EFFECT OF TANNINS IN COMMONLY FED FODDERS ON NUTRIENT AVAILABILITY IN GOATS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **Effect of Tannins in commonly Fed Fodders on Nutrient Availability in Goats** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship or other similar title, of any other university or society.

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CERTIFICATE

I hereby declare that this thesis entitled **Effect of Tannins in commonly Fed Fodders on Nutrient Availability in Goats** is a record of research work done independently by Dr. ALLY, K. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to her.

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INTRODUCTION

Though goats form only about 20 percent of the total livestock population in India, they contribute substantially to the national economy of the country to the tune of Rs. 4.15 billion of which 79 percent is from meat (Jakhar, 1992), besides the other valuable products such as milk, skin, hair and manure. The contribution of the goat is specially manifest? in the rural areas where the animals are closely associated with the economically backward classes. This contribution from the goats in terms of the nutrition of the rural folk, effective utilisation of family labour, generation of family income and utilisation of agro-industrial as well as domestic wastes is, however, several times more than the estimations made on the basis of economic returns.

Goat, being a small sized ruminant, is capable of integrating itself with dissimilar socio-economic conditions prevailing in our country. The dual purpose Malabari breed of goat, native to Kerala is medium in stature, alert in disposition, prolific in breeding and economic to sustain and has secured a place in the rural economy of the state.

Goats are sensitive animals with peculiar feeding habits. The natural browsing habit of the goats has acclaimed it to be the ideally suited animal for mountainous regions. In a state like Kerala which is blessed with an extensive tropical vegetation, the possibility of a flourishing goat industry is quite conceivable. Goats have unique preferences for shrubs and tree leaves, some of which are even rejected by other livestock. The special feeding habits of goats are particularly significant in areas where the quality and quantity of feed is scarce to meet the basic nutritional requirement for body function.

Leaf fodder from the trees and shrubs are good sources of protein, minerals and vitamin A. They also have the advantage of easy availability and accessibility in the farms, apart from providing nutrients and variety in the diet. Over 60 percent of the fodder requirements of goats are normally met from the shrubs and the top feeds. But many palatable browse species contain one or more anti-nutritional factors and/or inhibitors that bind or otherwise prevent the utilization of nutrients contained in plants. Among such inhibitors are tannins (Kumar and Vaithiyanathan, 1990), Saponins (Gupta, 1991), Oxalic acid (Banerjee, 1990), cyanogenetic glycosides (Gupta, 1991), nitrates and nitrites and certain essential oils (terpene based organic compounds) (Ensminger et al., 1990). Mimosine present in the leaves of *Leucaena leucocephala* species is another factor which when ingested in large quantities produce ill effects (Singh, 1990).

Plant tannins are complex phenolic polymers which vary in chemical structure and biological activity. Two groups of natural tannins are found, the hydrolysable tannins which occur mainly in the fruit pods and plant galls and condensed tannins commonly found in forages. The principal forage tannins are of the condensed type (McLeod, 1974).

The negative nutritional effects of the tannins are diverse but the major effect is to decrease the digestibility of protein and carbohydrates. This is most likely a consequence of the interaction of tannins with either protein or carbohydrates to form enzyme resistant substrates. Interaction with enzymes themselves may also lead to an interference with the digestibility of these substances (Lienar, 1990). Thus tannins are shown to depress the nutritive value of feeds by reducing voluntary feed intake (Patel et al., 1972), dry matter digestibility (Ahn et al., 1989), protein digestibility (Lohan et al., 1980) and adversely affect the rumen metabolism in general (McLeod, 1974).

Condensed tannins are reported to have a greater inhibitory effect on the activity of both enzymes and microorganisms, than hydrolysable tannins (Anjaneya Prasad, 1986). It is suggested that condensed tannins bind the protein irreversibly making them indigestible (Zelter *et al.*, 1970). On the other hand, hydrolysable tannins have less deleterious effect on protein digestion since they are readily hydrolysed under acidic conditions of the stomach (Brown *et al.*, 1966).

Although tannins have an adverse effect on digestibility of nutrients, low contents may improve the quality by protecting protein from bacterial degradation (Reid *et al.*, 1974). There are reports that legume fodders rich in tannins are better source of by-pass protein than low tannin legumes (Reid *et al.*, 1974). This protein protecting property of tannin is restricted to hydrolysable tannins only (McLeod, 1974). But studies have been focused more on the deleterious effects of high concentration of tannins in some of the feeds and forages than their protective function at lower levels of inclusions.

Tree leaves contain both condensed and hydrolysable tannins. The observations that tannin containing feeds exert no significant decrease in digestibility of crude protein (Gupta, 1986 and Desai and Shukla, 1978) or they improve nutritive value of herbage at lower concentrations suggest that it is not only the total tannin content that is responsible, but also the type of tannins and their level present in these feeds which determine the extent to which the digestibility of protein in ruminants can be affected and that the net effect on protein digestibility can be assessed only from the nitrogen balance of animals (Nath, 1983). Further, ruminants appear to tolerate relatively higher levels of tannins and no toxic effect or nutritional disorder was observed in cattle fed diets with five percent tannic acid (McLeod, 1974).

Though there are a number of reports on the deleterious effects of total tannins on the digestibility and nutrient availability in feeds and fodders, studies on the nature and extent of different tannins present in different fodders and their effect on nutrient availability in livestock especially goats are scanty and varied. Hence the present investigation was taken up with the objective of identifying the various tannin rich fodders commonly fed to goats and assessing the effects of the nature and extent of different types of tannins in them on the digestibility and availability of nutrients in goats.

Review of Literature

REVIEW OF LITERATURE

Tannins, which are found in families of dicotyledons such as leguminosae, tree leaves and forage crops are only a fraction of the poly-phenolic residues produced by plants (Anjaneya Prasad, 1986). Many tree leaves though similar to good quality fodder in chemical composition have low palatability and nutrient digestibility because of the presence of deleterious factors like tannins, essential oils or other aromatic compounds (Kumar and Vaithiyanathan, 1990).

2.1. Chemical nature of tannins

Freudenberg (1920) has classified the tannins into two groups, viz., the hydrolysable tannins and the condensed tannins based on the structure (McLeod, 1974).

2.1.1. Hydrolysable tannins

Hydrolysable tannins are those in which gallic acid and its congener hexahydroxydiphenic acid and ellagic acid are linked in sufficient proportion to a sugar by glycosidic linkage to provide poly-phenolic compounds of relatively high molecular weight (Gupta, 1986). They can be hydrolysed easily by hot mineral acids or tannin-acyl-hydrolysases to give glucose or some poly-hydric alcohol and the constituent acid (Makkar and Negi, 1986).

2.1.2. Condensed tannins

Condensed tannins are made up only of the flavone type and are often called flavolans because they are polymers of flavons such as flavan-3-ol or flavan-3,4, diols (Anjaneya Prasad, 1986). They have no carbohydrate core and they do not readily break down with acids, instead they undergo progressive polymerization under the action of acids to yield amorphous phosphorus (McLeod, 1974; Nath, 1986; Makkar and Negi, 1986; Gupta, 1986 and Makkar et al., 1987). The condensed tannins have been classified into procyanidin and prodelphidin groups on the basis of anthocyanidin and prodelphidin (Gupta, 1986). The condensed tannins are the most widespread and typical of plant tannins (Mangan, 1988).

2.2. Occurrence of tannins in tree leaves

Generally tree leaves and browse are reported to contain both types of tannins (Kumar and Vaithiyanathan, 1990). But McLeod (1974) observed that the principal forage tannins are of the condensed type. Pryor et al. (1972) in their experiment with supple jack (Ventilago vininatus) showed that the leaf contained 14 percent tannins. Devasia et al. (1976) reported that jack leaves contained 2.19 percent of total tannins on dry matter basis. James et al. (1977) observed the presence of tannin in jack (Artocarpus heterophyllus), Subabul (Leucaena leucocephala) and Banana (Musa paradiosiaca) to the extent of 5.2, 4.8 and 2.4 percent respectively on dry matter basis. A total tannin content of 4.68 percent in venga (Pterocarpus marsupium) leaves have been reported by Kunjikutty et al. (1980). Thomas et al. (1981) in their study on locally available tree leaves observed that the total tannin content in the various leaves ranged from 1.1-4.17 percent on dry matter basis. Negi (1982) reported that on dry matter basis sal seed contained 7-12 percent tannin, while Singh and Arora (1980) recorded a total tannin content of 11.76 percent in sal seed meal on dry matter basis, of which 6.48 percent was hydrolysable tannin and 4.8 percent condensed tannins. Lohan et al. (1983) in their work on Oak leaves showed that the leaf contained 2.5 percent of condensed tannin on dry matter basis. They also observed that out of the 26 fodder species analysed, 11 species contained no condensed tannin at all. Akbar and Gupta (1985) reported that the tannin content in Leucaena leucocephala ranged from 7.33 to 19.0 microgram per g, while Dogra et al. (1986) observed that the concentration ranged from 2.07 - 6.4 percent in various seasons. Panda et al.(1987) found that the leaves of Calliandra calothyrus contained 5.85 percent of tannins. Majgaonkar et al. (1987) observed that the leaves of Gmelina arborea contained 2.62 percent of the total tannins. A concentration of 1.7 percent of tannins in Glyricidia maculata was reported by Bharia et al. (1987). Gupta and Balaraman (1992) observed wide variation in the total and condensed tannins in the species of fodders they studied, the concentration ranging from 0.5-8.12 for total tannins and 0.0-5.2 percent for condensed tannins.

2.3. Effect of tannins on feed intake and nutrient utilisation

2.3.1. Voluntary feed intake

Singh and Arora (1980) observed no significant difference in dry matter intake in different groups of cross bred calves receiving diets with or without sal seed oil meal with a tannin content of 3.75 percent. But Singh (1982) reported an improvement in the palatability of Robinia pseudoacacia leaves with a decrease in tannin content. Panda et al. (1983) reported that the dry matter intake from Jaman (Eugenia jambolana) leaves with 6.5 percent tannin was less than pipal (Ficus religiosa) leaves with 0.7 percent tannin in goats. Van Hoven (1984) established an inverse relationship between the concentration of total tannin in the leaves and the level of feed intake by animals. A high level of tannin is reported to depress the feed intake by diminishing the permeability of gut wall (Mitjavila et al., 1977), by influencing the hormone level (Barry, 1984) or by making the leaves unpalatable (Burns and Copes, 1974). The presence of tannins in feed stuffs is found to adversely affect the voluntary feed intake (Anjaneya Prasad, 1986; Makkar and Negi, 1986 and Robbins et al., 1987). However, Akbar and Gupta (1990) in their study with different levels of Faba bean (Vicia faba) did not find any significant difference in dry matter intake of animals fed rations in which groundnut protein was replaced by faba bean seed at 25, 50 and 75 percent level. Sharma et al. (1990) in their study with Acacia nicolotica and Leucaena leucocephala leaves observed that both leaves were quite palatable eventhough the tannin content of A. nicolotica was very high. Teague (1991) reported that generally leaf and shoot intake from Acacia karoo were negatively related to tannin content. Bhatia et al. (1991) showed that treatment of pala (Zizyphus nummularia) leaves with poly-ethylene glycol increased the dry matter intake by 1.5 times. Menke and Leinmuller (1991) suggested that tannins may precipitate salivary protein causing an astringent taste in mouth, there by decreasing dry matter intake. In general, an inverse relationship has been found between protein precipitating capacity of tannins in tree leaves and palatability and voluntary intake in grazing and browsing animals. (Kumar and Vaithiyanathan, 1990; Waghorn et al., 1991; Pan and Maitra, 1991; Teague, 1991 and Menke and Lein muller, 1991).

2.3.2. Nutrient digestibility

The adverse effect of tannins on nutrient digestibility has been amply recorded by their effect on enzyme inhibition and on dry matter, protein and other nutrient digestibilities and their retention (Gupta, 1986) Tripathi (1974) observed that the breakdown of ground nut protein in the goat rumen was inhibited by banana leaf tannins.

Mitjavila *et al*.(1977) reported that added tannic acid in the diet of rats caused increased mucin secretion by intestinal mucosa and also inhibited oxygen consumption and succinic dehydrogenase activity in these cells. Lohan *et al*. (1981) found that the aqueous extract of Oak leaves (*Quercus inaca* inhibited the reactivity of ruminal fluid. McLeod (1974) and Makkar and Negi (1986) opined that the decrease in digestibility of nutrients by tannins may be due to their enzyme inhibitory activity. Lohan *et al*. (1983) observed that the urease and proteolytic activities were significantly lowered at high levels of Oak leaves in the ration. Kumar and Singh (1984) found that the tannins of pala (*Zizyphus nummularia*) leaves inhibited the proteolysis of casein and subsequent ammonia production in the rumen *in vitro*. Gupta (1986) suggested that the inhibition of enzyme by tannin may be accompanied by an increase in the production of enzyme by the animal system in order to counteract the effect of inhibition and ultimately may adversely affect the animal system depending upon the level of tannin in the diet. Makkar et al. (1990) observed that the tannins of Oak leaves decreased the activities of urease, carboxymethylcellulase, glutamate dehydrogenase and alanine-amino-transferase and increased the activities of glutamate-aminoligase in the rumen. The enzymes which acted in a neutral or slightly acidic pH were found to be more affected by tannins (Pace et al. 1991).

Sadanandan and Arora (1976) reported that incremental additions of tannic acid upto 7.5 percent in different treatments decreased microbial RNA, DNA and Protein synthesis in rats. The lower nucleic acid nitrogen and higher protein in the rumen liquor of buffaloes fed sal seed meal were attributed to a decrease in deamination by bacteria when ruminants are fed diets containing tannins (Sadanandan and Arora, 1979). Singh and Arora (1980) fractionated the total tannins in sal seed (Shorea robusta germate. F) to ethyl acetate and lead acetate fractions and found that both the fractions depressed microbial protein synthesis, the lead acetate fraction being more deleterious than the ethyl acetate fraction. Lohan et al. (1983) also observed a significant reduction in rumen bacterial nitrogen when the ration contained high levels of Oak leaves. They suggested that enzyme inhibition may be the consequence of microbial inhibition, or vice versa. According to Gupta (1986) different sources of tannins have different effects on anti microbial activity. Chiquette et al. (1988) by scanning and transmission electron microscopy showed that rumen bacteria formed multiple adherent micro-colony on high tannin leafand surface of the plant and these colonies did not penetrate the plant tissues as effectively as did bacteria associated with low tannin strains. Barry and Manley (1984) in their study with Lotus pedunculatus reported that the digestibilities of all nutrients measured were less for high tannin varieties of Lotus. They also observed that the presence of condensed tannins in Lotus increased post ruminal nonammonia nitrogen absorption, but depressed ruminal digestion of readily fermentable carbohydrates and hemicellulose. Van Hoven (1984) recorded a decline in IVDMD of greater kudu leaves with an increase in tannin content in these leaves.

2.3.3. Dry matter digestibility

Donelly et al. (1973) in their study with two varieties of Sericea lespedeza varying in tannin content reported that the dry matter digestibility in low tannin varieties was better than that of high tannin varieties. Mitjavila et al. (1977) observed that tannins slow down the digestion of dry matter in the rumen. A low digestibility coefficient of dry matter for jack (*Artocarpus heterophyllus*) leaves with 2.19 percent tannins has been reported by Devasia *et al*. (1976). Gupta (1991) in his study with khanyan (*Ficus cunia*) reported low dry matter digestibility in goats. In studies with *Leucaena leucocephala* and *L. diversifolia*, Dogra *et al*. (1986) observed better IVDMD for *L. leucocephala* with lower tannin than the other species. However no reduction in dry matter digestibility was recorded by Kunjikutty *et al*. (1980) in goats fed with venga (*Pterocarpus marsupium*) leaves containing 4.68 percent of total tannins.

In vitro dry matter disappearance was found to decline with an increasing tannin content in tree leaves (Waterman *et al*., 1980). A direct relationship between the low IVDMD of tree leaves and their tannin content has been reported by several other scientists. Panda *et al*. (1983) and Van Hoven (1984) also recorded a decrease in IVDMD of lucerne with an increase in tannic acid concentration. He also demonstrated that both the hydrolysable and condensed tannins have a negative influence on IVDMD, the influence of condensed tannins being more pronounced. Reed *et al*. (1985) observed that condensed tannins reduced the neutral detergent fibre digestibility but Robbins *et al*. (1987) could not find any effect on NDF digestibility due to tannins.

Reddy and Reddy (1984) in their study using mango leaves observed that high content of tannin in mango leaves depressed the digestibility of all nutrients in sheep. Chiquette et al. (1988) reported that the dry matter disappearance from high tannin variety of Lotus pedunculatus was less than from the low tannin variety. In feeding trials with Calliandra calothyrus, Panda et al. (1987) observed lower digestibility coefficient for all nutrients except NFE. A high negative correlation between tannin content and dry matter digestibility has been observed by Garrido et al. (1991). Pace et al. (1991) showed that the inhibitory effect of tannic acid was about twice that of condensed tannins.

However, no depressing effect on dry matter digestibility due to tannic acid was noticed by Singh and Roy (1981), Bharia et al. (1987) and Pan and Maitra (1991). Also no reduction in digestibilities of nutrients in the presence of tannins or supplemented tannic acid in the diet was observed by Ingalls et al. (1980); Singh and Arora (1980); Gupta et al. (1988) and Akbar and Gupta (1990).

2.3.4. Crude protein digestibility

Donelly et al. (1973) reported that the crude protein digestibility of low tannin variety of Serecia lespedeza in bullocks was better than the high tannin variety. Sadanandan and Arora (1976) reported that the protein digestion was less in rats fed diets with 2.5 to 5 percent added tannic acid. Tripathi (1976) observed that replacing the extracted sal tannin with the same amount of tannic acid inhibited protein digestion by about the same amount as the sal tannin before extraction in goats. He also showed that the break down of groundnut cake protein was inhibited by added tannic acid in goat rumen and that the inhibitory effect of tannic acid was more pronounced in the presence of soluble proteins of GNC, higher levels of tannic acid having more inhibitory effects than lower levels. Singh and Roy (1981) also reported depression of protein digestibility by tannic acid. However, Lohan et al. (1990) noted certain anomalies in the digestibility of leaf protein vis-a-vis their tannin content and they suggested that it may be due to the biochemical nature of tannins in different leaves. Sengar and Mudgal (1982) observed a decrease in crude protein digestibility by three percent by the addition of ten percent tannic acid. Negi (1982) showed that the tannin in sal seed not only hindered the utilisation of protein but also adversely affected the utilisation of protein of other feeds.

Singh and Nath (1983) reported that the crude protein digestibility was significantly depressed in calves given chemically treated deoiled sal seed meal included at 40 percent level. Panda et al. (1983) in their study with pipal (Ficus religiosa) and jaman (Eugenia jambolana) which contained 0.7 and 6.5 percent tannin respectively observed that the crude protein digestibility of jaman leaves was low in goats.

Akbar and Gupta (1990) observed no significant difference in the digestibility of nutrients including crude protein by the replacement of groundnut cake protein with faba bean protein at various levels of incorporation. Sharma et al. (1990) reported that tree leaves like Acacia karoo have very high amount of tannin which depress the digestibility of protein and consequently dry matter. However, no significant reduction in crude protein digestibility in tannin containing feeds has been reported by certain workers (Joshi and Upadhyay, 1976; Kunjikutty et al., 1980 and Yadav et al., 1990).

Tannins of tree leaves are reported to interact with dietary protein to form indigestible protein tannin complexes thereby depressing the digestion of proteins in ruminants (Gupta, 1986). McLeod (1974) suggested that tannins have greater affinity for protein than for cellulose and this has been attributed to the strong hydrogen bond affinity of the carbonyl oxygen of peptide group.

The digestibility of protein in plants containing significant amount of tannin is reported to be low by many workers (Reddy and Reddy , 1984; Van Hoven, 1984; Mitaru, 1984; Jaikishan _et al_., 1986; Anjaneya Prasad, 1986; Makkar and Negi, 1986; Panda _et al_., 1987; Dawra _et al_., 1988 and Makkar _et al_., 1988).

The low crude protein digestibility of the leaves has been attributed to the presence of a high concentration of tannin in them (Lohan _et al_., 1980 and Panda _et al_., (1983). Osbourne _et al_. (1971) suggested that the lower digestibility of crude protein in sainfoin observed by them in sheep may be because of the reaction of condensed tannins in sainfoin with the crude protein in it to form insoluble, indigestible protein complexes. Reed _et al_. (1982) reported that the condensed tannins present in the NDF fraction of cassava forage is highly correlated with the insolubility of crude protein in NDF.

Kumar (1983) reported that it is the condensed tannin content and their protein precipitating capacity, and not the phenolic content that reflect on the crude protein digestibilities in negative relationship. Ahn _et al_. (1989) in their study using 12 species of tropical browse legumes reported that in species which contained tannin, there was poor correlation between nitrogen digestibility and total condensed tannin content. Barry (1984) in his study with low tannin varieties of Lotus pedunculatus in sheep observed that the total nitrogen intake was less for high tannin variety but the faecal non ammonia nitrogen outgo was high for high tannin variety. Relative to non tannin containing fresh forages, condensed tannin in Lotus pedunculatus increased duodenal nitrogen flow and calculated absorption of amino acid from the small intestine (Barry, 1984). Barry and Manley (1984) observed that the presence of condensed tannins in Lotus pedunculatus markedly increased post ruminal NAN absorption.

Marquardt et al. (1977), reported that feeding 3.9 percent tannic acid caused reduced amino acid retention in chicks. However, Rodrigues (1978) could observe no significant difference in nitrogen retention between two groups of sheep given soyabean oil meal and the same treated with tannins from Acacia mearnsii. A positive balance for nitrogen in experimental goats fed with Calliandra calothyrus with a tannin content of 5.85 percent on dry matter basis has been reported by Panda et al. (1987).

Depression of protein digestibility may or may not be accompanied by growth depression or other adverse effects from tannin containing diets. Gupta (1986) suggested that whether the depression in protein digestibility by tannin is of advantage or disadvantage to the animal is dependent on the net effect on nitrogen balance. He further opined that if an animal exhibits depression in protein digestibility without causing a depression in nitrogen retention, the tannin containing feed will not be inferior to the nontanning containing feed.

2.3.5. Mineral utilisation

Tree leaves are reported to be rich in calcium and poor in phosphorus. and that animals fed on tree leaves generally exhibit positive calcium and negative to marginal phosphorus balances (Gupta, 1986., Kumar and Vaithiyanathan, 1990). Sadanandan and Arora (1976) in their study with fistulated buffaloes found that added tannic acid decreased the utilisation of phosphorus by rumen microbes. Kunjikutty et al. (1980) reported positive balance for calcium in goats fed venga (Pterocarpus marsupium) leaves, but all the animals showed negative balance for phosphorus.

Panda et al. (1983) reported negative balance for calcium and phosphorus in goats fed Jaman (Eugenia jambolana) leaves which contained 6.5 percent tannin on dry matter basis, while Reddy and Reddy (1991) could observe positive balance only for calcium with banana plants (Musa paradiosiaca) in cattle; the balance of phosphorus being marginally negative.

Gupta (1991) reported marginally negative phosphorus balance in goats fed with Khanyan leaves while Upadhyay et al. (1974) observed positive balance for calcium and phosphorus in animals fed with Leucaena leucocephala.

However, in studies conducted in goats with Calliandra calothyrus leaves having a tannin content of 5.8 percent on dry matter basis, Panda et al. (1987) reported positive balance for calcium and phosphorus in all the experimental animals. Similar observation was made by Akbar and Gupta (1990) in their study with faba bean (Vicia faba. L) in buffalo calves.

Yadav et al. (1990) reported positive balance for calcium and phosphorus in goats fed with Leucaena leucocephala. Nath (1983) is of the opinion that tannins do not affect calcium and phosphorus balance but he suggested more controlled studies in this regard. The availability of sulphur was found to be decreased in sheep with mulga (Acacia aneura) leaves containing tannin (Gartner and Hurwood, 1976). Kumar and Vaithiyanathan (1990) suggested that methionine acts as a methyl donor to inactivate tannins, though the role of sulphur is not well under stood. The above workers also observed that phenolic groups of tannin molecules associate with minerals and influence their utilisation, the mineral salt of tannic acid precipitating differentially at different pH values.

2.3.6. Animal productivity

The tannins present in various tree leaves are reported to decrease the voluntary feed intake, diminishing the utilisation of nutrients and cause toxicity and thus cumulatively have a negative influence upon the productivities of animals (Kumar and Vaithiyanathan, 1990). Sadanandan and Arora (1976) observed reduced growth rate and feed conversion in rats fed diets containing tannic acid. Marquardt et al. (1977) stated that condensed tannin was the major growth inhibitory substance causing depressed growth rate and reduced efficiency of feed utilisation in chicks fed water extract of faba bean (*Vicia faba* L.*Varminor*). Panda et al. (1983) recorded loss in body weights of goats when *Eugenia jambolana* leaves with 6.5 percent tannin were given as sole feed for seven days. Barry (1985) showed that high concentrations (7.6-9.0 percent) of tannin prevented maximum expression of live weight gain and decreased wool growth in growing sheep. Loss in body weight has also been reported when sheep were fed solely on pala leaves (Ziziphus nummularia) by Bhatia et al. (1991). Upadhyay et al. (1974) reported loss of body weight by feeding Leucaena leucocephala. Joshy and Upadhyay (1976) reported loss of fleece in sheep fed Leucaena leucocephala. Jones (1979) reported better live weight gain in ruminants when Leucaena leucocephala was added in ration, but at higher levels of inclusion, the dry matter intake was reduced. The large size and reactivity of tannin molecule prevents its direct absorption from the digestive tract. Hydrolysable tannins can be broken down in the intestine to the constituent phenols and sugar which are then absorbed. Absorbed phenols are usually detoxicated by means of conjugation of hydroxyl group with gluconates or sulphate ions but other reactions such as hydroxylation and methylation are possible depending on the species of the animal (McLeod, 1974). Both the condensed and hydrolysable tannins are reported to cause toxic effect (Kumar and Vaithiyanathan, 1990). The same authors reported that condensed tannins readily combine with dietary protein, salivary protein, digestive enzymes and rumen microbes and that these proteins bound with tannins are most unlikely to undergo normal metabolism. Condensed tannins are not broken down in the digestive tract and are unlikely to pass through the gut wall (McLeod, 1974). He also found that feeding with large quantities give rise to gastritis, intestinal irritation and liver and kidney damage, if detoxifying mechanisms are inadequate. Free tannins when they escape to blood can cause damage to certain vital organs (Singh and Menke, 1986). The hydrolysable products of hydrolysable tannins viz. gallic acid, hexahydroxydiphenic acid or ellagic acid when absorbed, caused several toxic manifestations (Van Hoven, 1984).

Nath (1983) opined that depending on the level of tannins in the diet tannins may not always be harmful in as much as they may protect proteins from rapid deamination by inhibiting deaminating bacteria or by forming protein complexes. He concluded that the level and type of tannins will perhaps determine the extent to which the digestion of protein in ruminant can be affected since hydrolysable tannins form complex with the proteins and protect them from bacterial deamination in the rumen. The threshold level of toxicity of tannic acid added directly to rumen contents in fistulated animals was three to five percent in cattle, but eight to ten percent in goats because goats produce an active tannase in the rumen mucosa (Begovic et al. 1978). High tannin containing leaves are reported to produce flaky sediments in the urine with an appreciable amount of protein and development of oedema in the submandibular region (Lohan et al. 1983). Horwood (1970) reported that dietary proteins are used effectively by ruminants if protected against bacterial degradation in the rumen, this being done by treating feed proteins with tannins, Since condensed tannins may bind the protein irreversibly making them indigestible (Zelter et al., 1970). The use of tannins for protein protection is restricted to hydrolysable tannins (McLeod 1974). Lohan and Negi (1981), suggested that the partitioning of tannins in tree fodders into condensed and hydrolysable forms will be useful in selection of species in which the tannins are present predominantly in a useful or innocuous form viz. hydrolysable form. The natural occurrence of tannins, in addition to protecting animals from bloat, could have a direct nutritional benefit by protecting leaf protein from degradation in rumen (Mangan, 1988). Reid et al. (1976) in their study in sheep reported that the nitrogen of sainfoin with 1.0 to 1.5 percent condensed tannin was not digested in the stomach and more was digested in the intestine than nitrogen of white clover. Waghorn (1990), opined that condensed tannins are not toxic to ruminants and when the concentration is below four percent of the dry matter they improve the nutritive value of herbage by binding to plant protein and protecting them from excessive degradation in rumen. Waghorn et al. (1991) suggested that a concentration upto 2-3 percent of dietary dry matter are probably optimal for maximising the nutritive value and only values exceeding 5.5 percent of dry matter inhibit microbial activity.

Materials and Methods

MATERIALS AND METHODS

The studies carried out during the course of the present investigation are described under:

3.1. Chemical analysis of different fodders commonly fed to goats for proximate principles, and tannin contents and identifying the tannin rich fodders

3.2. Feeding experiments involving digestion cum metabolism trial with selected tannin rich fodders to assess their nutrient availability in goats

Fourteen different locally available fodders commonly fed to goats were collected and analysed for their proximate principles, (AOAC, 1990) total tannin (Folin and Denis, AOAC, 1990) and condensed tannins (Kumar and Patnayak, 1986). Four fodder varieties viz. Subabul (*Leucaena leucocephala*), jack (*Artocarpus heterophyllus*), venga (*Pterocarpus marsupium*) and banana(*Musa paradiosiaca*) leaves, selected on the basis of their tannin contents and also on palatability and availability were used for the feeding experiments in the present investigation.

3.3. Six adult healthy female cross-bred (Saanen X Malabari) goats of approximately two - two and half years of age and of almost uniform body weight, maintained at the University Goat Farm, formed the experimental subjects for the study.

3.4. Methods

3.4.1. Feeding trials

In each digestion cum metabolism trial the animals were subjected to a preliminary feeding period of three weeks followed by a collection period of five days.

During the feeding trial the animals were fed solely on the fodder under investigation. Fresh leaves collected daily in the morning were used for feeding. Every day at 10 a.m. each animal was fed individually with weighed quantities of fodder, the quantity provided being enough for *ad libitum* consumption. At the same time, residue left behind from the previous day's feed was removed quantitatively and weighed. The animals were always provided with clean drinking water *ad libitum*. Records of daily fodder and water consumption and weekly body weights were maintained throughout the experimental period.

During the collection period, the animals were kept in metabolism cages specially constructed for goats, with all facilities for feeding and watering and collection of dung and urine uncontaminated with any feed residue or dirt. Representative samples of the leaves were taken daily for estimation of dry matter. Representative samples of balance fodder from the previous day were also collected daily to arrive at the total dry matter consumption. The dung was collected manually as and when it was voided. The dung collected each day was weighed accurately, mixed thoroughly and a representative sample at the rate of one tenth of the total quantity was stored in a deep freezer. The samples obtained during the entire collection period were later pooled and used for chemical analysis. The urine was collected in amber coloured bottles containing sufficient quantities of 25 percent sulphuric acid as the preservative. The total quantity collected each day was measured accurately and an aliquot at the rate of one tenth of the total volume was stored in amber coloured bottles under refrigeration. The pooled samples of urine from the five days collection were used for further chemical analysis. Blood samples were collected from all the animals at the end of each collection period using sodium citrate as anti-coagulant for the determination of normal physiological parameters.

The feed and dung samples collected during the metabolism trial were subjected to proximate analysis as per standard procedures (AOAC, 1990). The methods suggested by Van Soest and Wine (1967) and Van Soest (1963) were followed for the estimation of the neutral detergent fibre and acid detergent fibre content of the four selected fodders. The nitrogen content of urine was determined by Kjeldhal method (AOAC, 1990).

Haemoglobin was estimated by cyanmethaemoglobin method (Benjamin, 1974). Biuret method (Gornall et al., 1949) was employed for the determination of plasma protein. Plasma calcium and calcium content of leaves and dung were estimated using ElmerParker atomic absorption spectrophotometer employing hollow calcium cathode tubes. Inorganic phosphorus in plasma and phosphorus content of urine were estimated by the modified metol method using phosphorus kit supplied by Stangen immuno-diagnostics. The colorimetric method suggested by Ward and Johnston (1962) was followed for the determination of phosphorus content of leaves and dung, using spectronic-20.

The results were statistically analysed as per standard procedures (Snedecor and Cochran, 1967).

Results

RESULTS

The results obtained during the course of the present investigation are detailed under the following heads.

4.1. Chemical composition

The chemical composition of 14 locally available fodders commonly fed to goats are presented in Table 1. The chemical composition of the four selected fodders along with their fibre fraction are given in Table 2.

4.2. Tannin contents

The total tannin, condensed tannin and hydrolysable tannin contents of the 14 fodders are presented in Table 3.

4.3. Digestion cum balance experiments

Data on the dry matter intake, digestibility coefficients of nutrients, balance of nitrogen, calcium and phosphorus and haematological values of the goats fed the four fodders are set out in Tables 4 to 19.

4.4. Influence of nature and level of tannins on feed intake and nutrient utilisation in goats

4.4.1. Dry matter intake

The summarised data on dry matter intakes of goats (kg/100 kg body weight and g per metabolic live weight) fed the four fodders are given in Table 20 and 22 and their statistical analysis in Tables 21 and 23 respectively.

4.4.2. Water intake

The summarised data on water intake of goats fed the four leaves and its statistical analysis are given in Tables 24 and 25.

4.5. Digestibility and balance of nutrients

4.5.1. Dry matter

Summarised data on the digestibility coefficients of dry matter in the four leaves are given in Table 26 and their statistical analysis in Table 27.

4.5.2. Crude protein

Summarised data on the crude protein digestibility of the four selected fodders are given in Table 28 and their statistical analysis in Table 29.

4.5.3. Nitrogen Balance

Tables 30 and 31 give the summarised data on nitrogen balance of goats fed the four fodders and their statistical analysis respectively.

4.5.4. Crude fibre

Table 32 shows the summarised data on digestibility coefficients of crude fibre in the four fodders and the corresponding statistical analysis is presented in Table 33.

4.5.5. Ether extract

The summarised data on the digestibility coefficients of ether extract of the four selected fodders are given in Table 34 and their statistical analysis in Table 35.

4.5.6. Nitrogen free extract

The average digestibility coefficients of nitrogen free extract of the four fodders are presented in Table 36 and their statistical analysis in Table 37.

4.6.7. Calcium and Phosphorus balance

Summarised data on the calcium and phosphorus balances (g/day) of goats fed the four fodders are detailed in Tables 38 and 40 and their statistical analysis in Tables 39 and 41 respectively.

4.7. Haematological values

Summarised data on the haematological constituents, hemoglobin (g/100 ml), Plasma protein (g/100 ml) Plasma Calcium (mg/100 ml) and Plasma inorganic phosphorus of goats fed the four fodders are set out in Tables 42, 44, 46 and 48 and their statistical analysis in Tables 43, 45, 47 and 49 respectively.

Table 1. Percent chemical composition of locally available fodders commonly fed to goats (on dry matter basis)

Species of fodder	Dry Matter	Crude Protein	Crude Fibre	Ether Extract	Total Ash	Nitrogen free extract	Calcium	Phosphorus
1. Arayal (*Ficus religiosa*)	30.2	13.7	27.3	1.8	4.9	53.0	1.18	0.20
2. Kirni (*Manilkhra hexandra*)	28.3	15.3	8.3	1.4	6.5	68.0	1.30	0.15
3. Kaini (*Bridelia rhetusa*)	32.5	8.2	24.9	4.6	4.2	58.1	1.20	0.10
4. Poovam (*Schleichera trijuga*)	29.5	11.5	15.9	3.1	4.8	64.7	1.21	0.14
5. Athi (*Ficus ráceemosa*)	32.6	10.4	14.1	0.5	4.6	70.4	1.10	0.20
6. Peral (*Ficus bengalensis*)	35.0	21.3	10.3	1.9	4.5	62.0	1.28	0.10
7. Amapatty (*Trema orientalis*)	37.0	12.0	27.4	6.7	9.4	44.5	1.32	0.14

(contd....)

(Table 1 contd.....)

Species of fodder	Dry Matter	Crude Protein	Crude Fibre	Ether Extract	Total Ash	Nitrogen free extract	Calcium	Phosphorus
8. Thanni (Terminalia belerica)	30.8	16.4	14.2	4.7	11.4	53.3	2.00	0.61
9. Sapotta (Achras zapota)	36.8	11.5	23.5	4.6	5.1	55.3	1.20	0.12
10. Star apple (Donella roxburgdii)	34.8	8.8	27.3	3.1	5.0	55.8	1.20	0.42
11. Subabul (Leucaena leucocephala)	34.5	23.9	18.4	7.4	10.4	39.9	1.70	0.24
12. Jack (Artocarpus heterophyllus)	54.5	15.1	18.0	4.0	10.4	52.5	1.40	0.32
13. Venga (Pterocarpus marsupium)	58.3	14.9	26.3	4.2	10.5	44.1	1.50	0.21
14. Banana (Musa paradiosiaca)	25.9	12.1	23.0	5.8	7.7	51.4	1.20	0.52

Table 2. Chemical composition, fibre fractions and total tannin, condensed tannin and hydrolysable tannin contents of subabul, jack, venga and banana leaves (percent on dry matter basis)

Species of fodder	Dry Matter	Crude Protein	Crude Fibre	Ether Extract	Total Ash	Nitrogen free extract	NDF	ADF	Lignin	Cellulose	Hemi-Cellulose	Ca	P	Total tannin	condensed tannin	Hydrolysable tannin
Subabul (*Leucaena leucocephala*)	34.5	23.9	18.4	7.4	10.4	39.9	58.6	31.8	16.3	15.5	26.8	1.7	0.24	5.5	2.9	2.6
Jack (*Artocarpus heterophyllus*)	54.5	15.1	18.0	4.0	10.4	52.5	47.1	30.4	8.2	28.6	16.7	1.4	0.32	4.0	3.4	0.6
Venga (*Pterocarpus marsupium*)	58.3	14.9	26.3	4.2	10.5	40.1	55.2	32.6	14.0	18.6	22.6	1.5	0.21	4.7	3.0	1.7
Banana (*Musa paradiosiaca*)	25.9	12.1	23.0	5.8	7.7	51.4	75.5	53.9	14.0	39.9	21.6	1.2	0.52	3.7	1.6	2.1

Table 3. Total tannin, condensed tannin and hydrolysable tannin (g/loog DM) of locally available fodders commonly fed to goats.

Species of Fodder	Total Tannin	Condensed Tannin	Hydrolysable Tannin
1. Subabul (*Leucaena leucocephala*)	5.5	2.9	2.6
2. Jack (*Artocarpus heterophyllus*)	4.0	3.4	0.6
3. Venga (*Pterocarpus marsupium*)	4.7	3.0	1.7
4. Banana (*Musa paradiosiaca*)	3.7	1.6	2.1
5. Arayal (*Ficus religiosa*)	5.3	4.8	0.5
6. Kirni (*Manilkhra hexandra*)	6.0	2.4	3.6
7. Kaini (*Bridelia rhetusa*)	5.2	3.2	2.0
8. Poovam (*Schleichera trijuga*)	5.7	1.2	4.5
9. Athi (*Ficus raceemosa*)	3.6	3.0	0.6
10. Peral (*Ficus bengalensis*)	2.6	1.4	1.2
11. Amapatty (*Trema orientalis*)	4.2	2.2	2.0
12. Thanni (*Terminalia belerica*)	3.8	1.5	2.3
13. Sapotta (*Achras zapota*)	7.8	6.3	1.5
14. Star apple (*Donella roxburgdii*)	3.6	0.9	2.7

Table 4. Data on the dry matter consumption of goats fed subabul leaves.

Animal No.	Initial body weight (kg)	Body weight at the end of the expt. (kg)	Average body weight (kg)	Average daily dry matter intake (kg)	Dry matter intake - kg per 100kg body weight	Dry matter intake - g/ metabolic live weight (g/W kg 0.75)
0357	31.8	30.0	30.9	0.60	2.0	46
300	28.3	30.8	30.0	0.45	1.5	36
0028	28.0	27.3	27.5	0.62	2.3	52
0032	18.5	18.6	18.6	0.68	3.7	76
0337	29.5	29.5	29.5	0.45	1.5	36
0117	29.0	29.0	29.0	0.71	2.5	58
Mean	27.5	27.5	27.6	0.59	2.2	50.7
SE±	1.9	1.9	1.9	0.05	0.33	0.006

Table 5. Data on digestibility coefficients of nutrients in Subabul leaves

Animal No	Dry matter	Crude Protein	Crude fibre	Ether Extract	Nitrogen free extract
0357	54.0	66.9	54.8	50.7	48.0
300	47.6	63.0	48.9	41.2	50.0
0028	44.2	59.5	49.1	49.2	43.7
0032	43.2	61.2	43.0	42.5	44.0
0337	46.2	57.7	42.9	48.5	44.2
0117	52.6	73.9	55.8	72.6	44.5
Mean	48.0	63.7	49.1	50.7	45.7
SE±	1.8	2.4	2.3	4.6	1.07

DCP and TDN values of subabul leaves (percent)

	On dry basis	On fresh basis
DCP	15.0	5.17
TDN	50.93	17.57

Table 6. Data on balance of nitrogen, calcium and phosphorus (g per day) of goats fed subabul leaves.

Animal No.	Balance of nitrogen	Balance of calcium	Balance of phosphorus
0357	4.9	3.8	-1.9
300	2.1	2.9	-1.9
0028	4.5	3.3	-1.8
0032	3.9	4.3	-0.9
0337	3.8	2.0	-1.2
0117	4.6	3.3	0.03
Mean	4.0	3.3	-1.3
SE±	0.41	0.32	0.49

Table 7. Data on blood values of goats fed subabul leaves

Animal No.	Haemoglobin (g/100 ml)	Plasma protein (g/100 ml)	Plasma calcium (mg/100 ml)	Plasma phosphorus (mg/100 ml)
0357	12.0	7.3	8.2	6.4
300	13.0	7.8	8.5	6.3
0028	10.5	8.1	8.0	6.8
0032	11.5	8.0	8.7	6.0
0337	10.5	7.5	7.5	6.2
0117	10.2	7.6	8.4	6.5
Mean	11.3	7.7	8.2	6.3
SE±	0.14	0.16	0.17	0.5

Table 8. Data on the dry matter consumption of goats fed Jack leaves

Animal No.	Initial body weight (kg)	Body weight at the end of the expt. (kg)	Average body weight (kg)	Average daily dry matter intake (kg)	Dry matter intake - kg per 100kg body weight	Dry matter intake - g/ metabolic live weight (g/W kg 0.75)
0357	30.0	30.6	30.3	0.60	2.0	47
300	30.8	33.0	31.9	0.77	2.4	57
0028	27.3	27.8	27.5	0.72	2.6	60
0032	18.6	21.5	20.1	0.91	4.5	96
0337	29.5	30.7	30.0	0.58	1.9	45
0117	29.0	30.1	29.5	0.63	2.1	50
Mean	27.5	29.0	28.2	0.70	2.6	59.2
SE±	1.9	1.6	1.7	0.05	0.4	0.00

Tabel 9. Data on digestibility coefficients of nutrients in jack leaves

Animal No	Dry matter	Crude Protein	Crude fibre	Ether Extract	Nitrogen free extract
0357	48.5	49.3	70.9	43.1	52.5
300	46.4	56.9	53.9	37.2	66.5
0028	46.7	52.9	51.9	47.2	52.4
0032	54.7	59.2	50.9	47.1	60.1
0337	60.0	45.7	56.3	55.3	62.4
0117	44.4	60.2	54.2	53.4	41.2
Mean	50.1	54.0	56.4	47.2	56.0
SE±	2.5	2.4	3.0	2.7	3.6

DCP and TDN values of jack leaves (percent).

	On dry basis	On fresh basis
DCP	8.15	4.44
TDN	51.4	28.00

Table 10. Data on balance of nitrogen, calcium and phosphorus (g. per day) of goats fed jack leaves.

Animal No.	Balance of nitrogen	Balance of calcium	Balance of phosphorus
0357	2.6	5.6	0.3
300	5.7	4.8	1.9
0028	5.7	4.9	0.5
0032	6.4	9.2	1.7
0337	6.3	4.6	1.6
0117	4.3	5.6	0.6
Mean	5.2	5.8	1.1
SE±	0.59	0.08	0.28

Table 11. Data on blood values of goats fed jack leaves

Animal No.	Haemoglobin (g/100 ml)	Plasma protein (g/100 ml)	Plasma calcium (mg/100 ml)	Plasma phosphorus (mg/100 ml)
0357	11.8	8.0	8.6	6.8
300	12.8	7.5	8.2	7.0
0028	12.4	7.8	8.4	6.4
0032	11.5	7.4	8.2	6.6
0337	11.0	7.5	10.1	6.5
0117	11.5	7.3	9.0	6.1
Mean	11.7	7.6	8.8	6.6
SE±	0.82	0.09	0.25	0.12

Table 12. Data on the dry matter consumption of goats fed venga leaves

Animal No.	Initial body weight (kg)	Body weight at the end of the expt. (kg)	Average body weight (kg)	Average daily dry matter intake (kg)	Dry matter intake - kg per 100kg body weight	Dry matter intake - g/ metabolic live weight (g/w kg 0.75)
0357	30.6	30.3	30.4	0.46	1.5	36
300	33.0	31.9	32.5	0.38	1.2	28
0028	27.8	27.9	27.8	0.51	1.8	42
0032	21.5	21.7	21.6	0.59	2.7	59
0337	30.7	30.8	30.7	0.35	1.1	27
0117	30.7	30.8	30.4	0.63	2.1	49
Mean	29.1	28.4	28.9	0.49	1.73	40.2
SE±	1.65	1.54	1.58	0.05	0.25	0.004

Table 13.Data on digestibility coefficients of nutrients in goats fed venga leaves.

Animal No	Dry matter	Crude Protein	Crude fibre	Ether Extract	Nitrogen free extract
0357	59.0	41.5	57.1	34.5	53.0
300	51.0	59.2	50.0	50.1	55.5
0028	63.2	59.9	61.6	68.8	62.5
0032	44.6	42.7	40.4	50.9	59.1
0337	65.1	56.6	65.1	76.7	60.3
0117	36.3	56.5	41.1	35.7	65.0
Mean	53.2	52.7	52.5	52.8	59.2
SE$\pm$	4.6	2.4	4.3	6.4	1.65

DCP and TDN values of venga leaves(percent)

	On dry basis	On fresh basis
DCP	7.83	4.56
TDN	60.4	35.21

Table 14. Data on balance of nitrogen, calcium and phosphorus (g. per day) of goats fed venga leaves.

Animal No.	Balance of nitrogen	Balance of calcium	Balance of phosphorus
0357	3.4	3.1	-2.5
300	0.002	2.2	-1.2
0028	0.4	3.7	0.07
0032	3.0	4.4	-1.2
0337	5.3	5.4	0.2
0117	2.8	5.4	-0.9
Mean	2.5	4.0	-0.9
SE$\pm$	0.81	0.26	0.40

Table 15. Data on blood values of goats fed venga leaves

Animal No.	Haemoglobin (g/100 ml)	Plasma protein (g/100 ml)	Plasma calcium (mg/100 ml)	Plasma phosphorus (mg/100 ml)
0357	11.0	7.2	9.3	7.1
300	10.5	7.0	8.3	6.8
0028	11.5	7.2	8.4	6.6
0032	11.5	7.2	8.9	6.5
0337	11.5	7.3	8.6	6.4
0117	11.0	7.0	9.2	6.2
Mean	11.2	7.2	8.8	6.6
SE±	0.1	0.04	0.17	0.35

Table 16. Data on the dry matter intake of goats fed banana leaves

Animal No.	Initial body weight (kg)	Body weight at the end of the expt. (kg)	Average body weight (kg)	Average daily dry matter intake (kg)	Dry matter intake - kg per 100kg body weight	Dry matter intake - g/ metabolic live weight (g/w kg 0.75)
0357	30.3	29.5	30.0	0.41	1.4	32
300	31.9	31.6	31.7	0.51	1.6	38
0028	27.9	27.7	27.8	0.50	1.8	41
0032	21.7	21.5	21.6	0.42	1.9	42
0337	30.8	31.5	30.5	0.41	1.3	32
0117	30.8	27.4	28.7	0.55	1.9	40
Mean	28.9	28.1	28.4	0.47	1.7	37.5
SE±	1.5	1.5	1.5	0.03	0.11	1.92

Table 17. Data on digestibility coefficients of nutrients in banana leaves.

Animal No	Dry matter	Crude Protein	Crude fibre	Ether Extract	Nitrogen free extract
0357	56.4	60.1	65.5	31.5	58.7
300	70.7	75.8	79.1	57.2	70.8
0028	65.2	67.1	79.6	48.3	64.8
0032	76.9	86.3	81.8	65.9	77.0
0337	69.7	71.8	78.0	58.1	70.3
0117	74.2	74.8	77.7	68.9	76.5
Mean	68.9	72.7	76.9	54.0	69.7
SE$\pm$	3.0	3.6	2.4	5.1	2.9

DCP and TDN values of banana leaves (percent).

	On dry basis	On fresh basis
DCP	8.77	2.27
TDN	71.66	18.56

Table 18. Data on balance of nitrogen, calcium and phosphorus (g. per day) of goats fed banana leaves.

Animal No.	Balance of nitrogen	Balance of calcium	Balance of phosphorus
0357	4.0	5.2	0.3
300	1.9	4.2	1.1
0028	1.8	5.0	0.8
0032	3.1	4.2	1.2
0337	2.0	4.8	0.5
0117	4.6	4.2	1.1
Mean	2.9	4.6	0.8
SE±	0.49	0.09	0.15

Table 19. Data on the blood values of goats fed banana leaves

Animal No.	Haemoglobin (g/100 ml)	Plasma protein (g/100 ml)	Plasma calcium (mg/100 ml)	Plasma phosphorus (mg/100 ml)
0357	10.4	7.5	9.4	6.8
300	11.0	7.2	8.6	7.1
0028	10.6	7.1	7.9	6.6
0032	11.0	7.6	10.8	6.5
0337	11.0	7.4	9.8	6.6
0117	11.5	7.3	9.8	6.5
Mean	10.9	7.4	9.4	6.7
SE±	0.16	0.07	0.4	0.09

Table 20. Summarised data on dry matter intake of goats (kg/100 kg body weight) fed subabul, jack, venga and banana leaves.

Animal No.	Subabul	Jack	Venga	Banana
0357	2.0	2.0	1.5	1.4
300	1.5	2.4	1.2	1.6
0028	2.3	2.6	1.8	1.8
0032	3.7	4.5	2.7	1.9
0337	1.5	1.9	1.1	1.3
0117	2.5	2.1	2.1	1.9
Mean	2.25	2.58	1.73	1.65
SE±	0.33	0.39	0.24	0.10

Fig.2. The average dry matter intake (kg/100 kg body weight) of goats fed the four fodders

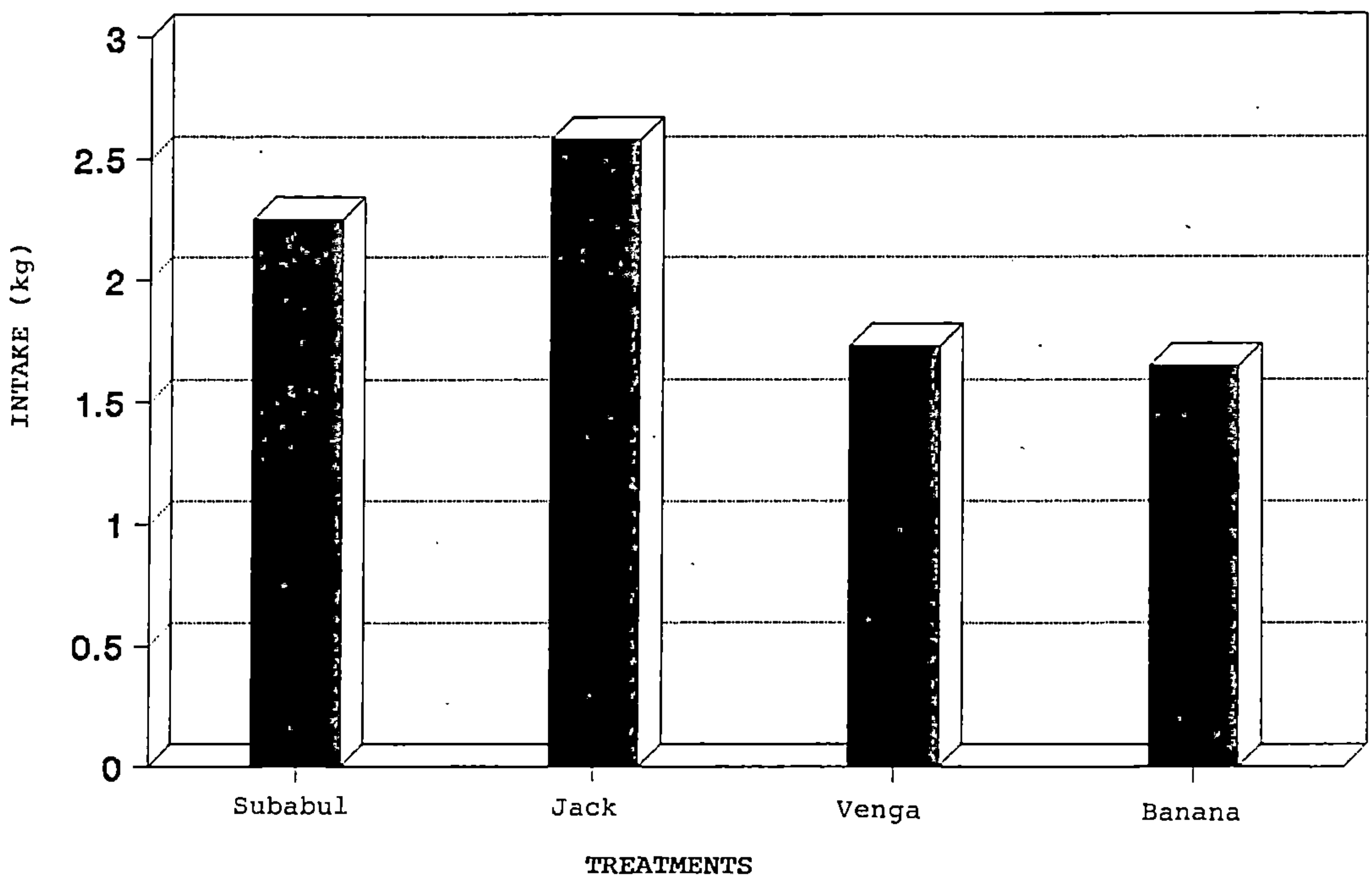

Table 21. Analysis of variance-Dry matter intake (kg/100 body weight) of goats fed the four fodders

Source	df	SS	MSS	F
Treatment	3	3.508	1.169	2.281^{NS}
Error	20	10.252	0.513	
Total	23			

NS - Not significant

Table 22. Summarised data on dry matter intake of goats (g/kg metabolic live weight) fed subabul, jack, venga and banana leaves.

Animal No.	Subabul	Jack	Venga	Banana
0357	46	47	36	32
300	36	57	28	38
0028	52	60	42	41
0032	76	96	59	42
0337	36	45	27	32
0117	58	50	49	40
Mean	50.7	59.2	40.2	37.5
SE±	6.18	7.73	5.08	1.82

Fig.1. The average dry matter intake (g/metabolic live weight) of goats fed the four fodders

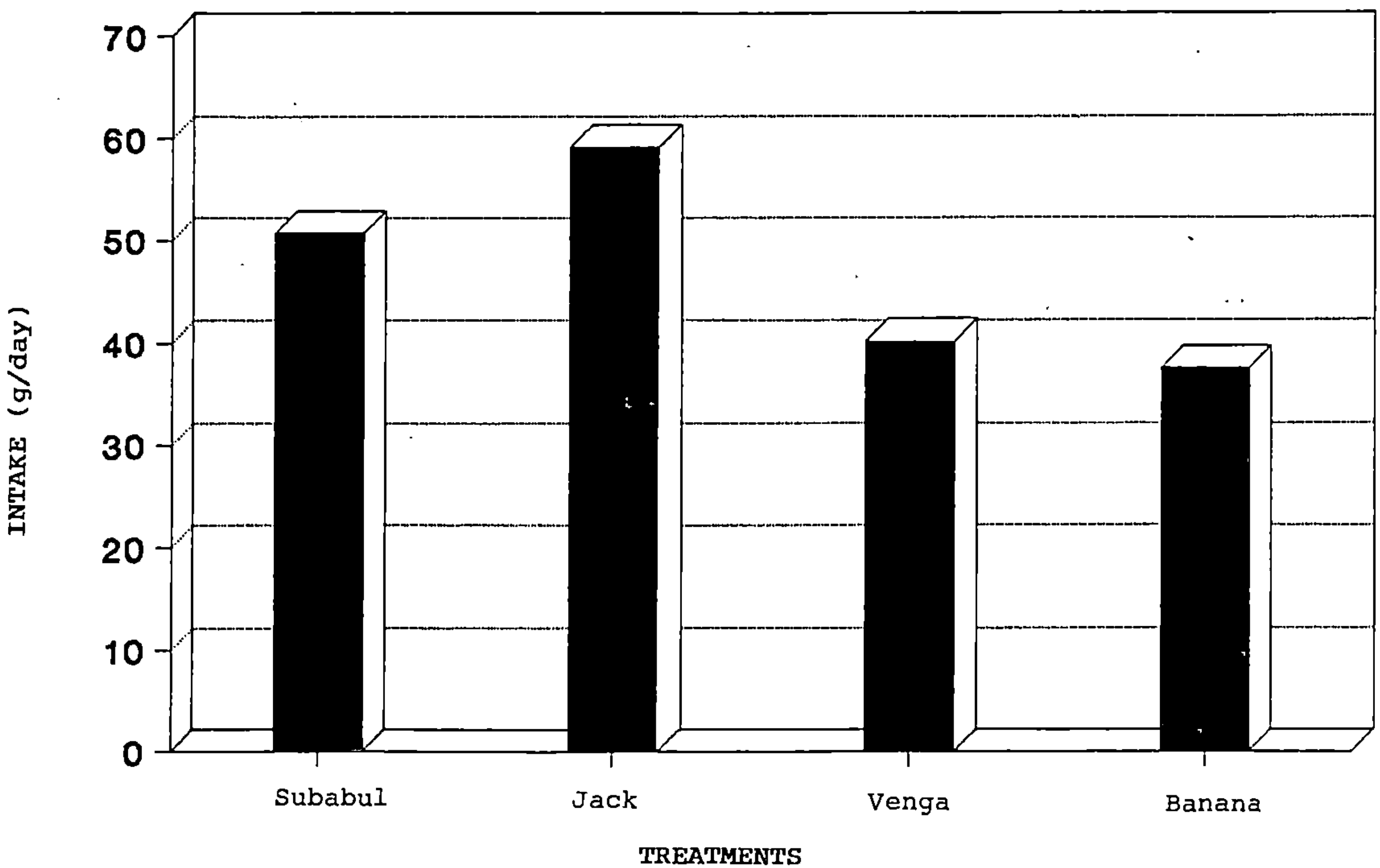

Table 23. Analysis of variance - dry matter intake (g/kg metabolic live weight) of goats fed the four fodders

Source	df	SS	MSS	F
Treatment	3	1790.123	596.708	3.13*
Error	20	3818.5	190.925	
Total	23			

* (P < 0.05)

Table 24. Summarised data on the daily water intake (l/day) of goats fed subabul, jack, Venga and banana leaves.

Animal No.	Subabul	Jack	Venga	Banana
0357	1.15	0.85	0.78	0.25
300	0.68	0.50	0.18	0.40
0028	0.91	0.70	0.46	0.75
0032	1.30	0.80	0.82	0.10
0337	0.54	0.60	0.05	0.80
0117	1.01	0.70	0.62	0.65
Mean	0.93	0.70	0.48	0.49
SE±	0.09	0.04	0.10	0.09

Table 25. Analysis of variance - daily water intake

Source	df	SS	MSS	F
Treatment	3	0.813	0.271	3.769**
Error	20	1.438	0.072	
Total	23			

** (P < 0.01)

Table 26. Summarised data on digestibility coefficients of dry matter in subabul, jack, venga and banana leaves.

Animal No.	Subabul	Jack	Venga	Banana
0357	54.1	48.5	59.0	56.4
300	47.6	46.4	51.0	70.7
0028	44.2	46.7	63.2	65.2
0032	43.2	59.7	44.6	76.9
0337	46.2	60.0	65.1	69.7
0117	52.5	44.4	36.3	74.2
Mean	48.0	51.0	53.2	68.9
SE±	1.9	2.5	4.03	3.98

Fig.3. The average dry matter digestibility in goats fed the four fodders

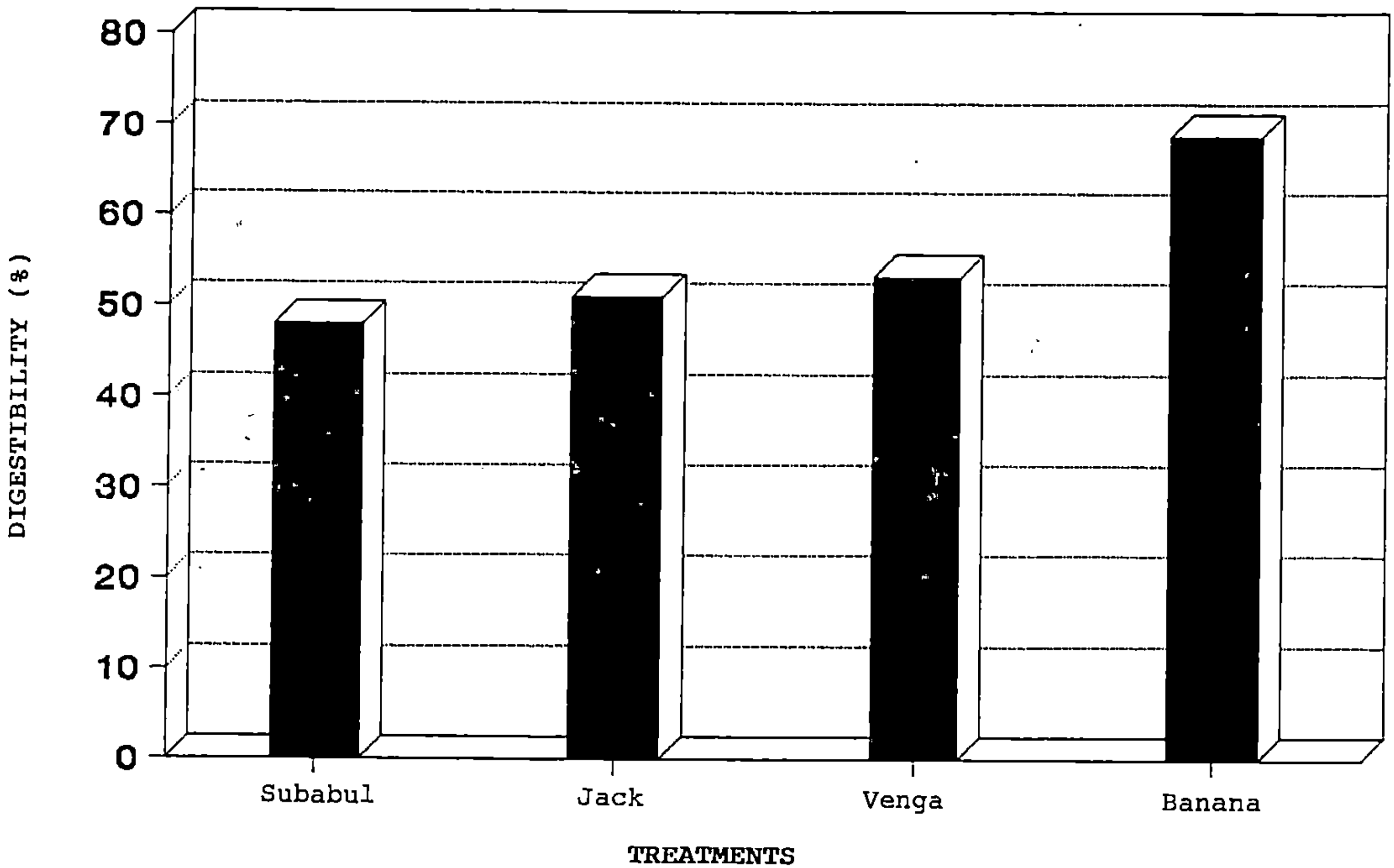

Table 27. Analysis of variance-Dry matter digestibility in goats fed the four fodders

Source	df	SS	MSS	F
Treatment	3	199.7	66.5	1.71^{NS}
Error	20	777.0	38.9	
Total	23			

NS - Not significant

Table 28. Summarised data on digestibility coefficients of crude protein in subabul, jack, venga and banana leaves.

Animal No.	Subabul	Jack	Venga	Banana
0357	66.9	49.3	41.5	60.1
300	63.0	56.9	59.2	75.8
0028	59.5	52.6	59.9	67.1
0032	61.2	59.2	42.7	86.8
0337	57.7	45.7	56.6	71.8
0117	73.9	60.2	56.5	74.8
Mean	63.7	54.0	52.7	72.7
SE$\pm$	2.4	2.4	2.4	3.6

Fig.4. The average crude protein digestibility in goats fed the four fodders

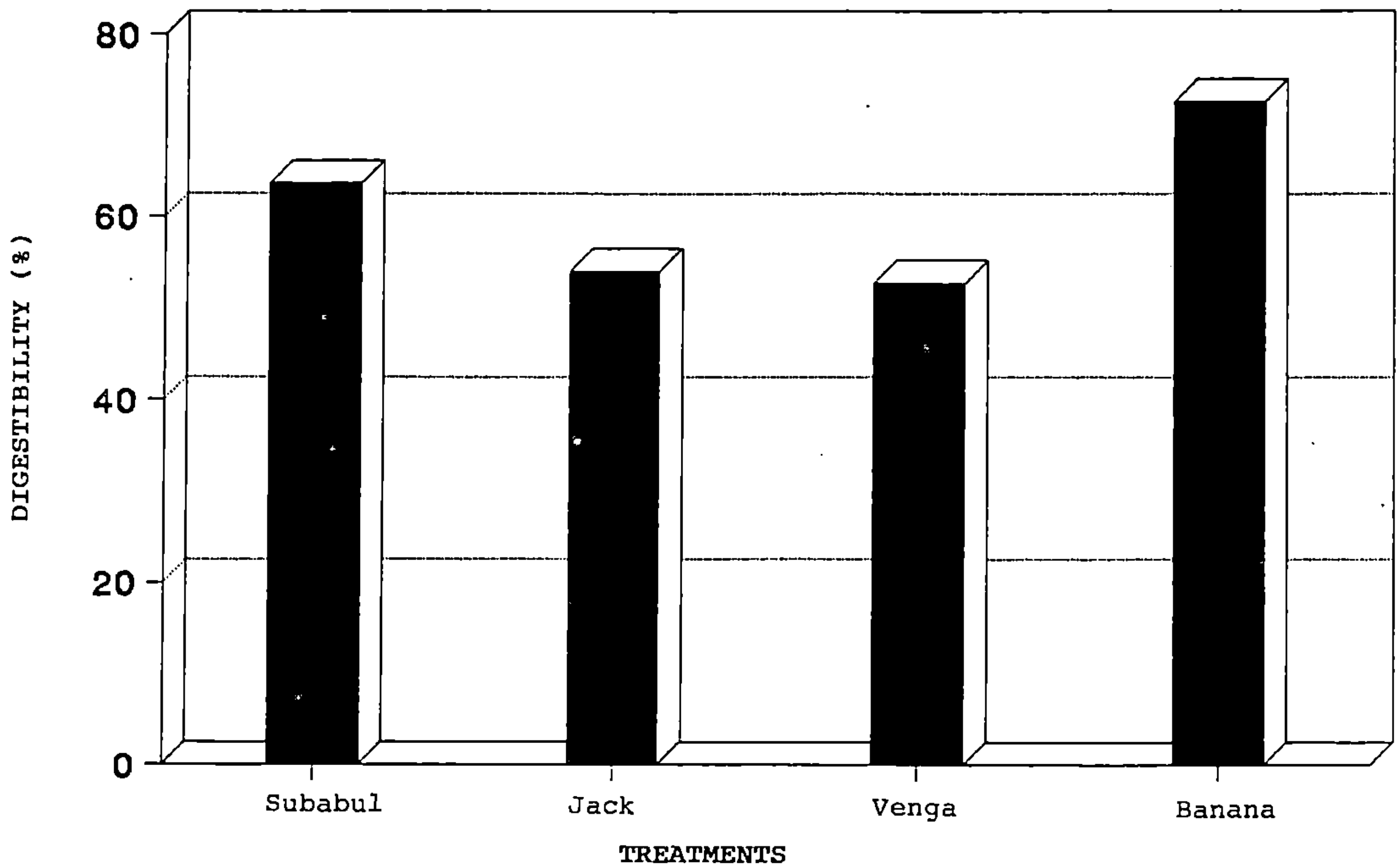

Table 29. Analysis of variance - Crude protein digestibility in goats fed the four fodders

Source	df	SS	MSS	F
Treatment	3	422.836	140.945	2.3189 NS
Error	20	1215.617	60.7809	
Total	23			

NS - Not significant

Table 30. Summarised data on nitrogen balance (g per day) of goats fed subabul, jack, venga and banana leaves.

Animal No.	Subabul	Jack	Venga	Banana
0357	4.93	2.6	3.4	4.0
300	2.1	5.7	0.002	1.9
0028	4.5	5.7	0.4	1.8
0032	3.9	6.4	3.0	3.1
0337	3.8	6.3	5.3	2.0
0117	4.6	4.3	2.8	4.6
Mean	4.0	5.2	2.5	2.9
SE±	0.41	0.59	0.81	0.49

Table 31. Analysis of variance-Nitrogen balance of goats fed the four fodders

Source	df	SS	MSS	F
Treatement	3	25.939	8.646	4.59**
Error	20	42.605	2.130	
Total	23			

** Significant at 1 % level

Fig.5. The average nitrogen balance (g/day) of goats fed the four fodders

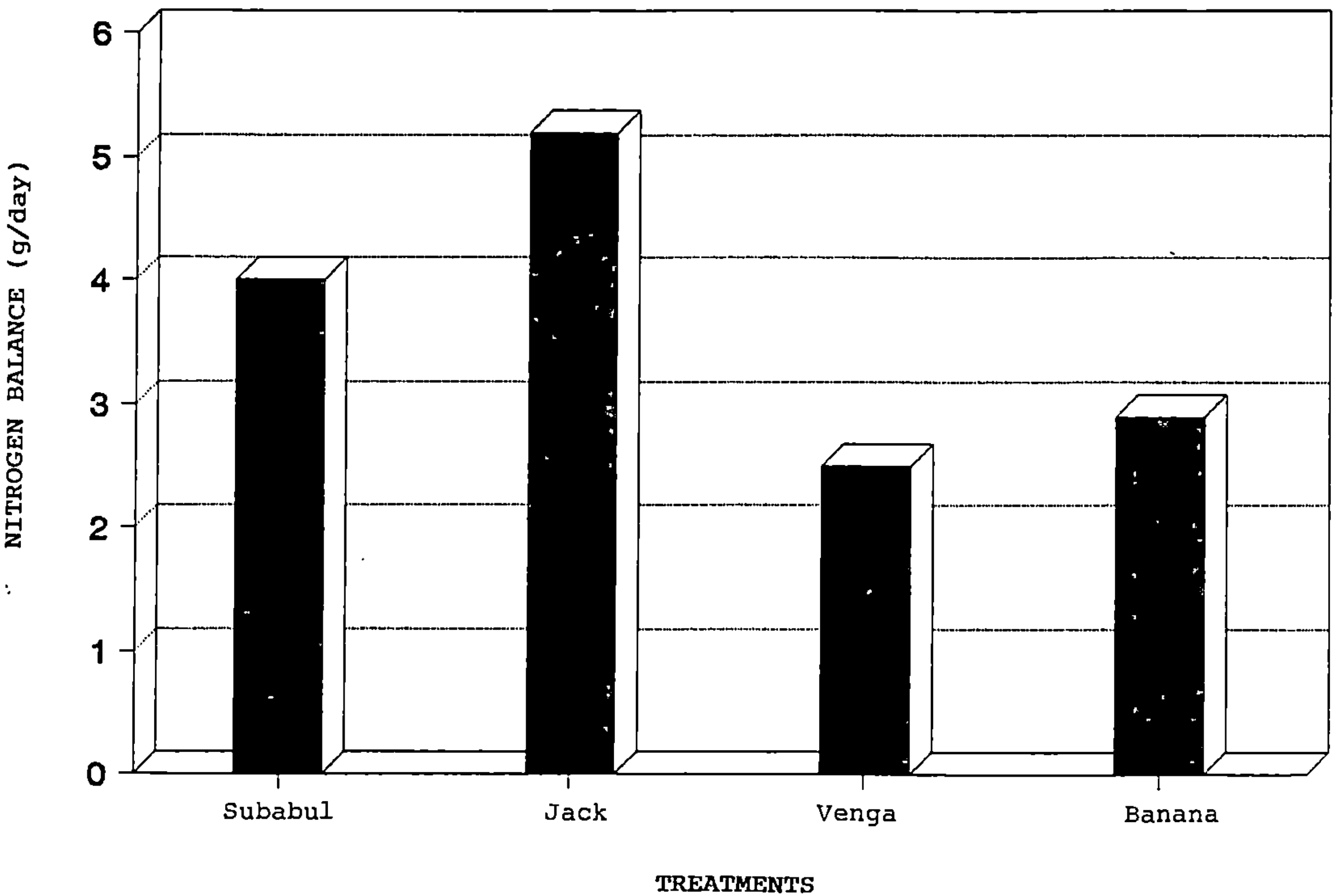

Table 32. Summarised data on digestibility coefficients of crude fibre in goats fed subabul, jack, venga and banana leaves.

Animal No.	Subabul	Jack	Venga	Banana
0357	54.8	70.9	57.1	65.5
300	48.9	53.9	50.0	79.1
0028	49.1	51.9	61.6	79.6
0032	43.0	50.9	40.4	81.8
0337	42.9	56.3	65.1	78.0
0117	55.8	54.2	41.1	77.1
Mean	49.0	56.4	52.6	76.9
SE±	2.3	3.0	4.3	2.4

Table 33. Analysis of variance - Crude fibre digestibility in goats fed the four fodders

Source	df	SS	MSS	F
Treatement	3	779.769	259.92	2.192[NS]
Error	20	2371.582	118.5791	
Total	23			

NS - Not significant

Table 34. Summarised data on digestibility coefficients of Ether extract in subabul, jack, venga and banana leaves.

Animal No.	Subabul	Jack	Venga	Banana
0357	50.7	43.1	34.5	31.5
300	41.2	37.2	50.1	57.2
0028	49.2	47.2	68.8	48.2
0032	42.5	47.1	50.9	65.9
0337	48.5	55.3	76.7	58.1
0117	72.6	53.4	35.7	63.9
Mean	50.8	47.2	52.8	54.1
SE±	4.6	2.7	2.7	5.1

Table 35. Analysis of variance - Ether extract digestibility in goats fed the four fodders

Source	df	SS	MSS	F
Treatement	3	162.763	54.25	0.34[NS]
Error	20	3116.374	185.82	
Total	23			

NS - Not significant

Table 36. Summarised data on digestibility coefficients of nitrogen free extrct in subabul, jack, venga and banana leaves.

Animal No.	Subabul	Jack	Venga	Banana
0357	48.0	52.5	53.0	58.7
300	50.0	66.5	55.5	70.8
0028	43.7	52.4	62.5	64.8
0032	44.0	60.1	59.1	77.0
0337	44.2	62.4	60.3	70.3
0117	44.5	41.7	65.0	76.5
Mean	45.7	55.9	59.2	69.5
SE$\pm$	1.1	3.6	2.1	2.9

Table 37. Analysis of variance - Nitrogen free extract digestibility in goats fed the four fodders

Source	df	SS	MSS	F
Treatement	3	1728.13	576.04	12.24**
Error	20	941.5	47.076	
Total	23			

** - (P<0.01)

Table 38. Summarised data on the calcium balance (g/day) of goats fed subabul, jack, venga and banana leaves.

Animal No.	Subabul	Jack	Venga	Banana
0357	3.8	2.8	1.6	2.6
300	2.9	2.4	1.1	2.1
0028	3.3	2.5	1.8	2.5
0032	4.3	2.6	2.2	2.1
0337	2.0	2.3	2.7	2.4
0117	3.3	2.8	2.7	2.1
Mean	3.3	2.6	2.2	2.3
SE±	0.32	0.08	0.26	0.09

Table 39. Analysis of variance-Calcium balance of goats fed four fodders

Source	df	SS	MSS	F
Treatement	3	5.161	1.72	6.15**
Error	20	5.595	0.28	
Total	23			

** - (P<0.01)

Table 40. Summarised data on the phosphorus balance of goats fed subabul, jack, venga and banana leaves.

Animal No.	Subabul	Jack	Venga	Banana
0357	-1.9	0.3	-2.5	0.3
300	-1.93	1.9	-1.2	1.1
0028	-1.8	0.5	0.07	0.8
0032	0.9	1.7	-1.2	-1.2
0337	-1.2	1.6	0.2	0.5
0117	0.03	0.7	-0.9	1.1
Mean	-1.3	1.1	-0.1	0.8
SE±	0.49	0.28	0.40	0.15

Table 41. Analysis of variance-Phosphorus balance of goats fed the four fodders

Source	df	SS	MSS	F
Treatement	3	22.488	7.496	9.959**
Error	20	15.054	0.753	
Total	23			

** (P<0.01)

Table 42. Summarised data on the blood values of goats fed subabul, jack, venga and banana leaves - Haemoglobin (g/100 ml).

Animal No.	Subabul	Jack	Venga	Banana
0357	12.0	11.8	11.0	10.4
300	13.0	12.2	10.5	11.0
0028	10.5	12.4	11.5	10.6
0032	11.5	11.5	11.5	11.0
0337	10.5	11.0	11.5	11.0
0117	10.2	11.5	11.0	11.5
Mean	11.2	11.7	11.2	10.9
SE±	0.14	0.21	0.2	0.16

Table 43. Analysis of variance-Haemoglobin level of goats fed the four fodders

Source	df	SS	MSS	F
Treatement	3	2.1016	0.7005	1.6005^{NS}
Error	20	8.7534		
Total	23			

NS - Not significant

Table 44. Summarised data on the blood values of goats fed subabul, jack, venga and banana leaves - Plasma protein (g/100 ml).

Animal No.	Subabul	Jack	Venga	Banana
0357	7.3	8.0	7.2	7.5
300	7.8	7.5	7.0	7.2
0028	8.1	7.8	7.2	7.1
0032	8.0	7.4	7.2	7.6
0337	7.5	7.5	7.3	7.4
0117	7.6	7.3	7.0	7.3
Mean	7.7	7.6	7.2	7.4
SE±	0.61	0.21	0.5	0.25

Table 45. Analysis of variance - Plasma Protein level in goats fed the four fodders

Source	df	SS	MSS	F
Treatement	3	22.34	7.61	2.58 NS
Error	20	58.54	2.95	
Total	23			

NS - Not Significant

Table 46. Summarised data on blood values of goats fed subabul, jack, venga and banana leaves (Plasma Calcium mg/100 ml).

Animal No.	Subabul	Jack	Venga	Banana
0357	8.2	8.6	9.3	9.4
300	8.5	8.2	8.3	8.6
0028	8.0	8.4	8.4	7.9
0032	8.7	8.2	8.9	9.0
0337	7.5	8.9	8.6	8.8
0117	8.4	9.0	9.2	9.2
Mean	8.2	8.6	8.8	8.8
SE±	0.17	0.3	0.17	0.4

Table 47. Analysis of variance-Plasma Calcium of goats fed the four fodders

Source	df	SS	MSS	F
Treatement	3	4.3389	1.4463	2.96[NS]
Error	20	9.7795	0.4889	
Total	23			

NS - Not Significant

Table 48. Summarised data on blood values of goats fed subabul, jack, venga and banana leaves - Plasma inorganic phosphorus mg/100 ml

Animal No.	Subabul	Jack	Venga	Banana
0357	6.4	6.8	7.1	6.8
300	6.3	7.0	6.8	7.1
0028	6.8	6.4	6.6	6.6
0032	6.0	6.6	6.5	6.5
0337	6.2	6.5	6.4	6.6
0117	6.5	6.1	6.2	6.5
Mean	6.3	6.6	6.6	6.7
SE±	0.5	0.12	0.35	0.09

Table 49. Analysis of variance - Plasma inorganic phosphorus of goats fed the four fodders

Source	df	SS	MSS	F
Treatement	3	0.33	0.11	1.35^{NS}
Error	20	1.69	0.0815	
Total	23			

NS - Not significant

Discussion

DISCUSSION

5.1. Chemical composition

The data presented in Table 1 on the chemical composition of the locally available tree leaves commonly fed to goats reveal that the various tree leaves are, in general, higher in dry matter, crude protein and calcium and lower in crude fibre and phosphorus when compared to those reported for the common grass fodders (James et al., 1977; Ranjhan, 1980; Thomas et al., 1981 and James and Gangadevi, 1991). The results on the chemical composition of the four selected fodders viz. subabul, jack, venga and banana reveal that the values are in general agreement with those reported by other workers in this regard (Singh and Mudgal, 1967; Johri et al., 1967; Upadhyay et al., 1974; Devasia et al., 1976; James et al., 1977; James, 1978; Jones, 1979; Kunjikutty et al., 1980; Ranjhan, 1980; Akbar and Gupta, 1985; Reddy et al., 1986; Kumar et al., 1987; Lohan et al., 1990; Yadav et al., 1990; Reddy and Reddy, 1991 and James and Gangadevi, 1991). Minor differences observed in the chemical composition are attributable to the location, stage of maturity and seasonal variations (Lohan et al., 1983; Kumar and Vaithiyanathan, 1990 and Makkar and Singh, 1991). The data given in Table 2 on the fibre fractions with respect to the tree leaves under investigation reveal that these fodders have a comparatively higher lignin content, the concentration ranging from 8.2 to 16.3 percent. Values ranging from 7.6-16.8 percent have been reported in the literature for various tree leaves (Ranjhan, 1980).

5.2. **Tannin content**

The data on the concentration of total tannins, condensed tannins and hydrolysable tannins given in Table 3 indicate that the tree leaves are rather high in total tannin content with the concentration ranging from 2.6 to 7.80 percent on dry matter basis, the result in this regard being in agreement with those of James et al. (1977); Kunjikutty et al. (1980) and Thomas et al. (1981). However, lower values for total tannin content have been observed for subabul leaves by Lohan et al. (1983) and for venga leaves by James and Gangadevi (1991). The minor differences observed by different workers in this regard may be due to location, seasonal differences and the stage of maturity of leaves (Feeney and Bostock, 1969; Lohan et al., 1983; Dogra et al. 1986; Kumar and Vaithiyanathan, 1990 and Makkar and Singh, 1991). The results also reveal that a greater proportion of the total tannins in majority of the tree leaves studied is found to be in the form of condensed tannins. This observation is in keeping with those of McLeod (1974) and Lohan et al. (1983) who reported that the principal forage tannins are of the condensed type. As regards the four fodders selected for the feeding trial, it can be seen that subabul and banana leaves had almost equal proportion of condensed and hydrolysable tannins while jack leaves and venga leaves had more of condensed tannins. The value obtained in the present study in regard to the concentration of condensed tannins in subabul is much higher than those reported by Lohan et al. (1983). However, Scanty literature is available on the extent of different types of tannins in the various tree leaves locally available in Kerala.

5.3. Digestion cum balance experiments

5.3.1. Subabul leaves

The data presented in Table 4 on the average dry matter intake of goats fed subabul leaves reveal that the animals consumed on an average 2.2$\pm$0.33 kg of dry matter per 100 kg body weight, the same per kg metabolic live weight (W $kg^{0.75}$) being 50.7g per day. The results obtained in the present study in this regard are in keeping with those reported by Upadhyay et al. (1974); Joshi and Upadhyay (1976) and Kumar et al. (1987). While a very low dry matter intake of 1.2 kg per 100 kg body weight has been reported by Singh and Mudgal (1967), a higher intake of 72.64 g/kg metabolic live weight has been observed by Balagopal and Ravi (1988) in their feeding experiments with subabul in goats.

The data on results of digestibility trial (Table 5) indicate that the average digestibility coefficients for the various nutrients were 48.0$\pm$1.81; 63.7$\pm$2.4; 49.1$\pm$2.23; 50.7$\pm$4.60 and 45.7$\pm$1.07 for dry matter, crude protein, crude fibre, ether extract and nitrogen free extract respectively, the same being in almost agreement with those observed by Joshi and Upadhyay (1976); Kumar et al. (1987) and Yadav et al. (1990). However, wide variations in the digestibility of dry matter in subabul leaves ranging from 51.44 - 71.36 percent have been reported by Banerjee (1990).

The DCP and TDN values calculated for subabul leaves were found to be 15.0 and 50.93 percent respectively on dry matter basis and 5.17 and 17.25 on fresh basis and are akin to those reported by Yadav et al. (1990). However, lower values have been reported for DCP by Singh and Mudgal (1967) and higher values for TDN by Upadhyay et al. (1974) and James (1978).

From the results obtained on balance studies (Table 6), it can be seen that though all the animals maintained a positive balance for nitrogen and calcium, a negative balance was observed with respect to phosphorus. The results obtained during the present study are in accordance with the observations of Yadav et al. (1990) and Upadhyay et al. (1974) in regard to the balance of nitrogen and calcium, who also could observe a positive balance for phosphorus in their studies with subabul in sheep.

Data given in Table 4 on the body weights of the animals recorded during the feeding trial with subabul indicate that the animals maintained their body weight during the experimental period of about one month. A loss of body weight at the rate of 55 g per day per head has been reported by Upadhyay et al. (1974) in their studies with rams fed subabul as the sole feed for them.

The haematological values viz. hemoglobin, plasma protein, calcium and phosphorus presented in Table 7 reveal that the values obtained for various blood constituents are all well within the physiological range reported for the species (Sastri, 1983 and Schalm, 1961).

5.3.2. Jack leaves

A perusal of the data on the dry matter intake of goats fed jack leaves presented in Table 8 reveals that the animals consumed on an average 2.6 kg dry matter per 100 kg body weight per day, the same expressed on the basis of metabolic live weight (W $kg^{0.75}$) being 59.2 g per day. It is evident that the leaves are quite palatable to goats.

The results on the digestion trial (Table 9) indicate that the digestibility coefficients of dry matter, crude protein, crude fibre, ether extract and nitrogen free extract were 50.1±2.5; 54.0±2.4; 56.4±3.0; 47.2±2.7 and 56.0±3.6 respectively, the same being higher than those reported by Devasia *et al*. (1976) in this regard. The DCP and TDN values worked out for jack leaves as 8.15 and 51.4 percent respectively on dry matter basis and 3.63 and 21.86 on fresh basis compare well with the figures reported by Devasia *et al*. (1976).

Data on the balance of nitrogen, calcium and phosphorus of animals fed jack leaves as the sole fodder presented in Table 10 indicate that all the animals showed positive balance for nitrogen, calcium and phosphorus, the average daily balances being 5.2, 5.8 and 1.1 g respectively.

A perusal of the data on the body weights of the experimental animals (Table 8) reveals that the animals gained in body weight, the average total gain in body weight being 1.5 kg during an experimental period of one month.

From the haematological values of the goats fed jack leaves detailed in Table 11, it can be seen that the values obtained for different blood parameters are all well within the normal ranges reported for the species by Sastri (1983) and Schalm (1961).

5.3.3. Venga leaves

The average dry matter intake of animals fed venga leaves (Table 12) was found to be 1.73 kg and 40.2 g per 100 kg body weight and per kg metabolic live weight respectively. However, Kunjikutty et al. (1980) recorded a higher intake of 4.18 kg dry matter per 100 kg body weight in their study with the same fodder in goats.

The results on digestion trials presented in Table 13 reveal that the average digestibility coefficients of the various nutrients were 53.2±4.6, 52.7±2.4, 52.5±4.3, 52.8±6.4 and 59.2±1.65 for dry matter, crude protein, Crude fibre, ether extract and nitrogen free extract respectively. The values obtained during the present investigation correlate well with those reported by Kunjikutty et al. (1980). The DCP and TDN values for venga leaves obtained in the present study were found to be 7.83 and 60.4 respectively on dry basis (4.56 and 35.21 on fresh basis) which agree well with those reported by Kunjikutty et al. (1980).

Data presented on the balance of nitrogen, calcium and phosphorus in Table 14 indicate that the animals given venga leaves showed positive balance for nitrogen. While all the animals had a positive balance for calcium, the balance of phosphorus was found to be generally negative, a finding which is expected because of the wide ratio of these minerals in these leaves. A similar observation on the balance of nitrogen, calcium and phosphorus has been recorded by Kunjikutty et al. (1980) in their study with venga leaves in goats.

All the experimental animals except two were found to maintain their body weight, as can be seen from the record on body weight of the animals presented in Table 12.

Data on haematological values detailed in Table 15 reveal that all the animals maintained normal values with respect to the various blood parameters.

5.3.4. Banana leaves

Data presented in Table 16 revealed that the average dry matter consumption of animals fed banana leaves was 1.7 kg/100 kg body weight and 37.5 g per kg metabolic live weight. The lower dry matter intake of animals from banana leaves when compared to the same from the other leaves indicates the lesser palatability of the leaves. Reddy and Reddy (1991) have also recorded a similar observation. Johri (1967) in his studies with banana leaves in cattle reported an intake of only 1.48 kg per 100 kg body weight.

The data on the digestibility coefficientsof nutrients in banana leaves given in Table 17 indicate that the various nutrients are well digested by goats, the same being 68.9±3.0, 72.7±3.6, 76.9±2.4, 54.0±5.1 and 69.7±2.9 for dry matter, crude protein, crude fibre, ether extract and nitrogen free extract respectively, which are in agreement with those reported by Johri (1967) in cattle. However, the values obtained in the present study are higher than those reported by James (1978) and Reddy and Reddy (1991) in this regard. The variations in the values reported by different authors may be mostly because of the differences in the varieties of banana leaves used. Wide variations in the chemical composition of different varieties of banana leaves have been observed by Kunjikutty (1969).

The DCP and TDN values for banana leaves were found to be 8.77 and 71.66 on dry matter basis (2.27 and 18.36 on fresh basis) which are essentially in agreement with those reported by Johri (1967) in his studies with cattle while at variance with those of James (1978) and Reddy and Reddy (1991) in this regard.

A perusal of the data (Table 18) on balances of nitrogen, calcium and phosphorus in goats fed banana leaves reveals that all the animals showed positive balances for nitrogen, calcium and phosphorus. A positive balance for nitrogen and calcium and a negative balance for phosphorus in animals fed banana leaves have been reported by Reddy and Reddy (1991).

An examination of the data on the body weights of animals fed banana leaves given in Table 16 indicate that there is a reduction in body weight in all animals except one animal, during the experimental period of about one month. The loss in body weights of the animals not accompanied by a negative nitrogen balance is suggestive of an inadequate energy intake consequent on low food intake.

The data detailed in Table 19 on the haematological values reveal that the values for different blood parameters recorded were well within the normal ranges reported for the species in literature (Sastri, 1983 and Schalm, 1961).

5.4. Influence of nature and level of tannins on feed intake and nutrient utilization in goats

5.4.1. Dry matter intake

From the summarised data on feed consumption of goats fed subabul, jack, venga and banana leaves set out in Table

22, (represented in Fig.1) and its statistical analysis in Table 23 it can be seen that the dry matter intake, expressed as g per kg metabolic live weight, of goats fed jack leaves with 4.0 percent total tannin containing 3.4 percent condensed tannin on dry matter basis is significantly higher (P<0.05) when compared to those fed venga and banana leaves, with 4.7 and 3.7 percent of total tannins and 3.0 and 1.6 percent of condensed tannins respectively. Animals fed subabul with 5.5 percent total tannins containing 2.9 percent condensed tannin also had a significantly higher (P<0.05) dry matter intake per kg metabolic live weight than those fed banana leaves. Data presented in Table 20 and 21 and represented in Fig.2 reveal that the dry matter intakes of goats (kg/100 kg body weight) fed jack and subabul leaves were higher than those fed venga and banana leaves, though not statistically significant. These observations are at variance with those of Burns and Copes (1974); Mitjavila et al. (1977); Singh (1982); Panda et al. (1983); Van Hoven (1984); Barry (1984); Anjaneya Prasad (1986); Makkar and Negi (1986) and Robbins et al. (1987) who recorded a decrease in palatability and feed intake with increase in tannin content. However, no significant difference in dry matter intake of animals due to tannins has been reported by Joshi and Upadhyay (1976); Singh and Arora (1980); Akbar and Gupta (1990) and Sharma et al. (1990).

The higher dry matter intake of goats fed jack and subabul leaves with more concentrations of condensed tannins and total tannins respecitively, in comparison to those of goats fed venga and banana leaves observed in the present study, may be because the level of condensed tannins in the leaves used in the present study did not exceed the threshold level of five percent below which no effect on dry matter intake will be observed as reported by McNaughton (1987) and Waghorn et al. (1991).

5.4.2. Water intake

A perusal of the summarised data on daily water consumption of goats fed subabul, jack, venga, and banana leaves detailed in Table 24 reveals that the water intake of goats fed subabul is significantly higher ($P<0.01$), than those fed venga and banana leaves (Table 25). The higher water intake observed in animals fed subabul may be due to the higher level of crude protein intake by animals fed these leaves (Ghosh et al., 1991). There are no studies reported on the effect of tannins in feed on the water metabolism of animals.

5.4.3. Digestibility and balance of nutrients

5.4.3.1. Dry matter

The summarised data set out in Table 26 (represented in Fig.3.) on the results of digestion trials reveal that the digestibility coefficient of dry matter in banana leaves with a lower total tannin (3.7 percent) and condensed tannin content (1.6 percent) is found to be higher than that obtained for subabul, jack and venga leaves with higher total tannin and condensed tannins, though the differences between the various leaves in this regard are not statistically significant (Table 27). A similar observation of reduced digestibility of dry matter has been made in feeds with a high tannin content by Donelly et al. (1973); Devasia et al. (1976); Mitjavila et al. (1977); Kunjikutty et al. (1980); Dogra (1986); Gupta (1991) and Garrido et al. (1991). However, no influence on the digestibility of dry matter due to tannins has been reported by Singh and Roy (1987); Bharia (1981) and Pan and Maitra (1991).

5.4.3.2. Crude protein

A perusal of the data on the digestibility of crude protein in the four leaves studied detailed in Table 28 and represented in Fig.4, indicates that though not statistically significant (Table 29), the digestibility coefficient of crude protein in banana leaves with a total tannin content of 3.7 percent on dry matter basis is higher than that observed for jack and venga leaves with a total tannin content of 4.0 and 4.7 percent respectively on dry matter basis. However, the observations made in the present study are at variance with those of Joshy and Upadhyay (1976); Akbar and Gupta (1990) and Yadav et al. (1990). A reduction in protein digestibility in feeds with a higher tannin content has been reported by Donelly (1973); Sadanandan and Arora (1976); Tripathi (1976); Panda et al. (1983) and Sharma et al. (1990). Joshi and Upadhyay (1976); Akbar and Gupta (1990) and Yadav et al. (1990) could not observe any difference in digestibility in feeds as a result of higher tannin content. Among the various leaves studied during the course of the present investigation, banana leaves recorded the lowest content of condensed tannins in comparison to subabul, jack and venga leaves. The higher digestibility coefficient of crude protein noted in the present study for banana leaves with the lowest level of condensed tannins (1.6 percent) supports the observations of McLeod (1974) that condensed tannins are chiefly responsible for the reduced utilisation of protein.

5.4.3. Nitrogen balance

The summarised data on nitrogen balance of goats fed subabul, jack, venga and banana leaves presented in Table 30 (represented in Fig.5) and their statistical analysis presented in Table 31 reveal that the animals fed jack leaves with a condensed tannin level of 3.4 percent showed significantly higher (P<0.01) nitrogen balance than those fed on subabul, venga and banana leaves having 2.9, 3.0 and 1.6 percent of condensed tannin respectively. The nitrogen balance of animals fed subabul was also significantly higher (P<0.01) than those fed either venga or banana leaves. Eventhough the digestibility coefficient of crude protein in jack leaves was less than that of banana leaves, the animals fed jack leaves showed a significant difference in nitrogen balance compared to those fed on banana or venga leaves. The higher nitrogen balance observed in animals fed jack leaves in the present study is mainly due to the higher dry matter intake of animals from these leaves, which is also reflected in the increased body weights of the animals fed the fodder during the experimental period. A positive balance of nitrogen in all the animals fed the various leaves with the highest nitrogen balance recorded for animals fed jack leaves containing the highest level of condensed tannins observed in the present study correlates well with the findings of Waghorn (1990) who opined that condensed tannins are not toxic to ruminants and when the concentration is below 4 percent of dry matter, they improve the nutritive value of herbage by binding to plant proteins and protecting them from excessive degradation in the rumen. Nath (1983) stated that depending on the level of tannins in the diet, the tannins may not always be harmful in as much as they may protect protein from rapid deamination by deaminating bacteria or by forming protein complexes. Legume forages that are rich in tannins are reported to be better source of bypass proteins than low tannin legumes by Reid et al. (1974) since tannins link with protein during mastication and reduce microbial degradation of plant proteins. Waghorn et al. (1991) suggested that condensed tannins at concentration upto 2-3 percent of dietary dry matter are probably optimal for maximising the nutritive value and only values exceeding 5.5 percent of dry matter inhibit microbial activity. Further, among the ruminants, goats are reported to have a higher tolerance to tannins by Begovic et al. (1978) who showed that the threshold level of tannic acid directly added to rumen contents was 8-10 percent in this species compared to 3-5 percent in cattle, because goats produce an active tannase in the rumen mucosa. The present observation also supports the view of Gupta (1986) who suggested that tannin containing feed will not be inferior to non-tannin containing feed even if there is depression in digestibility of crude protein without depressing the nitrogen retention in the animals. An overall evaluation of the results obtained in the present study in regard to the effect of tannins on crude protein utilisation indicate that a level of 5.5 percent of total tannins with 3.4 percent of condensed tannins in tree leaves has no deleterious effect on crude protein utilization adjudged in terms of digestibility of crude protein and nitrogen balance.

5.4.3.4. Crude fibre

The data presented in Table 32 on the digestibilities of crude fibre in the various leaves differing in tannin content indicate that banana leaves with a concentration of 3.7 percent of total tannins showed the highest digestibility coefficient for crude fibre than either subabul, jack or venga leaves with 5.5, 4.0 and 4.7 percent total tannins respectively though the differences between them are not statistically significant (Table 33). Subabul leaves with the highest concentration of total tannins (5.5) had the lowest digestibility coefficient for crude fibre. This observation is at variance with those of Nagpaul et al. (1973), Rai and Shukla (1977), Kurar and Mudgal (1980), Leroy and Zelter (1970) and Sinha and Nath (1983) who reported that digestibility of crude fibre remain unaffected by the level of tannin in the ration. A lower digestibility for the NDF fraction has been observed by Reed et al. (1985). However, Robbins et al. (1987 b) could not observe any effect on digestibility of NDF due to higher tannins.

5.4.3.5. Ether extract

The summarised data on the digestibility coefficients of ether extract from subabul, jack, venga and banana leaves shown in Table 34 and their statistical analysis presented in Table 35 reveal no significant differences between the various leaves indicating that the level of tannins in the leaves used in the present study does not appear to exert any influence on lipid utilisation in goats, this being in general agreement with those reported by Nagpaul *et al.* (1973), Rai and Shukla (1977), Kurar and Mudgal (1980) and Leroy and Zelter (1970).

5.4.3.6. Nitrogen Free Extract

A perusal of the data on the digestibility of NFE from subabul, jack, venga and banana leaves detailed in Table 36 and statistically analysed and presented in Table 37 indicates that there is a significant difference ($P < 0.01$) between the four leaves in regard to the digestibility of nitrogen free extract in goats. Banana leaves which had the lowest concentration of total tannin and condensed tannins (3.7 and 1.6 percent respectively of dry matter)recorded significantly higher digestibility for nitrogen free extract than subabul leaves with 5.5 and 2.9 percent of total tannins and condensed tannin respectively. The results obtained for jack and venga leaves were also lower than that for banana leaves. The observation made in the present study is in agreement with those of McLeod (1974); Makkar and Negi (1986); Barry and Manley (1984) and Makkar et al. (1990) who also reported lower digestibility of nutrients in tannin containing feeds. However, the present findings are at variance with those of Leroy and Zelter (1970); Kurar and Mudgal, (1980); Shukla and Talapada, (1973); Nagpaul et al. (1973) and Rai and Shukla (1977), who could not observe any reduction in digestibility of NFE due to tannins. Panda et al. (1987) recorded a decrease in digestibility of all nutrients except NFE in sheep in their study with Calliandra calothyrus with 5.85 percent of tannin on dry matter basis. The over all results on NFE digestibility indicate that condensed tannins at higher concentration exert deleterious effect on NFE utilisation in goats.

5.4.3.7. Calcium and Phosphorus balance

An evaluation of the summarised data on the balance of calcium in goats fed subabul, jack, venga and banana leaves and their statistical analysis presented in Table 38 and 39 respectively indicates that the calcium balance in goats fed subabul leaves was significantly higher ($P<0.01$) than those fed jack, venga and banana leaves. The higher calcium balance recorded in animals fed subabul is possibly due to the higher level of the mineral in these leaves. It was also observed that goats fed jack leaves had a significantly higher calcium balance than those fed venga leaves while no significant difference was seen between the animals fed venga and banana leaves.

From the Table 40 showing the summarised data on the phosphorus balance of goats fed subabul, jack, venga and banana leaves, it can be seen that the animals showed positive balance for phosphorus when they received jack and banana leaves as the fodder while, a negative balance was observed on feeding with venga and subabul leaves. Statistical analysis of the data presented in Table 41 shows that there is a significant difference ($P<0.01$) between the phosphorus balance of animals fed subabul, jack, venga and banana leaves. The phosphorus balance of animals fed jack and banana leaves with 4.0 and 3.7 percent of total tannin respectively on dry matter basis was found to be significantly ($P<0.01$) higher than those fed subabul and venga leaves with 5.5 and 4.7 percent total tannin on dry matter basis. However, no significant difference was observed between venga and subabul leaves in this regard. Nath (1983) stated that tannins do not seem to affect calcium and phosphorus balance in animals. The lower phosphorus balances seen in animals fed subabul and venga leaves in the present study may be possibly due to the comparatively lower phosphorus content (0.24 and 0.21 percent respectively on dry matter basis) of these leaves compared to jack and banana leaves with higher phosphorus levels (0.32 and 0.52 percent respectively).

5.4.3.8. Haematological values

Summarised data on the haematological values presented in Tables 42, 44, 46 and 48 and their statistical analysis in Tables 43, 45, 47 & 49 reveal no significant differences between the animals fed subabul, jack, venga and banana leaves with respect to haemoglobin, plasma protein, calcium and phosphorus levels. Scanty literature is available on the effect of tannins on the blood parameters in goats. The results obtained in the present study on the blood parameters of animals fed the four leaves show that the different levels of tannins in the leaves used in the present study do not exert any significant effect in goats in this regard.

From an overall evaluation of the results obtained during the present study, it can be inferred that a level upto 5.5 percent of total tannins and 3.4 percent of condensed tannins in tree leaves does not exert any significant influence on feed intake and nutrient utilisation in goats in as much as no significant differences were observed in dry matter consumption, digestibility coefficients of dry matter, crude protein, ether extract and crude fibre and balance of nitrogen in goats fed the four different fodders of varying levels of total and condensed tannins.

Summary

SUMMARY

An investigation was carried out to assess the nature and level of tannins in tree leaves on nutrient availability in goats. Fourteen different locally available tree leaves, commonly fed to goats, were analysed for their chemical composition, total tannins, condensed and hydrolysable tannins. Based on the tannin contents, as well as the palatability and local availability of the fodders, four tree leaves viz. subabul, jack, venga and banana were selected for the feeding experiments. Six adult non-producing Saanen x Malabari female goats belonging to the University goat farm, Mannuthy, formed the experimental subjects for the study. The experimental animals were maintained on the respective fodders as the sole feed, each for a period of one month at the end of which a digestion cum metabolism trial was carried out. The average dry matter intake, maintenance of body weight, digestibility coefficients of nutrients, balance of nitrogen, calcium and phosphorus and haematological values were chosen as the criteria for assessing the effect of tannins on nutrient availability in goats.

The salient observations made during the present study and the inferences drawn from the results are summarised below:-

(1) The different tree leaves studied are found to be higher in dry matter, crude protein and calcium but lower in crude fibre and phosphorus as compared to the common grass fodders.

(2) The total tannin content in the different tree leaves ranged from 2.6 to 7.8 percent on dry matter basis, with condensed tannins predominating in majority of the fodders.

(3) The significantly higher dry matter intake of animals fed subabul and jack leaves containing higher levels of total and condensed tannins respectively when compared to those fed on venga and banana leaves with lower levels of the same, indicate that the concentration of tannins in the fodders used in the present study does not seem to exert any deleterious effect on voluntary feed intake in goats.

(4) The average digestibility coefficients of various nutrients in banana leaves were higher than those in jack, venga and subabul leaves, though the differences between the various fodders in this regard were not statistically significant excepting for nitrogen free extract, indicating that the level of total and condensed tannins used in the present study does not

exert, in general, any deleterious effect on digestibility of nutrients in goats.

(5) The significantly higher nitrogen balance (g per day) of goats fed jack leaves with the highest level of condensed tannins when compared to those fed subabul, venga and banana leaves reveal that a level of 3.4 percent of condensed tannins is not enough to exert any significant effect on nitrogen retention in goats.

(6) The animals fed on all the four fodders maintained positive balances for calcium, the balance in animals fed subabul being significantly higher than those fed jack, venga and banana leaves.

(7) While the animals maintained on jack and banana leaves exhibited a positive balance for phosphorus, those fed subabul and venga were in negative balance for the same.

(8) All the experimental animals maintained normal levels with respect to haemoglobin, plasma protein, calcium and phosphorus indicating that the level of total tannins and condensed tannins in the leaves used in the present study does not seem to exert any untoward effect on the blood constituents of goats.

From an overall evaluation of the results obtained during the present study, it can be inferred that a level upto 5.5 percent of total tannins and 3.4 percent of condensed tannins in tree leaves does not exert any significant influence on feed intake and nutrient utilisation in goats, in as much as no significant differences were observed in dry matter consumption, digestibility coefficients of dry matter, crude protein, ether extract and crude fibre and balance of nitrogen in goats fed the four different fodders of varying levels of total and condensed tannins.

References

REFERENCES

Akbar, M.A. and Gupta, P.C. (1985). Proximate composition and tannin and mineral contents of different cultivars and various plant parts of Subabul (Leucaena leucocephala). Indian J. Anim. Sci. **55**(9): 808 - 12.

Akbar, M.A. and Gupta, P.C. (1990). Faba bean (Vicia faba.L) as a source of protein supplement in the ration of buffalo calves. Indian J. Anim. Sci. **60**(12): 1474 - 80.

Anjaneya Prasad, O. (1986). Tannins - Their chemistry, Relationship with digestibility and methods of detannification. Proceedings of the 5th Animal Nutrition Research workers Conference held at Udaipur from July -14-17 (1986) pp 61-63.

Ahn, J.H., Robertson, D.M., Elliot, R., Gutheridge, R.C. and Ford, C.W. (1989). Quality assessment of tropical browse legumes, tannin content and protein degradation. Anim. Feed Sci. Technol., **27**(1-2): 147-157.

AOAC, (1990) Official methods of analysis. Association of Agricultural Chemists, Washington, D.C.

Balagopal, R. and Ravi, R. (1988). Subabul (Leucaena leucocephala) as sole feed for sheep. Kerala J. Vet. Sci., **19**(2): 160-161

Banerjee, G.C. (1990). A Text Book of Animal Husbandry (7th ed). Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, Bombay, Calcutta.

Barry,T.N. (1974). The role of condensed tannins in the digestion of fresh Lotus pedunculatus. Can J. Anim. Sci. **64:** 181 - 182.

Barry, T.N. and Manley, T.R. (1984). The role of condensed tannins on the nutritional value of Lotus pedunculatus fed sheep. 2. Qualitative digestion of carbohydrates and proteins. Br. J. Nutr. **51**(3) : 493 - 504.

Barry, T.N. (1984). The role of condensed tannins in the digestion of fresh Lotus pedunculatus by sheep. Can. J. Anim. Sci. **64:** 181-182.

Barry, T.N. (1985). The role of condensed tannins in the nutritional value of Lotus pedunculatus fed sheep. 3. Rate of body and wool growth. Br. J. Nutr. **54:** 211-217.

* Begovic, S., Duzic, E., Saeirbrebegovic, A. and Tafro, A. (1978). Examination of variation of tannase activity in ruminal content and mucosa of goats on oak leaf diet and during intraruminal administration of 3-10 per cent tannic acid. Cited by Kumar, R. and Vaithiyanathan, S. (1990). Anim. Feed Sci. Technol., **30:** 21-38.

Benjamin, M.M. (1974). Outline of Veterinary Clinical Pathology. 2nd ed. The Iowa State University Press, U.S.A. p. 56.

Bharia, S.K., Majgaonkar, S.V. and Tara, V.A. (1987)). Effect of feeding Glyricidia maculata leaves on growth in crossbred heifers. Indian J. Anim. Nutr. **4**(4): 260-263.

Bhatia, D.R., Kumar, R. and Patnayak, B.C. (1991). Effect of feeding polyethylene glycol treated pala (Ziziphus nummularia) leaves in sheep. Indian J. Anim. Nutr., 8(1): 57-60.

*Brown, B.R., Brown, P.E. and Pike, W.T. (1966). Cited by Van Soest, P.J. (1982). Nutritional ecology of the ruminant: Published by O & B Books incorporated U.S.A.

*Burns, J.C. and Cope, W.A. (1974). Nutritive value of crownvetch forage as influenced by structural constituents, phenolics and tannin compounds. Argon. J. 66: 195-200.

Chiquette, J., Chang, K.J., Costerton, J.W. and Milligean, L.P. (1988). Effect of tannins on the digestibility of two isosynthetic strains of birds foot trefoil (Lotus corniculatus) using in vitro and in sacco techniques. Can. J. Anim. Sci., 68: 751-760.

*Dawra, R.K., Makkar, H.P.S. and Singh, B. (1988). Protein binding capacity of micro-quantities of tannins, Anal. Biochem. 169: 1-3.

*Desai, H.B. and Shukla, P.C. (1978). Orissa Vet. J. 10: 13-18. Cited by Gupta, P.C. (1986). Tannins - their chemistry, relationship with digestibility and methods of detanification. Proceedings of 5th Anim. Nutr. Res. workers conference held at Udaipur. July-14-17. 1986. pp.42-60.

Devasia, P.A., Thomas, C.T. and Nandakumar, M. (1976). Studies on feeding of goats. 1. Evaluation of the nutritive value of jack leaf (Artocarpus integrifolia). Kerala J. Vet. Sci. 7(1): 1.

Dogra, K.K., Sud, R.G. and Katoch, B.S. (1986). Seasonal variations in nutrient components, mimosine, tannin and in vitro digestibility of two Leucaena species under humid sub-tropics, Indian J. Anim. Nutr. 3(1): 33-36.

*Donelly, E.D., Anthony, W.B. and Longford, J.W. (1973). Nutritive relationship in low and high tannin Sericea lespedeza under grazing. Nutr. Abstr. Rev. 43.

*Ensminger, M.E., Olfield, J.E. and Heinemann, W.W. (1990). Feed and Nutrition 2nd ed. Ensminger publishing Co. California, U.S.A.

*Feeney, P.P. and Bostock, H. (1969). Seasonal changes in the tannin content of oak leaves. Phytochemistry 7: 871-880. (Cited by Kumar, R. and Vaithiyanathan, S. (1990). Occurrence, nutritional significance and effect on animal productivity of tannins in tree leaves. Anim. Feed Sci. Technol. 30(1-2):21-38.

*Freudenberg, K. (1920). Cited by McLeod, N. (1974). Plant tannins -- their role in forage quality. Nutr. Abstr. Rev., 44. 804-816.

Gartner, R.J.W. and Hurwood, I.S. (1976). The tannin and oxalic acid content of Acacia aneura (mulga) and their possible effects on S & Ca availability. Aust. Vet. J. 52: 194-196.

Ghosh, T.K., Biswan, S., Chakrabarty, N. and Mishra, S. (1991). Influence of dietary crude protein levels on water intake in goats. Indian J. Anim. Nutr. 8(3): 239-240.

*Gornall, A.G., Bardawill, C.J. and David, M.M. (1949). Determination of serum protein by the biuret reaction. J. Biol. Chem. 751-766.

Garrido, A., Gomez-Cabrera, A., Guerrero, J.E. and Marquardt, R.R. (1991). Chemical composition and digestibility in vitro of Vicia faba L. cultivars varying in tannin content. Anim. Feed Sci. Technol.,35(93-94): 205-211.

Gupta, B.C. (1986). Tannins - their chemistry, relationship with digestibility and methods of detannification. Proceedings of the 5th Animal Nutrition Research Workers Conference held at Udaipur from July 14-17, 1986: 42-60.

Gupta, B.K., Gupta, R.P. and Malik, N.S. (1988). Effect of replacement of green lucerne with subabul (Leucaena leucocephala) leaf meal in the diet on nutrient utilisation and growth in buffalo calves Indian J. Anim. Nutr. 5: 205.

Gupta, H.K. (1991). Nutritive value of Khanyan (Ficus cunia) leaves for goats. Indian J. Anim. Nutr. **8**(4): 293-94.

Gupta, H.K. and Balaraman, N. (1992). Tannins in relation to nutrient stature of top feeds of Eastern Himalayan region. Indian J.Anim. Nutr. **9**(1): 55-88.

Horwood (1970). Feeding protected protein to sheep and cattle. Australian Society of Animal Production Sydney (cited by McLeod, 1974. Plant tannins - their role in forage quality. Nutr. Abstr. Rev. **44**: 804-816.

Ingalls, J.R., Mckirdy, J.A. and Sharma, H.R. (1980). Nutritive value of faba bean bean in the diets of young Holstein calves and lactating dairy cows. Can.J. Anim. Sci. 60(9): 689-98.

Jakhar, B. (1992). Recent advances in goat production - Proceedings of and papers presented at 5th International Conference on goats held in New Delhi during 2-8 March, 1992.

Jaikishan, Khan, R.S., Dass, R.S. and Joshi, D.C. (1986). Nutritional evaluation of subabul (L. leucocephala) in the ration of growing goats. Indian J. Anim. Sci. 356(7): 805-808.

James, C.S. (1978). Suitability of Leucaena leucocephala as a fodder for stall fed goats. Kerala J. Vet. Sci. 9(2): 192-197.

James, C.S. and Gangadevi,P.(1991). Final Report of the ICAR Adhoc Project on Preservation and Nutritive quality of Miscellaneous fodders with special reference to subabul. Dept. Anim. Nutr. College of Veterinary and Animal Sciences, Kerala Agricultural University, Mannuthy.

James, C.S., Thomas, C.T. and Kunjikutty, N. (1977). A note on the chemical composition and tannic acid content of the locally available tree leaves. Kerala J. Vet. Sci. 8(2): 247.

Jones, A.J. (1979). The value of Leucaena leucocephala as a feed for ruminants in the tropics. World Anim. Rev. 31: 13-24.

Johri, P.N., Srivastava, J.P. and Uddin, N. (1967). Investigation on subsidiary feeds-1. Banana (Musa spp) leaves as cattle fodder. Indian Vet. J. **44**: 425.

Joshi, D.C. and Upadhyay, R.B. (1976). Nutritive value of Leucaena leucocephala in sheep. Indian Vet. J. **8**: 606-608.

Kumar, R. (1983). Chemical and biochemical value of fodder tree leaves tannins. J. Agric. Food Chem. **31**: 1361-1363.

*Kumar, R. and Patnayak, B.C. (1986). Studies on the use of polyethylene glycol in determination of tannins. Proceedings of the Anim. Nutr. Res. Workers Conference, Rajasthan Agricultural University, Udaipur, India pp. 74-75.

Kumar, N., Khatta, V.K., Gupta, P.C., Singhal, S. and Bhatia, D.R. (1987). Comparative growth, nutrient digestibility, carcass quality and semen characteristics of Bucks fed on subabul (Leucaena leucocephala) and Berseem (Trifolium alexandrium). Indian J. Anim. Nutr. **4**(4): 230-234.

Kumar, R. and Singh, M. (1984 a). Tannins, their adverse role in ruminant nutrition. J. Agric. Food. Chem. **32**(3): 447-453.

Kurar, C.K. and Mudgal, V.D. (1980). Effect of plane of nutrition on the utilization of nutrients in dry Beetal goats. Indian J. Dairy Sci. **33**(2): 276-278.

Kumar and Vaithiyanathan, S. (1990) Occurrence, nutritional significance and effect on animal productivity of tannins in tree leaves. Anim. Feed. Sci. Techol. 30(1-2): 21-38.

Kunjikutty, N. (1969). Studies on the nutritional status of farm animals maintained on standard rations with and without the incorporation of unconventional feeds and fodders of local importance. Thesis submitted to the University of Kerala in partial fulfilment of the requirements for the degree of Master of Science.

Kunjikutty, N., Annamma Kurian and Thomas, C.T. (1980). Evaluation of the nutritive value of venga (Pterocarpus marsupium) leaves for goats. Kerala J. Vet. Sci. 50(10): 175-180.

*Leroy, F. and Zelter. S.Z. (1970) Ann. Biol. Animale Biochem. Biophys. 10: 401-412. (cited by Gupta, P.C. (1986). Tannins - their chemistry relationship with digestibililty and methods of detannification. Proceeding of 5th Anim. Nutr. Res. workers conference held at Udaipur. July 14-17. 1986. pp.42-60.

Lohan, O.P., Lall, D., Pal, R.N. and Negi, S.S. (1980). Note on tannins in tree fodders. Indian J. Anim. Sci. 50:881-883.

Lohan, O.P., Lall, D., Makkar, H.P.S. and Negi, S.S. (1981). Inhibition of rumen urease activity by tannins in oak leaves. Indian J. Anim. Sci. 51(3):279-82.

Lohan, O.P., Lall,D. and Negi, S.S. (1983). Digestibility of untreated, lime treated and lime-sodium hydroxide treated deoiled sal seed meal and its influence on growth in calves. Indian J. Anim. Sci. 53(10):1053-1057.

Lohan, O.P. and Negi.S.S. (1981). Fractionation of tannins in oak tree leaves. Indian J. Anim. Sci. 51(11): 1019-1025.

Lohan, I.S., Singal, S.P., Gupta, P.C. and Yadav, N.K. (1990). Effect of subabul (Leucaena leucocephala feeding on testicular growth and the level of testosterone and thyroxine in males. Indian J. Anim. Nutr. 7(4): 309-310.

*Lienar, I.E. (1990). Cited in feed stuff evaluation by Wiseman, J. and Cole, D.G.A (1990). Butter worths, London.

Majgoankar, S.V., Patel, S.S. and Tara, V.A. (1987). Chemical composition and nutritive value of Gmelina arborea tree leaves. Indian J. Anim. Sci. 57(11):1235-36.

Makkar, H.P.S., Dawra, R.K. and Singh, B. (1990). In vitro effect of oak tannins on some hydrolytic and ammonia assimilating enzymes in the bovine rumen. Indian J. Anim. Nutr. 7(3):207-216.

Makkar, H.P.S. and Negi, S.S. (1986). Tannins - their chemistry, relationship in the digestibility and their methods of detannification. Proceedings of the 5th Animal Nutrition Research Workers conference held at Udaipur from July-14-17, 1986. pp. 68-70.

Makkar, H.P.S. and Singh, B. (1991). Distribution of condensed tannins (Proantho cyanidins) in various fractions in young and mature leaves of some oak species. Anim. Feed Sci. Technol., 32(4): 253-260.

Makkar, H.P.S., Singh, B. and Dawra, R. K. (1987). Tannin-Nutrient interaction. A review. International J. Anim. Sci., 2: 127-140.

Makkar, H.P.S., Singh, B. and Dawra, R. K. (1988). Effect of tannin rich leaves of oak (Quercus incaca) on various microbial enzyme activities of the bovine rumen. Br. J. Nutr., 60 287-296.

Mangan, J.L. (1988). Nutritional effects of tannins in animal feeds. Nutritional Research Review., 1: 209-231.

Marquardt, R.R., Ward, A.T., Campbell, L.D. and Cansfield, P.E. (1977). Purification, identification and characterization of a growth inhibitor in faba beans (Vicia faba. L. var minor) J. Nutr., 107 (7): 1313-1324.

McLeod, N. (1974). Plant tannins-Their role in forage quality. Nutr. Abstr. Rev. 44. 804-816.

*McNaughton, S.J. (1987), Adaptation of herbivores to season changes in nutrient supply. (Cited by Hacker, J.B and Ternouth, J.H.), Nutrition of Herbivores. Academic press, Sydney, pp 391-408.

*Menke, N.H. and Leinmuller, E. (1991). Tannins in ruminant feeds. Nutr. Abstr. Rev., 61 (11):838.

Mitaru, B.N., Reichert, R.D. and Blair, R. (1984). The binding of dietary protein by sorghum tannins in the digestive tract of pig. J. Nutr., 114 (10): 1787-96.

Mitjavila, C.L., Carrera, G. and Derache, R. (1977). Tannic acid and oxidised tannic acid on the functional state of rat intestinal epithelium. J. Nutr., **107** (12): 2113-2121.

Nagpaul, P.K., Verman, P.N. and Chawla, M.S. (1973). Some observations on the feeding of sal seed meal (Shorea robusta) to the animals. Indian Vet. J. **50**: 352-361.

Nath, K. (1983) Top Feed Resources: Their production, utilization and the constraints. C.S.W.R.I. Avikanagar, 239-258.

Nath,K. (1986) Tannins - Their chemistry, relationship with digestibility and methods of detannification - Proceedings the 5th Animal Nutrition Research work conference held at Udaipur July-14-17, 1986, pp 65-66.

Negi, S.S. (1982). Tannins in sal seed (Shorea robusta) and sal seed meal limit their utilization as livestock feeds. Anim. Feed. Sci. Technol. **7**: 161-185.

Osbourn, D.F., Terry, R.A., Cammela, S.B. and Outen, G.E. (1971). Proceedings of the Nutritional Society. **30**. 13.A.

*Pace, V., Settineri D. and Malossini, F (1991). Effect of tannins on enzyme digestibility of different feeds. Nutr. Abstr. Rev., **61** (8): 505.

Panda, S.K., Sahu, B.K. and Panda, N.C. (1987) Leaves of Caliandra calothyrus as fodder for goats. Indian J. Anim. Sci. **6**(2): 177-180.

Panda, S.K., Panda, N.C. and Sahu, B.K. (1983). Effect of tree leaf tannin on dry matter intake by goats. Indian Vet. J. **60**: 660-664.

Pan, S. and Maitra, D.N. (1991). Comparative efficiency of tannic acid and sal seed tannin treatment in reducing solubility of groundnut cake protein. Indian J. Anim. Sci. **61**(5): 563-66.

Patel, B.M. Shukla, P.C. and Talapada, P.M. (1972). Nutritive value of salseed (*Shorea robusta*, Gaerth) cake. Indian. Vet. J. **49**: 822-825.

Pryor, W.J., McDonald, W.J.F. and Seawright, A.A. (1972). Supple jack (*Ventilago vininatus*) feeding of sheep -Nutritional and Toxicological investigation. Aust. Vet. J. **48**: 339-344.

Rai, S.N. and Shukla, P.C. (1977) Influence of feeding deoiled sal-seed-meal (DSSM) with urea and molasses on digestibility and balance of nitrogen, phosphorus and calcium in lactating cows. Indian J. Anim. Sci. **47**: 111-115.

Ranjhan, S.K. (1980). Animal Nutrition and Feeding practices in India (2nd ed) Vikas publishing House Pvt. Ltd., New Delhi.

Reddy, G.V.N. and Reddy, M.R. (1984). Dry fallen mango tree leaves as roughage source in the complete feed for sheep. Indian J. Anim. Sci. **54** (11): 1046-50.

Reddy, M.V., Reddy, M.R. and Reddy, G.V.N. (1986) utilization of sunflower seed heads and subabul meal in complete diet of sheep. Indian J. Anim. Nutr. 3(2): 86-89.

Reddy, G.V.N. and Reddy, M.R. (1991) Utilization of banana plant (Musa paradiosiaca L.) as feed for cross-bred Cattle. Indian J. Anim. Nutr. 8(1): 23-26.

Reed, J.D., McDowell, R.E., Van Soest, P.J. and Horvath,P.J. (1982). condensed tannins:a factor limiting the use of cassava forage. J. Sci. Food. Agric. 33(3): 621-623.

*Reed, J.D., Horvath, P.J., Allen, M.S. and Van Soest, P.J. (1985). Gravimetric determination of soluble phenolics including tannins from leaves by trivalent yetterbium. Nutr. Abstr. Rev. 55(9). 488.

*Reid, C.S.W., Ulyath, M.J. and Wilson. J.M. (1974) proceedings of New Zealand Society of Animal Production. Proc. New Zealand Sci. Anim. Production 34: 85-93.

*Reid, C.S.W., Ulyath, M.J. and Wilson. J.M. (1976) Plant tannins-Bloat and Nutritive value. Nutr. Abstr. Rev. 40(4):86.

*Robbins, C.T., Haenley, T.A., Hagerman, A.E., Hjeljord, O., Bailer, D.L., Swartz, C. C. and Matuz W.W. (1987). Role of tannins in defending plants against ruminants; reduction in protein availability, Nutr. Abstr. Rev. 57(7): 398-399.

Rodrigues, C.O. (1978). Effect of pre-treatment with tannins on use of protein by sheep. Nutr. Abstr. Rev. 48(6): 283.

Sadanandan, K.P. and Arora, S.P. (1976). Influence of added tannic acid on growth and in vitro P^{32} phosphate utilization by rumen microbes. Indian J. Anim. Sci. 46(11): 593-597.

Sadanadan, K.P., and Arora, S.P. (1979). *J. Nuclear. Agris. Boil*-**8**: 1-3. Cited by Gupta, B.C. (1986). Tannins - their chemistry, relationship with digestibility and methods of detannification. Proceedings of the 5th Animal Nutrition Research Workers Conference held at Udaipur from July-14-17, 1986: 42-60.

Sastri, G.A. (1981)- Veterinary clinical Pathology, C.B.S. Publications and distributors Ltd., New Delhi 3rd ed. pp. 1-25.

Schalm, O.W. (1961) Veterinary haematology Ist Ed. Lea and Febiger, Philadelphia, [illegible] pp. 174-176.

Sharma,K., Singh, N. and Dogra, J.L. (1990). Performance of Barbari goats fed on *Acacia nicolotica* (desi babul) and *L. leucocephala* (Subabul) foliage. *Indian J. Anim. Sci*. **60**(6): 746-747.

Sengar, S.S. and Mudgal, V.D. (1982). Effect of feeding treated and untreated protein on the growth rate pattern and nutrient utilization in kids. *Indian J. Ani. Sci*. **52**(7): 517-523.

Shukla, P.C. and Thalapada, P.M. (1973). Study on feeding sal seed meal to adult animals. *Indian Vet. J*. **50**: 689-693.

Singh, K. and Arora, S.P. (1980). Effect of sal seed meal-tannin on protein synthesis, S^{35} incorporation and cellulose digestibility by rumen microbes *in vivo*. *Indian J. Anim. Sci*. **50**(10): 821-825.

Singh, R.V. (1982). Fodder trees of India, oxford and IBH. New Delhi. 296 pp.

Singh, P. (1990) - Fodder shrubs and trees for livestock production under harsh environment. Part II Asian Livestock April, 1990. pp.1-7.

*Singh, A.U., and Menke, K.H. (1986). Effect of condensed tannins on protein degradability and digestibility - Animal Research and Development. Vol.24(2): 7-22.

Singh, K. and Mudgal, V.D. (1967). Chemical composition and Nutritive value of Leucaena glauca. Indian. J. Dairy Sci. 20(4): 191-195.

Singh, R.P. and Nath, K. (1983). Digestibility of untreated, lime treated and lime-sodium hydroxide treated deoiled sal seed-meal and its influence on growth of calves. Indian J. Anim. Sci. 53(10): 1053-57.

Singh, H.M. and Roy, L.N. (1981). Effect of Bargad leaves tannin and tannic acid on volatile fatty acid (VFA) production in goat rumen. Indian Vet. J. 58(8): 837-840.

*Sinha, R.P. (1980). Ph.D. thesis Rohilkhand Univ. Bareilly cited by Gupta, B.S (1986). Tannins - their chemistry, relationship with digestibility and methods of detannification. Proceedings of the 5th Animal Nutrition Research Workers Conference held at Udaipur from July-14-17, 1986.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical methods. 6th Edn. Oxford - IBH publishing company, Calcutta.

*Teague, W.R. (1991). Patterns of selection of Acacia karoo by goats and changes in tannin levels and in vitro digestibility after defoliation. Nutr. Abstr. Rev. **61**(7):444.

Thomas, C.T., Kunjikutty, N., Annamma Kurian and James, C.S. (1981). A note on the chemical composition and tannic acid content of certain locally available tree leaves. Kerala J. Vet. Sci. **12**(2):271-73.

Tripathi, A.K. (1974). Effect of banana leaf tannins and tannic acid on protein degradation. J. Dairy Sci. **27**: 179-183.

Tripathi, A.K. (1976). Effect of sal seed tannins and tannic acid on protein degradation in goats rumen. Indian Vet. J. **52**(3): 195-200.

Upadhyay, V.S., Rekebi, A. and Pathak, P.S., (1974). Nutritive value of Leucaena leucocephala (LAM) DEWIT. Indian Vet. J. **51**(78): 535-38.

Van Hoven, W. (1984). Tannins and digestibility in greater kundu. Can. J. Anim. Sci. **64**(10): 177-178.

Van Soest, P.J. (1963). Use of detergents in the analysis of fibrous feeds II. A rapid method for the determination of fibre and lignin. J. Ass. Official Agr. Chem. **46**(5): 829.

Van Soest, P.J. and Wine, R.H. (1967). Use of detergents in the analysis of fibrous feeds IV. The determination of plant cell wall constituents, J. Ass. Official Anal. Chem. **50**: 50.

*Waghorn, G.C. (1990). Effect of condensed tannins on protein digestion and nutritive values of fresh herbage. Nutr. Abstr. Rev. **60**(10):616.

*Waghorn, G.C., Jones, W.T., Shelter, J.D. and Mcnabb, W.C. (1991). Condensed tannins and the nutritive value of herbage. Nutr. Abstr. Rev. **61**(10):737.

*Ward and Johnston (1962). Cited by Gupta, P.C., Khatta, V.K. and Mandel A.B. (1986). Analytical techniques in animal nutrition. Directorate of publication, Haryana, Agricultural University.

*Waterman, P.G., Mbi, C.N. Mckey, D.B. and Cartlan, J.S. (1980). Cited by Kumar, R. and Vaithiyanathan, S. (1990). Occurrence, nutritional significance and effect on animal productivity of tannins in tree leaves. Anim. Feed. Sci. Techol.30(1-2): 21-38.

Yadav, P.S. and Yadav, J.S. (1990). *In vitro* disappearance of dry matter protein and mimosine in different *L. leucocephala* based diets. Indian. J. Anim. Nutr. **7**(3): 195-98.

*Zelter, S.Z., Leroy, F. and Tissier, J.P. (1970). Cited by Gupta P.C. (1986). Tannins - their chemistry, relationship with digestibility and methods of detannification. Proceedings of the 5th Animal Nutrition Research Workers Conference held at Udaipur from July-14-17, 1986. pp.42.60.

*** Original not consulted**

ABSTRACT

The effect of nature and level of tannins in tree leaves on nutrient utilisation in animals was investigated using six adult non producing Saanen x Malabari female goats. Four commonly fed tree leaves viz., subabul, jack, venga and banana leaves selected on the basis of their tannin contents as well as the palatability and local availability were used for the feeding experiments. The experimental animals were maintained on the respective fodders as the sole feed, each for a period of about one month under identical managemental conditions. A digestion cum metabolism trial was carried out at the end of each feeding experiment. The data on body weight, average dry matter intake, digestibility coefficients of nutrients, balance of nitrogen, calcium and phosphorus and haematological values gathered during the experimental period were taken as the criteria for evaluating the effect of tannins on nutrient availability in goats.

The total tannin content in the different tree leaves studied ranged from 2.6 to 7.8 percent, with condensed tannins predominating in majority of the fodders.

The average dry matter consumption (g/ kg metabolic live weight) of goats when fed jack and subabul leaves with

4.0 percent and 5.5 percent total tannins respectively on dry matter basis were higher than when fed venga and banana leaves with 4.7 and 3.7 percent respectively of the same.

The digestibility coefficients of dry matter, crude protein, crude fibre, ether extract and nitrogen free extract in banana leaves with the lowest level of total and condensed tannins (3.7 percent and 1.6 percent respectively) were higher than in jack, subabul and venga leaves, the differences between the various leaves in this regard being not statistically significant, excepting for nitrogen free extract.

Though all the experimental animals maintained positive balances for nitrogen, the average nitrogen balance (g per day) was higher in goats fed jack leaves when compared to those given subabul, venga and banana leaves as the sole feed.

The animals fed all the four fodders maintained positive balances for calcium, the balance in goats fed subabul being significantly higher than those given the other fodders.

Though a negative phosphorus balance was recorded in goats fed subabul and venga leaves, the animals on jack and banana leaves as the sole fodder maintained positive balances for phosphorus.

The haematological constituents Viz., haemoglobin, plasma protein, calcium and phosphorus in goats fed the four fodders were all well within the normal ranges for the species.

A critical assessment of the overall results obtained during the course of the present study indicates that even a level of upto 5.5 percent of total tannins and 3.4 percent of condensed tannins in tree leaves does not appear to exert any deleterious effect on feed consumption and nutrient utilisation in goats.