Animal Feed Science and Technology 166–167 (2011) 308–320

Contents lists available at ScienceDirect

Animal Feed Science and Technology

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

Can enteric methane emissions from ruminants be lowered without lowering their production?

C. Grainger[a], K.A. Beauchemin[b,*]

[a] 9 Lilleys Rd, Warragul, VIC, 3820, Australia
[b] Agriculture and Agri-Food Canada, Lethbridge, Alberta, T1J 4B1, Canada

ARTICLE INFO

Keywords:
Dietary fat
Enteric methane
Ruminant
Greenhouse gas
Farming system

ABSTRACT

Methane emissions from ruminant livestock are a contributor to total global anthropogenic emissions of greenhouse gases. We review the most promising dietary and farm system strategies to mitigate enteric CH_4 emissions from ruminants, and their potential effects on animal production. Dietary supplementation with fat is the most promising dietary strategy, but the milk production and composition response to supplementary fat is complex and differs among diets. It is also affected by stage of lactation, degree of saturation of the added fat, amount of fat added, and the fat content and composition of the basal diet. To study effects of adding fat to diets on CH_4 emissions, a meta-analysis using data from 27 studies was conducted. For diets containing up to 130 g fat/kg of dry matter (DM), there was a linear relationship between total fat content of the diet and CH_4 yield (g/kg DM intake). The analysis re-run restricting diets to a practical feeding range of <80 g fat/kg DM, revealed a difference ($P<0.001$) between cattle (*i.e.*, dairy and beef) and sheep in their CH_4 response to dietary fat. For cattle, a 10 g/kg increase in dietary fat decreased CH_4 yield by 1 g/kg DM intake, but for sheep the decrease was 2.6 g/kg, although the relationship for sheep was less precise due to less data (*i.e.*, $n = 59$ for cattle and $n = 17$ for sheep). In the practical range of fat feeding, the relationship between concentration of fat in the diet and CH_4 yield was not affected by form of added fat (*i.e.*, oil *versus* seed), major fatty acids in the added fat (*i.e.*, C12:0 and C:14, C18:1, C18:2, and C18:3), or fat source (*i.e.*, canola, coconut, fatty acid, linseed, soya, sunflower, the basal diet without added fat). Data are also presented which show persistence of the reduction in CH_4 emissions as a result of fat supplementation. An update on other dietary strategies such as higher starch diets, use of monensin, exogenous enzymes and use of direct-fed microbials is also provided. Recent studies of dairy and beef farming systems which investigated effects of management strategies on CH_4 emissions and livestock production (*i.e.*, milk and beef) using modelling approaches and life cycle assessment are reviewed. Our review demonstrates that dietary and farm management options can be implemented to reduce CH_4 emissions from beef and dairy cattle without lowering their production.

This article is part of the special issue entitled: Greenhouse Gases in Animal Agriculture – Finding a Balance between Food and Emissions, Guest Edited by T.A. McAllister, Section Guest Editors; K.A. Beauchemin, X. Hao, S. McGinn and Editor for Animal Feed Science and Technology, P.H. Robinson.

Abbreviations: CP, crude protein; DDGS, distillers grains with solubles; DM, dry matter; GHG, greenhouse gases; LCA, life cycle assessment; SF_6, sulfur hexafluoride; TMR, total mixed ration.

* Corresponding author. Tel.: +1 4033172235; fax: +1 4033172182.
E-mail address: karen.beauchemin@agr.gc.ca (K.A. Beauchemin).

0377-8401/$ – see front matter
doi:10.1016/j.anifeedsci.2011.04.021

1. Introduction

Agriculture was responsible for 10–12% of total global non-CO_2 greenhouse gas (GHG) emissions in 2005, but emissions of CH_4 and N_2O increased globally by nearly 17% from 1990 to 2005, with both gases contributing equally to the increase (Smith et al., 2007). Enteric CH_4 fermentation accounted for about 32% of total non-CO_2 emissions from agriculture in 2005 (Smith et al., 2007). If CH_4 emissions grow in direct proportion to projected increases in livestock numbers, then global CH_4 emissions from livestock production are expected to increase 60% by 2030 (FAO, 2003). Efforts are being made by governments around the world to develop mitigations to reduce CH_4 emissions from ruminant livestock. However, livestock producers are unlikely to adopt these strategies if they reduce animal production and, hence, profitability.

Given the contribution of CH_4 to global GHG production, there have been several recent reviews of mitigation strategies to reduce enteric CH_4 emissions from livestock (*i.e.*, Beauchemin et al., 2008, 2009b; Eckard et al., 2010; Martin et al., 2010). In addition to these reviews, other papers in this issue offer in depth evaluation of specific CH_4 mitigation options, including use of plant derived essential oils, the potential for animal based options such as improved feed conversion efficiency, identifying high and low CH_4 emitting animals and the feasibility of manipulating the rumen microbiota. As a consequence, our review focuses on other promising dietary and farming system strategies with particular emphasis on effects on animal production and CH_4 emissions. In addition, emphasis is placed on achieving a net global reduction in potential GHG mitigations and, hence, use of life cycle assessment (LCA) is considered so that all on- and off-farm emissions are included (Weiske et al., 2006).

The potential for dietary supplementation with fat is a promising dietary strategy and is examined in detail for both total mixed rations (TMR) and pasture based grazing systems. An update is presented for other promising strategies including use of high starch forages, monensin, enzyme additives, yeasts and direct fed microbials. Recent studies of dairy and beef farming systems that used modelling approaches and LCA are reviewed. These studies investigated effects of management strategies on CH_4 emissions and livestock production (*i.e.*, milk and beef).

2. Dietary strategies

2.1. Fats

2.1.1. Fats – production responses

From a nutritional perspective, Jenkins (1997) categorized fat supplements for dairy rations by how they affect ruminal fermentation and fiber digestion. Calcium salts of fatty acids and hydrogenated fats are designed specifically to avoid problems related to reduced fermentation in the rumen. These fats have little or no negative effects on fiber digestion in the rumen at normal levels of supplementation because they are not released in the rumen. Another group of fats includes unaltered extracts from plant and animal sources that can cause reduced and abnormal digestion in cattle when added to provide >60–70 g fat/kg DM. Included in this group are fats of animal origin (*e.g.*, tallow, grease), extracted plant oils (*e.g.*, soybean, canola), oilseeds (*e.g.*, cottonseeds, sunflower seeds) and high fat byproducts such as residues from food processing plants (*e.g.*, brewers grains, cold pressed canola). Jenkins (1997) also proposed a model that described changes in milk production as fat level in the diet is increased. Initially, milk production increases as fat is increased in the diet (Phase 1) due to a higher energy density of the diet. In Phase 2, milk production remains stable because the value of the higher energy level of fat in the diet is offset by negative effects of the fat supplement, such as reduction in fermentability and/or digestibility while, in Phase 3 milk production declines as negative effects of the fat offset the increased energy which it provides.

Garnsworthy (1997) reviewed addition of fats to dairy cow diets and concluded that the milk response to supplementary fat is complex and not entirely predictable. He pointed out that cows in early lactation, and those of higher genetic merit, are more likely to realize a positive milk response associated from addition of fat to the diet. Onetti and Grummer (2004) conducted a meta-analysis of 41 studies published since 1980 to examine responses of lactating cows to three supplemental fat sources as affected by forage level in the diet and stage of lactation. They found that different milk yield responses to supplemental fats (*i.e.*, tallow, selected hydrolyzed tallow fatty acids, calcium salts of palm fatty acids) occurred dependant on the main forage (*e.g.*, maize silage, alfalfa hay) in the diet. For example, feeding tallow with maize silage as the basal diet did not increase milk yield, but milk yield increased when the diet was based on alfalfa hay. However, the opposite effect occurred when calcium salts of fatty acids were added to the same basal diets. Weiss and Pinos-Rodriguez (2009) also reported an effect of basal diet on the milk yield response to supplemental dietary fat. Supplementing diets with 22.5 g saturated fatty acids/kg DM had no effect on milk yield with high forage diets, but when the basal diet was low forage, milk yield increased.

Guidelines have been developed for addition of fat to TMR diets of dairy cattle (*e.g.*, Palmquist and Jenkins, 1980; Jenkins, 1997) with the aim of maximizing the milk production response and determining profitable feeding levels. Recommendations for maximum total dietary fat content are 60–80 g/kg DM and, for added fat, from 30 to 50 g/kg DM.

For pasture based diets, Schroeder et al. (2004) reviewed 18 experiments with a total of 25 comparisons that studied effects of fat supplementation on milk production. A higher milk production response as fat corrected milk occurred with supplements of saturated fat (*i.e.*, 7.3%) *versus* unsaturated fat (*i.e.*, −0.1%). The lower response was mainly due to a decrease in milk fat concentration for the unsaturated compared to the saturated fat supplement. The response was similar for early (*i.e.*, 5.1%) and mid lactation (*i.e.*, 5.2%) cows. Thus the milk response to supplemental fat is not affected by stage of lactation in cattle consuming pasture based diets, as has been reported in cattle fed TMR.