RESEARCH ARTICLE

Comparative Effects of *Moringa oleifera* Leaf Meal, Flaxseed and their Combination on Growth Metrics and Feed Efficiency of Crossbred Goat Kids

Srashti Dixit*, Ramesh Chandra, Arun Kumar Misra

Abstract

This study evaluated the effects of *Moringa oleifera* leaf meal (MOLM) and flaxseed supplementation on growth performance, feed efficiency and utilization of Alpine × Beetal crossbred goat kids. Female Alpine Beetal goat kids (n=32) of similar age (3 months old) and weight (10-12 kg) were randomly assigned to 4 dietary treatments (n=8 each): Control (basal diet), T1 (20% MOLM), T2 (20% flaxseed) and T3 (10% MOLM + 10% flaxseed). The feeding trial lasted for 120-days. The T1 group demonstrated significantly higher dry matter & nutrient intake, nutrient digestibility, final body weight, average daily body weight gain, feed conversion indices, and nitrogen retention followed by T3 compared to combined treatment and control diet ($p<0.05$). These results indicated that dietary incorporation of 20% MOLM effectively enhanced growth performance and feed efficiency in goat kids and T3 group outperformed T2 but did not exceed T1 performance. Thus it was concluded that *Moringa oleifera* leaf meal supplementation represents a sustainable dietary strategy for improving growth and productive performance in Alpine × Beetal crossbred goat kids.

Keywords: Feed intake, Flaxseed, Goat kids, Growth performance, *Moringa oleifera*.

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Introduction

Amid changing agro-climatic conditions and depleting resources, goats are emerging as the "Future Animal" for resource poor rural communities due to their exceptional adaptability and resilience against heat stress and illnesses (Choudhary *et al*., 2018). Despite this resilience, high pre-weaning kid mortality (~34.60%), primarily driven by low birth weight and diarrhea, remains a major bottleneck (Kumar *et al*., 2020). Because initial weight dictates subsequent growth trajectories, poor-quality roughages during dry seasons compound this issue, leading to severe weight loss or death (Tona *et al*., 2014). Consequently, exploring accessible, unconventional feed alternatives is critical. *Moringa oleifera* leaf meal (MOLM) and flaxseed offer sustainable solutions. As a fast-growing perennial, *Moringa oleifera* yields high biomass and supplies green fodder year-round (Kholif *et al*., 2016). Its leaves are rich in essential amino acids, minerals, vitamins and phenolics, containing 17.9-26.8% crude protein with an impressive 47% bypass protein fraction (Sultana *et al*., 2015). Additionally, flaxseed serves as an excellent source of high-quality protein, dietary fiber, energy and omega-3 fatty acids, which significantly improve growth, metabolic health and immune function for ruminants (Teama and El-Tarabany, 2016; El-Sayed *et al*., 2020). This study evaluated the comparative and combined effects of dietary MOLM and flaxseed supplementation on the growth performance, feed intake and utilisation of Alpine × Beetal crossbred kids.

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Materials and Methods

Location and Design of Experiment

120-days study was conducted at the Livestock Research Centre, ICAR-NDRI, Karnal (India), from February to May 2022, following institutional ethical guidelines. Thirty-two female Alpine Beetal kids (3 months old, 10-12 kg body weight) were selected and fed according to ICAR (2013) standards. Utilizing a completely randomized design, kids were divided into 4 groups (n=8): Control (basal diet, 60:40 roughage-to-concentrate ratio), T1 (20% concentrate replaced with MOLM), T2 (20% concentrate replaced with flaxseed) and T3 (10% MOLM + 10% flaxseed replacement).

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Procurement and Chemical Composition of Feed

Moringa leaves were harvested from the NDRI farm, shade-dried and ground. Flaxseed was purchased locally and mildly roasted at 140-145°C before offering to kids. The feeds were analyzed for proximate composition using AOAC (2005) method. The fibre fractions, *viz.* neutral and acid detergent fibres (NDF & ADF) were determined as per Van Soest *et al.* (1991). The minerals were estimated by using Atomic absorption (AAS) spectrophotometer method.

Weighing and Feed Intake of Kids

Kids were weighed at day zero and fortnightly thereafter to calculate average daily gain (ADG), feed conversion ratio (FCR) and feed conversion efficiency (FCE) by using the following formulae:

$$FCR = \frac{Dry\ matter\ intake\ (kg)}{Weight\ gain\ (kg)} \qquad FCE = \frac{Weight\ gain\ (g/day)}{Dry\ matter\ intake\ (g/day)}$$

A subsequent 7-day metabolic trial in specialized cages quantified nutrient intake, digestibility coefficient and nitrogen balance. Daily feed offered, refusals, urine and feces were collected. Aliquots of feed and feces (20%) were oven-dried overnight for dry matter (DM) evaluation. Fecal (1%) and 24-h urine samples were preserved in 25% H_2SO_4 for Kjeldahl nitrogen determination. The digestibility coefficients for Dry matter (DM), Organic matter (OM), Crude protein (CP), Ether extract (EE), Neutral detergent fibre (NDF), Acid detergent fibre (ADF) were calculated from the nutrient intake and nutrient outgo in feces during metabolism as given below:

$$Digestibility(\%) = \frac{Nutrient\ intake - Nutrient\ outgo\ in\ faeces}{Nutrient\ intake} \times 100$$

Statistical Analysis

Data was statistically analyzed using a one-way ANOVA and the significance of the difference between the mean values was determined by Tukey Post-hoc test (Snedecor and Cochran 1994) through SPSS version 22.0 software.

Results and Discussion

Proximate Composition of Feeds

The proximate composition of the experimental feeds is presented in Table 1. The DM of *Moringa oleifera* leaf meal (MOLM) was 91.80%. Its overall profile aligned with previous studies (Biswal, 2021; Meel *et al*., 2018), exhibiting the highest CP at 19.61% and the lowest NDF at 24.83% among all feeds. Contrary, CP level was slightly lower than some prior studies (Kholif *et al*., 2016) which may be attributed to variations from agro-ecological factors (Meel *et al*., 2018). Flaxseed contained 92.37% DM, recording the highest OM (95.51%) and EE (39.87%), reflecting its rich fatty acid profile, while yielding the lowest total ash (TA) at 4.49% (Langamu, 2021). The concentrate mixture (91.38% DM) met standard commercial requirements, notably possessing a low ADF of 14.36%. Maize and Berseem had DM contents of 31.39% and 11.24%, respectively, with Berseem showing an elevated TA of 10.36%. Wheat straw (92.32% DM) contained the highest fibrous fractions (79.24% NDF; 52.41% ADF) and the lowest CP (2.91%) and EE (1.06%), consistent with Langamu (2021).

Mineral Composition of Feeds

The mineral composition of the experimental feeds is presented in Table 2. In MOLM, the calcium concentration was 1.47%, which falls within the range of previous studies (Ajantha *et al*., 2018; Zaher *et al*., 2020; Biswal, 2021). Magnesium (Mg) levels aligned with Ajantha *et al.* (2018), while sodium and potassium were lower than values recorded by Zaher *et al.* (2020) and Ajantha *et al.* (2018). Additionally, MOLM contained higher concentrations of manganese, iron, zinc and copper compared to values reported by Zaher *et al.* (2020). Essential minerals like Zn, Cu and Fe act as vital cofactors for ruminal microbes, which enhances microbial fermentation, boosts nutrient digestibility, and stimulates voluntary feed intake. Overall, flaxseed nutrient profile agrees with previous studies (Morris, 2007). Flaxseed serves as an excellent mineral supplement; its high concentrations of Ca, Mg and phosphorus (Singh *et al.,* 2011) are critical for skeletal development and energy metabolism, ultimately promoting improved feed conversion efficiency and steady body weight gain in growing animals.

Effect of MOLM and Flaxseed on Digestibility Coefficient (%)

Nutrient digestibility coefficients (%) of kids are presented in Table 3. Compared to the control, all supplemented groups

Table 1: Proximate analysis of different feeds (on DM basis)

Parameter (%)	MOLM	Flaxseed	Concentrate	Berseem	Wheat straw
Dry matter	91.80	92.37	91.38	11.24	92.32
Organic matter	91.68	95.51	90.21	89.64	92.14
Crude protein	19.61	19.38	19.26	17.12	2.91
Ether extract	4.27	39.87	3.72	1.81	1.06
Total ash	8.32	4.49	9.79	10.36	7.86
Neutral detergent fibres	24.83	44.68	29.61	44.61	79.24
Acid detergent fibres	16.58	28.94	14.36	28.43	52.41

Values were derived from mean values of multiple replications of each sample

demonstrated significantly improved ($p<0.05$) nutrient digestibility, with T1 yielding the maximum enhancements. The elevated DM, OM, and CP digestibility observed in T1 aligned with previous studies (Meel *et al*., 2018; Biswal, 2021; Aggarwal *et al*., 2026). Increased DM digestibility in T1 group could be attributed to less dietary fiber concentration in MOLM than other feeds. Furthermore, enhanced CP digestibility could be attributed to abundant bypass protein in Moringa foliage. The increased OM digestibility in T1 corroborated with report of Kholif *et al.* (2016). Regarding ADF, T1 and T3 outperformed the control, consistent with Sultana *et al.* (2015), who associated higher Moringa levels with improved ADF breakdown, though Biswal (2021) observed non-significant variation. Conversely, flaxseed supplementation primarily influenced the T2 group. The notable CP and EE improvements in T2 aligned with Meteab *et al.* (2018) in Damascus goats fed 10% flaxseed. This enhanced CP digestibility is attributed to fat droplets in flaxseed that encapsulate the protein, shielding it from ruminal degradation and increasing intestinal absorption (Singh *et al*., 2011). Increased EE digestibility with flaxseed or its oil is further supported by Kholif *et al*. (2016) and Langamu (2021).

Effect of MOLM and Flaxseed on Feed & Nutrient Intake

The fortnightly feed and nutrient intake (DM, OM, CP, TDN, EE, NDF and ADF) of goat kids fed diet supplemented with MOLM and flaxseed over 120 days are presented in Table 4 and 5, respectively. Overall DM intake was significantly higher ($p<0.05$) in all treatment groups compared to the control, with T1 (20% MOLM) exhibiting the highest values. The increased DMI in T1 aligned with Biswal (2021) and Ukey *et al*. (2025) in Barbari goats fed 50% MOLM and Wankhede *et al*. (2022) utilizing 25% *Moringa* foliage. This improvement is widely attributed to optimal fiber fractions, a favourable forage to concentrate ratio and enhanced palatability (Sultana *et al*., 2015; Kholif *et al*., 2016), although some studies reported no significant effects on Mehsana and Surti kids (Damor *et al*., 2017; Pandey *et al*., 2022). Similarly, the elevated DMI in T2 aligned with the findings of Meteab *et al*. (2018) with flaxseed replacement, contrasting with the non-significant differences observed by Langamu (2021). Furthermore, CP and TDN intakes were significantly higher in T1. Groups T2 and T3 displayed parallel values, though all supplemented groups outperformed the control. This surge in CP and TDN intake in the MOLM group agreed with Kholif *et al*. (2016) and Wankhede *et al*. (2022). Similarly, increased EE, ADF and NDF intake in T1 group aligned with Biswal (2021). The rich phytonutrient matrix of Moringa leaves which is abundant in minerals (Ca, Mg, K, Zn, Fe, Cu), vitamins and β-carotene likely boosted diet palatability, rumen microbial activity and systemic nutrient availability (Kasolo *et al*., 2010).

Table 2: Mineral analysis of different feeds

Minerals	MOLM	Flaxseed	Concentrate	Berseem	Wheat straw
Calcium (Ca %)	1.47	0.21	0.94	1.76	0.62
Phosphorus (P %)	0.21	0.62	0.70	0.31	0.71
Magnesium (Mg %)	0.46	0.38	0.77	0.63	0.16
Sodium (Na %)	0.018	0.023	0.07	0.016	0.011
Potassium (K %)	1.31	0.78	0.63	3.31	1.24
Iron (Fe ppm*)	352.35	46.2	341.82	263.31	158.21
Manganese (Mn ppm*)	58.60	23.18	54.38	31.42	27.63
Zinc (Zn ppm*)	38.61	32.28	78.50	16.22	10.21
Copper (Cu ppm*)	18.72	0.0011	28.42	3.82	2.82

*ppm: parts per million. Values are derived from mean values of multiple replications of each sample

Table 3: Effect of MOLM and flaxseed on digestibility coefficient (%)

Parameter	Treatments			
	Control	T1	T2	T3
Dry matter	$58.30^{a}\pm0.05$	$67.04^{d}\pm0.05$	$61.94^{b}\pm0.06$	$62.83^{c}\pm0.03$
Dry matter	$58.72^{a}\pm0.02$	$68.98^{d}\pm0.02$	$62.71^{b}\pm0.03$	$63.65^{c}\pm0.03$
Crude protein	$55.78^{a}\pm0.06$	$63.80^{c}\pm0.06$	$58.57^{b}\pm0.08$	$59.81^{b}\pm0.04$
Ether extract	$63.99^{a}\pm0.02$	$69.03^{c}\pm0.08$	$66.15^{b}\pm0.13$	$65.40^{b}\pm0.07$
Neutral detergent fibre	$49.26^{a}\pm0.21$	$55.39^{c}\pm0.28$	$53.78^{bc}\pm0.23$	$52.43^{b}\pm0.23$
Acid detergent fibre	$39.87^{a}\pm0.15$	$43.18^{c}\pm0.05$	$40.12^{ab}\pm0.07$	$41.01^{b}\pm0.05$

Control (basal diet, 60:40 roughage-to-concentrate ratio), T1 (20% concentrate replaced with MOLM), T2 (20% concentrate replaced with flaxseed) and T3 (10% MOLM + 10% flaxseed replacement).
Mean bearing different superscripts ^{abcd} in a row differ significantly ($p<0.05$).

Table 4: Fortnightly dry matter intake of kids fed diet supplemented with MOLM and flaxseed (Mean ± SEM)

Fortnights	Control	T1	T2	T3
1	401.89^{a}±2.70	427.04^{c}±2.24	408.64^{ab}±1.89	415.89^{b}±1.85
2	421.69^{a}±2.88	446.58^{c}±3.07	427.03^{ab}±2.03	433.02^{b}±1.83
3	441.23^{a}±3.73	472.35^{c}±2.8	448.86^{ab}±2.30	454.91^{b}±1.83
4	460.35^{a}±4.80	501.25^{c}±3.69	470.90^{ab}±1.90	474.49^{b}±1.41
5	478.32^{a}±4.36	528.79^{c}±3.57	490.29^{ab}±2.43	500.78^{b}±3.26
6	499.94^{a}±4.80	555.20^{c}±3.65	521.65^{b}±2.50	524.11^{b}±3.23
7	520.54^{a}±4.66	573.88^{c}±3.23	543.78^{b}±3.12	553.65^{b}±3.15
Overall	460.56^{a}±0.34	500.73^{d}±0.19	473.02^{b}±0.16	479.69^{c}±0.30

Mean bearing different superscripts ^{abcd} in a row differ significantly ($p<0.05$).

Table 5: Overall nutrient intake of kids fed diet supplemented with MOLM and flaxseed (Mean ± SEM)

Parameters	Control	T1	T2	T3
CP intake (g/d)	87.89^{a}±0.30	105.20^{c}±0.08	96.73^{b}±0.07	97.63^{b}±0.13
TDN intake (g/d)	419.32^{a}±0.12	471.25^{c}±0.08	426.39^{b}±0.18	431.43^{b}±0.12
OM intake (g/d)	451.46^{a}±0.11	499.20^{c}±0.07	486.21^{b}±0.10	485.22^{b}±0.04
EE intake (g/d)	20.17^{a}±0.02	26.54^{d}±0.01	22.62^{b}±0.02	22.99^{c}±0.01
NDF intake (g/d)	331.50^{a}±0.19	350.52^{d}±0.06	340.83^{b}±0.08	343.36^{c}±0.06
ADF intake (g/d)	219.67^{a}±0.03	243.80^{d}±0.15	236.22^{b}±0.07	238.06^{c} ±0.07

Mean bearing different superscripts ^{abcd} in a row differ significantly ($p<0.05$).

Effect of MOLM and Flaxseed on Body Growth and Feed Conversion Indices

The effects of MOLM and flaxseed supplementation on fortnightly body weight, average daily gain (ADG) and feed efficiency indices are presented in Table 6. Body weight gain, and ADG were significantly higher ($p<0.05$) in the T1 group (20% MOLM), while the T2 and T3 groups exhibited analogous values. Concurrently, the feed conversion ratio (FCR) was significantly reduced and feed conversion efficiency (FCE) increased in T1, with T2 and T3 occupying intermediary positions. The marked improvements in body weight and ADG in T1 are attributed to MOLM's exceptional nutrient profile, superior palatability and high bypass protein content, which optimizes nitrogen utilization for growth. This weight gain aligned with Biswal (2021), Wankhede *et al*. (2022) and Ukey *et al*. (2025). However, Pandey *et al*. (2022) observed non-significant responses, suggesting variations based on breed and inclusion levels. The superior ADG in T1 matched the findings of Sultana *et al*. (2015) and Meel *et al*. (2018), driven by essential minerals and vitamins crucial for tissue development (Kasolo *et al*., 2010). For the flaxseed group (T2), the positive growth trend aligned with Langamu (2021), but contradicted Meteab *et al*. (2018), who reported no significant weight differences in Damascus goats. Furthermore, the optimized FCR and FCE in T1 indicate highly efficient nutrient utilization, matching observations of Jiwuba *et al*. (2016). The low tannin content paired with rich amino acid and mineral matrices in MOLM enhances diet digestibility, directly linking increased feed intake and superior feed efficiency to accelerated body weight gain (Meel *et al*., 2018).

Effect of MOLM and Flaxseed on Nitrogen Utilization

Nitrogen intake, nitrogen retention, N retention (% of intake), N absorbed and N absorbed (% of intake) were higher ($p<0.05$) in T1, whereas T2 and T3 showed parallel values but higher ($p<0.05$) than the control (Table 7). All groups had similar fecal nitrogen indicating dietary protein was adequate to meet the requirements for maintenance and growth. The higher nitrogen intake and retention in T1 may be partly attributed to the greater dry matter and nutrient intake, which improved the availability of dietary protein for absorption and deposition (Sultana *et al*., 2015). Biswal (2021) and Wankhede *et al*. (2022) also reported increased ($p<0.05$) nitrogen intake, nitrogen retention and % absorbed nitrogen in goat kids fed Moringa foliage. Conversely, Biswal (2021) observed non-significant differences in fecal N (g/d) between groups, concluding that fecal nitrogen was not substantially affected by nitrogen intake. These findings indicate that inclusion of MOLM and flaxseed resulted in better protein utilization for growth, without altering fecal nitrogen excretion.

Conclusion

The findings of the study revealed that dietary supplementation with 20% *Moringa oleifera* leaf meal (MOLM) significantly optimizes growth performance, feed efficiency and nitrogen retention in Alpine × Beetal crossbred kids, outperforming flaxseed and their combined mixture. While the combination improves performance over flaxseed alone, it offers no synergistic benefits beyond sole MOLM. Therefore, 20% MOLM could serve as the most sustainable,

Table 6: Effect of MOLM and flaxseed on fortnightly body weight (kg), average daily gain (ADG, g/day), feed conversion efficiency (FCE), and feed conversion ratio (FCR) of kids (Mean ± SEM)

Parameter	Fortnights	Treatments			
		Control	T1	T2	T3
Body weight (kg)	Initial BW	12.14±0.03	12.18±0.03	12.13±0.03	12.12±0.03
	1	12.89±0.36	13.42±0.03	13.35±0.03	13.34±0.03
	2	14.06±0.37	14.74±0.03	14.58±0.03	14.59±0.03
	3	15.25^{a}±0.38	16.28^{b}±0.03	15.83^{ab}±0.03	15.86^{ab}±0.03
	4	16.46^{a}±0.38	17.88^{b}±0.03	17.10^{ab}±0.04	17.16^{ab}±0.01
	5	17.70^{a}±0.38	19.53^{c}±0.03	18.42^{ab}±0.04	18.48b±0.01
	6	18.95^{a}±0.38	21.20^{c}±0.04	19.78^{b}±0.04	19.83^{b}±0.02
	7	20.22^{a}±0.38	22.90^{c}±0.04	21.09^{b}±0.04	21.20^{b}±0.02
	Overall	**15.95^{a}±0.04**	**17.27^{c}±0.04**	**16.55^{b}±0.01**	**16.57^{b}±0.01**
ADG (g/day)	1	49.99±23.35	82.66±0.59	80.83±0.32	81.24±0.26
	2	76.66^{a}±0.96	87.83^{c}±0.90	81.99^{b}±0.30	83.41^{b}±0.23
	3	80.08^{a}±0.62	102.24^{c}±0.53	83.24^{b}±0.31	84.99^{b}±0.33
	4	81.16^{a}±0.32	106.99^{c}±1.00	85.08^{b}±0.24	86.24^{b}±0.27
	5	82.74^{a}±0.26	109.99^{c}±0.71	87.74^{b}±0.24	88.16^{b}±0.39
	6	83.16^{a}±0.26	111.58^{c}±0.47	90.91^{b}±0.35	90.16^{b}±0.24
	7	84.25^{a}±0.41	113.24^{c}±0.26	93.74^{b}±1.25	91.33^{b}±0.33
	Overall	**76.86^{a}±3.26**	**102.08^{c}±0.09**	**86.22^{b}±0.13**	**86.50^{b}±0.02**
FCE	1	0.12±0.05	0.19±0.001	0.19±0.001	0.19±0.001
	2	0.18^{a}±0.002	0.19^{b}±0.001	0.19^{b}±0.001	0.19^{b}±0.001
	3	0.18^{a}±0.002	0.21^{b}±0.001	0.18^{a}±0.001	0.18^{a}±0.001
	4	0.17^{a}±0.002	0.21^{b}±0.002	0.18^{a}±0.001	0.18^{a}±0.0003
	5	0.17^{a}±0.002	0.20^{b}±0.002	0.17^{a}±0.001	0.17^{a}±0.001
	6	0.16^{a}±0.002	0.20^{c}±0.002	0.17^{b}±0.001	0.17^{ab}±0.001
	7	0.16^{a}±0.002	0.19^{c}±0.001	0.17^{b}±0.002	0.16^{a}±0.001
	Overall	**0.16^{a}±0.0002**	**0.20^{c}±0.0002**	**0.18^{b}±0.0001**	**0.18^{ab}±0.0001**
FCR	1	4.38±0.02	5.16±0.03	5.05±0.02	5.11±0.02
	2	5.50^{b}±0.07	5.08^{a}±0.05	5.20^{a}±0.02	5.19^{a}±0.016
	3	5.51^{b}±0.06	4.62^{a}±0.04	5.39^{b}±0.03	5.35^{b}±0.03
	4	5.67^{b}±0.07	4.68^{a}±0.06	5.53^{b}±0.02	5.51^{b}±0.01
	5	5.78^{b}±0.06	4.80^{a}±0.05	5.58^{b}±0.03	5.68^{b}±0.04
	6	6.01^{c}±0.07	4.97^{a}±0.04	5.73^{b}±0.02	5.81^{b}±0.03
	7	6.18^{c}±0.08	5.06^{a}±0.03	5.80^{b}±0.07	6.06^{c}±0.03
	Overall	**5.57^{b}±0.005**	**4.91^{a}±0.004**	**5.47^{b}±0.006**	**5.53^{b}±0.003**

Means bearing different superscripts (a,b,c,d) in a row differ significantly ($p<0.05$).

Table 7: Overall effect of MOLM and flaxseed on nitrogen utilization (Mean ± SEM)

Parameters	Treatments			
	Control	T1	T2	T3
N intake (g/d)	14.07^{a}±2.04	16.83^{c}±0.01	15.47^{b}±0.01	15.62^{b}±0.02
Faecal N (g/d)	6.22^{ab}±0.03	6.08^{a}±0.01	6.40^{b}±0.01	6.27^{ab}±0.007
Urinary N (g/d)	5.68^{c}±0.015	5.12^{a}±0.017	5.37^{b}±0.006	5.55^{bc}±0.006
Total N loss (g/d)	11.90^{b}±2.01	11.21^{a}±0.02	11.77^{b}±0.018	11.83^{b}±0.019
N balance (g/d)	2.16^{a}±0.03	5.61^{c}±0.02	3.66^{b}±0.01	3.78^{b}±0.02
N balance (% of intake)	15.22^{a}±0.18	33.37^{c}±0.14	23.87^{b}±0.09	24.25^{b}±0.13
N balance (% of absorbed)	27.34^{a}±0.38	52.25^{c}±0.17	40.66^{b}±0.08	40.48^{b}±0.26
N absorbed (g/d)	7.85^{a}±0.02	10.74^{c}±0.01	9.07^{b}±0.015	9.34^{b}±0.016
Absorbed N (% of intake)	55.81^{a}±0.05	63.84^{c}±0.06	58.60^{b}±0.08	59.84^{b}±0.19

Means bearing different superscripts (a,b,c,d) in a row differ significantly ($p<0.05$).

efficient and economically practical strategy for maximizing crossbred kid productivity.

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References

Aggarwal, U., Bhupender, Yadav, R.S., Maheshbhai, T.T., Chandraker, P., Pushpa, Ramesh Chandra, R. and Misra, A.K. (2026). Effect of moringa and chaya mixed pellet supplementation on growth and nutrient utilization of Barbari kids. *Indian Journal of Animal Research*, *1*, 5.

Ajantha, A., Kathirvelan, C., Purushothaman, M.R., & Visha, P. (2018). Study on nutrients, mineral and vitamin profile of *Moringa oleifera* leaf meal. *International Journal of Current Microbiology and Applied Sciences*, *5*, 2478-2481.

AOAC (2005). *Official Methods of Analysis*. 20th edn., Association of Official Analytical Chemists, Virginia, USA.

Biswal, S. (2021). Effect of feeding *Moringa oleifera* leaf meal on nutrient utilization, production performance and immunity in Barbari goats, *Doctoral Dissertation*. ICAR-National Dairy Research Institute, Karnal, India.

Choudhary, R.K., Roy, A., Roy, P.S., Singh, K.M., & Kumar, P. (2018). Effect of replacing concentrate mixture with Moringa leaves on performance of lactating Bengal goats in Kishanganj district of Bihar, India. *International Journal of Current Microbiology & Applied Sciences*, *7,* 2895-2900.

Damor, S.V., Pawar, M.M., Ankuya, K.J., Gami, Y.M., Srivastava, A.K., & Chauhan, H.D. (2017). Effect of replacing concentrate mixture with *Moringa oleifera* leaves on blood biochemical and mineral profile of Mehsana goat kids. *Life Science Leaflets*, *89,* 28-35.

El-Sayed, H.M., EL-Essawy, A.M., Nassar, M.S., & El-Bordeny, N.E. (2020). Effect of dietary incremental levels of flaxseed supplementation on productive performance of lactating Damascus goats. *International Journal of Environment and Agricultural Biotechnology, 5*(1), 123-132.

ICAR (2013). *Nutrient Requirement of Sheep, Goat and Rabbit*. Indian Council of Agricultural Research, New Delhi, India.

Jiwuba, P.D.C., Ahamefule, F.C., Okechukwu, O.S., & Ikwuneze, K. (2016). Feed intake, body weight changes and haematology of West African Dwarf goats fed dietary levels of *Moringa oleifera* leaf meal. *Agriculture*, *13*(1-2), 71-77.

Kasolo, J.N., Bimenya, G.S., Ojok, L., Ochieng, J., & Ogwal-Okeng, J.W. (2010). Phytochemicals and uses of *Moringa oleifera* leaves in Ugandan rural communities. *Journal of Medicinal Plants Research*, *4*(9), 753-757.

Kholif, A.E., Gouda, G.A., Morsy, T.A., Anele, U.Y., & Galyean, M.L. (2016). Effect of feeding diets with processed *Moringa oleifera* meal as protein source in lactating Anglo-Nubian goats. *Animal Feed Science and Technology*, *217,* 45-55.

Kumar, M., Minj, N., Prasad, S., Kumar, R., Kumar, R., & Himkar, H.K. (2020). Effect of feeding *Moringa oleifera* leaf powder on haemato-biochemical profile of growing female Black Bengal goat under intensive system of management. *Journal of Entomology and Zoological Studies*, *8*(2), 46-48.

Langamu, C. (2021). Effect of pre and post-partum feeding of *Azolla pinnata* and flaxseed on performance of crossbred does and their kids, *Doctoral Dissertation*, ICAR-National Dairy Research Institute, Karnal, India.

Meel, P., Gurjar, M.L., Nagda, R.K., Sharma, M.C., & Gautam, L. (2018). Growth performance of Sirohi goat kids fed different levels of *Moringa oleifera* leaves. *Journal of Entomology and Zoological studies*, *6*(4), 786-791.

Meteab, M., El-Sayed, H.M., El-Essawy, A.M., Nassar, M.S., & El-Bordeny, N.E. (2018). Impact of flaxseed inclusion in Damascus goat's ration on digestibility, some blood parameters and reproductive performance. *Arab Universities Journal of Agricultural Sciences*, *26*(2D), 2347-2357.

Morris, D.H. (2007). Flax primer: A health and nutrition primer. Flax Council of Canada, pp. 9-19.

Pandey, A., Modi, R.J., Lunagariya, P.M., & Islam, M.M. (2022). Effect of feeding *Moringa oleifera* meal on feed and nutrient intake, feeding behaviour and feed conversion ratio of Surti kids. *Journal of Animal Research*, *12*(4), 521-525.

Singh, K. K., Mridula, D., Rehal, J., & Barnwal, P. (2011). Flaxseed: a potential source of food, feed and fiber. *Critical Reviews in Food Science and Nutrition*, *51*(3), 210-222.

Snedecor, G.W., & Cochran, W.G. (1994). *Statistical Methods*. 8th edn., Iowa State University Press, Ames, Iowa, USA, pp. 124-130.

Sultana, N., Alimon, A.R., Huque, K.S., Sazili, A.Q., Yaakub, H., Hossain, J., & Baba, M. (2015). The feeding value of *Moringa oleifera* foliage as replacement to conventional concentrate diet in Bengal goats. *Advances in Animal and Veterinary Science*, *3*(3), 164-173.

Teama, F.E.I., & El-Tarabany, A.A. (2016). Physiological and biochemical response to omega-3 plus as a dietary supplement to growing goats under hot summer conditions. *Revista Brasileira de Zootecnia*, *45*(4), 174-180.

Tona, G.O., Ogunbosoye, D.O., & Bakare, B.A. (2014). The growth performance and nutrient digestibility of West African Dwarf goats fed graded levels of concentrate diet containing *Moringa oleifera* leaf meal. *International Journal of Current Microbiology and Applied Science*, *3*(8), 99-106.

Ukey, A.K., Singh, S.V., Biswal, S., Misra, A.K., Somagond, Y.M., Kumar, G., & Bhalakiya, N. (2025). Seasonal effects of *Moringa oleifera* as a concentrate replacement on health parameters and production performance in Barbari goats. *Animal Production Science*, *65*(9), AN24311.

Van Soest, P.V., Robertson, J.B., & Lewis, B. (1991). Methods for dietary fiber, neutral detergent fibre and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, *74*(10), 3583-3597

Wankhede, S.D., Dutta, N., Tambe, M.B., Kaur, N., Jadhav, S.E., & Pattanaik, A.K. (2022). Effect of dietary inclusion of *Moringa oleifera* foliage on nutrient metabolism, metabolic profile, immunity and growth performance of goat kids. *Emerging Animal Species, 3,* 100005.

Zaher, H.A., Alawaash, S.A., Tolba, A.M., Swelum, A.A., Abd El-Hack, M.E., Taha, A.E., & Abdelnour, S.A. (2020). Impacts of *Moringa oleifera* foliage substituted for concentrate feed on growth, nutrient digestibility, hematological attributes, and blood minerals of growing goats under Abu Dhabi conditions. *Sustainability*, *12*(15), 6096.