Int.J.Curr.Microbiol.App.Sci (2018) *7*(5): 1747-1753

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 05 (2018)**
Journal homepage: http://www.ijcmas.com

Review Article https://doi.org/10.20546/ijcmas.2018.705.203

Plant Derived Essential Oil in Ruminant Nutrition - A Review

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A B S T R A C T

Keywords

Essential oils, Ruminant, Performance, Feed additives

Article Info

Accepted:
16 April 2018
Available Online:
10 May 2018

Feed additives are products used in animal nutrition to improve the quality of feed and the quality of food from animal origin, or to improve the animals' performance and health. Use of herbal feed additives in animal nutrition is gaining importance due to ban of antibiotics as feed additives because of their possible contribution to emergence of antibiotic resistant bacteria and transferring to humans when they consumed animal products. Therefore, herbal feed additives have attracted public interest, replacing antibiotics. Among the various herbal feed additives, the inclusion of essential oils in ruminant diets is nowadays becoming a common practice, since dietary supplementation has been proven a simple and convenient strategy to modulate ruminal fermentation to improve nutrient utilization in ruminants. A wide range of essential oils have the potential to act as multifunctional feed supplements for animals including effects on growth performance, digestive system, pathogenic bacterial growth and lipid oxidation.

Introduction

The term essential oil dates back to the 16th century and derives from the drug *Quinta essentia*, named by Paracelsus von Hohenheim of Switzerland (Guenther, 1948). Essential oils, also known as volatile oils, are aromatic components found in many edible, medicinal, and herbal plants. Essential oils can be extracted from many parts of a plant, including the leaves, flowers, stem, seeds, roots and bark by steam distillation or solvent extraction (Greathead, 2003). But, the composition of the EO may vary among different parts of the same plant (Dorman and Deans, 2000). EOs are volatile, aromatic compounds synthesised by plants for antibacterial, antifungal and antiviral purposes, and to deter herbivorous insects and animals. They are important aromatic components of herbs and spices and contribute to natural preservation of foods. The antibacterial properties of EOs are well documented and recognised (Kalemba and Kunicka, 2003) both *in vitro* (Ouwehand *et al.*, 2010) and *in vivo* (Tiihonen *et al.*, 2010). Essential oil are more recently being investigated as rumen modifiers in ruminants (Wallace, 2005). Essential oils are considered safe for human and animal consumption, and are categorized as generally recognized as safe (GRAS; FDA, 2004) in the USA.

The antimicrobial properties of EO have been demonstrated against a wide range of microorganisms, including bacteria, protozoa and, fungi (Chao *et al.*, 2000). Essential oils have also been exploited for their activity against a wide variety of food-borne pathogens. For example, Escherichia coli O157: H7 was inhibited by oregano oil and its two main components carvacrol and thymol (Helander *et al.,* 1998; Elgayyar *et al.*, 2001).

The most important active compounds of EOs are categorized into two chemical groups: (mono- and sesqui-) terpenoids and phenylpropanoids that originate from different precursors of the primary metabolism and are further synthesized through separate metabolic pathways. Terpenoids (limonene, thymol, carvacrol, linalool, etc.) are characterized as deriving from an isoprene unit, namely a basic structure of five carbons (C5H8) through the mevalonate pathway (Zwenger, 2008).

On the other hand, phenylpropanoids (cinnamaldehyde, eugenol, anethole, etc.) derive mainly from the phenylalanine that is synthetized by the shikimate metabolic pathway and are compounds with a chain of three carbons bound to an aromatic ring of six carbons.

EOs and their components are hydrophobic, a characteristic that enables them to partition lipids in the bacterial cell wall and mitochondria, leading to their accumulation in the lipid layer and a disruption of the membrane integrity and ion transport processes, and resulting in disturbances of the cell osmotic pressure. A rapid dissipation of H^+ and K^+ ion gradients (proton motive sources) and depletion of the intracellular ATP pool is observed through the reduction of ATP synthesis and the increased hydrolysis. As a result, the trans-membrane electric potential in bacterial cell is reduced and the proton permeability of the membrane is increased slowing down bacterial growth. When the bacterial tolerance threshold is passed, the extensive loss of cell contents or critical molecules and ions leads to cell death (Burt, 2004).

Effects of EOs on rumen fermentation and VFA

Due to ability of essential oils to modify cell permeability in microbes and their toxicity to some strains of rumen microorganism, particularly the Gram-negative, essential oils are potentially promising natural alternatives to antibiotics and ionosphores for manipulating ruminal fermentation (McIntosh *et al.,* 2003 and Calsamiglia *et al.,* 2007) and improving feed efficiency and nutrient utilization by ruminants.

Gunal *et al.,* (2014) reported that adding essential oils (EO) like anise oil (ANO), cedar wood oil (CWO), cinnamon oil (CNO), eucalyptus oil (EUO), and tea tree oil (TEO) at different levels (125, 250, 500 mg/l) had no effect on the proportions of acetate, propionate, or acetate to propionate ratios in comparison with the control when examined in a rumen batch culture study. And the proportions of butyrate were also not affected ($P > 0.05$) by EO except for CNO cultures where butyrate was lower ($P < 0.05$) with the 250 and 500 mg/l cultures. Supplementation of thyme or cinnamon essential oil did not affect total VFA but decreased molar proportion of acetate and ratio of acetate to propionate, and increased the molar proportion of propionate.

Also, rumen molar concentration of butyrate was increased by adding cinnamon but no change was observed with thyme (Vakili *et al.,* 2013).

Effect of EOs on methane production

Methane is a potent greenhouse gas and its release into the atmosphere is directly linked with animal agriculture, particularly ruminant production. Enteric methane losses represent 2–12% of gross energy intake in ruminants depending on diet composition and feed intake (Boadi *et al.,* 2004). So, reduction of CH4 emissions from enteric fermentation is beneficial both for the animals (improved feed efficiency and productivity) and for the environment (mitigation of greenhouse effects) (Benchaar *et al.*, 2011). Methane is produced by a group of microorganisms called methanogens by the process methanogenesis.

The antimicrobial activity of EO has prompted interest in whether these compounds could be used to inhibit methanogenesis in the rumen. Five essential oils (EOs), namely, clove oil (CLO), eucalyptus oil (EUO), garlic oil (GAO), origanum oil (ORO), and peppermint oil (PEO), were tested *in vitro* at 3 different doses (0.25, 0.50, and 1.0 g/liter) for their effect on methane production by Patra and Yu (2012) and discerned that all the EOs significantly reduced methane production with increasing doses, with reductions by 34.4%, 17.6%, 42.3%, 87%, and 25.7% for CLO, EUO, GAO, ORO, and PEO, respectively, at 1.0 g/liter compared with the control. Similarly, Kamra *et al.*, (2005) investigated methanol and ethanol extracts of various spices, including fennel, clove, garlic, onion, and ginger for effects on methane production *in vitro*. Among the extracts tested, methanol extract of garlic was the most effective suppressant of methane, with a 64% reduction *in vitro* without adverse effects on feed digestibility.

There was reduction of methane production of 55%, 72% and 71% respectively with regard to the 1.0, 1.5 and 2.0 g/L oregano EO doses, while rosemary EO (2.0 g/L) reduced the methane production by 9% when tested *in vitro* (Cobellis *et al.*, 2015).

Effect of EOs on nitrogen metabolism

Rumen microbes synthesized microbial protein that flows to the small intestine and get absorbed by the host which serve as an excellent source of amino acids required for synthesis of milk and meat proteins. Microbial fermentation could lead to protein losses as ammonia that is environmental pollutants.

Essential oils could also positively influence protein metabolism and reduce rumen ammonia levels and lead to a more efficient utilization of dietary nitrogen by inhibiting deamination, i.e., the breakdown of amino acids to NH_3, possibly through the selective limitation of the activity of a specific group of bacteria within the rumen, the “hyper-ammonia-producing (HAP) bacteria” (*Prevotella* spp., *Ruminobacter amylophilus*, etc.) at the level of attachment and colonization (McIntosh *et al.,* 2003 and Calsamiglia *et al.,* 2007). The HAP bacteria comprise only around 1% of the rumen bacterial populations, but they possess a very high deamination activity (Russell *et al.*, 1988; Wallace, 2004). This could decrease the rate of ammonia production in the rumen, which may be beneficial nutritionally by increasing the efficiency of protein utilization in the rumen (Wallace *et al.,* 2002). Sallam *et al.,* (2011) reported dramatically declined in ammonia nitrogen by inclusion of essential oil of *Menthamicrophylla* at different dose levels (0, 25, 50 and 75 µl/75 ml buffered rumen fluid) to a basal substrate (50% roughage: 50% concentrate). Busquet *et al.*, (2006) demonstrated that some EO (*i.e.*, anise oil, cade oil, capsicum oil, cinnamon oil, clove, bud oil, dill oil, garlicoil, ginger oil, oregano, oil, and tea tree oil) and their main components (*i.e.*, anethol, benzyl salicylate, carvacrol, carvone, cinnamaldehyde, and eugenol) markedly inhibited NH3–N concentration at high concentrations (*i.e.*, 3000 mg/l), but effects were marginal at moderate doses (*i.e.*, 300 mg/l) and non-existent at low doses (*i.e.*, 3 mg/l).

Four essential oils i.e. cinnamon, garlic, oregano and rosemary oils were tested by Roy *et al.*, (2014) at concentration of 0, 30, 300 and 600 mg/litre (ppm) of total culture fluid and ammonia nitrogen concentration were studied in vitro using buffalo rumen liquor and revealed that ammonia-N concentration was decreased significantly (P<0.05) with all the four essential oils but was found minimum with oregano oil at dose of 600ppm (Table 1).

Table.1 Examples of some essential oils and their main components (Chao *et al.*, 2000)

Essential oil	Plant part	Botanical source	Main components	% of total
Angelica	Roots	*Angelica archangelica* L.	α-Pinene δ-3-Carene α-Phellandrene+myrcene limonene β-Phellandrene p-Cymene	24.7 10.5 10.8 12.9 10.4 7.7
Bergamot	Fruits	*Citrus bergamia* Risso et Poit	β-Pinene Limonene+β-phellandrene γ -Terpinene Linalool Linalyl acetate	7.7 39.4 8.6 11.1 28.0
Cinnamon	Inner bark	*Cinnamomum zeylanicum* Blu.	(E)-CinnamaldehydeEugenol	77.1 7.2
Coriander	Seeds	*Coriandrum sativum* L.	p-Cymene Linalool	6.1 72.0
Dill (Indian)	Seeds	*Anethum sowa* Roxb	Limonene trans-DihydrocarvoneCarvone Dillapiole	50.9 10.4 20.3 36.6
Eucalyptus	Leaves	*Eucalyptus citriodora* K. D. Hill	Citronellal Citronellol	72.8 14.5
Ginger	Roots	*Zingiber officinale* Rosc.	Camphene Neral Geranial+bornyl acetate β-Bisabolene ar-Curcumene β-Eudesmol	14.1 4.9 8.1 22.1 14.5 5.4
Juniper	Berries	*Juniperus communis* L.	α-Pinene Sabinene Myrcene	33.7 27.6 5.5
Orange	Peel	*Citrus sinensis* L. Osbeck	Limonene	91.5
Pepper	Fruits	*Piper nigrum* L.	α-Pinene β-Pinene Sabinene δ-3-Carene Limonene β-Caryophyllene	9.0 10.4 19.4 5.4 17.5 14.7
Rosemary	Whole plant	*Rosemarinus officinalis* L.	α-Pinene β-Pinene 1,8-Cineole Camphor	7.4 5.0 43.6 12.3
Tea	tree Branches	*Melaleuca alternifolia* L.	α-Terpinene 1,8-Cineole Terpinene-4-ol γ-Terpinene	10.4 5.1 40.1 23.0

Effects of EOs on ruminant performance

Essential oils (EO) have been shown to positively impact *in vitro* ruminal fermentation, but there are few *in vivo* studies that have examined animal responses. Several essential oils have antimicrobial properties that may affect rumen metabolism and influence milk production parameters. Spanghero *et al.,* (2007) reported that the dietary EOs (blend of oregano, cinnamon, thyme and orange peel Eos) supplementation had no effect on dry matter (DM) intake, water consumptions or faecal DM. Also, milk and milk component yields were not affected by EO feeding level. Valero *et al.,* (2014) observed better final weight, average daily gain, feed efficiency and hot carcass weight for bulls supplemented with 3 grams to animal day^{-1} of essential oils (cashew and castor oils) than for bulls fed control diet. But the feed intake, apparent digestibility, carcass conformation and tissue composition remain unaffected by the additives addition and concluded that the addition of essential oils in the diets of bulls finished in feedlot improve animal performance and carcass weight. Santos *et al.,* (2010) evaluated the efficacy of an EO complex, containing eugenol, geranyl acetate and coriander oil as major components, on the production of lactating dairy cows and found out that DM intake was numerically lower with EO feeding but milk yield was not impacted.

Essential oils have an antibacterial activity against Gram-negative and Gram-positive bacteria (Helander *et al.,* 1998). Several Gram-positive bacteria are involved in ruminal biohydrogenation of unsaturated dietary fatty acids (Harfoot and Hazlewood, 1988). Therefore, feeding EO could lower biohydrogenation of fatty acids by reducing the number, and the activity, of bacteria involved in the biohydrogenation of unsaturated fatty acids. There was no change in milk fatty acid profile when cows were supplemented daily with 750 mg of mixture of essential oils. Supplementing the same mixture at a higher concentration (*i.e.*, 2 g/day) increased the concentration of conjugated linoleic acid (CLA), a health-promoting fatty acid, in milk fat (Benchaar *et al.,* 2007).

Essential oil can be used as herbal feed additives in place of antibiotics to alter rumen fermentation, to improve nutrient utilization by ruminants. Due to antimicrobial properties against gram positive and gram negative bacteria, essential oils are found to be effective strategy to reduce methane emission from rumen fermentation.

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How to cite this article:

Khwairakpam Ratika and James Singh, R.K. 2018. Plant Derived Essential Oil in Ruminant Nutrition - A Review. *Int.J.Curr.Microbiol.App.Sci.* 7(05): 1747-1753.
doi: https://doi.org/10.20546/ijcmas.2018.705.203