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Beneficial effects of plant extracts in ruminant nutrition: A review

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ABSTRACT

Use of antibiotics in animal feeds was banned hence researches on alternative natural products that can modulate ruminal fermentation have been intensified. Plant extracts are considered as natural compounds that can replace antibiotics as safe and sustainable alternatives. Extracts contain some plant secondary metabolites (PSM) that are a natural resource and are largely unexploited in 'conventional' animal production systems. They are considered as a source of anti-nutritional factors and not as a source of exploitable performance-enhancing compounds. Recent and continuing changes to legislation controlling the use of animal feed additives have stimulated interest in bioactive PSM as alternative performance enhancers. Interest is largely on their manipulative role in digestive and absorptive processes of the hindgut.

The aim of the present review is to discuss the use of plants and their extracts to manipulate the rumen microbial ecosystem to improve the efficiency of rumen metabolism. The bioavailability of PSM and their actions on peripheral metabolism will be considered with a view to improve animal performance. In order to fully exploit their bioactive properties for the benefit of animal performance, modes of action need to be understood.

Key words: Beneficial effects, Plant extracts, Ruminants, Secondary metabolites

Secondary metabolites of plant extracts consist of several thousand molecules that are diversified both by chemical structures and biological activities. Among the biotic interactions, one can underline defensive or repulsive chemical strategies on one hand, and associative or attractive signals on the other hand. All these signals are linked to the plants producing specific secondary metabolites intended to be received by different plants, animals or microorganisms. For example, the defensive strategies of plants imply the production of bioactive compounds which can be toxic, anti-nutritional, deterrent or alerting against herbivores or pathogens. The plant can produce secondary metabolites (e.g., alkaloids) to intoxicate non adapted herbivores in response to the damage they cause to the plant. Other secondary metabolites are deterrent (e.g. tannins) to check the herbivores from eating the plants. These secondary metabolites represent "constraints" to which the herbivore needs to adapt. In turn, the herbivores developed different adaptive strategies to confront the phytotoxins e.g. ruminants when they eat mixtures of different plant species containing complementary or antagonistic toxins (e.g. tannin-plants with alkaloid-plants); this digestive chemical interaction leads to neutralize phytotoxins in the animal body. Apart from the animals defensive mechanism to secondary metabolites, there are also associative interactions between plants and animals. For example, some volatile compounds (e.g. terpenes) are released by the plants to attract pollinators; in addition to these volatiles, pigments such as anthocyaneins or carotenoids attract specifically some pollinators that the plant would "call". In soils deficient in nitrogen, legumes can release secondary metabolites (such as flavonoids) in their roots to attract symbiotic bacteria: such microorganisms will in turn fix the atmospheric nitrogen to transmit it to the plant for photosynthesis; on the other hand, the plant will provide the nutritive organic matter (compounds) for its microbial partner (nitrogen fixing bacteria).

In ruminants, plant extracts rich in secondary metabolites (e.g. PSM) such as *Salix babylonica* and *Leucaena leucocephala* extracts (Salem *et al.* 2010b, Jiménez-Peralta *et al.* 2011) or herbs, organic acids and essential oils (Hernández *et al.* 2004) seem to be candidates of interest as alternatives to antibiotic growth promoters (Patra *et al.* 2006, Jiménez-Peralta *et al.* 2011). Tannins are one of the several categories of useful antimicrobial phytochemicals (Cowan 1999) and results appear most promising (Mueller-Harvey

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Table 1. Impacts of different plants extracts on ruminal fermentation parameters in ruminants

Secondary metabolite	Plant species	Doses	Animal (species)	Impacts	Reference
Extracts	*Yucca shidigera, Quillaja saponaria*, and *Acacia auriculoformis*		Dairy cows	Higher microbial mass, lower proportion to VFA and lower gas production, higher true digestibility	Makkar *et al.* (1998)
Steroidal saponins	*Yucca shidigera*		Dairy cows	Increasing rumen digestibility of carbohydrates, improve the metabolizable feed energy	Cheeke (1998)
Sarsaponin	*Yucca shidigera*	5 g/d	Dairy cows	Increases gas production, defaunation, increased ruminal VFA production, decreasing methane production	Singer *et al.* (2008)
Saponins	Berseem fodder	45% of the diet	Cattle	Decreased methane production to 17%	Malik *et al.* (2010a)
Saponins	Lucerne fodder (first cut)	30 and 45% of the diet	Dairy cattle	Reduced methane emission, decreased protozoal numbers	Malik *et al.* (2010b)
Saponins	Lucerne fodder	Saponons @0.60% of DMI	Buffalo bulls	Reduce the protozoal population, increased DM intake and fermentability	Malik *et al.* (2009)
Leaf extracts	Some tree leaves	0, 0.25 and 0.5 m1/30 ml	Buffalo	Inhibited rumen methanogenesis	Patra *et al.* (2008)
Condensed tannins	Tanniniferous feeds	*In vitro* evaluation	Cattle	*Mclizgifera indica* and *Camelia assamica* were good sources of essential amino acids. *Prosopis juliflora*, *Acacia nilotica* seed meal, *Horea robusta, Madhuca indica* and *Tamarindus indica* were source of protein. *Acacia nilotica* pods were source of protein and energy	Barmani and Rap (2006)
Extracts	Herbs	5% of paddy straw	Cattle	*Asparagus recemosus, Euphorbia hirta, Cryptolepis buchanani, Urtica dioica* and *Bacopa monneiri* herbs had positive impacts on cattle performance	Kumar *et al.* (2006)
Saponins	Lucerne fodder	50% wheat straw	Calves	Reduction in methane emission	Malik and Singhal (2008a)
Saponins	Lucerne fodder	saponin @ 60 mg/kg DM	Bulls	Decreased protozoal population in the rumen	Malik and Singhal (2008b)
Saponins	Comercial grade saponins	0, 1, 2 and 4 %	Cattle	Saponins containing feeds or herbs may have potential for mitigating the methane emission during enteric fermentation in ruminants	Malik and Singhal (2008c)
Extract	*Yucca shidigera*	*In vitro*		Reduce methane production in ruminants across a wide range of forages fed in diets with different forage: concentrate ratios	Xu *et al.* (2010)
Leaves	Mixture of plants	40 g /100 kg BW	Buffalo	No adverse effect on ruminal fermentation or microbial protein synthesis	Kumar *et al.* (2011a)
Aqueous extracts	Herbs roots	2.0 mg/ml		Extract of *Moringa oleifera* seed and *Picrorhiza kurroa* root may have potential as feed additives to increase the efficiency of utilization of energy and N in ruminant diets	Alexander *et al.* (2008)
Extract		@3, 30, 300 and 3000 mg/1	Dairy cattle	Reduced acetate and increased propionate and butyrate proportions	Busquet *et al.* (2006)
Saponins	*Sapindus rarak*		Sheep	*Fibrobacter* sp. was not affected by the *Sapindus rarak* in both trials. Protozoal counts were decreased only in the long term trial	Wina *et al.* (2006)

Table 2. Impacts of different plants extracts on animal performance in ruminants

Secondary metabolite	Plant species	Doses	Animal species	Impacts	Reference
Extracts	Herbs	1% , 2.5% and 5%	Cattle	*Zingiber officinale* extract was effective only at 5% concentration and *Erythrina indica* ineffective in all the concentrations	Jeyathilakan *et al.* (2010)
Condensed tannins	*Ficus infectoria*	0, 1.0, 1.5 and 2.0% condensed tannins of the diet	Lambs	Condensed tannins from *Ficus infectoria* leaves at 1.5% in supplement could be used as an organic protectant of proteins for improving the performance of lambs	Dey *et al.* (2008)
Plant extracts	*Scindapsus officinalis*	10 mg/ml (1%) and 20 mg/ml (2%) in 20 mllock's solution	Sheep	At 1% concentration, extract residues, revealed no efficacy but cold aqueous extract residue gave 80% efficacy with the first worm losing motility after 12 h of immersion	Singh and Kumar (2006)
Condensed tannins	*Prosopis cineraria*	CT ranged from 5.6 g/ml to 5.7 g/ml	Sheep	Condensed tannins would help in reducing the pasture contamination with gastrointestinal parasitism	Swarnkar *et al.* (2008)
Extracts	*Azadirachta indica*	0.00 to 1.25 mg/ml	Sheep	Extract of *Azadirachta indica* leaves showed reduction in egg embryonation and egg hatching at a concentration of 1.25 mg/ml	Singh *et al.* (2008)
Extracts	Medicinal plant	Not mentioned	Dairy cattle and yak	Extracts of some medicinal plants and commercial antimicrobials showed sensitivity against different serotypes of *E. coli*	Dubal *et al.* (2009)
Extracts	*Salix babylonica* and *Leucaena leucocephala*	30 ml/h/d	Lambs	Daily administration of individual extracts of *Salix babylonica* and *Leucaena leucocephala* improved lamb performance by 22 and 21%, but that a mixture of both had a much lower benefit	Salem *et al.* (2011)
Sarsaponin	*Yucca schidigera*		Steers	Increased animal growth	Zinn *et al.* (1998)
Extracts	*Salix babylonica* and *Leucaena leucocephala*	30 ml/h/d	Lambs	Elimination of 47 and 40% of intestinal worm burdens with the *Leucaena leucocephala* and *Salix babylonica* extracts respectively	Salem *et al.* (2010b()
Condensed tannins	*Ficus infectoria*	0 and 1.5% CT	Dairy cows	*Ficus infectoria* leaves had potential source of condensed tannins, and positive impact on N retention and milk yield in lactating cows given concentrate mixture containing 1.5% condensed tannins from *Ficus infectoria* leaves	Dey *et al.* (2009)
	Asparagus racemosus	100- 200 mg/kg live body weight	Cows	*Asparagus racemosus* supplementation during both prepartum continued to postpartum resulted in an improvement in per day milk production and reduction in first postpartum oestrus interval, service period and services per conception, and rate of uterine involution in comparison to the control group	Kumar *et al.* (2011b)

2006) in ruminants. In recent years, the role of tannins has attracted increased interest because they reduce gastrointestinal parasites in mammals (Salem *et al.* 2010b).

The beneficial effects of plant extracts are related to their influence on microbial fermentation. It has been considered that these additives will be replaced by natural compounds and they form dietary protein complexes that also protect them from microbial fermentation. Once they bypass the rumen, the complexes dissociate under the acidic conditions in the abomasum and proteins become available to the host animal (Table 1).

The beneficial effects were attributed to the binding of ammonia to saponins. Besides the traditional use of plant extracts as flavour enhancers in foods, plant extracts may also be used as antimicrobials and antioxidants, thus, various novel applications have recently been proposed: (i) to decrease the ammonia level in the atmosphere, (ii) to suppress or stimulate microbial growth, (iii) to increase binding of ammonia during urea ammoniation of straw and binding of ammonia in the soil, (iv) to reduce odors from cattle manure in dairy barns (Makkar *et al.* 1998).

Plant extracts (Table 2) improved animal growth performance and nutrient digestion due to a positive effect of PSM on ruminal microorganism activity (Jiménez-Peralta *et al.* 2011, Xu *et al.* 2010) or increased amino acid flow to the duodenum (Muller-Harvey 2006). This can result in more muscle deposition and, consequently, higher slaughter weights and heavier carcasses and meat quality (Mapiye *et al.* 2010).

Some rumen bacterial species are capable of metabolizing phenolic compounds (Salem *et al.* 2010a) and may act as catalysts for fiber degradation by increasing access of fibrolytic bacteria to cell wall polysaccharides in the diet. Therefore, PSM have beneficial effects on rumen function due to their stimulating impact on ruminal fermentation, and increased degradabilities of CP and plant cell wall constituents, as well as increasing microbial protein production. Numerous recent studies have attempted to exploit PSM as natural feed additives to improve efficiency of rumen fermentation. PSM could enhance protein metabolism, decreasing ruminal methane production, reducing nutritional stress such as bloat and/or improving animal health and productivity (Patra *et al.* 2006). Anti-helmintic properties of PSM improve nutrient digestibility, ruminal fermentation activities and animal health (Salem *et al.* 2010b).

Plant extracts are rich in plant secondary metabolites that could positively affect nutrients feed intake and digestibility, ruminal fermentation activities and animal performance. Nonetheless, research is needed to adjust daily doses to the animal diet.

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