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Condensed Tannins in Forage Legumes[1]

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The use of tannin-containing forages has received attention from researchers around the globe because of potential benefits of condensed tannins to livestock health and nutrition as well as possibilities to reduce methane emission. This document targets two audiences: Extension faculty who need information on potential benefits and negative effects of condensed tannins to livestock production, and producers who intend to feed tannin-containing forages in their operation.

What are tannins?

Tannins are naturally occurring polyphenolic compounds derived from secondary metabolism in plants. They are vital for plant survival, but have no direct effect on growth or development. They play a major role in defense against herbivory or in response to abiotic stresses limiting plant growth. Under environmental stress, plants may increase tannin concentrations to store photosynthetic products that can be used in periods of cold or drought. They are known for having a bitter, astringent taste and a potential to reduce protein digestibility and cause intoxication in animals. As a result, they are commonly classified as antinutritional factors.

Tannins are divided into two groups, according to their chemical structure: hydrolysable and condensed. Hydrolysable tannins are complex molecules not found frequently in nature. They generally occur in dicotyledonous angiosperm species, such as oak trees, and when consumed, they are readily metabolized and may cause livestock poisoning.

Condensed tannins (CT), also known as proanthocyanidins, are the largest molecules found in angiosperms and gymnosperms (such as eucalyptus, pine, leucaena, and sainfoin; see Table 1). They are not readily absorbed in the gastrointestinal tract due to their ability to bind with proteins. Condensed tannins form strong bonded complexes that are not susceptible to enzymatic degradation in an anaerobic environment, causing proteins to bypass the rumen. The advantages or disadvantages of CTs depend on the proportions in the diet, their structural characteristics, the physiological stage of the animal, and the composition of the diet.

Negative Aspects of Condensed Tannins

Condensed tannins are located inside the plant cells and/or seed coat and are quickly released during chewing or cutting of forage. At first, tannins provide a bitter and astringent taste, which immediately reduces preference and eventually intake of the forage.

The antinutritional action of CTs occurs when their concentration in forages is greater than 5% of the DM. In this situation, CTs interact with various organic substances, such as cellulose, hemicellulose, pectin, and especially proteins, to form complexes that are not degraded by the ruminal microorganisms and enzymes produced in the gastrointestinal tract. This leads to low utilization of the feed consumed by the animals, since the practically intact nutrients are eliminated in the feces. This reduction in degradability of nutrients (especially crude protein, essential amino acids, and fiber) may result in a decrease in milk production, wool production, and animal weight gain.

It should be noted, however, that sheep and goats continuously exposed to forage species with high levels of tannins gradually develop different defense and/or adaptation mechanisms. In grazing systems, the animals become more selective, consuming tanniniferous species in smaller amounts or with tannin-free forages. Some animals present salivary gland enlargement and produce a larger volume of saliva, which may favor the formation of soluble complexes of tannin-protein or help in the swallowing of the feed. Additionally, some ruminal microorganisms (such as *Streptococcus caprinus* in goats) become capable of degrading the tannin-protein complexes or become more tolerant to the presence of tannins in the diet.

Positive Aspects of Condensed Tannins

Moderate concentrations of CT (between 2 and 4%) in dietary DM can bring benefits to the nutrition and health of ruminants. At these moderate levels, CTs bind to certain proteins and protect them from excessive ruminal degradation. These tannin-bound proteins pass through the rumen and are released into the duodenum, a portion of the gastrointestinal tract where the process of absorption of amino acids occurs more intensely, resulting in better utilization of dietary protein. It is important to mention the role of pH in CT dynamics along the digestive tract. Ruminal pH is close to neutral while the remainder of the digestive tract is acidic. In addition, microbial protein synthesis is maximized in the rumen, with increased flow of non-ammonia nitrogen into the intestine. Thus, when CTs are included in the diet, an improvement in the composition of milk fat and ruminant meat is observed due to the lower saturation of fatty acids in the rumen.

Some studies have also indicated that when concentrations are close to 0.5% in DM, CTs can reduce cases of foamy bloat (McMahon et al. 2000; Waghorn and Jones 1989). Foamy bloat occurs due to the high intake of forages (mainly high-quality legumes) with high soluble protein concentration. Under these conditions, CTs precipitate these proteins or reduce their rumen degradability, preventing the occurrence of the bloat. Moreover, CTs are often used in the control and reduction of parasitic infection in small ruminants, acting directly or indirectly on larvae present in the animal or on the pasture. Condensed tannins can minimize parasitic infection by three mechanisms: stimulation of the host's immune system due to the greater capacity to use the essential amino acids that reach the small intestine (duodenum) and subsequent compensation for loss of protein caused by parasites; injury of infecting larvae and adult parasites during the passage of CTs through the intestine that reduces parasite reproduction; and interference in the migration of larvae in the canopy profile, which makes it difficult to contact the parasite host (Mechineni et al. 2014).

From the environmental perspective, CTs optimize the partitioning of nitrogen (N) in the animal by decreasing N in the urine and directing its excretion to the feces. Shifting N excretion from urine to more stable fecal N may lower emissions of nitrous oxide, ammonia, and methane as well as nitrate leaching to waterways. As the CTs can be excreted bound to protein, the release of protein-nitrogen to the soil occurs more slowly, maintaining the fertility of the pastures for longer periods. Additionally, there is the possibility of reducing the methane emissions from ruminants, which is a current global concern. Tannins decrease methane production by directly inhibiting microorganisms that produce methane. *Lespedeza cuneata* was evaluated by the UF/IFAS Assessment with the Predictive Tool; it is predicted to be invasive and is **not recommended by UF/IFAS**.

Figure 1. Field of Lespedeza cuneata (variety: AU Grazer).
Credit: Flavia van Cleef, UF/IFAS

How to Feed Tannin-Rich Legumes

In general, the tanniniferous forages can be offered and consumed directly as hay or silage. The best form to offer will depend on the species and phenological stage of the plant. In addition, one must be aware of climatic and seasonal conditions, since these alter the CT concentration in the forage. Direct feeding of tannin-containing forages is mainly done when the CT concentration in the forage is low, as it is in pintoi peanut (*Arachis pintoi*, 2.5% CT), birdsfoot trefoil (*Lotus corniculatus* L., 2.0–4.7% CT), and alfalfa (*Medicago sativa*, 0.5–0.9% CT). The intake of these low-tannin forage legumes can be stimulated through previous exposure of the animals to the tanniniferous plants, or provision of concentrates or more attractive forages (grass or legumes).

Exercise caution when offering forages with greater CT concentrations to ruminants. These animals are considered more tolerant to tannins than non-ruminants, but they may experience toxicity when CT intake exceeds the effective degradation capacity of ruminal microorganisms. In these cases, strategies should be implemented to reduce CT consumption. In some cases, tannin-containing legumes have other antinutritional compounds, such as mimosine, saponin, or cyanogenic glycosides, which may limit their intake by livestock. Therefore, the presence of other antinutritional compounds that may act in conjunction with or even counteract CTs should be considered in order to avoid formulation of diets that could impair feed intake and animal performance. Animals will mostly avoid consuming fresh herbage of species with high CT concentrations. However, supplying it as hay improves intake because the solubility of CT is seemingly reduced. In this context, forage may be provided during short periods of grazing, used as a protein bank, associated with grasses, or supplied in balanced quantities (fresh, hay, or silage). Ensiling tends to decrease tannin concentration because of the acidic environment caused by fermentation. Bird-resistant sorghum, for example, was bred to increase CT concentration to approximately 10.5% versus 4.2% in the non-bird-resistant variety. This level is too high for fresh forage consumption by ruminants, but when ensiled, tannin concentration decreases and *in vitro* dry matter digestibility (IVDMD) increases.

Final Considerations

Diets should be formulated with the primary objective of meeting the nutritional requirements of the animals. Use of tanniniferous forages to achieve nutritional benefits should be considered as complementary nutritional management with a secondary objective (e.g., parasite control, reduction of bloating, increased rumen undegradable protein, or reduction in methane emission). The CT concentrations considered adequate or excessive are not fixed and may fluctuate depending on the chosen forage species and other components of the diet.

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Tables

Table 1. Condensed tannin (CT) concentrations (% dry matter) of legumes.

Plant Species	CT Concentration (%)	References
Lespedeza (*Lespedeza cuneata* [Dum. Cours.] G. Don)	6–13	Mechineni et al. 2014; Muir et al. 2017; van Zyl et al. 2017
Sainfoin (*Onobrychis viciifolia* Scop.)	2.8–7.8	Azuhnwi et al. 2011; Wang et al. 2014
Birdsfoot trefoil (*Lotus corniculatus* L. var. *corniculatus*)	0–5.0	Berard et al. 2011; Grabber et al. 2014

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