

Dietary Incorporation of Moringa (*Moringa oleifera*) and Hedge lucerne (*Desmanthus virgatus*) leaves in Pelleted Concentrate Feeds: Impacts on Intake, Growth Performance, Digestibility and Nutritional worth in Camel (*Camelus dromedarius*) Calves

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Abstract

The present study evaluated the effect of incorporation of Moringa and Hedge lucerne leaves into pelleted concentrate feed on nutrient intake, growth performance, body measurements, digestibility, rumen degradability and practical nutritional worth in camel calves. Three dietary treatments were formulated: a control pelleted concentrate feed without any leaf incorporation (T_1), pelleted concentrate feed containing 10% moringa leaves (T_2), and pelleted concentrate feed containing 10% hedge lucerne leaves (T_3). Results indicated that DMI, CFI, NDFI, ADFI and EEI were significantly ($P < 0.05$) higher in the leaf-incorporated pelleted concentrate diets compared to control. Camel calves fed moringa-based diet exhibited superior average daily gain and improved feed conversion ratio relative to T_1 treatment group. Body measurements, including heart girth and tail length were significantly enhanced in T_2 and T_3 treatment groups. Digestibility of dietary protein and ether extract was significantly ($P < 0.01$) higher on moringa-based diet. *In-vitro* rumen degradability and practical nutritional worth indices (DCP, TDN, ME) also improved in the leaf-incorporated feeds; more advantage was observed with moringa leaf-based feed. Overall, incorporation of leaf based pelleted concentrate diet (Moringa and Hedge lucerne) improved nutrient utilization, growth performance and dietary energy value without adverse effects which revealed their properties as sustainable alternative feed resources for livestock feeding system.

Introduction

Feed scarcity, increasing costs of conventional concentrate ingredients and competition between human and livestock food resources remain major constraints to sustainable livestock production, particularly in arid and semi-arid regions (FAO 2020; Makkar 2023). Camel production systems, though well adapted to harsh environments, are increasingly transitioning toward semi-intensive and intensive management systems, where balanced and cost-effective feeding strategies are essential to maximize growth and productivity (Faye 2020; Al-Hazmi et al. 2022). Tree legumes and fodder shrubs have gained attention as alternative feed resources due to their high crude protein content, favourable amino acid profile, bioactive compounds and adaptability to marginal area (Patra et al. 2019; Makkar et al. 2021). Among these, Moringa and Hedge lucerne are significant for their high nutritive value, digestibility, and antioxidant potential (Leone et al. 2018; Devendra et al. 2021). Moringa leaves are rich in rumen-degradable and bypass protein, minerals and polyphenols, which may enhance rumen fermentation efficiency and nutrient utilization (Moyo et al. 2020; Nouman et al. 2022). Another promising fodder is Hedge lucerne, which is known for its adaptability, moderate tannin content and positive effects on fibre digestion when used judiciously (Dalzell et al. 2019; Suybeng et al. 2021). Pelleting of concentrate feeds has been shown to improve feed intake, reduce selective feeding, enhance nutrient density, and stabilize rumen fermentation (Abd El-Tawab et al. 2019; Zhang et al. 2023). Incorporation of leaves into pelleted concentrate diets can further enhance the utilization of unconventional feed resources while maintaining physical and nutritional uniformity. However, information on the combined effects of leaf-incorporated pelleted concentrate feeds on intake, growth, digestibility, rumen degradability and nutritional worth in camel calves remains limited. Therefore, the present study was undertaken to evaluate the effect of

Moringa and Hedge lucerne leaves incorporated into pelleted concentrate feed on nutrient intake, growth performance, body measurements, nutrient digestibility, *in-vitro* rumen degradability and practical nutritional worth in camel calves.

Materials and methods

Ethics approval

The protocol of experiment was sanctioned by Institutional Animal Ethical Committee (IAEC) of the College of Veterinary and Animal Science, Bikaner (RAJUVAS), IAEC/CPCEA (Approval No.- IAEC/RES/14/03). Animals were cared and managed as per protocol and directives of IAEC.

Location of experiment

The study was conducted at ICAR-National Research Centre on Camel (NRCC), located in the Jorbeer area of Bikaner city, Rajasthan, India. The Centre is situated at 28°01' N latitude and 73°11' E longitude, with a time zone of GMT + 05:30 h. The climate is characterized as hot and arid, with low and erratic annual rainfall ranging from 260 to 440 mm. Ambient temperatures generally range from 30 to 48°C during summer and from 4 to 28°C during winter. The experiment was carried out from May to December 2024, during which the minimum and maximum ambient temperatures ranged from 15°C to 41°C, respectively, while relative humidity varied between 22% and 60%.

Experimental Feed and Animals

Three iso-nitrogenous pelleted concentrate feeds were formulated on DM basis using conventional roughages (T_1), 10% Moringa leaf incorporated pelleted concentrate feed (T_2), and 10% Hedge lucerne leaf incorporated pelleted concentrate feed (T_3). The roughage component consisted of crop residue of groundnut (*Arachis hypogea*) and guar (*Cymopsis tetragonaloba*) mixed in 50:50 ratio. The nutrient requirements of the experimental animals were formulated to meet ICAR (2013) standards. Fifteen healthy un-weaned female camel calves of similar age (3–4 months), body weight and uniform conformation were randomly selected from the camel herd of ICAR-NRCC, Bikaner. The calves were randomly allotted to three treatment groups (@ 5 each) for a feeding trial of 180 days.

Statistical analysis

The data generated during the experiment was subjected to statistical analysis using by SPSS statistical software (2011) Version 20.0 and the data were statistically analyzed using one-way and two-way ANOVA procedures for difference between treatments and periods. The difference between means was declared significant at $P < 0.05$ and $P < 0.01$. Duncan's multiple range test was conducted for comparing among the averages.

Result and discussion

Chemical composition analysis of experimental feed

The chemical composition of feed is usually considered as preliminary index for the assessment of quality of feed. Moringa leaves contained 23.22% DM, 91.31% OM, 25.06% CP, 17.35% CF, 4.42% EE, 17.37% total ash, 35.77% NFE, 39.53% NDF, 32.24% ADF, 7.29% hemicellulose, 22.40% cellulose and 7.28% lignin. Hedge lucerne leaves showed comparatively higher DM (25.03%), OM (91.88%), CP (26.30%) and EE (16.22%), with CF, NDF, ADF, hemicellulose, cellulose and lignin contents of 14.45%, 34.60%, 7.79%, 13.31% and 9.88%, respectively. The pelleted concentrate feeds in T₁, T₂ and T₃ treatment groups had comparable DM (95.99–96.76%) and OM (95.64–96.67%) contents. CP was higher in leaf-incorporated pelleted concentrate diets (T₂: 18.24%; T₃: 18.02%) treatment groups compared to control (T₁: 17.14%). EE ranged from 3.43 to 4.38%, while T₃ treatment groups recorded the highest CF (9.71%) and lowest NFE (49.56%) and T₂ treatment groups revealed the lowest CF (6.70%) and highest NFE (54.96%). Total ash varied from 6.64 to 8.70%. Fibre fractions (NDF and ADF) were higher in T₃ treatment group, whereas hemicellulose was lowest in T₃ treatment group. Cellulose and lignin contents varied moderately among treatments.

Nutrient Intake

Leaf incorporation significantly influenced nutrient intake patterns (Table 1). DMI (kg/d) was significantly higher ($P < 0.05$) in T₂ and T₃ compared to the control. Fibre fraction intakes (CFI, NDFI, and ADFI) and EEI were also significantly increased in leaf-incorporated diets. However, DMI in terms of 100 kg/ body weight and $W^{0.75}$ did not differ significantly among treatments.

Growth Performance and Feed Efficiency

Camel calves fed moringa and hedge lucerne based pelleted concentrate feeds revealed significantly higher final body weight and average daily gain compared to the control (Table 2). Feed conversion ratio was significantly improved (lower FCR) in T₂ and T₃, indicating enhanced feed efficiency with leaf incorporation.

Body Measurements

Body measurements showed significant improvements in T₂ and T₃ (Table 3). Heart girth, tail length and body height (cm) were significantly greater in T₂ and T₃, denoting better skeletal and muscular development compared to T₁.

Nutrient Digestibility

Digestibility coefficients of CP and EE were significantly higher ($P < 0.05$) in the moringa-based diet (Table 4). DMD and OMD were numerically improved in T_2 , while fibre digestibility remained comparable among treatments.

In-vitro Rumen Degradability

In-vitro dry matter and crude protein degradability were significantly higher in T_2 compared to T_1 (Table 5), indicating improved rumen degradability of nutrients in moringa-incorporated pellets.

Practical Nutritional Worth and Digestible Nutrient Intake

Diets containing moringa leaves displayed significantly higher digestible crude protein, total digestible nutrients and metabolizable energy values; although the energy: protein ratio remained statistically comparable (Table 6). Digestible crude protein intake expressed on a metabolic body weight basis was significantly higher in T_2 (Table 7), while other digestible nutrient intake parameters remained comparable across treatments.

Table 1
Effect of Moringa and Hedge lucerne leaves on nutrient intake in different treatment groups

Attributes	Treatment groups			SEM	P value		
	T ₁	T ₂	T ₃		T	P	T×P
DMI (kg/d)	2.84 ^a	3.11 ^b	3.10 ^b	0.05	0.001	0.001	0.912
DMI (kg/100kg BW)	1.87	1.78	1.88	0.04	0.362	0.127	0.999
DMI (g/kg W ^{0.75})	65.32	64.66	66.89	1.57	0.515	0.001	0.998
OMI (kg/d)	1.93	2.06	2.04	0.04	0.004	0.058	0.991
OMI (kg/100kg BW)	1.31	1.23	1.29	0.04	0.241	0.001	1.000
OMI (g/kg W ^{0.75})	45.58	44.21	45.59	1.12	0.527	0.001	1.000
CPI (kg/d)	0.34	0.36	0.37	0.00	0.091	0.051	0.819
CFI (kg/d)	0.59 ^a	0.65 ^b	0.63 ^b	0.01	0.001	0.001	0.745
EEI (kg/d)	0.06 ^a	0.08 ^b	0.08 ^b	0.00	0.001	0.001	0.998
NDFI (kg/d)	0.72 ^a	0.78 ^b	0.79 ^b	0.03	0.002	0.003	1.000
ADFI (kg/d)	0.22 ^a	0.36 ^c	0.31 ^c	0.00	0.001	0.001	0.446

T = treatment effect; P = period effect; T × P = interaction between treatment and period.

SEM: Standard error for means. Means within a row bearing different superscripts (a, b, c) differ significantly ($P < 0.05$)/($P < 0.01$); DMI-Dry matter intake; OMI-Organic matter intake; CPI-Crude protein intake; CFI-Crude fibre intake; EEI-Ether extract intake; NDFI-Neutral detergent fibre intake; ADFI-Acid detergent fibre intake

Table 2
Effect of Moringa and Hedge lucerne leaves on live body weight (kg), average daily gain (g/d) and feed conversion ratio in different treatment groups

Attributes	Treatment groups			SEM	P value		
	T ₁	T ₂	T ₃		T	P	T×P
Initial weight (kg)	109.40	119.60	109.40	6.92	0.001	0.001	1.000
Final weight (kg)	150.36 ^a	170.20 ^b	162.87 ^b	10.85			
Average daily gain (g/d)	530.00 ^a	644.44 ^b	636.66 ^b	25.61	0.001	0.004	0.172
Feed conversion ratio	6.45 ^b	5.13 ^a	5.29 ^a	0.33	0.015	0.126	0.196

T = treatment effect; P = period effect; T × P = interaction between treatment and period.

SEM: Standard error for means. Means within a row bearing different superscripts (a, b) differ significantly ($P < 0.01$).

Table 3
Effect of Moringa and Hedge lucerne leaves on body measurements in different treatment groups

Attributes	Treatment groups			SEM	P value		
	T ₁	T ₂	T ₃		T	P	T×P
Body height (cm)	154.26 ^a	154.15 ^a	155.43 ^b	0.80	0.002	0.001	1.000
Body length (cm)	115.00 ^b	116.78 ^b	117.55 ^b	1.53	0.001	0.001	1.000
Heart girth(cm)	152.58 ^a	154.66 ^b	155.24 ^b	1.04	0.001	0.001	1.000
Tail length (cm)	43.70 ^a	46.66 ^b	45.86 ^c	0.82	0.001	0.001	0.963

T = treatment effect; P = period effect; T × P = interaction between treatment and period.

SEM: Standard error for means. Means within a row bearing different superscripts (a, b) differ significantly ($P < 0.01$)

Table 4
Effect of Moringa and Hedge lucerne leaves on nutrient and fibre fractions digestibility in different treatment groups

Attributes (%)	Treatment groups			SEM	P value
	T ₁	T ₂	T ₃		
DMD	56.44 ^{ab}	57.89 ^b	53.90 ^a	0.70	0.052
OMD	60.23 ^a	66.89 ^b	64.79 ^{ab}	1.18	0.051
CPD	61.87 ^a	69.68 ^b	63.66 ^a	1.15	0.004
CFD	40.95	45.13	42.41	1.20	0.387
EED	54.03 ^a	62.29 ^b	51.00 ^a	1.75	0.010
NDFD	49.71	48.61	42.32	2.87	0.561
ADFD	41.74	40.92	36.78	2.86	0.778

T = treatment effect; SEM: Standard error for means. Means within a row bearing different superscripts (a, b) differ significantly ($P < 0.05$)/($P < 0.01$); DMD-Dry matter digestibility; OMD-Organic matter digestibility; CPD-Crude protein digestibility; CFD-Crude fibre digestibility; EED-Ether extract digestibility; NDFD-Neutral detergent fibre digestibility; ADFD-Acid detergent fibre digestibility.

Table 5
Effect of Moringa and Hedge lucerne leaves on *invitro* rumen degradability in different treatment groups

Attributes (%)	Treatment groups			SEM	P value
	T ₁	T ₂	T ₃		
IVDMD	66.95 ^a	71.84 ^b	69.11 ^{ab}	0.84	0.040
IVOMD	68.13	67.32	66.95	0.61	0.763
IVCPD	58.38 ^a	64.01 ^b	60.19 ^{ab}	0.96	0.030

T = treatment effect; SEM: Standard error for means. Means within a row bearing different superscripts (a, b) differ significantly ($P < 0.05$); IVDMD- *In-vitro* dry matter digestibility; IVOMD- *In-vitro* organic matter digestibility; IVCPD- *In-vitro* crude protein digestibility.

Table 6
Effect of Moringa and Hedge lucerne leaves on practical nutritional worth in
different treatment groups (Nutritive value g/kg DM)

Attributes	Treatment groups			SEM	P value
	T ₁	T ₂	T ₃		
DCP (g/kg)	69.93 ^a	79.02 ^b	71.94 ^a	1.33	0.004
TDN (g/kg)	555.75 ^a	618.84 ^b	599.40 ^{ab}	11.04	0.043
ME (Mcal/kg)	2.45 ^a	2.73 ^b	2.64 ^{ab}	0.04	0.044
Energy: Protein ratio	7.96	7.83	8.34	0.14	0.350

T = treatment effect; SEM: Standard error for means. Means within a row bearing different superscripts (a, b) differ significantly ($P < 0.05$)/($P < 0.01$); DM-Dry matter; DCP-Digestible crude protein; TDN-Total digestible nutrient intake; ME-Metabolisable energy.

Table 7

Effect of Moringa and Hedge lucerne leaves on digestible nutrients intake in different treatment groups

Attributes	Treatment groups			SEM	P value
	T ₁	T ₂	T ₃		
DDMI					
kg/d	1.32	1.48	1.20	0.09	0.559
kg/100kg BW	0.85	0.87	0.75	0.26	0.751
g/kg W ^{0.75}	53.43	54.34	49.47	3.83	0.877
DOMI					
kg/d	1.27	1.52	1.29	0.10	0.575
kg/100kg BW	0.81	0.90	0.80	0.07	0.835
g/kg W ^{0.75}	28.92	32.67	28.63	2.42	0.778
DCPI					
kg/d	0.16	0.20	0.16	0.01	0.421
kg/100kg BW	0.10	0.12	0.10	0.00	0.641
g/kg W ^{0.75}	3.02 ^a	3.77 ^b	3.31 ^{ab}	0.46	0.025
TDNI					
kg/d	1.31	1.58	1.32	0.10	0.539
kg/100kg BW	0.84	0.93	0.82	0.07	0.814
g/kg W ^{0.75}	29.83	33.91	29.37	2.50	0.748
MEI					
Mcal/d	5.77	6.98	5.84	0.47	0.538
Mcal/100kg BW	3.71	4.12	3.61	0.32	0.584
kcal/kg W ^{0.75}	131.27	149.21	129.24	11.02	0.815
T = treatment effect; SEM: Standard error for means. Means within a row bearing different superscripts (a, b) differ significantly (P < 0.05)					

Discussion

Higher DMI was observed in T₂ and T₃ treatment groups due to better feed palatability and balanced nutrient availability, rather than differences in body size, since feed intake per unit metabolic weight was similar across all the treatments. Pelleting prevents selective feeding, resulting in more uniform nutrient intake in different treatment groups. In addition, Moringa and Hedge lucerne leaves provide easily fermentable carbohydrates and moderate fibre, which enhanced rumination and saliva secretion, supports sustained feed intake (Patra and Saxena 2020; Zhang et al. 2023). The present results agree with several earlier reports showing positive effects of Moringa and Hedge lucerne supplementation on feed intake and growth performance (Tona et al. 2014; Imran et al. 2016; Aharwal et al. 2018; Sonawane et al. 2019; Wandara et al. 2020; Patir et al. 2023). However, some studies reported no significant effect on dry matter, organic matter, or crude protein intake (Sarkar et al. 2021; Sharma et al. 2024).

The better growth performance and improved feed conversion ratio observed in T₂ treatment group due to the higher crude protein intake, improved protein digestibility and greater *in-vitro* protein degradability. This dual protein supply improves microbial protein synthesis and the efficient use of metabolizable protein, leading to higher average daily gain and better feed efficiency (Leone et al. 2018; Nouman et al. 2022).

The body measurements, particularly heart girth and body height in calves receiving leaf-incorporated pelleted concentrate diets reflect improved muscle and skeletal development due to dietary protein quality and energy availability. The presence of natural antioxidants, saponins and phenolic compounds in Moringa leaves may have contributed to stabilization of rumen microbial membranes and improved enzymatic activity, thereby enhancing lipid and protein hydrolysis (Faye 2020; Al-Hazmi et al. 2022; Patra et al. 2019; Suybeng et al. 2021; Elaidy et al. 2017; Kumar et al. 2018; Badawi et al. 2022; Bhokre et al. 2020; Sharma et al. 2024; Thirumeignanam et al. 2020; Maiti et al. 2022; Mouli and Sharada 2024).

Higher *in-vitro* dry matter and crude protein degradability was observed in Moringa leaf incorporated pelleted concentrate diet which was suggestive of improved fermentability and microbial accessibility of nutrients. Pelleting combined with Moringa incorporation likely increased surface area exposure and reduced particle size, facilitating faster microbial colonization and enzymatic action (Dalzell et al. 2019; Makkar et al. 2021).

Earlier observations (Dey et al. 2014; Maranatha et al. 2020), also revealed improved *in-vitro* dry matter and organic matter digestibility with inclusion of *Moringa oleifera* leaf meal at 10% in complete feeds. In contrast, Nouala et al. (2006) observed no significant differences in *in-vitro* true digestibility at 10–20% Moringa supplementation. Variations among studies may be attributed to differences in plant secondary metabolites and nutrient interactions.

Improved practical nutritional worth (DCP, TDN, ME and Energy: protein ratio) in the Moringa leaves incorporated diet provide strong nutritional justification for the superior performance. The comparable energy: protein ratio across different treatments indicates that the diets provided a balanced supply of energy and protein, which is essential for optimal growth of camel calves. Moreover, higher DCP and ME

in T₂ treatment groups indicated a stable energy-protein relationship. Maintaining this balance prevents unnecessary loss of protein or energy which supports consistent growth of camel calves while maintaining metabolic efficiency. Even though digestible nutrient intake was similar among different treatments, the higher nutrient density and better feed conversion in T₂ treatment group suggest more efficient use of nutrients for growth rather than maintenance. This indicates the beneficial role of Moringa leaves in improving nutrient utilization and growth efficiency in camel calves (Aharwal et al. 2018; Abdel-Raheem and Hassan, 2021; Wankhede et al. 2022; Srivastav et al. 2023; Sherasiya et al. 2022; Mouli and Sharada 2024) which were suggestive of inclusion rate dependent effects on animal species.

Conclusion

Incorporation of Moringa and Hedge lucerne leaves into pelleted concentrate feed significantly improved nutrient intake, growth performance, feed efficiency, body development, digestibility, rumen degradability and dietary energy value in camel calves. Inclusion of Moringa leaves @ 10% level in the pelleted concentrate feed is the best proposition to achieve growth performance, digestibility of nutrients and nutritional worth in camel calves. These findings revealed that leaf-incorporated pelleted concentrate feeds can serve as nutritionally efficient and sustainable alternatives to conventional concentrate feeds in livestock production systems.

Declarations

Author contributions

All authors contributed to the conception and design of the study. All authors read and approved the final manuscript.

Data availability

The data that support the finding of this study are available from the corresponding author upon reasonable request.

Declarations Ethical approval

The protocol of experiment was sanctioned by Institutional Animal Ethical Committee (IAEC) of the College of Veterinary and Animal Science, Bikaner (RAJUVAS), IAEC/CPCEA (Approval No.- IAEC/RES/14/03). Animals were cared and managed as per protocol and directives of IAEC.

Conflict of interest: None

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