Scientific Papers. Series D. Animal Science. Vol. LVIII, 2015
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

STRATEGIES TO REDUCE METHANE PRODUCTION IN RUMINANTS

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Abstract

Ruminant animals play an important role in the food chain for evaluate cellulose and non-protein nitrogenous (NPN) compounds absorbed partially or not by other farm animals and humans. However, ruminant animals also bring some disadvantages. Methane, produced as a natural consequence of the ruminal digestion and it is a potential green house gas, is a problem, both ecologically and economically. Methane emissions from ruminant livestock are a contributor to total global anthropogenic emissions of greenhouse gases which have a global warming potential. Also methane produced by ruminants represents a loss of energy for ruminants.
Methane is formed in the fore-stomach (reticulorumen, more commonly known as the rumen) of ruminants by a group of microbes called methanogens, which form a subgroup of the domain Archaea. Their effect on producing methane is mentioned.
In this review, current approaches towards mitigation of methane in pastoral farming are summarised. The strategies to diminish methane output from livestock are required for ecological and economical dairy production. Research strategies based on vaccination, enzyme inhibitors, phage, homoacetogens, feed supplements, and animal selection are reviewed. Numerous studies have been completed on use of plant secondary metabolites (PSM) in substitute for chemical feed additives because some of them modify rumen fermentation and reduce CH4 production. Also this review describes the basic conceptual aspects of ruminal methanogenesis, which is a way of keeping a low H2 pressure in the rumen by reducing CO2, and steps where it may be possible to intervene to reduce CH4 production

***Key words**: Methane, Plant secondary metabolits, Ruminant, Greenhouse gas.*

INTRODUCTION

Agriculture was responsible for 10–12% of total global non-CO_2 greenhouse gas (GHG) emissions in 2005, but emissions of CH4 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 CH4 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.

Lowering global methane emissions is an important part of any effort to reduce anthropogenic GHG emissions. However, reducing the number of ruminants being farmed is not an option as the worldwide demand for meat and milk is predicted to double by 2050 (FAO, 2008).

FATS – EFFECTS ON CH_4 EMISSIONS

One of the energy sources is fat and it can reduce production of methane. İn case of using fat as energy source, the microbial flora in the rumen and energy use efficiency can change and methane production can reduce (McGinnetal, 2004). Thus, in a study with dairy cows did by Giger-Reverdinetal (2003) reported that adding fatty acids with a carbon quantity of medium length (8-16 C) reduces the methane production and this reduction is proportional with fat's degree of unsaturation. Martin et al. (2008) claimed that adding raw linseed, extracted linseed and line seed oil to dairy cow rations reduce the methane production substantially and they concluded that reduction of feed fermentation with fat addition. This inhibits cellulolytic bacteria and protozoons.

There are five possible mechanisms by which lipid supplementation reduces CH_4: by reducing fibre digestion (mainly long-chain fatty acids); by lowering DMI (if total dietary fat exceeds 6-7%) the suppression of methanogens (mainly medium-chain fatty acids); the suppression of rumen protozoa; and to a limited extent, through biohydrogenation (Johnson and Johnson, 1995; McGinn et al., 2004; Beauchemin et al., 2008).

There is opportunity to add fat supplements to TMR to reduce enteric CH_4 emissions. Use of by product feeds from agricultural/food processing industries, which contain fat, is a useful approach to reducing enteric CH_4 emissions and global GHG emissions, particularly since GHG emissions arising from producing the by-product are accounted for by the primary product, at least in some jurisdictions. Examples of by-products that contain fat and are suitable for adding to ruminant diets are whole cottonseed, brewers grains, cold pressed canola, and hominy (maize) meal.

Using DDGS in cattle diets to supply digestible energy often lowers diet starch content, but generally increases dietary fat content and enteric CH_4 is reduced in a manner commensurate with increased dietary fat concentration. The effect was demonstrated recently by McGinn et al. (2009) in growing beef cattle fed a diet in which barley grain (350 g/kg DM) was replaced by dried maize DDGS. Incorporating DDGS in the diet increased the dietary fat content from 20 to 51 g/kg DM and enteric CH_4 decreased from 23.8 to 19.9 g CH_4/kg DM intake. This reduction in CH4 is equivalent to a 1.26 g/kg DM intake decline/10 g/kg increase in dietary fat, which is consistent with the overall rate of decline we report for other fat sources.

Like fish oil, micro-algae are rich in omega-3 fatty acids, which have been shown to reduce CH_4 production in vitro (Fievez et al., 2007). Micro-algae can be mass produced (Rosenberg et al., 2008). For example, MBD Energy Limited (Melbourne, VIC, Australia) use waste CO_2 gases from coal-fired power plants combined with sunlight and waste water to produce algae meal which can be used as livestock feed. The oil contained in this meal could be useful in reducing CH_4 emissions from ruminants, due primarily to its negative impacts on methanogen growth in the rumen, but testing is required in animals to as certain that enteric CH4 production is reduced without lowering feed intake or digestibility.

FORAGE QUALITY

Improving forage quality, either through feeding forage with lower fibre and higher soluble carbohydrates, changing from C4 to C3 grasses, or even grazing on less-mature pastures, can reduce CH_4 production (Ulyatt et al., 2002; Beauchemin et al., 2008). Methane production per unit cellulose digested has been shown to be three times that of hemicellulose (Moe and Tyrrell, 1979), while cellulose and hemicellulose ferment at slower rates than do non-structural carbohydrates, thus yielding more CH_4 per unit substrate digested (McAllister et al., 1996).

HIGHER STARCH DIETS

It is well known that feeding grain based diets lowers enteric CH4 emissions (g/kg DM intake) compared with feeding forage based diets (Johnson and Johnson, 1995). Starch fermentation promotes propionate production in the rumen creating an alternative hydrogen sink to methanogenesis (Murphy et al., 1982), lowers ruminal pH and inhibits growth of rumen methanogens (Van Kessel and Russell, 1996), and decreases rumen protozoal numbers limiting transfer of hydrogen from protozoa to methanogens (Williams and Coleman, 1988). Whether feeding more grain reduces net farm GHG emissions is less certain, and ultimately depends on the farming system (Beauchemin et al., 2010). Nevertheless, the scope for increasing the amount of grain fed to ruminants is limited and feeding grain ignores the importance of ruminants in converting fibrous feeds, unsuitable for direct human consumption, to the high quality protein sources milk and meat (Garnett, 2009).

RATIO OF FORAGE/CONCENTRATED FEED

It was reported by several researchers that reducing the ratio of roughage/concentrated feed and pelleting of the forage cause an increase in the production of propionic acid and reduction in the formation of methane (Johnson and Johnson, 1995; Reynolds et al., 2001). However, Reynolds et al. (2001) reported that loss of energy reduced substantially in the beef heifers with methane. In another study it was expressed that adding concentrated feed in the rations of beef cattles reduced methane emission (Olivera et al., 2007).

HOMOACETOGENS

Autotrophic H_2-utilising acetogenic bacteria, also known as homoacetogens, are able to employ H_2 as an energy source for growth, using it to reduce CO_2 to acetate. Redirection of the rumen fermentation by the activity of homoacetogens has been postulated as a way of increasing feed-use efficiency (Joblin K., 1999). Instead of feed energy being lost as methane, the energy represented by the H_2 would be diverted to acetate formation and hence enhance animal productivity. In addition, a reduction in methane production would occur.

VACCINATION AGAINST RUMEN METHANOGENS

Vaccination against rumen methanogens has the potential to reduce methane emissions by decreasing the number or activity of methanogens in the rumen. Such a vaccination approach against rumen-dwelling organisms has met with success in vaccinating animals against the rumen dwelling bacterium *Streptococcus bovis* (Gill et al., 2000; Shu et al., 2001).

In an Australian study, immunisation of sheep with a whole-cell preparation from three methanogens reduced methane production (per kg/DMI) by 7.7% (Wright et al., 2004). However, when the study was repeated with a mixture of five methanogens, vaccination failed to demonstrate any methane abatement, although it changed the microbial fauna in the rumen (Williams et al., 2009). These results highlight the difficulty of producing effective vaccines to reduce methane emissions in ruminants based on crude whole-cell preparations, which are more likely to target selected methanogen species.

BACTERIOPHAGES

Bacteriophages are present in all biological ecosystems. Their relative simplicity and modular structure (Brussow et al., 2004) makes them important agents for genetic exchange between various microbial hosts (Stanton, 2007; Chen and Novick, 2009). Furthermore, their ability to penetrate and subsequently lyses their host cells makes phages and their genes potential sources of mitigation strategies.

In contrast to the nearly 300 bacteriophage genomes reported (Ackermann and Kropinski, 2007), only six archaeal phages have been sequenced and described so far, and only two are from methanogens: Methanobacterium phage psi M1 and M2 (a variant of M1) (Pfister et al., 1998), and Methanothermobacter phage psi M100 (Luo et al., 2001).

More methanogen phages need to be identified, sequenced and characterised to identify and employ such phage-based strategies effectively. However, the high specificity of phages may be a limiting factor in their effectiveness in reducing the total methane emissions, since there appears to be a high diversity of methanogens in the rumen (Janssen and Kirs, 2008).

PLANT SECONDARY COMPOUNDS

Condensed tannins (CT) have been shown to reduce CH_4 production by 13–16% (DMI basis) (Waghorn et al., 2002; Woodward et al., 2004) mainly through a direct toxic effect on methanogens. Plant saponins also potentially reduce CH_4, and some saponin sources are clearly more effective than others, with CH4 suppression attributed to their anti-protozoal properties (Beauchemin et al., 2008)

DIETARY SUPPLEMENTS

Dietary supplements can potentially profitably reduce CH_4 emissions from intensive ruminant production systems, with many strategies already available for on-farm implementation. Yeast cultures of *Saccharomyces cerevisiae* potentially stimulate acetogenic microbes in the rumen, consuming H_2 to form acetate (Chaucheyras et al., 1995), and thus potentially reducing CH_4 production.

Enzymes, in the form of cellulases and hemicellulases added to the diets of ruminants, improved ruminal fibre digestion and productivity (Beauchemin et al., 2003) and reduced CH_4 by 28% in vivo and 9% *in vivo*, respectively, perhaps by reducing the acetate-to-propionate ratio (Beauchemin et al., 2008).

Dicarboxylic acids, like fumarate, malate, and acrylate, are precursors to propionate production in the rumen and can act as an alternative H_2 sink, restricting methanogenesis. McAllister and Newbold (2008) reviewed studies that showed 0%– 75% reductions in CH4 achieved by feeding fumaric acid.

Halogenated analogues, such as bromochloromethane (BCM) and chloroform, are potent inhibitors of CH_4 formation in ruminants, with BCM reducing CH_4 emissions by 57%, 84%, and 91% (DMI basis) in feed-lot steers, at increasing dose rates (Tomkins and Hunter, 2004).

ANIMAL BREEDING

Animal breeding has long been shown to increase productivity and to reduce susceptibility to disease, and has the potential to contribute towards reducing methane emissions from livestock. Breeding for increased productivity reduces methane emission intensity by increasing the proportion of feed energy used for production purposes while diluting the maintenance requirements (Chagunda et al., 2009). However, productivity increases also require the use of increasing amounts of concentrate feeds.

CONCLUSIONS

Reduction of ruminal methane production in ruminants is a difficult issue. The variations in technological and economic infrastructures in the regions where, livestock carried out and in the feeding habits , requires the implementation of different strategies in this area. But it can be useful if some of the precautions taken in part in solving this problem. We can achieve progress towards reducing methane production from biotechnology, reducing the number of animals by increasing the efficiency of animal, producing high quality of forages and pastures, the use of high alternative forage and concentrate feeds which has high content of substances such as tannin and saponin and also using of probiotics which, can compete with methanogens by suppressing them with secondary plant components such as essential oils.

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