Anti-Quality Factors in Rangeland and Pastureland Forages

Edited by Karen Launchbaugh
Rangeland Ecology and Management
University of Idaho

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Tannins: Anti-Quality Effects on Forage Protein and Fiber Digestion[1]

Jeffrey L. Beck[2] and Jess D. Reed[3]

Introduction

Tannins are naturally occurring plant compounds mainly found in woody species that have a large influence on the nutritive value of forages. Tannins are widespread among forbs, shrubs, and trees but are uncommon in grasses. More specifically, about 17% of annual plants, 14% of herbaceous perennials, 79% of deciduous woody plants, and 87% of evergreens contain tannins. The word tannin was coined from the ability of many of these plant chemicals to tan animal skins into leather, by forming insoluble complexes with protein that stabilize hides against decomposition. When eaten, tannins produce bitter or astringent tastes that result from binding with salivary proteins in the mouth. An example, familiar to many, is the astringent "pucker" of red wines caused by tannins in red grape skins. Although humans may value this taste, tannins in red grape skins are thought to deter insect herbivory.

Tannins form strong chemical complexes with proteins, sugars, and starches that are stable over a pH range from the neutral environment of the rumen (pH 7.0) to acidic conditions in the stomach (pH 3.5). In plants, the ability of tannins to form insoluble complexes with proteins and polysaccharides (e.g., sugars and starches) can effectively reduce herbivory from mammals, birds, reptiles, and insects. When herbivores forage on tannin-rich plants, tannin–protein complexes can reduce the digestion of forage protein. Tannins directly affect digestibility of plant cell walls by binding with microbial enzymes in the rumen. Tannins may further reduce digestibility of cell wall carbohydrates by forming indigestible complexes with cellulose and hemicellulose. Reduced digestibility of cell wall compounds restricts the digestible energy that animals gain from forage plants.

Tannins in Plants

The amount of tannin present in plants depends on a plant's developmental stage and environmental conditions under which plants grow. Tannins are secondary products not involved in plant growth or reproduction; therefore, there are no minimum requirements for tannins in plants. In other words,

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[1]*Based on: Reed, J. D. 2001. Effects of proanthocyanidins on the digestion and analysis of fiber in forages. Journal of Range Management. 54:466-473.*

[2]*Graduate Research Assistant, Fish and Wildlife Resources Dept., University of Idaho, Moscow, ID 83844.*

[3]*Professor, Animal Sciences Dept., University of Wisconsin-Madison, Madison, WI 93706.*

tannins are not used by the plants that produce them, but, rather are by-products of plant chemical reactions. Domestication of tanniniferous forage plants led to selection of plants with lower tannin concentrations to improve palatability. Thus, tannin levels in food and forage crops are usually lower than in rangeland species.

Several important forage legumes contain significant levels of tannins, including lespedeza (*Lespedeza* spp.), trefoil (*Lotus* spp.), sainfoin (*Onobrychis viciifolia*), crown vetch (*Coronilla coronata*), and sulla (*Hedysarum coronarium*). Sorghum (*Sorghum vulgare*) contains tannins and thus, animals provisioned with this forage grain can experience reduced digestibility of protein and fiber. On rangelands, foraging herbivores usually encounter tannins in browse species. North American rangeland browse species containing tannins include acacia (*Acacia* spp.), blackbrush (*Coleogyne ramosissima*), ceanothus (*Ceanothus* spp.), oak (*Quercus* spp.), red elderberry (*Sambucus racemosa*), huckleberry (*Gaylussacia* spp.), salmonberry (*Rubus spectabilis*), and willow (*Salix* spp.). Fireweed (*Epilobium angustifolium*), mulesears (*Wyethia amplexicaulis*), and swordfern (*Polystichum munitum*) are examples of herbaceous rangeland plants containing tannins.

Chemical Nature of Tannins

Tannins can be chemically categorized as hydrolyzable or condensed. Hydrolyzable tannins occur in oak leaves in temperate regions, and in acacia shrubs in tropical areas. Acacia is an important source of browse forage in Africa, Australia, and the southwestern United States. Hydrolyzable tannins do not affect forage digestibility in ruminants, but can be metabolized into compounds that cause liver damage.

In general, the terms proanthocyanidins and condensed tannins are synonyms. Plant chemists prefer the term proanthocyanidin because it is more closely related to their chemical structure. Most nutritionists use the term condensed tannins, because these tannins are water-soluble compounds that precipitate or condense proteins (i.e., cause them to separate from solution and form solid compounds). We will hereafter not distinguish between insoluble and soluble tannins, but will instead refer to this class of forage anti-quality chemicals as tannins.

Research on how tannins affect nutritive value is complicated by inadequate laboratory procedures for determining the kind and amount of tannins in forage. It is beyond the scope of this paper to review this problem but, in essence, it is important to understand the limitations of chemical tannin analysis to make sense of the potential effects of tannins on fiber and protein digestion.

How Tannins Affect Herbivores

The ability of tannins to bind proteins and convert them into useless inert compounds can have several negative effects on animal nutrition. When tannins are eaten, they can bind dietary protein in the rumen or stomach, which reduces the amount of protein the animal can metabolize and use. These ingested tannins can also bind

proteins and cell tissues in rumen microbes, which kills them and reduces the efficiency of fiber fermentation in the rumen. Furthermore, tannins can bind and kill the cells along the digestive tract of animals causing digestive disorders. Tannins are rarely so toxic that they cause death, but rather, reduced digestive efficiency and protein availability can cause significant weight loss in wildlife and livestock.

Tannins in forages have both negative and positive effects on nutritive value. In high concentrations, they reduce intake and digestibility of protein and carbohydrates, which leads to reduced animal performance. Leaves of woody browse plants often contain enough tannins to reduce protein digestibility by 50%. In low to moderate concentrations, tannins can prevent bloat by binding with cellular complexes produced during mastication. In the rumen, tannins eliminate foaming properties of legume forage proteins and reduce the rate of gas production during fermentation. Tannins can also increase the flow of protein compounds through the rumen to the small intestine thereby escaping microbial fermentation (i.e., bypass protein). This is important because problems associated with extensive breakdown of proteins and amino acids in the rumen reduce protein quality and limits livestock production in modern feeding systems. Tannins eaten by animals can also protect them against infestations or diseases caused by parasitic worms. For example, lambs grazing sulla, a legume forage that contains tannins, had lower fecal parasite egg counts and worm burdens than lambs grazing alfalfa (*Medicago sativa*), which does not contain tannins. This reduction in worm burdens led to higher average daily gains for lambs ingesting tannins.

Some tannins can be quite toxic if eaten in excess. Oak poisoning has occurred in cattle in many parts of North America and Europe usually through ingestion of oak buds and leaves in spring and acorns during fall. Tannins in oak such as tannic acid and gallic acid are the chemicals that cause oak poisoning. Oak poisoning can be fatal. Initial symptoms include anorexia, depression, clear watery nasal discharge, rumen stasis, excessive thirst, and frequent urination. Constipation is followed by excretion of dark, thin, mucus-like, and often bloody feces. Ultimately, oak poisoning causes kidney, liver, and gastrointestinal lesions.

Animal Response to Tannins

Most herbivores forage selectively and consume plants of relatively low tannin concentration. For example, goats browsing blackbrush prefer previous year's growth to current year's growth apparently because it has lower tannin content, even though the current year's growth contains more nutrients. Studies of browsing herbivores like beaver, domestic goats, moose, mule deer, and white-tailed deer have revealed these herbivores counteract the negative effects of tannins by secreting tannin-binding salivary proteins (e.g., proline) from enlarged salivary glands. When browsing animals eat tannin-containing plants these salivary compounds bind with the tannins, making them inactive. These tannin–salivary protein complexes thus provide browsing animals the ability to maintain greater digestion of fiber and protein when ingesting tannin-rich forages, than grazing herbivores like cattle and sheep.

Some herbivores can degrade and absorb some condensed tannins. Deer and sheep in one study were fed alfalfa pellets mixed with quebracho tannins (a commercial tannin extract used in leather tanning). Sheep excreted about 40% of the ingested tannins, suggesting about 60% was absorbed and metabolized, while deer feces contained all of the quebracho tannins, suggesting deer absorbed none.

Management Implications

Because tannins are rare in most grasses, management of animals browsing on tannin-rich woody plants and forbs is a key concern for managers. A better understanding of the relationship between tannin structure and function is necessary to manipulate tannins in forages through breeding and selection or through genetic engineering. The interaction between tannins and fiber and digestion is an important component of this research. There is a fine line between the potentially positive effects of tannins and their negative effects on intake, digestion, and performance. Research is needed to define the chemical structure of tannins in grasses, herbs, browse, and seed coats to determine tannin reactivity with proteins and enzymes, and to suggest optimal kinds and amounts of tannins for ruminant diets. The effect of tannins on the nutritive value and selection of rangeland species in the diets of ruminant herbivores is another important research topic. Specific management considerations include:

- Products are being developed to enhance the ability of foraging ruminants to overcome the negative effects of tannins and related polyphenolic compounds on rangelands. These products are currently used in South Africa, Australia, and Zimbabwe, and may someday be available in the United States. These products are designed to complex and deactivate tannins during digestion. For example, polyethylene glycol is a tannin-binding polymer that improves animal performance by preventing adverse effects of tannins on protein digestibility and digestive enzyme activity.

- Manipulating rangeland vegetation to reduce plants with high tannin concentrations is very difficult because many dominant woody species contain high tannin levels. However, forages with low concentrations of tannins can be selected for pasture settings.

- Caution should be used when interpreting forage quality lab reports for high-tannin forages. Actual protein and fiber digestibilities my be higher than reported values because of negative effects of tannins in laboratory procedures.

- Animals ingesting substantial quantities of tannin-rich browse, may require protein supplements to account for reduced forage protein digestibility. This practice may be especially necessary when animals are lactating because of higher protein requirements.

- Livestock grazing oak woodlands should be checked frequently for signs of oak poisoning. Managers should move affected animals to oak-free areas and consult a veterinarian if symptoms persist. A preventative measure against oak poisoning is to supplement the diet with a feed mixture containing calcium hydroxide.

References for More Information

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