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Role of Tannins on Animal Performance: An Overview

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1. Introduction

Animal husbandry is one of the important activities of farmers in the developing countries including India. Priority for fulfilling the feed requirements of large human population with limited recourses provides the greatest challenge for sustaining and enhancement of livestock productivity. In India 60-70% of the forage requirements for goats are tree browses, tree legumes being particularly important [6]. Browses are particularly important in extensive livestock systems, and become more important when the supply of alternative feeds is restricted such as during dry seasons and periods of drought. The term plant secondary metabolite is used to describe a group of chemical compounds in plants that are not involved in the primary biochemical processes of plant growth and reproduction. The function of these secondary metabolites in plants is to protect the plants against predation, infection or by restricting grazing by herbivores. Browse trees are well adapted to adverse agro-ecological conditions and are important sources of livestock feed in the tropics. However, most browse trees contain secondary plant compounds such as tannins, alkaloids, non-protein amino acids, cyanogenic glycosides, oligosaccharides, saponins, etc. that substantially limit utilization by ruminants [9].

Tannins are among the important anti-nutritional compounds in most browse trees. High levels of tannins are known to exert negative effects, including a reduction of voluntary feed intake and nutrient digestibility as well as impairment of ruminal fermentation [20]. However, it has also been shown that a gradual increase in the intake of secondary compound containing plants may increase the ruminant's ability to tolerate or degrade them. There are several factors like environment, agronomic practices, soil nutrients, and physiological stage during plant development and post harvest processing techniques which are responsible to determine the concentration of secondary plant metabolites in the different plant parts [21]. Hydrolysable tannins can undergo significant transformation in the rumen due to the presence of microbial enzymes which breaks the ester bond, and there

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is sufficient evidence in the literature to support rumen microbial adaptation and degradation of those secondary compounds [18]. Thus tanniniferous feeds can be an important part of the diets of livestock in higher potential areas, not just in areas where high usage often reflects a lack of alternative feeds.

2. Structure and chemical properties of tannins

The word "Tannin" was originally coined by Seguin to describe the substances present in vegetable extracts, which are responsible for converting animal skin into leather and tannins also contribute to the astringency of many popular drinks, for example tea and wine. Tannins are defined as naturally occurring water-soluble polyphenols of varying molecular weight that differ from other natural phenolic compounds and their ability to precipitate proteins from solutions. Tannins are a heterogeneous group of high molecular weight phenolic compounds with the capacity to form reversible and irreversible complexes with proteins (mainly), polysaccharides (cellulose, hemicellulose, pectin, etc.), alkaloids, nucleic acids and minerals [30].

2.1 Tannins are usually two major types

hydrolysable (HT) and condensed tannins (CT), and are considered to have both adverse and beneficial effects depending on their concentration and nature besides other factors such as animal species, physiological state of animal and composition of diet [15]. The nutrient binding and astringent effect of tannins contained in tree leaves generally affect their intake and digestion in animals. When HT are metabolized the final products such as *gallic acid, ellagic acid,* other phenolic acids and their derivatives become toxic [15]. The ability of CT to form strong complexes with protein is their most important anti-nutritional effect of reducing the availabilities of nutrients during the process of digestion.

The CT is termed "proanthocyanidins" because HCl/butanol treatment releases bright red anthocyanadin chloride. Condensed tannins are polymers of flavanol (flavan-3-ol) units, linked by carbon-carbon bonds that are not susceptible to anaerobic enzyme degradation. Condensed tannins are heterogeneous compounds and both size and structure affects their reactivity and impact on digestion. The CT conserve nitrogen (N) in an ecosystem has credibility in low fertility environments because CT always increase the N content of faeces and decrease urinary N output [34]. Hydrolysable tannins have a very different structure to CT, comprising a central sugar attached to several gallic acid groups. However, the tannin chemistry in relation to animal nutrition is less useful because there are some compounds, such as catechin gallates, which have properties of both the hydrolysable and condensed tannins.

3. Occurrence of tannins in tropical tree leaves

Tannins are widely distributed in plant kingdom. The levels in plants vary greatly between species, within species, stages of development, location and from year to year. They are found in wood, bark, leaves and fruits of many species. It is found in higher concentration in tropical plants and high temperature stress enhances synthesis of tannins [16]. Tannins have been found in variety of plants utilized as food and feed. These include pakar (*Ficus sp*.), wattle (*Accacia sp*.), oak (*Quercus sp*.), eucalyptus (*Eucalyptus sp.*), birch (*Betula sp*.), willow (*Salix caprea*), pine (*Pinus sp*.), quebracho (*Scinopsis balansae*) etc. and the plant parts containing tannins include bark, wood, fruit, fruit pods, leaves, roots and plant galls. The negative correlation between alkaloids and tannins (both HT and CT) has an advantage as a feed for ruminants. Because when tannins and alkaloids co-occur they may cause greater negative effects for ruminants than when they occur independently owing to a synergistic effect [17]. However, a positive correlation between tannins (condensed tannins and total phenols) and alkaloids in consumable parts of plants including *Cassia fistula*, *Schinus molle*, *Chorisia speciosa* and *Eucalyptus camaldulensis* [29].

4. Beneficial effect of tannins

Waghorn and Shelton, [33] observed higher animal performance when diet contains low levels of tannins, which has been generally attributed to the protection of feed protein from degradation in the rumen, leading to increase in the flux of essential amino acids (EAA) to small intestine and increase in the absorption of EAA to blood. In small quantities, especially condensed tannins (CT) are useful as they prevent bloat, protect proteins and prevent establishment of gastrointestinal parasites. The condensed tannin (CT) in *Lotus corniculatus* (20-45 g CT/kg DM) fed to sheep reduces rumen forage protein degradation due to reversible binding to these proteins and reduced the populations of proteolytic rumen bacteria [19].

Condensed tannins form complexes with proteins that are stable over the pH range of 3.7-7.0, but dissociate in the abomasums and anterior duodenum. Forages with moderate concentration of tannins were also associated with less emission of greenhouse gases such as methane from animals [28]. Dey *et al.* [7] reported that lambs supplemented with varying levels of CT (1%, 1.5% and 2%) of the diet had positive nitrogen balance irrespective of dietary treatment. Recently, inclusion of tannins in diets has been shown to enrich CLA content in meat and milk. Tannins can exert beneficial effects environmentally by shifting N excretion from urine to faeces and decreasing methane output [22].

5. Detrimental effect of tannins

At higher level (5-9 %) tannins in feed reduced digestibility of fibre in the rumen by inhibiting the activity of bacteria and anaerobic fungi. Tannins may indirectly affect rumen function by reducing rumen ammonia level through decreased protein degradation in the rumen [14]. Sheep can adapt to a diet containing *Acacia* leaves, indicating that there are rumen microorganisms that detoxify their deleterious effects. Goats utilize tannin rich feeds better than sheep [13]. The high forage CT concentration (> 55g CT/kg DM) generally reduces voluntary feed intake and digestibility of nutrient and depress body and wool growth in grazing ruminants.

It is well established that ruminants have a higher tolerance to tannins than non-ruminants due to extra mastication, large amount of saliva and rumen fermentation. Within the same animal species, response to tanniniferous diets depend largely on the physiological capacity of the animals to adapt to high tannin levels in the diet. The CT has more profound digestibility-reducing effect than HT, whereas the latter may cause varied toxic manifestations due to hydrolysis in the rumen. The HT is degraded by micro-organisms in the rumen, and absorption of the degraded products results in a high load of phenols in the blood stream, which is beyond the capability of the liver to detoxify [15].

6. Effect of tannins on rumen microbes

Tannins inhibit ruminal microbial activity directly, by complexing with the bacterial cell envelop, or indirectly by reducing the availability of protein nitrogen and sulphur for microbial use. Sotohy *et al.* [32] reported that the numbers of total bacteria in the rumen of goats decreased significantly when the animals were fed tannin rich plant (*Acacia nilotica*) and the decrease in the numbers was directly proportional to the level of this feed in the diet. Animals fed on tannin rich *Calliandra calothyrsus*, the population of *Ruminococcus spp*. and *Fibrobacter spp*. were reduced but fungi, protozoa and proteolytic bacteria were less affected by this diet. Dietary tannins can adversely affect fermentation by bacteriostatic and bactericidal activities and by inactivating ruminal enzymes [8]. The CTs have been shown to inhibit the growth of many ruminal bacteria including bacteria associated with ruminal biohydrogenation [25].

Electron microscopy indicated that sainfoin proanthocyanidins bound to cell coat polymers of *Streptococcus bovis, Butyrivibrio fibrisolvens, Prevotella ruminicola* and *Ruminobacter amylophilus* but abnormal cell growth and division was observed only in *S. bovis and B. fibrisolvens*. Hydrolysable tannins are apparently metabolised by the ruminal microflora to phenolic compounds such as gallic acid, which is neither hepatotoxic nor nephrotoxic to animals. However, pyrogallol the decarboxylated product of gallic acid is produced in high concentration in the rumen of sheep and causes methaemoglobinaemia. Tannic acid can be absorbed through intact or injured gastrointestinal tract and ultimately cause kidney and liver necrosis [36]. The ester bonds and depside bonds of HTs are both cleaved in the rumen by *Selenomonas ruminantium* and *Streptococcus* spp. which produce esterase, tannin acylhydrolase [3, 11] to form gallic acid and ellagic acid. Gallic acid is then decarboxylated in the rumen to pyrogallol and converted to resorcinol and phloroglucinol before cleavage of the phloroglucinol ring to acetate and butyrate by rumen microorganisms. Singh *et al*. [31] reported that the rumen protozoa, fungi and cellulolytic bacteria were reduced however; tannin degrading/tolerating bacteria were increased due to feeding of pakar (*Ficus infectoria*) leaves to goat. Goel *et al*. [11] also observed that *Streptococcus* species isolated from non-adaptive cattle were converted from diplococi to an elongated chain of 40-50 cells with increasing concentrations of tannic acid in the media. Tolerance mechanism of bacteria to tannins may also involve degradation of tannins by bacteria.

7.Effect of tannins on methane emission

Carulla *et al.* [5] suggested that inhibition of methanogens by CT was primarily the result of suppressed fiber degradation that limits H_2 derived from synthesis of acetate. Depressed fiber degradation could be due to reduced number of cellulolytic bacteria, formation of tannin-cellulose complexes and impaired bacterial adhesion to substrate and fibrolytic activity of rumen microbes [2]. Goetsch *et al.* [10] reported that CT from different sources had disparate influence on N digestion, but similar effects on ruminal microbial CH_4 emission by goats, possibly by altering activity of ruminal methanogenic bacteria though change in actions of other bacteria or protozoa may also be involved. Thus, various CT sources could be used in future strategies to reduce ruminal CH_4 emission. Patra *et al.* [23] reported that the CT-containing forage K decreased CH_4 emission by goats regardless of its level and the effect per unit of K or CT increased with decreasing K. Nonetheless, the impact of K, CT on CH_4 emission appeared attributable to changes in methanogenic bacterial activity, but which might also involve alterations of protozoal activity. This suggests that relatively low dietary levels of CT could be employed to lessen CH_4 emission without marked detrimental effects on other conditions such as total tract N digestion.

8. Animal performance

Since tannin consumption can affect voluntary feed intake and its digestive utilization, there are likely to be consequences on the productivity of the animals that consume them. In general, high tannin intakes have a clear negative effect on productivity; nutrient availability is reduced because of the complexes formed between tannins and several types of macromolecules, voluntary feed intake and digestibility are reduced, the digestive physiology of the animal may be impaired, and there may be mucosal perturbations, etc. Besides, dietary tannins have been implicated to increase metabolic faecal nitrogen excretion, which may also account for a reduction of apparent protein digestion. All these factors might increase the faecal N output on tannin-based diets [24].

Dietary tannins generally tend to decrease DMI. Reduced DMI is thought to be caused by the astringent taste and decreased palatability possibly resulting in food avoidance. Many mammals, especially browsers, are able to produce proline-rich salivary proteins (PRP) that are able to bind to dietary tannins to inactivate them [15]. Cattle and sheep are devoid of PRP so the decrease in DMI due to astringent taste mechanism associated with tannins may not occur in sheep and cattle. There are some exceptions to suppress DMI of animals by tannin but in some cases there is an increase in DMI due to tannin supplementation [1]. Wang *et al*. [35] observed that the grazing of *L. corniculatus* (34 g CT kg-1 DM) reduced feed intake but increased the gain in live weight, carcass weight, and dressing proportion, compared with a group supplemented with polyethylene glycol (PEG), which binds to tannins and inactivates them. These authors observed a 23% improvement in live weight gain when lambs grazed *Holcus lanatus* (4.2 g CT kg-1 DM). Bhatta *et al.* [4] revealed that the inclusion of 75 g tamarind seed husk, a tannin rich by-product (140 g CT kg”1) per kg diet of cross-bred dairy cows also resulted in increased body weight gain and milk protein content in mid lactation. Priolo *et al.* [27] reported that tannin-containing feeds cause converse effects on meat and milk fatty acid composition, depending on the amounts of condensed tannins ingested by the animals, while meat colour is evidently paler when condensed tannins are present in the diet of goats and ewes.

Some researchers indicated that the continuous ingestion of tannins containing forages might lead to a partial physiological adaptation to these compounds by reducing their harmful effects. Polyethylene glycol is an excellent binding agent which forms complexes with condensed tannin without interfering the palatability and digestion of feeds consumed by animals. It has been shown that the supplementation of PEG to animals given a tanniniferous diet, eliminates the effects of condensed tannin on meat quality [26]. Krueger *et al.* [12] reported that HT and CT supplementation at low levels does not have detrimental effects on animal performance or other economically important traits and would make a good candidate for further research on tannin effects of food borne pathogens. There is evidence that the structure of tannins may influence physiological effects such as nitrogen metabolism, rumen microbial populations, intake and performance of animals, which has not been studied well in ruminant nutrition [22].

9. Conclusion and future perspectives

The development of different strategies to counter the toxic effects of tannin metabolites and played important role in health as well as production of livestock in tropics. Tannins might also inhibit the growth of proteolytic bacteria, which can reduce proteolysis. These increase non-ammonia N flow in the intestine for absorption. Moderate concentrations (depending upon the type of tannins) of tannins in diets improve body weight and wool growth, milk yields and reproductive performance.The future research should focus on for developing probiotic that may modify or inhibit the toxicity of tannins within the rumen ecosystem. The potential isolates may then be exploited for the successful trans-inoculation and genetic manipulation of ruminal microflora to achieve long term protection against tannin toxicity. Chemical analysis should be towards the measurements of binding capacity with plant proteins and effects on enzyme activity, because the relationships between chemical structure and astringency are not yet clearly defined. The combination of animal and management strategies is most likely to have the best outcome for producers.

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