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Effect of complete feed block with tree leaves rich in hydrolysable and condensed tannins on nutrient utilization, rumen fermentation and growth performance of lambs

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Abstract

Thirty lambs (Avishaan genotype, 10 weeks old, 14.0 ± 0.2 kg live weight) were randomly assigned into three equal treatment groups to study the effect of complete feed blocks (CFB; concentrate and roughage at 70:30 ratio) with three different tanniniferous tree leaves on intake and utilization of nutrients, rumen fermentation, microbial protein synthesis and growth performance. The treatments were T1 (Control), CFB1 with *Vigna sinensis* hay; T2, CFB2 with *Acacia nilotica* leaves rich in hydrolysable tannins (HT); and T3, CFB3 with *Ziziphus nummularia* leaves rich in condensed tannins (CT). The three CFBs were fed *ad libitum* to the respective groups of lambs for a period of 12 weeks. There was lower ($p < .05$) intake of dry matter (DM), total carbohydrates (TCHO) and fibre components in T2 compared with T1 and T3. However, the digestibility of nutrients except crude protein (CP) was higher in T2. Diet had no effect ($p > .05$) on the LW gain in lambs. Amongst the three groups, T3 showed enhanced N utilization with a comparable microbial protein synthesis, the lowest being in T2. The T2 group of lambs had higher propionate and lower non-glucogenic: glucogenic short-chain fatty acids ratio. It may be concluded that tanniniferous tree leaves at 30% of total mixed ration can meet the requirement of nutrients for desired post-weaning growth.

KEYWORDS
complete feed block, growth performance: lamb, nutrient utilization, tannin

1 | INTRODUCTION

Use of tannin containing legumes in ruminant diets has now been the principal focus of qualitative manipulation of host environment for enhancing protein nutrition and providing resilience against gastrointestinal parasitism (Hoste et al., 2016). Top feeds rich in plant secondary metabolites (PSM) like babool (*Acacia nilotica)* and pala (*Ziziphus nummularia*) are abundantly available in the arid and semi-arid regions and are being used as a feed resource for small ruminants (Bhatta, Shinde, Sankhyan, & Verma, 2002; Sharma & Sahoo, 2017).

Tanniniferous leaves yield positive effect on rumen fermentation, digestibility and animal performance (Dey, Dutta, Sharma, & Pattanaik, 2008). Tree leaves of *A. nilotica* and *Z. nummularia* have potential effect on methane mitigation and in vitro degradability (Pal, Patra, Sahoo, & Kumawat, 2015). There is limited information

on types of tannin polyphenols and their effects on feed intake, ruminal attributes, nutrient utilization and post-weaning growth performance of lambs. The two plant species, *A. nilotica* and *Z. nummularia*, are abundantly available in arid and semi-arid regions and are also rich source of hydrolysable (HT) and condensed tannins (CT) (Pal et al., 2015). Thus, the present study was carried out to evaluate the effect of feeding complete feed block (CFB) containing polyphenol-rich tree leaves *A. nilotica* and *Z. Nummularia* on intake, apparent total tract digestibility, nutrient utilization, N balance, microbial protein synthesis (MPS), rumen fermentation and growth performance of weaner lambs.

2 | MATERIALS AND METHODS

2.1 | Location and experimental design

The study was carried out in the Division of Animal Nutrition of Central Sheep and Wool Research Institute, Avikanagar, Rajasthan, India. The care and management of lambs and the biological sampling procedures were approved by the Institute Animal Ethics Committee (IAEC-CSWRI/2017/IXX13455) under the supervision of Committee for the Purpose of Control and Supervision of Experiments on Animals. The lambs were housed in a well-ventilated enclosure with provision of open paddock to facilitate adequate exercise for 2 hr in the morning (07:00–09:00 hr) and evening (16:00–18:00 hr).

Thirty weaner lambs of both sexes (male and female) belonging to the newly developed genotype, "Avishan" (10 weeks of age, average live weight [LW] 14.0 ± 0.2 kg) were randomly assigned to three treatment groups T1, T2 and T3, each having ten lambs (five male and five female). The three groups were fed on CFB containing cowpea (*Vigna sinensis*) hay with negligible tannins (T1), *A. nilotica* leaves rich in HT (T2) and *Z. nummularia* leaves rich in CT (T3).

2.2 | Diet and feeding

The CFBs were prepared by mixing concentrate (65%) with molasses (5%) and chaffed (1–2 cm) forages (30%). The mixture was compressed at 5,000 psi (351.5 kg/cm^2) to prepare 3.0 kg blocks of 20 × 20 cm size.

The lambs were individually fed on the respective CFBs *ad libidum* and the feeding trial was continued for 12 weeks (i.e., up to 22 weeks of age). They had access to clean drinking water. Feed offered and residues left were measured daily, and representative samples were pooled and stored after drying (60 ± 2°C) in a forced-air oven for further analysis. Besides, the samples of roughages of different CFB were also collected separately prior to making CFB and stored for after drying for further analysis. A record of daily feed intake and weekly LW was maintained for assessing the plane of nutrition and growth performance of lambs during the post-weaning periods.

2.3 | Metabolism trial

A metabolism trial of nine days was conducted at the end of the experiment including three days of adaptation in the metabolic cages and six days of collection of feed, faeces and urine. Sample aliquots of faeces and urine voided in 24 hr by the individual animal were collected and processed for storage and analysis. The feed and faeces samples were dried at 60 ± 2°C in a forced-air hot air oven for dry matter (DM; method 930.15 of AOAC, 2000) estimation, which were pooled and ground to pass through a 1-mm sieve and stored in air-tight polypropylene containers. A separate aliquot of faecal samples was preserved with dilute (25% v/v) sulphuric acid for nitrogen (N) estimation. Similarly, urine excreted by the animals over 24 hr was collected under acidic (dilute sulphuric acid) condition and sampled for estimation of N and purine derivatives (PD).

2.4 | Feed analysis

The feed and faeces samples were analysed for DM, ash (942.05), N or crude protein (CP; 984.13) and ether extract (EE; 954.02) as per AOAC (2000). Neutral detergent fibre inclusive of ash (aNDF) was determined after α-amylase treatment and subsequently processed for acid detergent fibre (ADF) as per Van Soest, Robertson, and Lewis (1991). Acid detergent lignin (sa) was assayed by solubilization of the cellulose with sulphuric acid (Robertson & Van Soest, 1981).

The polyphenol fractions of different forages and CFB were measured by method given by Hagerman, Harvey-Mueller, and Makkar (2000). Polyphenols were extracted with the help of Sonicator (Sonirep 150, Ultrasonic Disintegrator and process timer, MSE, UK) in 70% acetone solution after treating with 2% acetic acid and petroleum ether. Total phenolics (TP) and non-tannin phenolics (NTP) in the extract were measured by the Folin–Ciocalteu method (Makkar, 2003) with tannic acid as a standard. Condensed tannins in the samples were measured from the leucocynidin equivalent by using the butanol HCl method (Porter, Hrstich, & Chan, 1986). Total tannin polyphenols and HT were calculated by difference.

The metabolizable energy (ME) intake was calculated from digestible OM (DOM) intake by the formula, ME intake (Mcal/kg DM) = DOM intake (kg) × 3.5814 (adapted from AAC, 1990).

2.5 | Purine derivatives and microbial protein synthesis

Aliquots of acidified (pH < 2.0) urine samples were pooled over six days of metabolism trial and stored at −20°C until analysis. Prior to analysis, the samples were diluted (10 times) and filtered through 0.22 μm Millipore filter into HPLC vial. The HPLC protocol of Hagerman et al., (2000) was followed by using a C18 reverse phase column with a mobile phase (10 mM potassium phosphate buffer, pH 4.0) at a flow rate of 0.5 ml/min and column temperature 25°C. The unknown sample peaks were detected in a UV detector set at

218 nm, and the chromatograph was compared against the standards of allantoin, uric acid, xanthine and hypoxanthine for calculating PD excreted through urine. The MPS was estimated from intestinal microbial N flow after calculating urinary PD excretion by employing the following equations:

$$Y = 0.84X + (0.15LW^{0.75}e^{-0.25X})$$

$$\text{Microbial N (g/d)} = 70X \div (0.116 \times 0.83 \times 1{,}000)$$

where Y = excretion of purine derivatives (mmol/day); X = absorption of microbial purines (mmol/day); and LW = live weight in Kg.

2.6 | Rumen fermentation attributes

Rumen liquor samples (50 ml) were drawn into a 100-ml glass jar 4 hr post-feeding by a stomach tube connected to a suction pump. The pH was recorded immediately using a portable pH meter (Piccolo® pH tester by Hanna instruments), and then, the content was strained through four layers of muslin cloth and stored at −20°C in polypropylene bottles with a few drops of saturated mercuric chloride solution. The samples were analysed for total *N* (TN; AOAC, 2000), trichloroacetic acid (TCA)-precipitable *N* (Sahoo, Sankhyan, & Karim, 2012) and ammonia *N* (NH_3-N; Weatherburn, 1967). For the assay of short-chain fatty acids (SCFA), the strained rumen liquor (SRL) was treated with metaphosphoric acid (25%; w/v), centrifuged (6,012 *g*, for 5 min at 4°C) and the supernatant was analysed in a gas chromatograph (Model 1000, Series 011124002, DANI) as per the method described by Sahoo, Singh, and Sharma (2011).

2.7 | Statistical analysis

Data obtained from the experiment were subjected to one-way analysis of variance (ANOVA) by using statistical software SAS (2013). Repeated-measure analysis was employed for assessing weekly LW change of lambs in different groups. The significance between the treatments was declared at $p < .05$ by applying Tukey's test.

3 | RESULTS

3.1 | Chemical composition

The three forages incorporated in the CFBs had a similar CP but differed in their EE and lignin contents with a higher value in *Z. nummularia* than *V. sinensis and A. nilotica* (Table 1). All the CFBs had similar CP, OM, aNDF and ADF contents, but the EE and lignin were higher in CFB3 than CFB1 and CFB2. The hemicellulose content was higher in *A. nilotica*, while cellulose was lower in *Z. nummularia*; a similar compositional alteration was also reflected in CFB2 and CFB3 respectively. The polyphenolic composition (g/kg DM) revealed a high TP (163) in *A. nilotica* followed by *Z. Nummularia* (52.5) and a negligible quantity (3.88) in *V. sinensis*. *A. nilotica* had higher TTP (148) and HT (140), while *Z. nummularia* had a higher CT (28.3). The polyphenolic composition in CFB2 and CFB3 was consistent with the component forages used for the preparation of the CFBs.

3.2 | Intake and digestibility of nutrients during the metabolism trial

The lambs in T2 had lower ($p < .05$) feed and nutrient (DM, OM, TCHO, aNDF and ADF) intake except for CP and EE compared with T1 and T3 (Table 2). On the contrary, the apparent total tract digestibility of all the nutrients was significantly ($p < .05$) higher in T2 as compared to T1 and T3 with the exception of CP. There were similar intake and digestibility of nutrients in T1 and T3.

3.3 | Nutrient intake and growth performance

The average feed (DM) and nutrient (DOM, CP and ME) intake per unit LW of lambs during the 12 weeks of experimental period are depicted in Table 3. The DM intake in T2 revealed a significant ($p = .027$) difference when expressed in relation to unit metabolic body size ($LW^{0.75}$Kg). The intake of both DOM and ME per kg LW was significantly ($p = .042$) higher in T2 than T1.

Lambs in T1, T2 and T3 showed an average daily gain of 150, 126 and 143 g, respectively, during the post-weaning period (10–22 weeks of age), and the repeated measures analysis revealed a significantly ($p < .05$) lower trend in LW gain in T2 during the experimental period of 8 to 12 weeks compared with T1 and T3 (Table 3).

3.4 | Nitrogen balance and microbial protein synthesis

The urinary excretion was higher ($p < .001$) in T2 followed by T1 and T3. The N balance was similar in T1 and T3, but lower in T2, which was also reflected in its utilization when expressed as a proportion of N intake or absorbed. Above all, the lambs in T3 excreted less N through the urine with a better utilization of absorbed N.

The excretion and absorption of PD and MPS were lower in lambs of T2 than T1, while the values in T3 were intermediate (Table 4).

3.5 | Rumen fermentation attributes

Lambs in T2 and T3 showed significantly ($p = .001$) higher total N than T1, while NH_3-N was lower ($p < .001$) in T3 and TCA-precipitable N was higher in T2 compared with other dietary groups (Table 5). The proportional distribution of SCFA revealed higher C2 in T2, whereas the concentration of iso-acids (iso-butyrate; iso-valerate) was higher

TABLE 1 Chemical composition of complete feed block (CFB) and their roughage components

Composition (g/kg DM)	*Vigna sinensis* hay	*Acacia nilotica* leaves	*Ziziphus nummularia* leaves	CFB1	CFB2	CFB3
Dry matter	892	902	865	888	902	899
Organic matter	882	876	874	909	896	902
Crude protein	144	145	140	153	155	150
Ether extract	25.4	25.7	32.1	52.1	53.0	54.8
Neutral detergent fibre (aNDF)	608	695	657	374	400	389
Acid detergent fibre (ADF)	451	468	473	252	257	259
Lignin (sa)	108	124	196	60.4	64.9	86.6
Hemicellulose	157	227	184	122	143	130
Cellulose	343	344	277	192	192	172
Total phenols	3.88	163	52.5	2.70	45.2	16.3
Total tannin phenols	2.89	148	31.1	2.09	40.4	9.4
Non-tannin phenols	1.00	15.0	21.4	0.60	4.79	6.89
Condensed tannins	1.19	7.79	28.3	1.79	2.28	8.19
Hydrolysable tannins	1.70	140	2.78	0.27	38.1	1.20

Abbreviations: CFB1, concentrate mixture + cowpea (*Vigna sinensis*) hay (70:30); CFB2, concentrate mixture + babool (*Acacia nilotica*) leaves (70:30); CFB3, concentrate mixture + pala (*Ziziphus nummularia*) leaves (70:30).

in T1 and lowest in T3. There was lower non-glucogenic to glucogenic fatty acids ratio (NGR) and acetate (C2): propionate (C3) ratio and higher C3 to C2 + C4 ratio.

4 | DISCUSSION

The forages, *V. sinensis*, *A. nilotica* and *Z. nummularia*, had similar N/CP and supplied 140–145 g CP kg^{-1} DM in the CFBs which is considered adequate for post-weaning growth in lambs (ICAR, 2013; NRC, 2007). The lambs in control group fed on CFB1 had access to negligible tannins at 0.21% compared with those on CFB2 and CFB3 having 4.04 and 0.94% respectively. The variability in other nutrients and polyphenolic contents in the three CFBs was ascribed to the use of different forage sources. The level of TP and its fractions especially HT and CT contents were within safer level. Furthermore, no gross pathological changes were observed in vital organs during the carcass evaluation. Similar polyphenolic composition in these tree leaves was also observed earlier (Rana, Wadhwa, & Bakshi, 2006; Singh, Sahoo, Sharma, & Bhat, 2005). *Z. nummularia* leaves, although contained higher lignin, did not affect CFB intake of lambs as evident from comparable DM intake in T3 (Table 3).

The three CFBs formulated with a 70:30 concentrate; roughage ratio was found adequate to meet CP and energy requirement of lambs during the early post-weaning growth phase. However, amongst the three groups, lower feed (DM) consumption in T2 leads to a decreased intake of OM, TCHO including the fibre fractions (aNDF, ADF). A lower feed (DM) intake in T2 during the post-weaning phase (10–22 weeks of age) was compensated by higher nutrient digestibility resulting in similar availability of digestible nutrients (DOM) or ME as that of T1 and T3. Development of conditioned aversions during its passage through the buccal cavity and a reduced fermentation in the rumen finally affects nutrient utilization summing up the negative effects on feed consumption. Nonetheless, lambs in T2 recorded higher digestibility of CFB with HT-rich *A. nilotica* leaves that apparently compensated for the loss stemmed from reduced feed intake. Lambs in all the three groups consumed adequate energy and protein to meet the requirement of 150 g ADG (ICAR, 2013; NRC, 2007) except for the lambs in T2. A higher FCR value in T2 inferred that lambs converted nutrients less efficiently compared with T1, while T3 followed closely in amassing LW during the post-weaning phase.

Nitrogen intake in lambs was similar in all the three groups, but its excretion through urinary route was higher in T2 that fed on CFB with high HT containing *A. nilotica* leaves. On the contrary, lambs in T3 fed on high CT containing *Z. nummularia* leaves conserved N with a lower urinary excretion. This difference in N metabolism may be attributed to role of CT in protein protection (Min & Solaiman, 2018), while HT had no such effect (Dey et al., 2008). Similarly, lambs in T2 exhibited lower excretion and absorption of PD with concomitant

TABLE 2 Intake and apparent total tract digestibility of nutrients in lambs on complete feed block with polyphenol-rich tree leaves during the metabolism trial

Attributes	T1	T2	T3	*SEM*	*p* value
Feed and nutrient intake (g/d)					
Dry matter	913[a]	730[b]	897[ab]	39.0	.024
Organic matter	832[a]	668[b]	812[ab]	37.9	.028
Crude protein	145	121	138	6.8	.082
Ether extract	52.7	54.5	59.5	2.35	.292
Total carbohydrates	633[a]	495[b]	614[a]	31.7	.016
Neutral detergent fibre (aNDF)	312[a]	218[b]	297[a]	16.0	.002
Acid detergent fibre	224[a]	177[b]	224[a]	11.3	.013
Digestibility (g/kg DM)					
Dry matter	0.677[b]	0.720[a]	0.666[b]	0.0089	.002
Organic matter	0.697[b]	0.779[a]	0.706[b]	0.0062	<.001
Crude protein	0.760	0.778	0.753	0.0110	.275
Ether extract	0.728[b]	0.828[a]	0.769[b]	0.0077	<.001
Total carbohydrates	0.680[b]	0.775[a]	0.689[b]	0.0064	<.001
Neutral detergent fibre (aNDF)	0.519[a]	0.507[a]	0.468[b]	0.0100	.006
Acid detergent fibre	0.440[b]	0.476[a]	0.421[b]	0.0085	.001

Note: T1 (Control), complete feed block (CFB) with cowpea hay; T2, CFB with babool leaves; T3, CFB with pala leaves. [a,b,c]Means bearing different superscript differ significantly ($p < .05$).

Abbreviation: *SEM*, standard error of mean.

TABLE 3 Plane of nutrition and growth performance of lambs fed on complete feed block with polyphenol-rich tree leaves during the post-weaning (10–22 weeks of age) phase

Attributes	T1	T2	T3	*SEM*	*p* value
DM and nutrient intake					
DM (g/d)	637	580	644	21.6	.196
DOM (g/d)	405	407	412	14.1	.906
CP (g/d)	91.7	84.1	90.2	3.47	.519
ME (Mcal/d)	1.449	1.458	1.474	0.5050	.906
Live weight (LW) gain					
Initial LW (kg)	14.1	14.0	14.1	0.56	.999
Final LW (kg)	26.7	24.6	26.1	1.22	.401
Gain in LW (kg)	12.6	10.6	12.0	0.58	.057
Average daily gain (g/d)	150	126	143	7.0	.057
Feed conversion ratio (intake/kg gain)					
DM (kg)	4.25	4.60	4.51	0.176	.304
DOM (kg)	2.70[b]	3.23[a]	2.88[ab]	0.110	.041
ME (Mcal)	9.66[b]	11.55[a]	10.32[ab]	0.394	.041

Note: T1 (Control), complete feed block (CFB) with cowpea hay; T2, CFB with babool leaves; and T3, CFB with pala leaves. [a,b,c] Means bearing different superscript differ significantly ($p < .05$). ME intake (Mcal/kg DM) = Digestible OM intake (kg) × 3.5814 (adapted from AAC, 1990).

Abbreviations: CP, crude protein; DM, dry matter; DOM, digestible organic matter; LW, live weight; ME, metabolizable energy; *SEM*, standard error of mean.

decrease in microbial N production. It is worthwhile to mention that the level of HT in CFB2 was below the toxic level and there were no noticeable gross pathological lesions in vital organs of lamb that were slaughtered for carcass studies. Concurrently, the effect of CFB2 feeding on ruminal fermentation attributes was also not adverse in T2, which exhibited higher TCA-precipitable N and propionate concentration with lower NGR and C2: C3 ratio and higher C3: (C2 + C4) ratio compared with T1 and T3. Within the safe level of inclusion, the degradation metabolites of HT might have contributed to pro-nutritional effect (Singh & Sahoo, 2004) for a positive

TABLE 4 Nitrogen balance and microbial protein synthesis in lambs on complete feed block with polyphenol-rich tree leaves during the metabolism trial

Attributes	T1	T2	T3	*SEM*	*p* value
N balance (g/day)					
Nitrogen Intake	23.2	19.3	22.1	1.17	.082
Faecal N	5.57	4.30	5.49	0.391	.066
Urinary N	6.83[a]	8.07[a]	4.82[b]	0.396	<.001
N absorbed	17.6	15.0	16.7	0.89	.141
N retained	10.8[a]	6.94[b]	11.8[a]	0.82	.001
N retained/N intake	0.46[a]	0.36[b]	0.53[a]	0.026	<.001
N retained/N absorbed	0.60[b]	0.46[c]	0.71[a]	0.031	<.001
Purine derivatives (PD) and microbial protein synthesis (MPS)					
PD excreted (mM/d)	19.1[a]	15.2[b]	17.4[ab]	0.74	.007
PD absorbed (mM/d)	24.2[a]	20.4[b]	22.7[ab]	0.95	.024
Microbial N produced (g/d)	17.6[a]	14.8[b]	16.5[ab]	0.69	.024
Microbial N/kg DM intake	19.4	20.5	18.6	1.03	.388
Microbial N/kg DOM intake	30.6	28.7	29.1	1.58	.612
MPS/100 g DM intake	12.2	12.8	11.6	0.65	.388
MPS/100 g DOM intake	19.2	17.9	18.2	0.99	.612

Note: T1 (Control), complete feed block (CFB) with cowpea hay; T2, CFB with babool leaves; and T3, CFB with pala leaves. [a,b,c] Means bearing different superscript differ significantly ($p < .05$).
Abbreviations: DM, dry matter; DOM, digestible organic matter; *SEM*, standard error of mean.

ruminal metabolic environment, and it was evident with higher apparent total tract digestibility of nutrients. Explanation for higher digestibility of fibre components in T2 could be the degradation and utilization of HT as an energy source in the rumen. Pal et al., (2015) also reported higher in vitro ruminal OM degradability and microbial biomass production in *A. nilotica* .

Z. nummularia with CT content of 28.3 g/kg DM provided 0.82% CT in CFB3, which was below the reported antinutritional/ toxic level (Barry & Mcnabb, 1999). Reduction in digestibility of fibre fractions (NDF, ADF) in T3 could be related to the formation of the indigestible complex of proanthocyanidins or CT with polysaccharides (Reed, Soller, & Woodward, 1990). It has been established that a low level of CT in the diet exert positive effects on rumen fermentation, nutrient utilization and animal performance (Barry & Mcnabb, 1999; Patra & Saxena, 2011; Singh & Sahoo, 2004). The positive nutritional effects of the plant tannin compounds depend primarily on their influence on rumen microbial population and consequent modulation of the metabolic events. Aderao, Sahoo, Bhatt, Kumawat, and Soni (2018) observed positive effects on ruminal attributes, viz. higher substrate degradability, propionate production and lower methanogenesis with TMR having HT containing *A. nilotica*. Similar positive ruminal attributes were observed in T2 on HT-rich diets, but the effect was not translated into animal performance due to probable adverse effect on microbial protein synthesis and N utilization. On the other hand, T3 exhibited positive effects of CT on ruminal attributes, viz. reduced ammonia N with increased propionate and relatively improved C2:C3 ratio. Thus, they produced similar growth and feed efficiency as it was in T1. Forage CT reacts with protein in a pH-dependent manner (Zhu, Phillipson, Greengrass, Bowery, & Cai, 1997) that facilitates the protection of protein from ruminal degradation and thereby improve protein utilization by ruminants (Waghorn, 2008). A higher concentration of propionic acid is often referred to as a positive shift (glucogenic) in ruminal fermentation, which may be explained by partial diversion of hydrogen sink from methane to propionate thereby reducing the fermentable energy loss (Puchala et al., 2012; Saminathan, Sieo, Abdullah, Wong, & Ho, 2015). The lambs in T3 exhibited superior N utilization efficiency with a reduced urinary excretion. Carulla, Kreuzer, Machmüller, and Hess (2005) observed similar reduced urinary N excretion in sheep supplemented with *A. mearnsii* tannins. Conservation of N through urinary route has the potential advantage due to reduced loss of N as ammonia. With a similar DM and DOM intake, the EMPS was comparable in T3 and T1. Supplementation of CT through tanniniferous tree leaves may thus be a practical means of protecting dietary protein from ruminal degradation, and thereby increasing intestinal uptake and decreasing urinary excretion, leading to improved N utilization and competitive animal performances. Contrary to this, HT-rich *A. nilotica* effected higher urinary N excretion with a lower efficiency of utilization, thus affected growth performance of lambs in T2.

TABLE 5 Rumen fermentation attributes of lambs fed on complete feed block with polyphenol-rich tree leaves

Parameters	T1	T2	T3	*SEM*	*p* value
pH	6.80	6.82	6.74	0.031	.241
Total N (mg/dL)	114[b]	127[a]	127[a]	2.2	.001
Ammonia N (mg/dL)	26.8[a]	25.1[a]	22.3[b]	0.13	<.001
TCA-precipitable N (mg/dL)	64.9[b]	71.8[a]	63.8[b]	0.81	<.001
Acetic acid (C2; mM/L)	24.7	22.9	27.2	3.51	.694
Propionic acid (C3; mM/L)	6.98[b]	11.2[a]	10.2[a]	1.011	.046
Isobutyric acid (C4i; mM/L)	0.64	0.55	0.30	0.121	.159
Butyric acid (C4; mM/L)	4.65	4.46	6.20	0.921	.362
Isovaleric acid (C5i; mM/L)	0.61	0.53	0.33	0.120	.283
Valeric acid (C5; mM/L)	0.44	0.65	0.57	0.101	.359
Proportional distribution of SCFA (%)					
Acetic acid (C2)	64.2	57.8	60.7	1.74	.058
Propionic acid (C3)	18.7[b]	27.0[a]	22.4[ab]	2.00	.032
Isobutyric acid (C4i)	1.72[a]	1.41[a]	0.68[b]	0.28	.049
Butyric acid (C4)	12.5	11.0	14.2	1.64	.411
Isovaleric acid (C5i)	1.67[a]	1.31[a]	0.75[b]	0.24	.050
Valeric acid (C5)	1.18	1.52	1.28	0.13	.202
Branch-chain fatty acids (mM/L)	1.69	1.73	1.20	0.214	.201
Total SCFA (mM/L)	38.0	40.3	44.7	5.67	.702
NGR	4.12[a]	2.59[b]	3.58[ab]	0.417	.041
C3:(C2 + C4) ratio	0.24[b]	0.41[a]	0.31[ab]	0.043	.029
C2:C3 ratio	3.54[a]	2.04[b]	2.67[ab]	0.281	.038

Note: T1 (Control), complete feed block (CFB) with cowpea hay; T2, CFB with babool leaves; T3, CFB with pala leaves. $\text{Branch} - \text{chain fatty acids (BcFA)} = \text{valerate} + \text{iso} - \text{valerate} + \text{iso} - \text{butyrate (C5 + C5i + C4i)}$.
$\text{NGR (Non - glucogenic: Glucogenicratio)} = [(\text{Acetate} + 2 \times \text{Butyrate} + \text{BcFA} \div (\text{Propionate} + \text{BcFA})]$ or $[(\text{C2} + 2\text{C4} + \text{C5} + \text{C5i} + \text{C4i}) \div (\text{C3} + \text{C5} + \text{C5i} + \text{C4i})]$.
[a,b,c] Means bearing different superscript differ significantly ($p < .05$).
Abbreviations: DM, dry matter; OM, organic matter; ME, metabolizable energy; SCFA, short-chain fatty acids; and *SEM*, standard error of mean.

Weaning of lambs at 10 weeks of age and early adaptation to adequate solid feed through high grain TMR supported rapid rumen development. This supports the concept of higher productivity through establishment of a functional rumen at the earliest (Cozzi et al., 2002; Sahoo, Kamra, & Pathak, 2005).

5 | CONCLUSION

Complete feed block with tanniniferous forages (e.g., *A. nilotica*, *Z. nummularia*) at 30% levels can be successfully and safely utilized in feeding of weaner lambs without any adverse effects. The observed negative effects can be minimized by going for feeding a mixture of *A. nilotica* and *Z. nummularia*, which would supply a mixture of HT and CT to enhance the feed intake, digestibility and nutrient utilization.

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ANIMAL WELFARE STATEMENT

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to and the appropriate ethical review committee approval has been received. The authors confirm that they have followed EU standards for the protection of animals used for scientific purposes [and feed legislation, if appropriate].

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