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Essential oils and opportunities to mitigate enteric methane emissions from ruminants

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ABSTRACT

The well documented antimicrobial activity of essential oils has prompted interest in whether these bioactive compounds can be used to selectively inhibit rumen methanogenesis. A number of studies have recently evaluated the ability of essential oils to reduce enteric CH_4 production. Most studies conducted have been *in vitro* and short term. Essential oils derived from thyme, oregano, cinnamon, garlic, horse radish, rhubarb and frangula have decreased CH_4 production *in vitro* in a dose dependent manner. However, inhibition of CH_4 production occurred at high doses (*i.e.*, >300 mg/L of culture fluid) and was, in many cases, associated with a decrease in total volatile fatty acid concentrations and feed digestion. Some essential oils, such as garlic, cinnamon, rhubarb and frangula, may exert a direct effect on methanogens. Evidence for *in vivo* antimicrobial activity of essential oils has been equivocal to date, probably because of the capacity of rumen microbes to adapt and degrade these secondary metabolites. Further, many of the concentrations of essential oils that have favourably affected rumen fermentation *in vitro* are too high for *in vivo* use as they would likely have deleterious effects on efficiency of rumen fermentation, palatability and possibly cause toxicity. Based on available results, it appears that some essential oils (*e.g.*, garlic and its derivatives and cinnamon) reduce CH_4 production *in vitro*. However, there is a need for *in vivo* investigation to determine whether these compounds can be used successfully to inhibit rumen methanogenesis. The challenge remains to identify essential oils that selectively inhibit rumen methanogenesis at practical feeding rates, with lasting effects and without depressing feed digestion and animal productivity.

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1. Introduction

There is interest in reducing CH_4 emissions from domestic ruminants. Methane is a potent greenhouse gas (GHG) and it has a global warming potential 25 times that of CO_2. According to an FAO report (Steinfeld et al., 2006), livestock account for ~37%

Abbreviations: ADF, acid detergent fibre; ATP, adenosine triphosphate; CP, crude protein; DM, dry matter; GHG, greenhouse gas; NDF, neutral detergent fibre; VFA, volatile fatty acid; DAS, diallyl sulphide; DADS, diallyl disulphide; DATS, diallyl trisulphide.

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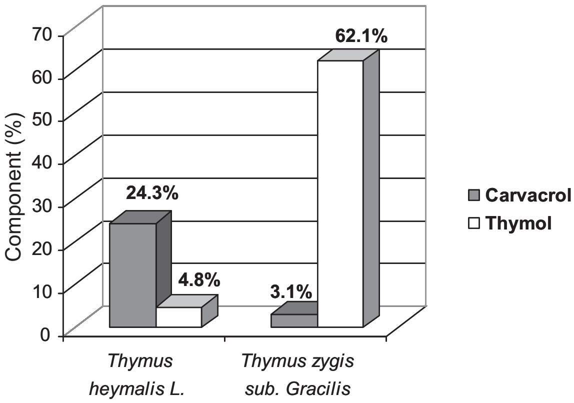

Fig. 1. Concentrations (%) of carvacrol and thmyol in essential oils extracted from two species of thyme (adapted from Martínez et al., 2006).

of global anthropogenic CH_4 emissions with most of it from enteric fermentation in ruminants, which is produced as a result of microbial fermentation of feeds in the rumen and, to a lesser extent, in the hindgut. Enteric CH_4 is a loss of productive energy typically between 2 and 12% of gross energy intake in ruminants depending on level of feed intake and diet composition (Johnson and Johnson, 1995; Boadi et al., 2004). Therefore, reducing enteric CH_4 emissions from ruminants is beneficial from a nutritional (*i.e.*, improved feed efficiency and animal productivity) and environmental (*i.e.*, reduced contribution of the agricultural sector to total GHG emissions) perspective. Accordingly, several dietary strategies have been suggested to mitigate enteric CH_4 emissions from ruminants (McAllister et al., 1996; Boadi et al., 2004; Beauchemin et al., 2009). Ionophores such as monensin have been extensively investigated for their ability to reduce CH_4 production in ruminants and their effectiveness has been demonstrated, although their inhibitory effects do not always persist (Beauchemin et al., 2008, 2009).

In North America, ionophores are used in dairy and beef cattle diets to improve efficiency of milk and meat production. However, use of ionophores in livestock production is not permitted in Europe after the ban on growth promoters in January 2006 (OJEU, 2003). Although this ban is currently limited to the EU, there is increased pressure from the public in other parts of the world, including North America, to ban or restrict use of antimicrobials in food animal production for other than therapeutic purposes. For example, a recent report of the Pew Commission on Industrial Farm Animal Production in the United States (PCIFAP, 2008) recommended restricting use of antimicrobials in food animal production in order to reduce the risk of antimicrobial resistance to antibiotics used to treat infections in humans. Consequently, research has been very intensive, particularly in Europe, to develop alternatives to antibiotic growth promoters in livestock production. Plant secondary metabolites, due to their well documented antimicrobial activity, are viewed as potential alternatives.

Plants produce an array of diverse secondary metabolites which, when extracted and concentrated, may exert antimicrobial activities against a wide variety of microorganisms including bacteria, fungi and viruses (Chao et al., 2000; Greathead, 2003; Burt, 2004). Several studies, most of them *in vitro*, have been published on effects of essential oils and their components on rumen microbial fermentation with a focus on N metabolism and volatile fatty acid (VFA) concentrations (Calsamiglia et al., 2007; Benchaar et al., 2008b). However, the potential of essential oils and their constituents to selectively inhibit rumen methanogenesis has only recently been evaluated. Over the last 5 years, there has been an increased body of knowledge in this area. This review aims to provide a critical evaluation of the potential of plant derived essential oils to inhibit rumen methanogenesis. A number of studies have recently been published on the capacity of herbs, spices and plants to reduce rumen CH_4 production (Bodas et al., 2008; Garcìa-González et al., 2008a,b; Patra et al., 2010) but without identifying the secondary metabolites responsible. For the purpose of our review, only data from studies that have specifically investigated impacts of essential oils on methanogenesis are discussed.

2. Essential oils

2.1. Definition

Essential oils are complex mixtures of volatile lipophilic secondary metabolites. Traditionally extracted from plants by boiling water and steam distillation, methods also include solvent extraction, supercritical CO_2 extraction, and expression extraction (*i.e.*, a method used to extract essential oils from plants). They are plant specific and are responsible for a plant's characteristic flavour and fragrance. There can be a great deal of variation in essential oil yield and composition among plants of the same species, and within different parts of the same plant (Cosentino et al., 1999; Burt, 2004). For instance, Martínez et al. (2006) reported that the composition of the essential oil extracted from *Thymus* varied depending on the species. The volatile fraction of the essential oils extracted from *Thymus zygis* ssp. *Gracillis* contained higher concentrations of thymol, and a lower concentration of carvacrol, than oil extracted from *Thymus hymmalis* Lange (Fig. 1). Delaquis et al. (2002) reported