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The role of tannins in forage legumes

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Abstract. Plant tannins, polyphenolic secondary compounds, are synthesized to meet ordinary physiological demands of plants and as a response to biotic and abiotic stress. Tannins have been described as having adverse or beneficial effects, depending on their concentration and structure, plant source and the species, physiological state and diet of the animals. Proper concentrations of condensed tannins (20 – 50 g kg^{-1} of DM) are expected to increase the efficiency of protein digestion and to minimize detrimental effects associated with a heavy load of internal parasites, with positive consequences for animal performance and health. Moreover, lower CH_4 emissions by ruminants consuming forages containing low levels of condensed tannins were noticed. This paper reports an update of current use of legume tannins in feedstuff and their effects in animals. It also refers to the implications concerning the improvement of nutrient utilization and the environmental sustainability in meat and dairy farming.

Keywords. Polyphenols – Condensed tannins – Leguminous plants – Fodder – Animal health.

Le rôle des tanins dans les légumineuses fourragères

Résumé. *Les tanins végétaux, composés polyphénoliques secondaires, sont synthétisés pour répondre aux exigences physiologiques ordinaires, mais aussi comme une réponse aux stress biotiques et abiotiques. Les tanins ont été décrits comme ayant des effets néfastes ou bénéfiques, selon la concentration en tanins et la structure, l'origine de la source et les espèces animales, l'état physiologique et l'alimentation. Des concentrations appropriées de tanins condensés (20-50 g kg-1 de MS) augmentent l'efficacité de la digestion des protéines et minimisent les effets néfastes associés à une lourde charge de parasites internes avec des conséquences positives pour les performances et la santé des animaux. En outre, la baisse des émissions de CH_4 par les ruminants consommant des fourrages contenant de faibles niveaux de tanins condensés a été remarquée. Cet article présente une mise à jour sur l'utilisation actuelle des tanins en alimentation et sur leurs effets sur les animaux et discute les implications connexes sur l'amélioration de l'utilisation des nutriments et la durabilité environnementale pour la production de viande et l'élevage laitier.*

Mots-clés. *Polyphénoliques – Tanins condensés – Fourrage – Santé animale.*

I – Introduction

Tannins are polyphenols with various molecular weights and variable complexity and are synthesized in plants not only as a genetically controlled response to physiological demands and evolution-controlled defence needs, but also under the impact of environmental stress (Min *et al.,* 2003). In the past, tannins were often described as antinutritional factors as they can affect negatively on animal production. However, tannins have both adverse and beneficial effects, depending on their concentration and nature, besides other factors such as animal species, physiological state and composition of the diet. Condensed tannins (CT) are expected to bind strongly to proteins and protect them from degradation by rumen microbes. Forage containing CT have been reported to minimize the detrimental effects due to a heavy load of internal parasites (Min *et al.,* 2003). The consumption of forages containing CT may affect gastrointestinal nematode abundance and animal performance in a number of ways that involve direct effects on the parasite and indirect effect through improved protein supply (Piluzza *et al.,* 2014). CT are also thought to be among the plants protective factors evolved to prevent predation by herbivores, and invasion by pathogenic bacteria, fungi and insects (Barry, 1989). CT are found in a number of important forage genera within the family Fabaceae, including

Coronilla, Hedysarum, Lespedeza, Lotus spp., *Onobrychis, and Trifolium* (Piluzza *et al.,* 2014). It is very important to update information on the content and nature of tannins present in the feedstuffs, and on the effects and fate of tannins in animals. This paper deals with the role of tannins in leguminous plants and in animal productivity and focuses on natural products with promising nutritional, animal health and environmental effects.

II – Tannin localization in leguminous species

Tissue-specific localization has been observed in a number of legume species (Table 1). The content of tannins varies with the phenological stage of plants (Häring *et al.,* 2007; Molle *et al.,* 2009; Theodoridou *et al.,* 2010; Guglielmelli *et al.,* 2011), and in the different plant organs (Piluzza and Bullitta, 2010; Theodoridou *et al.,* 2010). The dynamics of CT concentration in growing plants is important for the nutrition and health of ruminants. However, for Mediterranean forage species there are few reports detailing the changes in CT content in different tissues and across different phenological stages.

Young shoots in the vegetative stage of the shrub legumes *Cytisus purgans* (andorra broom), *C. scoparius* (scotch broom), *Genista florida* and *G. occidentalis* had low levels of CT (less than 6.5 g kg^{-1} DM), generally considered unlikely to significantly affect nutrient digestion in ruminants (Frutos *et al.,* 2002). However, high CT content has been detected in the shoots and flowers of *C. scoparius* and *G. florida* samples collected in June. The CT concentration in the leaves of *Chamaecytisus palmensis* (tagasaste) has been found to vary between accessions. Moreover, varietal selection and harvesting management could be used to modulate tannin and alkaloid levels in this perennial leguminous shrub (Assefa *et al.,* 2008).

Considering that CT levels vary widely across plant species, tissues and developmental stage, together with variability arising from adopted method and standard, it is necessary to establish common procedures in order to compare results from different laboratories.

Table 1. Condensed tannin localization in forage, grain and shrub legumes

Species	Localization	Species	Localization
Astragalus cicer	Whole plant	*Trifolium repens*	Flowers
Hedysarum coronarium	Stems,leaves, flowers whole plant, leaf blades, petioles	*Trifolium pratense*	Flowers
Lotus corniculatus	Whole plant, roots, leaves, stems	*Vicia faba*	Seed hull, seed coat
Lotus pedunculatus	Whole plant	*Vicia sativa*	Seed
Lotus tenuis	Shoot	*Ceratonia siliqua*	Fruits
Lotus uliginosus	Leaves, stems, shoots	*Chamaecytisus palmensis*	Buds, leaves, stems, bark
Medicago sativa	Seed coat	*Cytisus purgans*	Shoots
Onobrychis viciifolia	Whole plant, leaf blades, petioles, stems, racemes, leaves, roots	*Genista occidentalis*	Shoots

Modified from Piluzza *et al*., 2014.

III – Beneficial effects on ruminants

Moderate CT concentrations (20-50 g kg^{-1} DM) enhance forage nutritive value in grazing ruminants by reducing protein degradation by rumen bacteria and increasing protein degradation in the intestine, without depressing rumen fibre digestion or voluntary intake (Min *et al.,* 2003). CT increased live-weight gains in sheep consuming *H. coronarium* compared with those consuming lucerne or perennial pasture (Niezen *et al.,* 1995). This was also confirmed in sheep consuming *L. corniculatus* when compared with those receiving PEG (polyethylene glycol), which deactivates CT (Decandia *et al.,* 2000). Also, increased milk production and wool

growth were observed in sheep grazing on *L. corniculatus*, when compared with sheep treated with PEG (Min *et al.,* 2006). Girard *et al.,* (2015), found that forage legumes rich in CT may increase n-3 fatty acid levels and sensory quality of lamb meat. Because of the widespread resistance to synthetic chemical anthelmintics, there is a strong impetus to explore novel approaches for a more integrated management of parasitic infections with gastrointestinal nematodes. Tannin containing legumes are useful as a model for nutraceutical against digestive parasites in livestock (Hoste *et al.,* 2015). However, if present in large quantities (> 50 g kg^{-1}), CT can adversely affect nutrition of grazing herbivores by reducing intake and inhibiting protein digestibility (by inhibiting digestive enzymes or by direct systemic toxicity), leading to a reduction in feed intake and depressing the digestibility of almost all nutrients (Barry, 1989).

IV – Effects of tannins on methane emissions from ruminants

There is public and political concern regarding the need to reduce methane emissions from livestock. For countries that have signed the Kyoto protocol, reduction in CH_4 production from grazing ruminants fed forage diets is an important research area (Ramirez-Rastrepo and Barry, 2005). There have been reports of lower CH_4 emissions by ruminants consuming forages containing low or moderate levels of CT (Piluzza *et al.,* 2014). Methane yields from sheep and cattle fed plant species of varying CT content are presented in Fig. 1 in grazing ruminants. Tavendale *et al.* (2005) found inhibitory effects of polymeric CT fractions from *L. pedunculatus* on the growth of *Methanobrevibacter ruminantium*, a predominant rumen methanogen. The effect of CT fractions on pure cultures of methanogens may be greater than the effect of CT-containing plants in mixed rumen fluid. In another study, it was found that quebracho-supplemented ruminal fluid incubated with minced wheat forage produced less gas and CH_4 *in vitro* (Min *et al.,* 2006). Guglielmelli *et al.* (2011) found that sainfoin forage, at the stage between early and late flowering, could reduce *in vitro* CH_4 production, highlighting the importance of plant phenological stage for CH_4 emission. Bueno *et al.* (2015) found that CT have greater effects in large ruminants than in small ruminants..

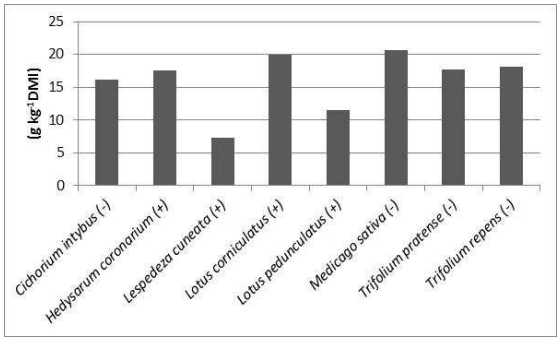

Fig.1. Methane emissions from ruminants fed forages with (+) or without (-) condensed tannins. (Modified, from Piluzza *et al*., 2014).

V – Conclusions

The mechanisms by which tannins exert their effects on animal health and performance are not completely understood. Therefore, it is important to utilize the appropriate tannin-containing plant species/varieties in ruminant feeding. The finding that CT can reduce ruminant CH_4 emissions has important environmental implications. Future studies are required to evaluate the sustainability of CT supplementation in CH_4 mitigation and rumen methanogenesis, without detrimental effects on productivity or health. As a natural and ecologically friendly tool to improve nutrient utilization for meat and dairy farming, the exploitation of forage legume

containing CT has an important role to play in agriculture. Further research is necessary, focused on the definition of appropriate strategies to better exploit tannin-containing plant species and /or varieties in ruminant feeding, thereby improving animal husbandry and contributing to environmental sustainability.

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