.M. Salem and S. López, and Editor for Animal Feed Science and Technology, P.H. Robinson.

Abbreviations: ADF, acid detergent fibre; aNDF, neutral detergent fibre; A:P, ratio of acetate to propionate; CP, crude protein; DE, digestible energy; DM, dry matter; GHG, greenhouse gas; HWSC, hot water soluble carbohydrate; ME, metabolisable energy; OM, organic matter; RFC, readily fermentable carbohydrate; SC, structural carbohydrate; SMCO, S-methyl cysteine sulphoxide; VFA, volatile fatty acid.

* Corresponding author. Tel.: +64 6 351 8150; fax: +64 6 351 8032.
E-mail address: xuezhao.sun@agresearch.co.nz (X.Z. Sun).

0377-8401/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.anifeedsci.2012.07.013

1. Introduction

Methane is one of the six greenhouse gases (GHG) specified in the Kyoto Protocol and accounts for 0.37 of the aggregate GHG emissions in New Zealand, 0.86 of which is from enteric fermentation of grazing ruminants (New Zealand Ministry for the Environment, 2012). Thus, CH_4 emitted from ruminants is a major GHG from the New Zealand agricultural sector.

There are three general approaches to mitigate CH_4 emissions from ruminants being manipulation of rumen microbes, selection of animals, which naturally emit less CH_4, and nutritional management (Iqbal et al., 2008). Within nutritional interventions, concentrates, oils, ionophores, nitrate and sulphate have been examined and some of them are effective (Beauchemin et al., 2008; Iqbal et al., 2008; Nolan et al., 2010; van Zijderveld et al., 2010), but all are difficult to apply to pastoral ruminant production systems. A forage based approach would be practicable and promising, especially if the forages were productive and with a high feeding value (*i.e.*, intake × nutritional value). Birdsfoot trefoil (*Lotus corniculatus*) fed to dairy cows (Woodward et al., 2004) and forage chicory (*Cichorium intybus*) (Waghorn et al., 2002; Swainson et al., 2008) fed to sheep reduced CH_4 yields/unit dry matter (DM) intake compared with perennial ryegrass (*Lolium perenne* L.) or perennial ryegrass based pasture, although in some cases there were no reductions (Sun et al., 2011, 2012).

Forage brassicas are extensively used as animal feed due to their rapid growth, high yield and nutritive value, the latter being a function of high metabolisable energy (ME) and non-structural carbohydrate content and low neutral detergent fibre (NDF) content (Belesky et al., 2007). Kale, rape, turnips and swedes are commonly grown in New Zealand, with over 250,000 ha planted annually early last decade (Beare et al., 2003), which has increased to ∼500,000 ha in recent years (A.V. Stewart, PGG Wrightson Seeds, Christchurch, New Zealand; pers. comm.).

Brassicas contain secondary plant metabolites including polyphenol oxidase (Parveen et al., 2010), S-methyl cysteine sulphoxide (SMCO) (Barry et al., 1982, 1985), which may account for 2–15 g/kg DM (Whittle et al., 1976; Griffiths and Macfarlane Smith, 1989), and glucosinolates (Tripathi and Mishra, 2007). Studies with rapeseed oil meal as a source of glucosinolates have shown that feed intake, live weight gain and fertility were negatively affected (Tripathi and Mishra, 2007). Although there are no reported studies on effects of any of these secondary plant metabolites on ruminal methanogens, human gut bacterial communities are altered by adding glucosinolate-containing vegetables to the diet (Li et al., 2009).

Methane is formed in the rumen by methanogens, which use hydrogen formed during fermentation of ingested feed. Nitrate and sulphate in the diet can be effective alternative hydrogen sinks in the rumen, and can reduce ruminal CH_4 production in sheep (Nolan et al., 2010; van Zijderveld et al., 2010). Brassicas are known nitrate accumulators and sometimes cause toxicity due to high concentrations (Bolan and Kemp, 2003), and this could also impact ruminal CH_4 formation.

The primary objective was to measure CH_4 emissions from sheep fed forage brassicas, in comparison with perennial ryegrass, which is the predominant component of pasture in New Zealand, using open respiration calorimetry. The secondary objective was to measure concentrations of glucosinolates, SMCO, nitrate and sulphate in the forage, as well as digestion and rumen metabolic characteristics of sheep fed these forages to determine associations with CH_4 production.

2. Materials and methods

2.1. Animals and forages

The study was conducted at AgResearch Grasslands, Palmerston North, New Zealand, during winter from May to July 2010. Sixty healthy one-year-old Romney cryptorchid sheep with similar liveweight (36 ± 1.0 kg) were selected from a flock of 300 sheep. They were drenched to control internal parasites with 8 ml of "Hi Mineral Oral Drench for Sheep" containing 1 g/l abamectin, 40 g/l levamisole HCl, 0.5 g/l selenium as sodium selenate and 2.2 g/l cobalt as cobalt EDTA (Merial New Zealand Ltd., Auckland, New Zealand). During the indoor acclimatisation and experimental periods, the sheep were fed fresh forage twice a day in equal amounts at 09:00 and 16:30 h, with free to access to water. All manipulations were conducted approved by the Grasslands Animal Ethics Committee, and were in accordance to the Animal Welfare Act 1999.

Forage kale (*Brassica oleracea* L. *cv.* Kestrel), turnip (*B. campestris* L. *cv.* Appin), and swede (*B. napus* L. *cv.* Dominion) crops were each grown on 1 ha in a sedimentary Kairanga sandy loam at AgResearch Grasslands Aorangi Research Farm (40°20′S, 175°28′E; 15 m above the sea level) near Palmerston North, New Zealand. They were sown at 3.5, 2 and 1 kg seed/ha, respectively, on 17 December 2009, following seed treatment with pesticides (Superstrike, Wrightson Limited, Christchurch, New Zealand). Prior to sowing, 250 kg/ha of diammonium phosphate (containing 180 g N, 200 g P and 10 g S per kg; Cropmaster, Ravensdown Limited, Hornby, New Zealand) was broadcast onto the cultivated ground. After sowing, 1 l/ha of pre-emergence herbicide (containing 900 g dimethenamid/l; Frontier, BASF New Zealand Limited, Manukau, New Zealand) in 200 L water/ha and 750 ml/ha of herbicide (containing 30 g aminopyralid/l; Tordon Max, Dow AgroSciences Ltd., New Plymouth, New Zealand) in 200 L water/ha plus Uptake Spraying Oil (CRT Limited, Dunedin, New Zealand) were applied. Five weeks after sowing, urea was applied at 150 kg/ha.

Forage rape (*B. napus* L. *cv.* Titan) was sown at 4 kg/ha with diammonium phosphate at the rate of 120 kg/ha in a Manawatu fine sandy loam soil on 23 February 2010 at AgReserch Grasslands. Perennial ryegrass (*cv.* a mix of Delish and Banquet) was established with white clover (*Trifolium repens* L.) in Kairanga fine sandy loam soil in autumn 2006 at AgResearch Grasslands Aorangi Research Farm, but white clover was removed with a herbicide containing 100 g/l haloxyfop-R methyl ester at 2.5 l/ha ('Gallant', Dow AgroSciences New Zealand Limited) in May 2009 to achieve a ryegrass sward.