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Research Article

Performance of sheep fed on fallen leaves-based complete diet

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Abstract

Fallen leaves are either burnt or spoiled in rainwater, which not only causes environmental pollution but also loss of valuable biomass. To address the problems, the study was conducted to explore the use of fallen leaves as animal feed. Twenty number of one year-old sheep were distributed uniformly into 4 groups as C, T1, T2, and T3 and fed complete rations for 60 days, after which a metabolic trial was conducted. The ration of the control group (C) contained a paddy straw and concentrate mixture in a 60:40 ratio, while in treatment groups, 100% of the paddy straw was replaced by fallen willow (T1), poplar (T2), and chinar leaves (T3). Crude protein content of fallen willow leaves was 9.02%, and that of poplar and chinar was 7.25% and 6.75%, respectively. Dry matter intake (kg/day) was higher (P<0.05) in the treatment groups (1.14-1.16 kg/d) compared to control (1.00 kg/d). Body weight gain (total gain of 9.80 kg and average daily gain of 163.33 g/d) was higher (P<0.05), while the cost of production (Rs 101.28 per kg gain) was lower (P<0.05) in T1 compared to other dietary groups, which were statistically similar to one another. Feed conversion ratio was the best (P>0.05) in T1 (7.03), while nutrient digestibility, %DCP, and %TDN of the ration were the lowest (P<0.05) in T3 compared to all other groups. It is concluded that 100% of paddy straw can be replaced by fallen tree leaves, especially willow, in TMRs for the economical feeding of sheep without any adverse effect on their growth and production.

Keywords: Fallen leaves, Growth, Nutrient utilisation, Paddy straw replacement, Production economics

Highlights

- Fallen leaves of willow had better nutritive value than poplar, followed by chinar.
- Inclusion of fallen leaves improved the palatability of diets for sheep
- Willow leaves-based TMR enhanced weight gain, nutrient utilization and production economics in sheep
- Paddy straw can be fully replaced by fallen willow leaves in sheep TMR without affecting performance.

INTRODUCTION

Shrinkage of land under fodder cultivation due to urbanization and quality deterioration of grazing lands due to overgrazing has contributed currently to a net deficiency of 35.6% green fodder and 10.95% dry fodder in the country (Yadav et al., 2025), and the respective fodder deficiency figures for Union Territory of Jammu and Kashmir are approximately 54.01% and 40.20% (Wani et al., 2024). Under such fodder scarcity circumstances, there exists a vast scope for enhancing the feed resources through use of unconventional/underutilized feed materials to reduce the gap between demand and supply of fodders for livestock feeding.

In the Kashmir Valley, large quantities of fallen tree leaves are available in autumn every year, representing a huge underutilized feed resource. Traditionally, these leaves are either burned as fuel for Kangri (local heating pots), incorporated into soil as organic matter, or left to decompose in rainwater, often contributing to environmental pollution. However, many of these leaves are palatable and readily consumed by livestock, indicating their potential as an alternative forage source for ruminants. Fallen leaves can effectively replace up to 20 per cent of roughage in complete feed blocks for sheep during periods of feed scarcity (Mishra et al., 2013). In this context, the present study hypothesizes that fallen tree leaves can serve as a viable sole roughage component in complete rations for sheep, supporting sustainable feed resource management in the region.

MATERIALS AND METHODS

Collection of fallen leaves and preparation of experimental diets: Fallen leaves of Willow (*Salix alba*), Poplar (*Populus deltoides*) and Chinar (*Platanus orientalis*) were collected in the late autumn season from different locations in the Kashmir valley, dried, crushed and stored for an experimental feeding trial. Four experimental complete diets with 60:40 roughage to

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concentrate ratio were prepared to meet nutrient requirements recommended for growing sheep (Indian Council of Agricultural Research [ICAR], 2013). Control diet (C) was formulated based on paddy straw as sole roughage source, while in treatment diets, 100% of the paddy straw was replaced by fallen leaves of Willow (T1), Poplar (T2), and Chinar (T3), respectively.

Experimental design and feeding: The experiment was conducted at Mountain Research Centre for Sheep and Goat, SKUAST-K, Shuhama, Srinagar, in which twenty male Corriedale sheep (17.93±1.29 kg body weight and age of about 1 year) were distributed equally into 4 dietary groups in a completely randomized design. The animals were fed individually their respective experimental diets *ad libitum* for 60 days, during which measured quantity of feeds were offered twice daily to the animals in the morning and evening and the residues left were also collected and measured every day to calculate the daily feed intake by the experimental animals. All the experimental animals were offered clean and fresh drinking water twice a day.

Growth studies and feeding economics: At the start of the feeding trial, the body weight of the experimental animals was recorded in the morning before feeding and watering for two consecutive days, and the average was considered as the initial body weight and then periodically recorded at fortnightly intervals. To know the actual effect of the diet, body weight gain as average daily gain (ADG, g/d) and feed conversion ratio (FCR) were calculated. Feeding economics was determined based on the cost of experimental feed, average feed consumed and weight gain by the experimental animal during the trial.

Digestibility study and chemical analysis: At the end of the feeding experiment, a six days duration digestibility trial was conducted using cages to study the nutrient utilization in experimental animals. Feeds and fodders offered, residue left and faeces voided by the animals were measured on 24 h basis, and representative samples (approximately 10% of total amounts of each day) of the same were taken, pooled for each animal, dried in hot air oven at 100±5ºC for overnight, grinded to pass through 1 mm sieve and preserved in airtight containers for further analysis.

The preserved samples were then analyzed for proximate principles (Association of Official Analytical Chemists [AOAC], 2005) to determine digestible nutrient contents of the diets in terms of digestible crude protein (%DCP) and total digestible nutrients (%TDN). Fibre fractions were analysed according to (Van Soest et al., 1991). Calcium and phosphorus content in the feeds was estimated as per the method given by Talapatra (1940).

Statistical analysis: The data generated in the experiment were analyzed by one-way ANOVA using SPSS (2011) Software for Windows, Base 23.0, Marketing Department, SPSS Inc., Chicago, USA. In the CRD statistical model employed, the fixed factor was the diet representing the different fallen leaves as a roughage source fed to the sheep to evaluate their effect on the response variables for comparing the influence of different diets. Each experimental unit (sheep) was randomly assigned to one diet treatment, assuming homogeneity among experimental units. The CRD model partitions total variation into variation due to treatment effects and experimental error. Effects were considered significant at $P<0.05$, indicating a statistically meaningful difference among treatment means.

RESULTS

Chemical composition of experimental feeds: Crude protein (CP) content of concentrate mixture was 21.0%, and that of experimental paddy straw, willow, poplar, and chinar leaves based total mixed rations (TMRs) were 10.86, 13.81, 12.75 and 12.45%, respectively. Ether extract (EE) content was higher in fallen leaves (2.2-2.9%) than paddy straw (1.2%), while the highest values were estimated in concentrate feed (4.15%). Chemical composition of the complete feeds offered to the experimental animals in various groups is presented in Table 1.

Feed consumption and body weight gain: Dry matter (DM) intake, body weight (BW) changes and feed conversion ratio (FCR) in the experimental animals are presented in Table 2. DM intake (kg per day) was higher ($P<0.05$) in groups fed fallen leaves-based TMRs compared to those fed paddy straw-based TMR, with no significant difference among the treatment groups. No significant differences ($P>0.05$) were evident among the groups for DM intake as a percentage of body weight, with values ranging from 4.63% to 5.43%.

Average daily gain (ADG) was significantly ($P<0.05$) higher in sheep fed willow leaf based TMR (163.33±9.95 g/day) compared to those fed diets based on paddy straw (120.28±6.87g/day), poplar leaves

Table 1. Chemical Composition (on %DM basis) and cost of feeds and fodders used in the experiment

Feeds and Fodders	CP	CF	EE	TA	NFE	NDF	ADF	C	HC	ADL	AIA	Ca	P	Cost (Rs.)/q
Paddy straw	4.10	34.80	1.20	10.13	49.77	77.20	52.80	37.40	24.40	10.40	5.50	0.66	0.42	1500
Willow leaves	9.02	27.75	2.20	13.75	47.28	56.70	51.00	11.80	5.70	33.30	1.18	4.02	0.24	400
Poplar leaves	7.25	23.75	2.40	12.80	53.80	64.70	55.50	16.20	9.20	33.00	2.37	3.20	0.17	400
Chinar leaves	6.75	29.15	2.90	9.39	51.81	73.25	67.30	13.10	5.95	48.00	0.91	2.03	0.24	400
Concentrate feeds	21.00	12.30	4.15	18.42	44.13	35.10	20.70	11.50	14.40	6.30	3.11	3.10	0.53	3000
Total mixed rations (TMRs)														
TMR (C)	10.86	25.80	2.38	13.45	47.51	60.36	39.96	27.04	20.40	8.76	4.55	1.64	0.46	2100
TMR (T_1)	13.81	21.57	2.98	15.62	46.02	48.06	38.88	11.68	9.18	22.50	1.95	3.65	0.36	1440
TMR (T_2)	12.75	19.17	3.10	15.05	49.93	52.86	41.58	14.32	11.28	22.32	2.66	3.16	0.32	1440
TMR (T_3)	12.45	22.41	3.40	13.00	48.74	57.99	48.66	12.46	9.33	31.32	1.79	2.46	0.36	1440

Table 2. Feed intake and body weight changes of sheep fed fallen leaves-based TMR

Parameter	C (control)	Dietary groups		
		T_1	T_2	T_3
Feed intake				
Total DM intake (kg)	59.88^{a}±1.35	68.12^{b}±0.94	69.55^{b}±1.63	68.12^{b}±0.21
Daily DM intake (kg/d)	1.00^{a}±0.02	1.14^{b}±0.02	1.16^{b}±0.03	1.14^{b}±0.01
DM intake (% BW)	4.63±0.26	5.10±0.29	5.43±0.28	5.29±0.37
Body weight (BW) changes				
Initial BW (kg)	18.14±0.91	17.71±1.45	17.61±1.26	18.26±1.55
Final BW (kg)	25.36±1.01	27.51±1.45	25.56±1.37	25.49±1.45
Average daily BW gain (g/d)	120.28^{a}±6.87	163.33^{b}±9.95	132.50^{a}±8.46	120.55^{a}±5.93
Feed conversion ratio	8.40^{ab}±0.47	7.03^{a}±0.34	8.91^{b}±0.67	9.51^{b}±0.52

Means bearing the different superscripts in a row differ significantly (P<0.05)

(132.50±8.46 g/day), and chinar leaves (120.55±5.93 g/day) with no difference observed among them in which the lowest ADG was recorded in paddy straw-based TMR-fed group. Feed conversion ratio (FCR) was significantly (P<0.05) improved in sheep fed the willow leaf-based TMR (7.03±0.34), representing better feed efficiency compared to those fed poplar (8.91±0.67) or chinar (9.51±0.52) leaves-based TMRs, which were statistically comparable with each other. The control group had an intermediate FCR value (8.40±0.47) that was statistically similar to all the treatment groups fed different tree leaves-based TMRs.

Nutrient digestibility and nutritive value of experimental TMRs: Significant differences were observed among the dietary groups for digestibility coefficients (%) of all the nutrients except EE (Table 3). Dry matter (DM) digestibility was higher (P<0.05) in animals fed on paddy straw-based TMR than those fed on fallen leaves-based TMRs, with the lowest values observed in animals fed on chinar leaf-based TMR. Likewise, CP digestibility was lower (P<0.05) in poplar and chinar leaves-based TMR-fed groups than those fed paddy straw-based TMR, while no difference was evident between the paddy straw and willow leaf-based TMR-fed groups. EE digestibility was similar among all the groups, with the lowest value in the chinar leaf-based TMR-fed group. Crude fibre (CF), Neutral detergent fibre (NDF), Acid detergent fibre (ADF), cellulose (C) and hemicelluloses (HC) digestibility were higher (P<0.05) in paddy straw than fallen leaves-based TMRs.

Digestible crude protein (DCP) content was the highest (P<0.05) in the willow leaf-based TMR group (9.07%), followed by the control (7.46%) and poplar leaf-based TMR group (7.33%), while the chinar leaf-based TMR group had the lowest value (6.94%). In contrast, total digestible nutrients (TDN) were higher (P<0.05) in the control group (65.61%) compared to all treatment groups in which the willow leaf-based TMR had higher TDN (57.67%) than poplar (55.08%) and chinar (54.32%) leaf-based TMRs.

Production economics: The cost of fallen leaves was ₹400/quintal, paddy straw was ₹1500/quintal, and concentrate feed was ₹3000/quintal. Cost of paddy straw-based TMR was ₹21.00 per kg which got reduced by the replacement of straw to ₹14.40 per kg for fallen leaves-based TMRs (Table 4). Cost of production (/kg gain) ranged from ₹101.29 to ₹ 176.37, with the lowest values for animals fed on fallen willow leaf-based TMR followed by fallen poplar leaf, chinar leaf and paddy straw-based TMR fed groups.

Table 3. Digestibility coefficients (%) of nutrients and nutritive values (%) of fallen leaves-based TMRs in sheep

		Dietary groups		
Nutrients	**C (control)**	**T_1**	**T_2**	**T_3**
DM	71.00^{c}±0.25	63.10^{b}±1.11	60.47^{b}±0.82	56.94^{a}±1.10
CP	68.73^{b}±1.92	65.63^{b}±0.38	57.49^{a}±0.78	55.72^{a}±0.70
CF	74.88^{c}±0.25	60.40^{b}±1.19	52.97^{a}±1.12	55.81^{a}±1.13
EE	76.65±2.96	75.68±5.03	74.84±2.00	69.40±2.57
NFE	73.10^{c}±0.66	66.28^{b}±1.08	64.83^{b}±0.81	60.66^{a}±1.27
NDF	67.88^{b}±0.68	51.01^{a}±1.71	48.64^{a}±1.13	48.11^{a}±1.96
ADF	65.74^{c}±0.73	55.84^{b}±1.41	49.13^{a}±1.43	53.28^{b}±1.20
C	76.58^{c}±1.34	52.76^{b}±4.71	49.62^{ab}±1.21	43.02^{a}±3.54
HC	72.09^{c}±0.86	45.97^{b}±0.71	45.26^{b}±0.49	43.16^{a}±0.68
Nutritive values (%)				
DCP (%)	7.46^{b}±0.21	9.07^{c}±0.05	7.33^{b}±0.10	6.94^{a}±0.09
TDN (%)	65.61^{c}±0.24	57.67^{b}±0.96	55.08^{a}±0.68	54.32^{a}±0.88

Means bearing the different superscripts in a row differ significantly (P<0.05)

Table 4. Production economics of sheep fed fallen leaves-based TMR

	Dietary groups			
Parameter	**C (control)**	**T_1**	**T_2**	**T_3**
Cost of TMR (Rs/kg)	21.00	14.40	14.40	14.40
Total Feed intake (kg)	59.88^{a}±1.35	68.12^{b}±0.94	69.55^{b}±1.63	68.12^{b}±0.21
Total BW gain (kg)	7.22^{a}±0.41	9.80^{b}±0.60	7.95^{a}±0.51	7.23^{a}±0.36
Cost of production (Rs/kg gain)	176.37^{c}±9.97	101.28^{a}±4.91	128.31^{b}±9.66	137.07^{b}±7.52
Reduction in production cost (%)	-	42.57	27.25	22.28

Means bearing the different superscripts in a row differ significantly (P<0.05)

DISCUSSION

Among fallen leaves, the CP content was highest in willow leaves (9.02%), followed by poplar (7.25%) and chinar (6.75%). Roque et al. (2018) also reported that CP content of fallen leaves ranges from 4.9-22.5% with an average value of 10%. Among the feed resources used in the experiment, the lowest CP content (4.10%) was estimated in paddy straw. CP content of experimental TMRs was lower than the recommended value for growing sheep by ICAR (2013). Crude fibre (CF) content was highest in paddy straw, followed by fallen leaves. Among fallen leaves, CF content was higher in chinar leaves, followed by willow and poplar leaves. Among TMR, CF content was higher in the paddy straw-based diet, which may be due to the higher CF content of paddy straw than fallen leaves. However, lignin content was higher in fallen leaves-based TMR than in paddy straw-based TMR, which might be due to the higher lignin content of fallen leaves than paddy straw. Higher lignin content in fallen leaves might be due to the presence of small twigs, which were also incorporated in diet formulations. Neutral detergent fibre (NDF), cellulose, hemicellulose and acid-insoluble ash (AIA) content were higher in paddy straw than fallen leaves; however, acid detergent fibre (ADF) was higher in chinar leaves than paddy straw which may be due to more lignin content of chinar leaves (48%). Kazemi (2021) reported that that fallen leaves possess appreciable content of CP, EE, fibre fractions, ash, Ca and P that contribute to the overall nutritional value of the leaves, making them potentially viable as feed ingredients for ruminants. Variations in chemical composition of fallen leaves in the present study with those of earlier reports might be due to differences in species and locations of collection of fallen leaves.

DM intake was higher in sheep fed fallen leaves-based TMRs probably due to better palatability of fallen leaves than paddy straw. In contrast, Ganai et al. (2024) reported no effect of feeding a mixture of tropical tree foliage on dry matter and organic matter intakes in goats. Higher BW gain in sheep fed willow leaf-based TMR could be due to more protein and Cain takes in the group because of their higher content in willow leaves than other fallen leaves and paddy straw. Also, less DM intake (kg/d) in the paddy straw-based

TMR-fed group might have contributed to lesser nutrient intake that could have resulted into lower BW gain in sheep. Kazemi (2021) reported that the ADG of finishing goats ranges from 100-142 g fed on experimental diets containing different fallen leaves replacing 50% of alfalfa hay and corn silage in comparison to the control group. While Hintsa et al. (2018) reported that replacement of concentrate mixtures with varying proportions of Oldman saltbush (*Atriplex nummularia*) leaves in the diet of highland sheep did not result in significant differences in ADG compared to that of the control group. In the present study, differences of ADG with those of the earlier reports might be due to the use of leaves of different plant species.

Better FCR in willow leaf-based TMR-fed group might be due to higher BW gain in the sheep of the respective group in comparison to other groups. From the previously referenced study, Hintsa et al. (2018) observed no significant difference in FCR between highland sheep fed diets containing Oldman saltbush leaves and those fed the control diet, indicating that incorporating Oldman saltbush as a partial replacement for concentrate mixtures does not compromise the efficiency of feed utilization in sheep.

DM digestibility was higher in the control than the treatment groups, which might be due to higher lignin content in fallen leaves, particularly chinar, than paddy straw. Higher DM intakes in the treatment than the control group could also have contributed in lowering the DM digestibility, as feed intake at higher levels causes decline in digestibility efficiency (Kamal et al., 2024). Lower CP digestibility in poplar and chinar leaves-based TMR-fed groups might be attributed to the presence of tannin in fallen leaves that binds protein and decreases their digestibility. Higher fibre digestibility in paddy straw than fallen leaves-based TMRs might be due to higher lignin content of fallen leaves than paddy straw that reduces the digestibility of fibre fractions of TMR. Kazemi (2021) reported that the digestibility of DM, CP, and NDF in finishing goats fed rations containing fallen leaves replacing corn silage and alfalfa hay ranged from 63.39 to 65.42%, 65.70 to 70.80%, and 39.90 to 42.57%, respectively. In the present study, higher DCP content in willow leaves-based TMR might be due to the highest protein content and higher digestibility of CP in fallen willow leaf-based TMR than paddy straw and other fallen leaves-based TMRs. Better TDN in paddy straw than fallen leaves-based TMR scould be attributed to better digestibility of nutrients in paddy straw-based TMR.

Lowest production cost in willow leaf-based TMR-fed group might be due to the highest ADG and lowest FCR in animals of respective group in comparison to other groups. Replacement of paddy straw by fallen leaves in the TMRs led to a significant reduction in the production cost with decreases of 43%, 27%, and 22% in groups fed willow, poplar, and chinar leaf-based TMRs, respectively, compared to the control group.

It is concluded that 100% of the paddy straw can be replaced by fallen leaves, specially willow in TMR for sheep without any adverse effect on their growth and production, as an alternative strategy to alleviate the fodder deficiency. However, further studies with a large number of animals and for a long duration are required.

Conflict of interest: The authors have no conflict of interest in this study.

Author's contribution: HAA: Conception and design of experiment; YAB: Acquisition of data, performed statistical analysis of data; AMG: Performed interpretation of the result and provided technical efforts; JF: Preparation of first draft of the manuscript. The final manuscript was read and approved by all authors.

Data availability statement: Data of research conducted is preserved by the authors and will be made available on request.

Ethical approval: This study was conducted after approval from the "Institutional Animal Research and Ethical Committee" obtained vide reference number AU/FVS/Acad/EC-23/PF/4341-46.

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