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Review Article

A Review: Tanniniferous Feed Resources in Ruminant Production

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ABSTRACT

Uses of unconventional feeds are alternate sources to mitigate the shortage of grains and their byproducts. Since various unconventional feeds are produced in huge quantities every year and available comparatively at cheaper rate, therefore, the feed industry has a preference to use these materials in order to have maximum benefit from locally available unconventional feeds. Less than 4% in diet is however, advantageous to ruminants as it acts as natural protein protectant and thus reduces the degradation of protein by forming Tannin Protein Complex (TPC) in the rumen and subsequently enhances the amino acids availability in lower gut, thereby increases the rumen bypass protein. It reduces proteolysis of forage protein in the rumen, reduces rumen and plasma ammonia concentrations, reduces blood plasma concentration and increases the net absorption of essential amino acids especially branched chain amino acids from the small intestine. Tannin containing diet improved milk production and reproduction performance in dairy cows. Tannin is also hydrolyzed in the animal system and releases some antioxidants like catechin, epicatechin, catechin gallate, gallic acid etc., which have therapeutic values. These metabolites have certain properties like anti-oxidative and enhancer of reproduction performance. Catechin serves as powerful antioxidant against lipid peroxidation when phospholipid bilayers are exposed to aqueous oxygen radicals. The effect of tannins on animals ranges from beneficial to toxicity depending on the type of animals, age of animals, type and level of tannins in the feeds, the biological activity of tannins, level of tannin intake, quality of basal diets etc.

Keywords: Tanniniferous Feedstuffs; Unconventional Feeds; Growth; Reproduction; Milk Production; Antioxidant

INTRODUCTION

Livestock sector plays an important role in Indian economy and is an important sub-sector of Indian Agriculture. A high demand for food and restricted access of many poor farmers to external inputs leaves the production of animal feeds often at low priority for farmers in many developing countries. So, Feed shortage is the chronic problem in tropics and subtropics where available feed are poor in quality. To mitigate this problem a large number of agro-forest un-conventional feed resources such as crop residues, tree leaves, fodder trees and browses have been tested for their nutritional values and some of them were found to be promising. Tannins are among these factors found as secondary plant compounds in the fodders, tree leaves and browse plants. Secondary plant compounds are thought to be produced as a defense mechanism against tissue invasion by microorganisms and destruction by herbivore (insects, birds, animals). Tannins are present in the leaves, stems, flowers, and seeds of plants [1].

Tannin

The term tannin was coined by Seguin in 1796. It was originally referred to the substances with ability to tan leather. "Tannins are defined as naturally occurring water soluble polyphenols of varying molecular weight, which differ from most other natural phenolic compounds in their ability to precipitate proteins from solutions". They are widespread in the plant kingdom (Pteridophytes, Gymnosperms and Angiosperms), are found in leaves, fruits, bark, wood and can accumulate in large amounts in particular organs or tissue of the plant [2]. Tannins are considered plant secondary substances as they are not involved in metabolic pathways. After lignin they are the second most abundant group of plant phenolics. The presence of a large number of phenolic hydroxyl groups enables them to form large complexes, mainly with protein, and to a lesser extent with other macromolecules like cellulose and pectin [3].

Tannin in animal nutrition: Animals, normally consuming tannin rich feeds, appear to develop immunity against tannins. The presence of tannins in diets at less than 4% (on DM basis) is advantageous to protect dietary proteins from excessive rumen degradation and enhance amino acid absorption and utilization by the ruminants, reduce occurrence of pasture bloat reduce methane production in goats. However, tannins at greater than 4% in diet may

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have deleterious effect on feed utilization by reducing palatability and intake nutrient digestibility; and animal production. Tannins reduce the digestibility of nutrient either by binding the nutrients directly or by inhibiting the action of digestive enzymes of both microbial and animal origins. Feeding quabracho tannin at the level of 50 g/kg basal diets in sheep reduced ruminal ammonia nitrogen, total volatile fatty acids, cellulase and xylanase enzyme activity [4-11].

Adaptation to tanniniferous feedstuffs in ruminant animals: Animals normally consuming tannin rich feeds appear to develop defensive mechanism against tannins. In some animals the salivary proline rich protein are considered to be the first defense line against dietary tannins. In these animals, less protein is required to bind all the tannins resulting qualitative saving of nitrogen. The adaptive mechanisms of rumen microbes to high levels of tannin in the feed might be secretion of extra cellular polysaccharides which have affinity to bind tannins and or through formation of thick high tannin affinity glycoprotein and thus prevent tannin to cause adverse effects on rumen microbes [12-14].

Feral goats and camels feed on acacia spp and *Calliandra callothyrsus*, which have high level of tannins, were capable of tolerating tannin in the diets due to presence of high populations of tannin resistant bacteria like *Streptococcus caprinus* and *Selenomonas ruminantum* K_2. In addition, this higher ability of goats to tolerate CT tannin to extent might be due to their higher urea recycling capacity per day and higher salivary secretion capacity [15].

Effect of tannin *in vitro* nutrient digestibility: Bhargava reported that tannic acid (HT) at 6% (w/w) with GNC reduced protein solubility by 76% found that treatment of tannic acid (HT) at 10% (w/w) with GNC reduced in vitro NH_3 production by 91%. Dey concluded that tropical tree leaves (*Artocarpus heterophyllus*, *Ficus glomerat*a, *Ficus bengal*ensis, and *Ficus infectoria*) supplementation (at 1%-2% condensed tannins equivalent levels) significantly reduced the *in vitro* nitrogen degradability of groundnut cake. Herves reported that quebracho tannin at a rate of 15% with soybean oil meal can be used as a chemical additive to decrease rumen degradation of soybean oil meal in sheep without affecting intestinal digestibility. Use of tannin at 0%,2%,4% and 8 percent level from Quebracho, Acacia and Chesnut separately with soybean meal to investigate the degradation of its protein , it was found that *in vitro* ammonia, isobutyrate and isovalerate production decreased by addition of tannin to the soybean meal. Reduction of ammonia and isobutyrate per unit of tannin was higher ($p<0.05$) for chestnut tannin than Quebracho and Acacia tannin which proved that Chestnut tannin was more potent in protecting soybean meal protein from ruminal degradation. Barman and Rai found that increasing levels of babul pods from 0 to 65 per cent in Total Mixed Ration (TMR) significantly reduced IVDMD, IVOMD and IVCPD from 66.64 to 52.75; 67.19 percent to 54.71 percent and from 77.15 percent to 46.65 percent, respectively. The *in vitro* gas production was also significantly reduced from 174.07 ml/g to 148.0 ml/g substrate in TMRs ranging from 0 percent to 12 percent tannin. Gas production (ml/g substrate) during the first 24 h reduced significantly with increasing levels of tannin. This reduction was attributed to the reduction of in vitro digestibility of DM and OM. Gas production was more variable between 24 h and 48 h and did not follow a particular trend. Tannin concentration was negatively correlated with IVDMD, IVOMD, IVCPD and IVGP but these parameters were positively correlated with IVGP. Increasing tannin levels significantly reduced DM, OM, CP digestibility and gas production of *in vitro* incubation with rumen liquor of all species i.e. cow, buffalo and goat.

The effects of tannin were noticeably less in goat than cattle or buffalo. DM, OM, CP digestibility and gas production in goat liquor were reduced by 13%, 15%, 33% and 9% compared to 20%, 19%, 49% and 20% in cattle as the tannin content was increase in manner of 4%, 6%, 8%, 10% and 12 percent in TMR. This suggests that the rumen microorganisms in goat are most able to cope up with babul pods tannin and agrees with the discovery by O'Donovan and Brooker that *Streptococcus caprinus* was more resistant to tannic acid than *S. bovis*. The tannin effects on DM, OM and CP digestibility in buffalo liquor were slightly less than in cattle. The overall ranking of all *in vitro* TMR digestibility were higher in goat>cattle>buffalo in the presence or absence of tannin. Dubey replaced maize grain up to 66 percent with babul pods of 4per cent tannin level in TMR along with Calcium hydroxide and PEG-4000 treatment and did not find reduction for in vitro digestibility of TMRs. This shows that maize grain can be replaced with babul pods up to 66 per cent, without affecting digestibility if, tannin is chemically treated. Tandon found *in vitro* dry matter, organic matter and crude protein digestibility at 0%, 40%, 60%, 80% and 100 % replacement levels of barley and sorghum with babul pods in TMRs was similar to 100 per cent replacement [16-25].

Effect on *in vitro* NH_3-N concentration: Barman and Rai found that high level of tannin (equivalent to 12%) in diets resulted in delay in production of NH_3-N in rumen and it was reduced significantly with increased level of babul pods in the diet. There were 24%, 38% and 45 per cent reduction in NH_3-N production and 4%, 23% and 35 per cent reduction in NPN when tannin levels were increased by 4%, 8% and 12 per cent respectively in the diets compared to control. The declined in NH_3-N concentration with increased levels of tannin was due to cumulative effect of binding of tannin to dietary protein as well as reduction in protease activity. Tannin at 2.5% (on DM basis) reduced the release of NH_3-N during silage making. In vitro NH_3-N production from soybean protein was reduced by addition of 2%, 4% and 8% tannin from Quebracho, Acacia and chestnut separately compared to 0 per cent tannin and reduction in NH_3-N production per unit weight of tannin was higher for chestnut tannin than Quebracho or Acacia tannin as reported by Gonzalez. Inclusion of 10% and 20% salseed meal in concentrate mixture, did not affect the same in lactating cows. Although, Ruminal ammonia concentration was reduced by 21 percent at a concentration of 0.25 per cent hydrolysable tannin under *in vitro* Rusitec fermentation system, Supplementation of 0.1 percent and 0.2 percent hydrolysable tannin to lamb fed on basal diet containing concentrate and hay (1:1) and wheat straw ad lib did not alter ruminal NPN [12,26-29].

Effect of tannin on in sacco or rumen nutrient degradability: Dentinho observed that although the phenolic crude extract from *Cistus ladanifer L.* (0 g/kg, 12.5 g/kg, 25 g/kg, 50 g/kg, 100 g/kg and 150 g/kg levels) effectively reduced the in sacco soybean protein degradation in the rumen, and increased flux of feed protein to post rumen, it also had a negative effect on *In Vitro* Intestinal Digestibility (IVID). The effective DM and CP degradability reduced from 69% to 52% and 69% to 40 %, respectively as total phenolic concentrations increased from 0 g/kg to 150 g/kg DM of soybean meal. Martinez reported that use of graded levels of tannic acid (0 g/kg, 10 g/kg, 25 g/kg and 50 g/kg DM) decreased the effective protein degradability of barley grain. Gurbuz evaluated the nutritive values of leaves from four varieties of *Vitis vinifera* such as Kabarcik, Mahrabasi and Kibris were evaluated based on their chemical composition, in vitro gas production, Dry Matter (DM) and Crude Protein (CP) degradation. Condensed Tannin (CT) of fodder leaves ranged from 6.41%-10.58%. The CT concentration negatively correlated with gas production, DM and CP and comparatively he found that leaves of Kabarcik, might have a higher potential nutritive value for sheep in terms of rumen and whole tract digestion. But Rioux reported that higher tannin (3.8%) cultivar of birdsfoot trefoil silage (*Lotus corniculatus L.*) not influenced the effective degradability of DM (82%) and CP (94%) at k=0.5%/h. Harves reported that quabracho tannins at a rate of 15 g/100g of Soy Bean Meal (SBM) can be used as chemical additive to decrease rumen degradation. This enables proteins to by-pass degradation in the rumen and undergoes enzymatic hydrolysis in the abomasums and absorbed from small intestine. Furthermore, tannins form complexes with surfaces of bacterial cell wall and with bacterial enzymes which alter the bacterial growth and reduce proteolytic enzymes activities [30-36].

Effect of tannin on nutrient intake and digestibility: Tannins may reduce intake by decreasing palatability and by negatively affecting digestion. Palatability is reduced because tannins are astringent. Astringency is the sensation caused by the formation of complexes between tannins and salivary glycoprotein. Astringency may increase salivation and decrease palatability [10]. Therefore, low palatability depresses feed intake and, thus, animal productivity. Tannins in *Lotus pendiculatus* (8%) reduced VFI in sheep by 27% [7]. found that decrease in ruminal turnover and rate of digestion was the main cause of decrease in intake of sheep feeding on *L. pendiculatus*. Tannins at more than 4% reduce palatability, intake of DM, OMD and NDFD in ruminants [5]. Tannins at higher levels have negative linear relationship with nutrient digestibility. Proanthocyandins are not absorbed through the digestive tract. Instead, free tannins and complexes forms remain in the rumen, decreasing protein and plant cell wall digestibility. Several studies have shown that tannins decrease organic matter and fibre digestion. The lower digestibility is the result of the interaction of tannins with cellulase enzymes and rumen bacteria [37]. Feed consumption and nutrient digestibility of tree leaves in goat were not affected by the presence of tannin at 3.4% and 5.5% level, however, Phosphorous balance was found negative while that of calcium and N balance was positive while in another study the ruminal ammonia concentration was reduced by 21% when used 0.25% hydrolysable tannin was used in Rusitech reported that inclusion of 4% *Acacia nilotica* tannins in the diet of crossbred cows reduced dry matter intake, organic matter digestibility and NDF digestibility significantly ($p<0.05$) than control whereas, it did not affect dry matter intake and the nutrient utilization in case of crossbred calves except NDF digestibility (<0.05). However, he did not find any significantly difference in dry matter intake, dry matter, organic matter and crude protein digestibility at 3% Acacia nilotica tannins in the diet of crossbred cows. Supplementation of 1 g and 2 g hydrolysable tannin/kg DM to lamb fed on basal diet containing concentrate and hay (1:1) and wheat straw ad lib did not alter ruminal NH_3-N, pH, TVFA, protozoal count, apparent OM and fibre digestibility [24,29,38].

Effects of tannins on growth performance: Tannins may reduce intake by decreasing palatability and by negatively affecting digestion. Palatability is reduced because tannins are astringent. Astringency is the sensation

Wina reported large increase in average daily gain in goats fed diet containing water soaked *Acacia villosa* leaves and cassava flour (71 g/day) compared to those fed diet containing unsoaked leaves and water soaked leaves (38.9 and 44.7 g/day) ($p<0.05$). Soaking, reduce tannin in Acacia leaves, improved digestibility and intake of Acacia leaves. In the presence of cassava flour, soaking improved average daily gain. Diets supplemented with water soaked Acacia leaves probably also need an energy supplement and cassava flour was found to be one of the feed ingredients that was satisfactory. Low total intake and low growth rates were also observed in animals eating A. sieberiana pods and leaves of *A. cyanophyll*. Rubanza reported that supplementation with browsed tree leaves resulted in improved weight gains ($p<0.05$) of animals fed on *Leucaena leucocephala* than those supplemented with *A. nilotica* and *A. polyacantha* (compared to the control group, which lost weight). Improved weight gains were mainly due to the corrected dietary CP in the basal diet from browse supplements and probably due to improved feed digestibility and nutrients supply to the animals [39,40].

Supplementation of animals with *A. nilotica* and *L. leucocephala* leaves at 20% of the expected DMI, optimized weight gains. Dubey reported that in all the treatment groups, body weight did not differ significantly. Also reported that 16.7% *A. nilotica* pods equivalent to 3% tannins in the diet may be considered safe level of untreated *A. nilotica* pods whereas 27.8% *A. nilotica* pods equivalent to 5% tannins in the diet treated with either calcium hydroxide or polyethylene glycol may be considered safe level in diet of growing crossbred calves without affecting body weight gain.

Effects of tannins on antioxidant activity: Inhibition of the autoxidation of co-existing substances by tannins is regarded as being due to polyphenolic structures that can produce stable free radicals. The long lasting inhibitory effects of tannins Feeny may be due to the presence of many phenolic hydroxyl groups which produce stable free radicals one after another. The formation and solubilization of precipitates with several metal ions is accompanied by reduction of the metal ions. Terao reported that catechin serve as powerful antioxidant against lipid peroxidation when phospholipid bilayers are exposed to aqueous oxygen radicals. Nishida concluded that feeding of diets containing 20% of the dietary dry matter as green tea waste silage to Holstein steers has no negative impact on ruminal fermentation and Increases their plasma antioxidant activity and concentration of vitamin E. These were the effects of flavonoids, including the catechins found predominantly in tea. Gallic acid also showed strong antioxidant activity by preventing lipid per oxidation. Percival reported that the mice consumed wine rich in phenolic components as catechin, epicatechin, gallic acid, allergic acid showed increased antioxidant activity and did not result in lower T lymphocytes and natural killer cells in the blood when the injection of Lipopolysaccharides (LPS), a compound derived from bacteria, was given to mice [41].

Effects of tannins on milk yield and milk composition: Tannins can be used as feed additive to reduce the degradation of protein in the rumen. Tannins form complexes with protein that are less soluble and accessible to proteolytic enzymes in the rumen. Inclusion of 10% and 20% salseed meal did not affect the health of the animal and rumen fermentation pattern. No significant difference in milk yield obtained in untreated, 10% tannic acid as well as 1% formaldehyde treated groundnut cake in lactating goats. The gross energetic efficiency of milk production was found to be 20.35%, 22.77% and 24.23% respectively for the above 3 groups [17]. Barry and McNabb reported that higher concentrations of condensed tannins in *Lotus corniculatus* and *L. pedunculatus* reduced the rate and solubilization as well as degradation of leaf protein in the rumen of grazing sheep and increased duodenal ammonia nitrogen flow. Condensed tannins level of 30 g/kg to 40 g/kg DM in *L. corniculatus* increased the absorption of essential amino acids from small intestine and increased wool growth, milk yield and reproduction rate without affecting voluntary feed intake. But condensed tannin level of 75 g/kg to 100g/kg DM of *L. pedunculatus* decreased the voluntary feed intake and rumen carbohydrate digestion and had negative effect on growth and wool production. They also reported that feeding of diets containing 5 g condensed tannin per kg DM reduced the frothy bloat in cattle and reduced intestinal parasitic infestation in sheep. Milk yield increases significantly from 9.46 (Control) to 10.35 kg/d/animal on feeding 3% Tannins from *Acacia nilotica* pods in crossbred cows ration. However, Barman reported that inclusion of 4% *Acacia nilotica* tannins reduced milk production significantly, whereas increased milk protein percentage ($p<0.05$) in lactating crossbred cows with higher efficiency of energy utilization. Tandon, reported that inclusion of 16.5% *A. nilotica* pods in diet equivalent to 3% tannin did not increase significantly the milk yield, rather very well maintained the production. That means the replacement of energy of barley/sorghum grain to the extent of 80% is quite useful in saving the cereal grains for human consumption and use of non-conventional feed such as *A. nilotica* pods may boost the animal productivity [24].

Effects of tannins on reproductive performance: Nutrition is one of the most significant factors that influences the ovulation rate in sheep but mechanism for the effect of nutrition on ovulation rate are not clear. The effect of nutrition on ovulation rate is probably connected with the metabolic hormonal control of the ovary min reported increased plasma concentrations of branched chain amino acids resulting in increased ovulation rate and fecundity which showed increased reproductive ability using (17 gCT/kg DM) diet. Luque reported that grazing *L. corniculatus* (24 gCT/kg DM) by ewes had an ovulation rate up to 14% higher than ewes grazing pasture. Higher mean ovulation rate of ewes grazing *L. corniculatus* were due to increase in fecundity (multiple ovulation/ovulating ewe) which was the result of improved ($p<0.05$) efficiency of feed utilization. Min reported that ewes grazing on *L.corniculatus* containing 18 g total CT/kg DM without supplementation of Polyethylene Glycol (PEG) increased ovulation rate at cycle 3 (1.79 *vs* 1.48) and lambing percentages (1.69 *vs* 1.22) as compared to pasture diet devoid of *L. corniculatus*. Min reported that low concentration of CT (20 gCT/kg-45 gCT/kg DM) reduce rumen forage protein degradation due to reversible binding to these proteins and to reducing the population of proteolytic rumen bacteria. CT in several forage plants (eg. *L. corniculatus* and *sulla*) have been shown to offer advantages for ruminants and have resulted in increased ovulation rate and lambing percentage as well as reducing bloat risk and reducing internal parasite burdens. This is probably related to action of CT in increasing EAA absorption from small intestine; in the case of internal parasite, their inactivation by CT is also involved. However, high forage CT concentration (>55 gCT/kg DM) generally reduce voluntary feed intake and digestibility, and depress rates of body and wool growth in grazing ruminants. It was concluded that moderate concentration of CT can be used to increase the efficiency of protein digestion and to improve animal health.

Tannin toxicity and amelioration: Hydrolyzable tannins are known to be toxic to ruminants. The acute disease of cattle and sheep is associated with the consumption of oak species (*Quercus spp*.) and several tropical tree legumes (e.g. *Terminalia oblongata* and *Clidema hirta*). Microbial tannases that hydrolyze galloyl esters are present in the rumen. The gallic acid released is further metabolized by microbes to pyrogallol and other low-molecular-weight phenols that are absorbed from the rumen. These phenols may be further metabolized by conjugation to glucuronic acid after absorption. The toxicity of pranthocyanidin to ruminants is difficult to separate from their profound effect on the digestion of protein and carbohydrates. The consumption of tropical tree legumes such as species of Acacia are associated with increased mortality of ruminants. These species may contain high levels of proanthocyanidins and low levels of protein. Proanthocyanidins are not absorbed but may affect the mucosa of the digestive tract, which could decrease absorption of other nutrients. Proanthocyanidins will decrease the absorption of essential amino acids when present at high concentrations. The amino acids most susceptible are methionine and lysine. Decreased methionine availability could increase the toxicity of other plant compounds such as cyanogenic glycosides, because methionine is involved in the detoxification of cyanide via methylation to thiocyanate [42-45].

Inactivation of tannins in feed resources: Tannins present in feeds and fodders at higher concentration adversely to affect animal performance. Therefore, it is desirable to deactivate these tannins or to reduce to the harmless level to the animals. In principle, deactivation of tannin methods can be applied to any feed resource rich in tannins. Chemical detoxification of tannins includes use of alkalis, organic solvents, oxidizing agents, wood ash and metallic ions [46,47]. Alkali treatment promotes oxidation of phenolics at higher pH and decrease polymerisation of CT [48]. Various alkalis like sodium hydroxide, potassium hydroxide, calcium hydroxide, sodium carbonate, sodium bi-carbonate and limewater have been tried to remove tannins. Out of them sodium hydroxide, potassium hydroxide, calcium hydroxide and limewater have been proved to be most efficient in different feeds. The reduction in tannins in oak leaves using alkalis ranged between 70% and 90%. The reduction in tannins due to alkali treatment is due to oxidation of phenolics by oxygen (present in air) at higher pH values. Treatment of sal seed meal by sodium hydroxide was reported to reduce 68%-74% tannins [49]. Aemiro reported treatment of babul pods and mango seed kernel by 3 per cent calcium hydroxide resulted in 81% and 85% reduction in tannin respectively. The treatment resulted in improvement in in vitro organic matter digestibility of babul pods and mango seed kernel by 17.8% and 22.6% respectively. Dubey and Rai also found that 1-day treatment of babul pods with 3%

calcium hydroxide at 20% moisture resulted in 15.64% increase in IVOMD. Cumulative gas production in response to alkali and PEG treatments at 24 hours and 48 hours post inoculation was less pronounced in *Acacia nilotica* as compared to *Dicrostachys cinerea* fruits. In Acacia nilotica sodium hydroxide solution (0.6%) was most effective in reducing the detrimental effect of tannins on in vitro fermentation. Gas production was increased by 29% as a result of tannin inactivation (PEG) while treatment with 20% wood ash solution caused a 26% increase. Soaking *Acacia villosa* leaves in calcium hydroxide solution (20g/l) removed about 75% tannins. Feeding of the soaked leaves to goats on sugar cane tops basal diet and 100 g of cassava flour did not improve intake (56.5 *versus* 59.7 g/kg (W 0.75) and digestibility (0.60 versus 0.56) of Acacia leaves [39]. Urea treatment of tree leaves at 20g/ kg DM reduces the tannin content by 66%-70%. Addition of urea and then storage (urea-ammoniation) increased the extent of tannin inactivation. Urea treatment was practiced to improve the nutritive value of some feed stuffs. This is because they are highly alkaline which destabilizes tannin protein complexes and oxidizes tannin to phenols. It was reported to be effective in tannin deactivation and also resulted in increased crude protein content of feeds [50-53].

CONCLUSION

It could be concluded that tannin used below threshold level is beneficial in enhancing the milk production and efficiency of energy utilization in ruminant's diet. Less than 4% in diet is however, advantageous to ruminants as it acts as natural protein protectant and thus reduces the degradation of protein by forming Tannin Protein Complex (TPC) in the rumen and subsequently enhances the amino acids availability in lower gut, thereby increases the rumen bypass protein. "However, in case of high level of tannin may require a treatment to have better response of the diet". Therefore, a better information of tannins properties, metabolism and its influence on efficiency of nutrient utilization in ruminant ration is utmost important. Hence, proper management of feeding practices may be important to utilize these feed resources for strategic supplementation.

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