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What Are Tannins?

Tannins, a group of chemical compounds produced by a number of broadleaf forage plants, can bind proteins. Typically, grasses don't contain tannins, although sorghum (*Sorghum bicolor*) has a significant tannin content. Tannins are often found in higher concentrations in broadleaf plants adapted to warm climates. For example, sericea lespedeza (*Lespedeza cuneata*) is a forage cultivated in the midwestern and southern U.S. that can accumulate tannins to as much as 18% of herbage dry matter (Mueller-Harvey, 2006).

Because tannins bind salivary proteins, they produce an astringent or puckery sensation in the mouth when foods with a high tannin content (such as unripe fruits) are eaten. Tannins are effective in preserving (tanning) leather because they bind to the collagen protein in animal skins, preventing microbial breakdown. The French word "tannin" is related to the German word "tannenbaum" (meaning fir tree), and is derived from an older Latin term for oak bark, which was an early source of tannins for leather-making.

Proteins are needed to carry out the metabolic activities in living cells, so the content of protein is high in plant cells. For this reason, tannins in plants are segregated in vacuoles, which are water-filled structures in the center of most plant cells, or in special compartments called tannin sacs (Fig. 1). This segregation keeps tannins from interfering with plant metabolism.

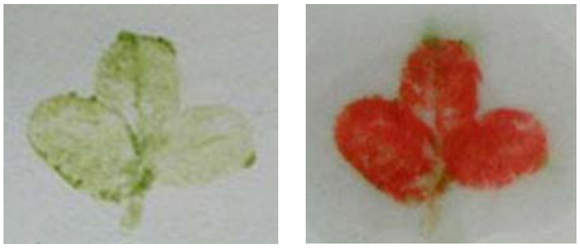

Figure 1. Cell sap pressed from the tannin sacs of three sainfoin leaflets before (left) and after (right) staining for tannins.

What Western Forage Plants Contain Tannins?

The amount of tannin, the location of tannins in leaves, stems or flowers, and the chemical structure of tannins vary greatly among the plants that accumulate these compounds. Alfalfa (*Medicago sativa*) can produce tannins, but they only occur in seed coats; white clover (*Trifolium repens*) produces tannins, but they only occur in flowers. In these cases, the amount of tannin consumed by ruminants grazing these forages is negligible. Two forage plants that grow well in the western United States and contain significant tannins are birdsfoot trefoil (*Lotus corniculatus*) and sainfoin (*Onobrychis viciifolia*, Fig. 2). Both of these forages express tannins in their leaves.

Figure 2. Sainfoin

Much of the research on tannin-containing forages has been carried out by animal and forage scientists in New Zealand, where cattle and sheep are raised primarily on perennial ryegrass (*Lolium perenne*) pastures. In an effort to identify forage species capable of improving ruminant production on pastures, many legume and other forb species were studied and the beneficial traits of tannin-containing forage plant species were documented.

The tannin produced by birdsfoot trefoil has routinely been found to increase ruminant productivity, and there is evidence that the tannins produced by sainfoin and sulla (*Hedysarum coronarium*) may also have positive effects on ruminant productivity. However, the results of studies on sainfoin and sulla are not consistently positive (Waghorn, 2008).

What Do Forage Tannins Do?

Two general traits of tannins relevant to grazing ruminants are the prevention of bloat (Lees, 1992) and the suppression of internal parasites (Hoste et al., 2006). Pasture bloat occurs when a substantial amount of fresh, high-protein forage, such as alfalfa, is digested quickly, resulting in a rapid increase in the protein content of the rumen. This causes the rate of microbial fermentation in the rumen to increase, and results in rapid accumulation of carbon dioxide and methane gases in the rumen. Microbial slime, plant cellular membranes and proteins all combine with fermentation gases to create a stable foam that's perceived as a liquid at the valve leading from the rumen into the esophagus, causing it to remain closed (Howarth et al., 1991). As the gases trapped in the rumen continue to accumulate, the rumen becomes distended, interfering with breathing and blood flow. Left untreated, bloat can result in death from suffocation or cardiac arrest. Tannin-containing forages are non-bloating because tannins bind excess plant proteins, precipitating them out of rumen fluid, and in the process, preventing the creation of the stable foam that's characteristic of pasture bloat.

The suppression of internal parasites by tannins, specifically the suppression of numerous nematode species, has been documented for sainfoin and birdsfoot trefoil, and for purified tannins from woody plant species used as dietary supplements (Younie et al., 2004). The effect of tannins on nematodes depends on the tannin concentration and chemical structure as well as the species of nematode. The effectiveness of tannins also differs by the stage of growth of the nematode, and the location in the gastrointestinal tract where the tannin is active.

How Do Tannin-Containing Forages Alter Forage Utilization?

Compared with grasses, legumes have less fiber and the fiber in legumes is digested more rapidly than the fiber in grasses (Smith et al., 1972). Therefore, legumes are digested more quickly than grasses, which means that intake and productivity can be higher on legume than on grass pastures (Crampton et al., 1960). The problem with a diet consisting of highly digestible legume forages is that their protein content is much higher than the dietary requirements of ruminants, and their energy (carbohydrate) content is relatively low. In the rumen, this problem is solved when microbes use the carbohydrate "backbone" of proteins as energy. However, the ammonia this creates isn't good for the ruminant or for the environment.

In tannin-containing forages, excess plant proteins that become bound to tannins leave the rumen without being digested. Unfortunately, the tannin chemistry or concentration in most forages results in irreversible binding of proteins. In these cases the protein is never digested, and both forage intake and digestibility are reduced (Reed, 1995). As a result, forages such as big trefoil (*Lotus pedunculatus*) can prevent bloat, but also reduce ruminant productivity (Barry and Duncan, 1984).

Like other tannins, those in birdsfoot trefoil (Fig. 3) bind excess plant proteins in the rumen, preventing bloat. However, unlike most tannins, they release these proteins in the abomasum in response to low pH. This allows the protein to be digested and absorbed in the small intestine (Waghorn et al., 1987) and results in high productivity in both sheep (Douglas et al., 1995) and cattle (Wen et al., 2002). In Utah, season-long average daily gains of 2.87 to 3.35 lbs. per day have been achieved on birdsfoot trefoil pastures (MacAdam et al., 2011).

Tannin Environmental Benefits

High-protein forages can result in high nitrogen concentrations in both milk and urine, but when birdsfoot trefoil is fed and excess proteins are digested in the abomasum instead of being used for energy in the rumen, the nitrogen concentration of milk and urine is reduced and more nitrogen is excreted as solid waste. This has been shown in studies by Woodward and others (2009) where urinary nitrogen was reduced as birdsfoot trefoil was increased relative to perennial ryegrass in dairy cow diets, and by Misselbrook and others (2005), where ammonia emissions from dairy manure were reduced when cows were fed birdsfoot trefoil silage instead of alfalfa silage.

The rate of nitrogen released into the soil from the manure of sheep fed birdsfoot trefoil was reduced compared with the manure of sheep fed white clover (Crush and Keogh, 1998). Over time, this would increase the rate of soil organic matter accumulation in pastures planted with birdsfoot trefoil. Birdsfoot trefoil tannins have also been shown to reduce the enteric (digestive) methane production of dairy cows compared with cows fed perennial ryegrass (Woodward et al., 2004).

Figure 3. Birdsfoot trefoil flowers and seedpods.

Conclusions

The inclusion of highly digestible legumes such as birdsfoot trefoil in pasture plantings can increase the productivity of grazing livestock. Because forage legumes produce their own nitrogen as long as they're inoculated with the proper *Rhizobium* bacterium at planting, they can meet their own nitrogen fertilization needs as well as those of associated pasture grasses. Since birdsfoot trefoil and other tannin-containing forage legumes are non-bloating, they can be planted as 50% or more of mixtures with no risk of bloat.

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