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Nutrient digestibility and economic evaluation of *Moringa oleifera* leaf meal and flaxseed supplementation to crossbred goat kids

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Abstract

The experiment was conducted on 32 female Alpine x Beetal female goat kids of similar age and body weight to evaluate the effect of *Moringa oleifera* leaf meal and flaxseed supplementation on nutrient digestibility and feed cost. Kids were divided into 4 groups with eight kids in each group. All kids received a basal diet of roughage (Berseem and wheat straw in the ratio 50:50) and concentrate mixture in the ratio 60:40. The control group offered basal diet, in T₁ and T₂ groups concentrate mixture was replaced by 20% moringa leaf meal and 20% flaxseed respectively; in T₃ group concentrate was replaced with 10% moringa leaf meal plus 10% flaxseed. During the whole experiment, a weighed quantity of feed was provided to each kid. A metabolic trial of seven days was conducted for evaluation of digestibility of different nutrients in kids. Results revealed that in T₁ group exhibited superior nutrient digestibility ($p < 0.05$) which indicated better utilization of Moringa leaf meal by the goat kids and benefit: cost ratio was increased for T₁ group suggesting economic benefits of moringa meal. It was concluded that supplementation of concentrate with 20% moringa leaf meal could improve the digestibility of goat kids and reduce the feed cost of rearing goat kids.

Keywords: Kids, Moringa, flaxseed, digestibility, cost

Introduction

When compared to other ruminants, goats are known for their exceptional nutrient use efficiency (NBAGR, 2016) [32]. Because they produce meat, milk, hides and are reliable sources of household income, goats are essential to food security and rural economic development (Daramola *et al.*, 2005) [13]. Despite their resilience, kid mortality is a major problem, especially in the early stages of life, which can reach 34.60% (Hegde and Deo, 2020) [21], which affects farm productivity and profitability. The high expense of quality feed resources and their seasonal scarcity are two major factors affecting livestock productivity. A promising alternative that can increase productivity and lower financial losses related to early mortality is the use of non-conventional feed resources (NCFRs) and inexpensive feed supplements into goat rations (Hegde and Deo, 2020) [21]. Farmers with limited resources mainly rely on crop residues and poor-quality roughages that are low in nitrogen, high in lignocellulose, and lacking in vital vitamins and minerals, which impairs animal performance and digestibility (Gerbregiorgis *et al.*, 2012) [16].

As demonstrated by Nurfeta *et al.* (2010) [33], supplementing such roughages with concentrate diets improves both intake and digestibility. According to Babeker and Bdalbagi (2015) [7], traditional feed items including grains, cereals and legumes are usually either unavailable or too expensive in many regions. In order to satisfy the nutritional needs of livestock, it is imperative to find protein-rich feed substitutes that are plentiful and quickly cultivable. Alternative feeding strategies that use locally available, nutrient-dense feed components and balanced amino acid profiles have become more popular due to the economic reality (Halmemies, 2018) [20]. Because of remarkable growth characters and high biomass production per unit area, Moringa has become a particularly interesting alternative feed resource (Korsor *et al.*, 2017) [24], in goat nutrition as a protein supplement since it offers year-round green fodder and drastically lowers feed expenses (Moyo *et al.*, 2012; Kholif *et al.*, 2015) [31, 22]. Another beneficial feed supplement is flaxseed, which is distinguished by its high concentration of omega-3 fatty acids, especially alpha-linolenic acid

(ALA), as well as significant amounts of protein, dietary fiber and vital minerals (Morris, 2007; Gopalan *et al.*, 1976; Payne, 2000) [30, 18]. Although both moringa and flaxseed have been shown to be beneficial as alternative feed supplements, little is known about how they work together to affect feed economy and digestibility in goat kid systems. The goal of the current study was to assess the economic viability and nutrient digestibility of adding flaxseed and *Moringa oleifera* leaf meal (MOLM) as dietary supplements to goat kid feeding regimens.

Materials and Methods

Location and experimental animals

The study was carried out for 120 days, from February 2022 to May 2022, at the National Dairy Research Institute's Livestock Research Farm (LRC) in Karnal, Haryana.

A total of 32 Alpine X Beetal crossbred female kids, each three months of age and weighing between 10 and 12 kg, were randomly selected and divided into four groups of eight. Following the institutional ethical committee's instructions, the experiment was carried out. The kids were kept in sheds that were well-ventilated and shielded. Kids were acclimated for five days before being fed experimentally.

Design of experiment

The design of experiment was completely randomized design (CRD) with four different treatments. Four experimental treatments were:

C = Roughage + concentrate (60:40)

T₁ = Roughage + 20% concentrate replaced with MOLM

T₂ = Roughage + 20% concentrate replaced with flaxseed

T₃ = Roughage + 20% concentrate replaced with 10% MOLM and 10% flaxseed

Procurement of experimental feeds

Moringa leaves were collected from NDRI, Karnal's Integrated Farming System (IFS) areas. Leaves were dried in the shade after being roughly pulverized into tiny bits that were typically 2 cm in diameter. The leaves were pounded into a powder and given to the kids. Flaxseed was bought at the Karnal local market. It was mildly roasted on an electric heater at 140-145 °C while being constantly stirred and offered to the kids after roasting and cooling for an hour.

Feed sample analysis

A seven day metabolic trial was conducted at the end of trial. Samples of residues of feed offered to kids and faeces were collected daily and taken for dry matter estimation in hot air oven for 24 hours at 100 °C. Fecal samples were analyzed for proximate principles (Organic matter, Crude protein, Ash and Ether extract) by the method named Association of Official Analytical Chemists (AOAC, 2005) and cell wall constituents (Neutral detergent fibres and Acid detergent fibres) were analyzed by the Van Soest, 1991 method. Feed samples were also analyzed for mineral estimation by Atomic absorption (AAS)-spectrophotometer method. Proximate and mineral analysis of different feeds has been presented in Table 1 and Table 2, respectively.

Nutrient digestibility of feeds

The nutrient (DM, OM, CP, EE, NDF and ADF) digestibility coefficients were calculated from the nutrient intake and nutrient outgo in faeces during metabolism as given below:

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

Statistical analysis

The Statistical Package for Social Sciences version 22.0 computer program was used to statistically analyze the data using a one-way Analysis of Variance (ANOVA) test and determine the significance of the difference between the mean values of various parameters using the Tukey Post-hoc test.

Economic evaluation

Economics of feeding was calculated at the end of the trial by the Partial Budget analysis (Stemmer *et al.*, 1998) and Cost: Benefit ratio was calculated to access the economic profitability of feed supplements (Amir and Knipscheer, 1989) [5]. The feed cost was calculated based on actual cost of feed and fodder at Livestock Research Centre, ICAR-NDRI (Karnal). The costs of MOLM, concentrate feed, green and dry fodder were ₹ 25/kg, ₹28/kg, ₹ 2/kg and ₹ 7/kg respectively. The total feed cost per goat kid during the experimental period was calculated and from that, feed cost per kg live body weight gain was calculated. The income from body weight gain was calculated from market rate of goat kid on the basis of live body weight gain and from that net profit from body weight gain and net profit/kg live body weight was worked out.

Results and Discussion

Proximate composition of feeds

The proximate composition of feeds has been presented in Table 1. The DM content of MOLM was 91.80%. The composition (% DM basis) in terms of Organic matter (OM), crude protein (CP), ether extract (EE), total ash (TA), neutral detergent fibre (NDF) and acid detergent fibre (ADF) was in the normal range and similar to the values reported by Biswal (2021) [11], Meel *et al.* (2018) [28] and Tona *et al.* (2014) [39]. The CP value was highest in MOLM (19.61%) and NDF (24.83%) was lowest as compared to other feedstuffs (flaxseed, concentrate, berseem, maize and wheat straw). Leitathem (2019) [27] and Damor *et al.* (2017) [12], found relative higher values of CP. The CP content in moringa leaf ranges between 13-33% depending on the maturity and the proportion of leaves and stems used in the diet (Kholif *et al.*, 2015) [22]. The CP content in the present study was low as compared to other studies because the twigs of about 1 cm diameter were also ground along with leaves to prepare the meal. The variation in the nutritive value of *Moringa oleifera* could be due to the age of harvest, soil type and fertility, season, level of dryness of leaves, proportion of leaf and stem and agro ecological zone where trees are growing (Meel *et al.*, 2018) [28].

The DM content of flaxseed was 92.37% and the composition (% DM basis) was in normal range and highest than other feedstuffs. The composition was similar to the values reported by Langamu (2021) [26], Girgo *et al.* (2020) [17] and Ali (2017) [4]. The OM (95.51%) and EE (39.87%) was found higher and TA (4.49%) was lowest in flaxseed as compared to other feedstuffs. High EE represents the higher fatty acid content of flaxseed.

The DM content of concentrate mixture was 91.38%. The composition was within normal range. The ADF content (14.36%) was lower than the other feedstuffs. The values were similar to commercially available feed: CP minimum

of 20%; EE minimum of 3% and moisture maximum of 11%.

The DM content of maize and berseem were respectively 31.39% and 11.24%. The composition was within the normal range. The TA content (10.36%) was higher in berseem. The values were similar to the findings of Girgo *et al.* (2020)^[17] and Leitanthem (2019)^[27].

The DM content of wheat straw was 92.32%. The NDF (79.24%) and ADF (52.41%) content were found higher whereas EE content (1.06%) and CP (2.91%) were less than other feedstuffs. The findings were similar to values reported by Girgo *et al.* (2020)^[17].

Mineral composition of feeds

The mineral composition of feeds has been presented in Table 2. The Ca concentration in MOLM was 1.47% which was slightly higher than the value of 1.38% given by Biswal (2021)^[11] and lower than 2.2%, 1.85% and 1.60% reported by Zaher *et al.* (2020)^[42], Leitanthem (2019)^[27] and Ajantha *et al.* (2018)^[3]. Mg content was comparable with the value of 0.43% given by Ajantha *et al.* (2018)^[3], lower than 4.81% given by Leitanthem (2019)^[27] and higher than 0.22% given by Zaher *et al.* (2020)^[42]. Na and K values are lower than the values of (0.07% and 0.12%) and (1.63% and 1.38%) given by Zaher *et al.* (2020)^[42] and Ajantha *et al.* (2018)^[3]. Mn, Fe, Zn and Cu were higher than the values 30.38ppm, 331ppm, 26.1ppm and 5.7ppm reported by Zaher *et al.* (2020)^[42]. Kozat (2007)^[25] reported that iron is commonly deficient in many plants but in Moringa leaves it was found in abundance. It can be used as source of Fe in feed. Zn also has anti-viral, anti-bacterial, anti-fungal and anticancerous properties (Brisibe *et al.*, 2009)^[10]. Moringa also has average amount of Cu, which is responsible for maintaining the immune status of animals. Copper combines with zinc to increase superoxide dismutase activity (Guo *et al.*, 2010)^[19]. The present Ca, K and Fe are in accordance with the values reported by Morris (2007)^[30]; Gopalan *et al.* (1976)^[18]; Payne, 2000. Flaxseed is a good source of Ca, Mg and P along with 30 g portion of the seed constitutes 7-30% of the recommended dietary allowances (RDAs) for these minerals Singh *et al.* (2011)^[35].

Effect of MOLM and flaxseed nutrient digestibility of kids

The digestibility coefficient (%) of different nutrients have been presented in Table 3. Nutrient digestibility was found ($p<0.05$) higher in all treatment groups than control. However, T₁ group being the highest. There was significant increase in digestibility of DM, OM, CP, EE, NDF and ADF of T₁, T₂ and T₃ groups than control and T₁ being the highest. CP and EE digestibility were non significant in T₂ and T₃. While, NDF digestibility was non significant in T₁ and T₂. T₂ was non significant with T₃ and Control group for ADF digestibility. The increase in DM, OM and CP digestibility in T₁ was similar with the findings of Aggarwal *et al.* (2026)^[1], Leitanthem *et al.* (2022)^[27], Biswal (2021)^[11] and Meel *et al.* (2018)^[28]. Bakshi *et al.* (2004)^[8] stated that the DM digestibility is dependent on the cell wall constituents of the diets with feedstuffs having lower fibre being more digestible than those with high. The enhanced by-pass protein content in moringa leaves may be the cause of the increased CP digestibility with increasing moringa levels (Becker, 1995). Higher OM digestibility in T₁ group was also in accordance with the findings of Kholif *et al.*

(2015)^[22] and Fadiyimu *et al.* (2010)^[15]. There was no significant difference between T₁ and T₂ for NDF digestibility. ADF digestibility was found higher ($p<0.05$) in T₁ and T₃ groups than T₂ and control groups. No significant difference was found between T₂ and control for ADF digestibility. The increase in ADF digestibility in T₁ group was in accordance with the findings of Sultana *et al.* (2015)^[37] who reported increase ($p<0.05$) in ADF digestibility with increased level of moringa foliage. Contrary to this, Biswal (2021)^[11] reported no significant difference in ADF digestibility. While, Langamu, 2021^[26] found non significant effect on DM digestibility of Barbari goats supplemented with flaxseed. The higher CP and EE digestibility in T₂ group was in accordance with the findings of Meteab *et al.* (2018)^[29] who reported increased ($p<0.05$) CP and EE digestibility in Damascus goats supplemented with 10% of flaxseed. The higher CP digestibility for flaxseed groups may be attributed to protein in flaxseed is a matrix surrounded by the fat droplets leading to protection of the protein from deterioration in the rumen, therefore, greater availability of protein in the intestinal tract, thus increasing its digestibility (Khorasani *et al.*, 1992)^[23]. Langamu (2021)^[26] and Kholif *et al.* (2015)^[22] reported higher EE digestibility in goats supplemented with 10% of flaxseed and flaxseed oil, respectively.

Economic evaluation

The economic evaluation has been presented in Table 4. The feed cost per kg of live body weight gain was found lowest in T₁ group followed by control, T₃ and T₂. The inclusion of flaxseed increased the cost of feeds for T₂ and T₃, while MOLM reduced the feeding cost as compared to control. The net return (₹) per kg live body weight gain were 26.57, 39.73, 28.97 and 28.87 for control, T₁, T₂ and T₃, respectively. The income and net return per kg live body weight gain was highest in group T₁ followed by T₂, T₃ and control. The benefit-cost ratio for group T₁, T₂, T₃ and control were 4.88, 3.14, 3.41 and 3.68, respectively. The lowest feed cost/kg gain and highest return was found in group T₁ followed by control, T₃ and T₂. Thus, results indicated lowest feed cost per kg of live body weight gain and highest profit per kg of live body weight gain of goat kids when 20% of concentrate feed was replaced by Moringa leaf meal. Therefore, T₁ proved to be more economical than other groups. According to Kholif *et al.* (2015)^[22], leaf meal and tree foliage are inexpensive sources of protein used in ruminant feeding. The results obtained in the present study are in agreement with Biswal (2021)^[11], Meel *et al.* (2018)^[28], Ali (2017)^[4] and Elaidy *et al.* (2017)^[14] who observed significant reduction in cost per kg live body weight gain with increasing level of supplementation of moringa leaf meal. Similarly, Langamu (2021)^[26] reported increased Benefit-cost ratio in the kids supplemented with flaxseed.

It was concluded that 20% supplementation with *Moringa oleifera* leaf meal could improve the digestibility and reduce the feed cost in crossbred goat kids. Thus Moringa leaf meal could be identified as promising supplement for sustainable and cost-effective feeding strategies for optimizing nutrient utilization and reducing input costs in small ruminant production systems, ultimately contributing to improved food security and rural livelihoods in resource-constrained environments.

Table 1: Proximate analysis of different feeds

Parameter%	MOLM	Flaxseed	Concentrate	Berseem	Wheat straw
DM	91.80	92.37	91.38	11.24	92.32
OM	91.68	95.51	90.21	89.64	92.14
CP	19.61	19.38	19.26	17.12	2.91
EE	4.27	39.87	3.72	1.81	1.06
TA	8.32	4.49	9.79	10.36	7.86
NDF	24.83	44.68	29.61	44.61	79.24
ADF	16.58	28.94	14.36	28.43	52.41

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

Table 2: Mineral analysis of different feeds

Minerals	MOLM	Flaxseed	Concentrate	Berseem	Wheat straw
Calcium (%)	1.47	0.21	0.94	1.76	0.62
Phosphorus (%)	0.21	0.62	0.70	0.31	0.71
Manganese (%)	0.46	0.38	0.77	0.63	0.16
Sodium (%)	0.018	0.023	0.07	0.016	0.011
Potassium (%)	1.31	0.78	0.63	3.31	1.24
Iron (ppm*)	352.35	46.2	341.82	263.31	158.21
Manganese (ppm)	58.60	23.18	54.38	31.42	27.63
Zinc (ppm)	38.61	32.28	78.50	16.22	10.21
Copper (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	T ₁	T ₂	T ₃
DM	58.30 ^a ±0.05	67.04 ^a ±0.05	61.94 ^b ±0.06	62.83 ^c ±0.03
OM	58.72 ^a ±0.02	68.98 ^a ±0.02	62.71 ^b ±0.03	63.65 ^c ±0.03
CP	55.78 ^a ±0.06	63.80 ^c ±0.06	58.57 ^b ±0.08	59.81 ^b ±0.04
EE	63.99 ^a ±0.02	69.03 ^c ±0.08	66.15 ^b ±0.13	65.40 ^b ±0.07
NDF	49.26 ^a ±0.21	55.39 ^c ±0.28	53.78 ^{bc} ±0.23	52.43 ^b ±0.23
ADF	39.87 ^a ±0.15	43.18 ^c ±0.05	40.12 ^{ab} ±0.07	41.01 ^b ±0.05

DM: Dry matter, OM: Organic matter, CP: Crude protein, EE: Ether extract, NDF: Neutral detergent fibre, ADF: Acid detergent fibre. Mean bearing different superscripts in a row differ significantly ^{abcd} ($p < 0.05$)

Table 4: Economic evaluation for different feeds given to goat kids

Particulars	Treatments			
	Control	T ₁	T ₂	T ₃
Feed intake (gm/kid/day)				
Concentrate	168.01	146.11	138.02	139.97
Green fodder	1365.83	1484.87	1402.80	1422.50
Dry fodder	166.29	180.78	170.79	173.19
MOLM	-	36.35	-	17.40
Flaxseed	-	-	34.13	17.29
Cost of feed (₹/kid/day)				
Concentrate (₹28/kg)	4.20	3.65	3.45	3.49
Green fodder (₹2/kg)	2.73	2.96	2.80	2.84
Dry fodder (₹7/kg)	1.16	1.26	1.19	1.21
MOLM (₹25/kg)	-	0.79	-	0.38
Flaxseed (₹80/kg)	-	-	2.73	1.38
Feed cost/kg live BW gain	96.02	76.46	108.48	101.82
Income from live BW gain (₹450/kg)	37.91	50.96	42.18	41.09
Net return	29.82	42.3	32.01	31.79
Benefit: Cost ratio	3.68	4.88	3.14	3.41

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