FOR AND AGAINST THE USE OF CONDENSED TANNINS FOR SMALL RUMINANT PRODUCTION – A CRITICAL ANALYSIS

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ABSTRACT

Indo-Pak subcontinent has a rich history of small ruminant farming. There are many indigenous breeds of sheep and goat contributing to the national economy and food security of the region. Small ruminant farming reared by the pastoralists, settlers and nomadic people mainly relies on the rangelands and temporary community pastures. Historically, the shepherds offer their flocks the leaves and soft stems of many trees and shrubs, now known to have tannin contents. The performance of the animals has always found better with the animals fed on traditional forages containing tannins. Until last couple of decades, there was no scientific evidence of the beneficial and/or adverse effects of tannins. There are, however, many researches published during the last few years, which have reflected upon the multiple benefits or harmful effects of the condensed tannins in small ruminants. More of the published research advocates the use of tannins for enhancing the animal production. Nevertheless, a debate is needed to use, disuse, judicious use and significance of animal feeds supplemented with tannin or the tannininferous forages. This paper offers a critical analysis of the conclusions based on the research on tannin feeding and potential of tannin containing forages in improving nutrient utilization and availability of proteins for better performance in small ruminants. Suitable recommendations have been made based on logical discussion on *"pros and cons"* of tannin feeding.

Key Words: Tannins, Benefits, Adverse effects, Small ruminants

INTRODUCTION

Tannins are polyphenolic compounds, which may be present in any part of plant, including roots, stems or trunk, bark, leaves, fruit and even hairs. Based on their molecular structure, they are usually classified either as hydrolysable tannins (HT) or CT (proanthocyanidins). Among these, CT are the most common types of tannin found in forage legumes, trees and shrubs (Barry and McNabb, 1999). Structurally, CT are complexes of oligomers and polymers of flavanoid units linked by carbon-carbon bonds (Hagerman and Butler, 1981; Foo *et al*., 1986) without a monosaccharide nucleus. The CT exist as oligomers of flavan-3-ols (catechin) or flavan-3, 4-diols (epicatechin) and those occurring in temperate forages have a relative molecular mass of 2,000 to 4,000 comprising 10 to 12 oligomers of CT (Foo *et al*., 1986). These differences can produce an infinite variety of chemical structures, which in turn affect the physical and biological properties of the CT. Condensed tannins form pH reversible bonds with forage proteins, which reduce degradation of protein to ammonia by rumen microorganisms, yet release protein at the low pH (2.5–3.5) in the abomasum (Jones and Mangan, 1977). Reactivity of CT differs between species of plants that contain these compounds and hence CT from some plants increases the net absorption of essential amino acids more than others (Barry and Mc Nabb, 1999; Min *et al*., 2003).

Small ruminant production is an important agricultural small and medium enterprise of the farmers. Tremendous increase in cultivated lands and increasing animal population pressure have led to squeezing the rangelands for grazers. Thus, animal nutritionists have been actively engaged in exploiting the nutritional potential of traditional forages to pay off the shortage of good quality food. Indo-Pak subcontinent has a rich history of small ruminant farming with many indigenous breeds of sheep and goat which contribute not only the national economy but also as food source. Rangelands and temporary community pastures are the main source of food for small ruminants reared by the pastoralists, settlers and nomadic people. Historically, the shepherds offer the leaves and soft stems of many trees and shrubs to their flocks which have, now known to contain tannin contents. The performance of the animals has always found better with the animals fed on traditional forages containing tannins. Until last couple of decades, there was no scientific evidence of the beneficial and/or adverse effects of tannins. There are, however, many researches published during the last few years, which have reflected upon the multiple benefits or harmful effects of the condensed tannins in small ruminants (Aerts *et al*., 1999). More of the published research advocates the use of tannins for enhancing the animal production. Nevertheless, a debate is needed to use, disuse, judicious use and significance of animal feeds supplemented with tannin or the tannininferous forages.

This paper presents a critical analysis of the conclusions based on the research conducted to enhance the small ruminant production by improving nutrient utilization and availability of proteins through feeding and exploiting the potential of tannin containing forages. Moreover, based on discussion on *"pros and cons"* of tannin feeding, suitable recommendations have been made to operate the animal performance.

Biological features of tannins

Tannins are functionally known by their competence to bind with proteins which forms the bases of many biological effects of tannins (Hagerman and Butler, 1991). They can have detrimental effect against many microorganisms and fungi (Bernays *et al*., 1989) which may be one of the major reasons of their evolution (Swain, 1979; Bernays *et al*., 1989; Ayres *et al*., 1997; Aerts *et al*., 1999). Intense deposits of tannin contents occur in the epidermis of leaves and stems of many leguminous forage plants, herbs and grasses with different concentrations including *Onobtychis viclifolia* (sainfoin), *Lotus* (*L.*) *corniculatus* (birdsfoot trefoil), *L. pedunculatus* (big trefoil), *Hedysarum coronarium* (sulla), and *Lespedeza cuneata* (sericea lespedeza) (Jones *et al*., 1976; Terrill *et al*., 1989, 1992). Interestingly, it has been reported that plants higher in tannins produced fewer leaves as compared to those having low tannins (Coley, 1986).

Beneficial and toxic effects of condensed tannins

The beneficial and toxic effects of condensed tannins on production and performance have extensively been studied in small ruminants. However, it appears that tanniniferous feeds can produce beneficial effects in low concentration while high levels are inevitably detrimental in small ruminants (Wiegand *et al*., 1996; Min *et al*., 2003). Low to moderate concentrations of tannins (2-5 % dry weight) significantly increased the net absorption of amino acids, sulphur and nitrogen digestibility which ultimately enhanced wool growth, ovulation rate, live weight gain, growth rate and milk production and quality (Waghorn *et al*., 1987; McNabb *et al*., 1993; Wang *et al*., 1994, 1996a; Terrill *et al*., 1992; Min *et al*., 1999). Moreover, tannins have also been reported to possess anthelmintic activity against many helminthes including *Teladorsagia circumcincta*, *Heamonchus contortus* and *Trichostrogylus clubriformis* (Niezen *et al*., 1998; Paolini *et al*., 2003a; Molan *et al*., 1999; Molan *et al*., 2000; Waghorn and Molan, 2001; Molan *et al*., 2002; Paolini *et al*., 2005). In contrast, high concentrations of tannins (>5 % dry weight) in feed of small ruminants may lead to reduced voluntary feed intake, % digestion of amino acids in small intestine, rumen fiber digestibility, growth rate, wool growth and digestion of sulphur and nitrogen (Barry and Duncan, 1984; Barry 1985; Barry *et al*., 1986; Waghorn *et al*., 1994; Pritchard *et al*, 1988, 1992). A summary of beneficial and detrimental effects of tannins in relation with their concentrations is shown in the Table 1.

Possible explanations of tannin effects

a. Nutritional aspect in sheep

To determine the nutritional effects of tannins in the sheep, all the experiments were performed on both untreated and tannin inactivated plant materials that have been treated with polyethylene glycol (MW 3350). The beneficial effects of tannins in sheep are associated with the greater outflow and absorption of amino acids especially in sheep fed with the forages containing tannin percentage ranging from 2-4% (Waghorn *et al*., 1987; Wang *et al*., 1994, 1996b; Min *et al*., 1999). Enhanced growth rate and increase in production performance and nutritive value of milk in sheep may be due to increased availability of essential amino acids (Waghorn *et al*., 1987; Wang *et al*., 1994). Increase outflow of sulphur containing amino acids which are key precursors of wool production may contribute to increased wool production (Wang *et al*., 1994; McNabb *et al*., 1993). Although, microorganisms are essential agents in the rumen for degradation of structural components of plant cells but, on the other hand, they also utilize the ammonia and some essential amino acids for synthesis of their cellular proteins. Tannins make complexes with the proteins in which prevent the degradation of proteins in rumen thus increase flow of proteins to the intestines (Waghorn *et al*., 1987, 1994; McNabb *et al*., 1996). This is evident from the experimentations of Barry *et al*. (1986) who found a linear relationship between increased tannin concentration and increased surge of non-ammonia nitrogen. Moreover, the pH value in rumen (6.0-7.0) is very favorable for the formation of stable complexes between tannin and proteins. When the complexes come in intestines, the lower pH (2.5-3.5) separates the bond between tannin contents and proteins resulting in enhanced digestion of essential amino acids in the intestines of sheep (Waghorn *et al*., 1987, 1994). This greater quantity of proteins is available to be absorbed in the intestine of sheep. In contrast, high tannin concentration reduces percentage digestion of proteins thus leads to reduced growth rate, wool production and milk quality and quantity (Waghorn *et al*., 1994).

b. Control of parasites

Although, most of the parasitic control programs are based on chemotherapeutic control (Waller, 1999; FAO, 2002) but, various problems have been evolved with this practice such as increasing problem of development of resistance by the parasites to several families of drenches (McKenna *et al*., 1995; Vermunt *et al*., 1995; Chandrathani *et al*., 1999; Chartier *et al*., 2001; Leathwick *et al*., 2001), hazards of chemical residues and toxicity (Kaemmerer & Buttenkotter, 1973), un-economical, non-adaptability and non-availability of drugs in remote areas. Recent reports on the small ruminants suggest that tannin containing fodder decrease the detrimental effect of gastrointestinal parasites by killing larval and adult worms (Athanasiadou *et al*., 2000). For example, Athanasiadou *et al*. (2001) found significantly lower faecal egg count from the sheep drenched with 16% W/W of Quebracho extract (QE). However, worm burden in the digesta of abomasums was significantly lower in sheep treated with 8% W/W of QE. Nevertheless, enhanced feed intake, live weight gain and feed conversion efficacy was observed in sheep treated with 8% W/W of QE while 90% of sheep drenched with 16% W/W of QE stopped eating by day 30 (Athanasiadou *et al*., 2001).

These results could be attributable to toxic effects of tannins as higher concentrations of tannins reduce feed intake and absorption of other available nutrients in rumen of sheep (Reed, 1995). Similarly, various scientists observed lower faecal count and worm burden with no parasitic species difference in the sheep drenched with several concentrations of condensed tannins (Niezen *et al.*, 1998; Paolini *et al*., 2003a, 2005; Molan *et al*., 1999, 2000, 2002; Waghorn and Molan, 2001). Tannins bind with free available proteins in the gastrointestinal tract and reduced nutrient availability of nutrients would have resulted in larval and worm starvation and death (Athanasiadou *et al*., 2001). Additionally, tannins would also bind with cuticle of larvae which is high in glycoproteins ensuing in death of larvae (Thompson and Geary, 1995). Moreover, increased availability of proteins due to condensed tannins in the feed of sheep has also been found responsible for enhanced immune response against parasites (Coop and Kyriazakis, 1999).

c. Bloat safety

Bloat is frequent muddle in small ruminants caused by the formation of stable protein broth in the rumen of animals fed with high nutritive value legumes including white clover or Lucerne. These protein foams avert the fermented gases to liberate from the rumen resulting in expansion of rumen. The course of bloat formation is very acute and leads to serious damage of vital organs such as lungs and heart (Mangan, 1959) and ultimately leading to death of animals. While, moderate concentration of tannins in the food of animals destabilizes the protein foams which refers them bloat safe (Tanner *et al*., 1995).

d. Reduced proteolytic enzyme activity and growth of rumen bacteria

CTs considerably reduce the proteolytic enzyme activity and growth of bacteria in the rumen of sheep (Jones *et al*., 1993). CTs form complexes with the cell coat polymers of bacteria and proteolytic enzymes secreted by them which enable the protein to sidestep in the rumen. These complexes subsequently release the protein when come in the acidic condition of abomasum. These protein molecules undergo enzymatic hydrolysis in the small intestine leading to availability of enormous number of amino acids to be absorbed from the intestine (Jones and Mangan, 1977; Martin and Martin, 1983; McNabb *et al*., 1998). Although, studies have not been conducted to determine the effect of CTs on proteolytic activity and growth of all ruminal microbes but data published so far is demonstrating that CTs had not affected the total microbial protein synthesis in the rumen or abomasal microbial protein flow (McSweeney *et al*., 2001; Min *et al*., 2002, 2003)

CONCLUSIONS

Adverse effects of tannin feeding in ruminants is associated with their low palatability and affinity to create linkage with nutrients. Tannin interference with digestion is a function of astringency, concentration and potential sites for binding. However, use of tanniniferous diets in proper proportion and concentration can improve animal productivity in addition to alleviating their negative effects.

RECOMMENDATIONS

1. Relatively low concentration of tannins (0.5% of DM intake) is sufficient to destabilize the bloat proteins while high concentration (2-4% of DM intake) is needed for improvement of protein utilization.
2. High concentration (> 5% of dry weight) should be avoided to prevent its toxic effects like reduced feed intake and feed conversion efficiency.
3. Tannins containing forages should be added in the feed of small ruminants for sustainable control of gastrointestinal parasites.

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Table 1. Condensed tannin content and/or beneficial/toxic action of different plants

Plant	**Content** (% DM)	**Toxic/beneficial effect**	**Reference (s)**
Acacia aneura	–	Damage to the structure of intestinal villi for a prolonged period	Brooker *et al*., 2000
Acacia aneura	12.00	Reduced dry matter intake, wool growth, and nitrogen and sulphur digestion	Pritchard *et al*., 1988, 1992
Acacia aneura	> 5	Antinutritional effects	Pritchard *et al*., 1988
Acacia karoo	2.22	Reduction in feed conversion efficiency (FCE)	Kahiya *et al*., 2003
Acacia nilotica	0.17		
Festuca arundinacea	0.20	Lesser immune response as compared to *Lespedeza cuneata*	Min *et al*., 2003a
Dietary CT	–	May enhance animals' immune response to the parasite infection	Niezen *et al*., 2002; Min *et al*., 2003a
Eucalyptus Melliodora	> 5.00	Anti nutritional effects	Foley and Hume,1987
Hedysarum coronarium	–	Higher antibody titers of secretory-excretory antigens against adult worms	Niezen *et al*., 2002
Hedysarum coronarium	10.00	Reduced FCE and parasite burdens	Niezen *et al*., 1995; 1998, 1998a
Hedysarum coronarium	5.20	Fed to sheep and goats, had a higher nutritive value	Ulyatt *et al*., 1976; Niezen *et al*., 1995; Min *et al*., 2003a
Lespedeza cuneata			
Hedysarum coronarium	4.00–5.00	Increased wool growth rate	Terrill *et al*., 1992
Hedysarum coronarium	–	Diarrhoea associated with a heavy parasite burden could be alleviated by feeding PA-containing	Niezen *et al*., 1995
Khaya	–	Anthelmintic activity	Ademola *et al*.,

Plant	**Content** (% DM)	**Toxic/beneficial effect**	**Reference (s)**
senegalansis			2004
Lotus corniculatus	–	Higher live weight gain, carcass weight and carcass dressing-out per centage, higher serum total protein and albumin concentration, and lower serum gastrin concentration and faecal lungworm larval count, compared with lucerne-fed deer	Hoskin *et al*., 2000
*Lotus corniculatu*s	–	Protect plant proteins against rumen degradation and increase the flow of amino acids to the small intestine	Waghorn *et al* 1987, 1994
*Lotus corniculatu*s	2.00–4.00	Increased absorption of essential amino acids from the small intestine by 62%	Waghorn *et al*., 1987a
*Lotus corniculatu*s	–	Increased milk and wool production in sheep	Barry and McNabb, 1999; Min *et al*., 1999
*Lotus corniculatu*s	–	Increased milk production in dairy cows	Woodward *et al*., 1999
*Lotus corniculatu*s	2.00–4.00	Increases in wool growth (11%), live weight gain (8%), milk yield (21%) and ovulation rate (15–30%) without increasing voluntary feed intake, thus improving production efficiency	Terrill *et al*., 1992; Wang *et al*., 1996, 1996b; Min *et al*., 1999
*Lotus. corniculatu*s	3.00	Increased absorption of plant methionine and cysteine	Wang *et al*., 1996b
*Lotus corniculatu*s	4.00–5.00	Increased production of milk protein lactose	Wang *et al*., 1996
*Lotus corniculatu*s	5.00–6.00	Increased net absorption of methionine and increased supply of cystine for body synthetic reactions	McNabb *et al*., 1993
Lespedeza cuneata	5.20	Greater immune response	Min *et al*., 2003a
Lespedeza cuneata	4.60	57% reduction in FEC and a 61% reduction in total fecal egg output in	Min *et al*., 2002

Plant	Content (% DM)	Toxic/beneficial effect	Reference (s)
		goats	
Lotus pedunculatus	–	Absorption of P is greater (22%) throughout the GI tract due to CT	Waghorn *et al*., 1994
Lotus pedunculatus	6.00–12.00	Depressed voluntary feed intake, inhibited rumen fibre digestion and reduced animal productivity	Terrill *et al*., 1992; Wang *et al*., 1996, 1996b; Min et a1., 1999
Lotus pedunculatus	6.30–0.60	Depressed feed intake, digestibility, and animal production in sheep	Barry and Duncan, 1984; Waghorn *et al*., 1994
Lespedeza cuneata	> 5.00	Antinutritional effects	Windham *et al*., 1990
Lespedeza cuneata	4.60	Reduced fecal egg production	Min *et al*., 2004
Lotus pedunculatus	–	Reduced the rate of larval development (91%), eggs hatching (34%) and mobility of L_3 larvae (30%)	Molan *et al*., 2000
Lotus corniculatus			
Hedysarum coronarium			
Onobrychis viciifolia			
Lotus corniculatus	5.00	To prevent rumen frothy bloat in cattle	Barry and McNabb, 1999
*Lotus pedunculatu*s	2.20–3.50	Increase the absorption of amino acids from sheep small intestine	Waghorn *et al*., 1987a
Lotus pedunculatus	6.00	Reduced voluntary intake and fibre digestibility	Barry and Duncan, 1984
Lotus pedunculatus	8.00–9.00	Reduced rates of body and wool growth	Barry, 1985
Lotus pedunculatus	9.00–10.00	Reduced rumen fibre digestion	Barry *et al*., 1986
Lotus	5.00–	Reduced dry dry matter intake and	Waghorn *et al*.,

Plant	**Content** (% DM)	**Toxic/beneficial effect**	**Reference (s)**
pedunculatus	6.00	reduced % digestion of amino acids in small intestine	1994
Lotus spp.	–	Reduced establishment of *O. circumcincta* worms	Niezen *et al*., 1998
Onobrychis viciaefolia	–	Decrease in faecal egg output	Paolini *et al*., 2003a
Onobrychis viciifolia	–	Inhibit egg hatching and larval development of *Trichostrongylus colubriformis*	Molan *et al*., 1999; Waghorn and Molan, 2001; Molan *et al*., 2002
Lotus corniculatus			
*Lotus penduncul*atus			
Dorycnium rectum			
Dorycnium pentaphylum			
Onobrychis viciifolia	5.00–8.00	Fed to sheep and goats, had a higher nutritive value	Ulyatt *et al*., 1976; Niezen *et al*., 1995; Min *et al*., 2003a
Onobrychis viciifolia Scop.	–	Lower levels of nematode egg excretion, reduced intestinal worms (50%), better host resilience	Paolini *et al*., 2005
Quercus lusitania var. *infectoria*	–	Larvicidal agents	Redwane *et al*., 2002
Rubus fructicosus	7.40	Inhibitory effect on L_3 and adult worms of *Teladorsagia circumcincta*, *Heamonchus contortus* and *Trichostrogylus clubriformis*	Paolini *et al*., 2004
Quercus robur	5.30		
Corylus avellana	14.20		
Rumex oblusifolius	–	Bloat could be eliminated	Waghorn and Jones, 1989
Schinopsis	–	Decreased the viability of L_3 of *Haemonchus contortu*s,	Athanasiadou *et*

Plant	Content (% DM)	Toxic/beneficial effect	Reference (s)
spp. (Quebracho: CT)		*Teladorsagia circumcincta* and *Trichostrongylus vitrinu*s and in sheep decreased faecal egg count and worm burden and improve the performance of parasitized sheep	*al.*, 2001
	–	Reduced FEC	Paolini *et al*., 2003
Spondias mombin	–	Anthelmintic activity	Ademola *et al*., 2005
Crataegus spp.	–	Used as an astringent for the digestive system in humans	Haslam, 1996