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Original Article

Effectiveness of second-grade *Trigonella foenum-graecum* seed supplementation on voluntary intake, nutrient utilization, and growth performance in Black Bengal goats

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Abstract

Background: Fenugreek (*Trigonella foenum-graecum*) seeds contain bioactive compounds that may enhance nutrient utilization and growth in small ruminants. However, fenugreek is often expensive and may compete with human food requirements. **Aims:** This study evaluated the effect of second-grade fenugreek seed supplementation with concentrate ration on intake, nutrient digestibility, and growth performance of Black Bengal goat kids. **Methods:** A total of 18 post-weaned Black Bengal female kids were selected and divided into three groups. The control group was fed a basal diet (a mixture of roughage and concentrate) without supplementation with fenugreek seed. The two treatment groups were fed the basal diet supplemented with fenugreek seeds at 2% and 4% of the dry matter of the concentrate mixture, respectively. Fenugreek seed samples were tested monthly to determine total phenolics, flavonoids, saponins, and alkaloids. The experiment was conducted for 120 days, followed by a 7-day digestibility trial. **Results:** The study revealed that total crude protein intake was significantly ($P<0.05$) higher in the treatment groups compared with the control group without affecting the dry matter intake. Fenugreek seed supplementation significantly ($P<0.05$) increased the digestibility of dry matter, organic matter, ether extract, neutral detergent fiber, acid detergent fiber, hemicellulose, and total carbohydrate compared with the control group. The treatment groups had significant ($P<0.01$) increases in average daily gain and improved the feed conversion ratio, digestible crude protein, and total digestible nutrients intake significantly ($P<0.01$) compared with the control group. **Conclusion:** Hence, supplementing second-grade fenugreek seeds at 2% and 4% of concentrate dry matter improves nutrient intake, digestibility, growth performance, and economic returns.

Key words: Digestibility, Fenugreek seeds, Growth, Phytochemical, Post-weaned

Introduction

The utilization of traditional and alternative feed resources has gained significant attention in the livestock industry, especially in regions where resources are limited. Among the numerous unconventional feedstuffs, fenugreek seed (*Trigonella foenum-graecum*) has emerged as a promising option for supplementation in the diets of small ruminants due to its valuable nutritional composition and potential health benefits (Ibidhi and Salem, 2022). It is one of the oldest medicinal plants that has multifaceted properties beyond its culinary applications as it is rich in carbohydrates (45%), protein (20-30%), fats, and minerals (Ca, P, Fe, Zn, Mg) (Niknam *et al*., 2021).

Saponin, an active substance present in fenugreek, substantially affects growth, feed intake, and reproduction in animals (Dhull *et al*., 2021). Goel *et al.* (2008) suggested that a few saponins enhance the permeability of intestinal mucosa, increase appetite, and curb constipation. Herbs containing saponin could be applied to satisfy the nutrient necessities and activate the endocrine system (Goel *et al*., 2008). Several studies conducted on cattle have shown that these seeds have positive impacts on nutrient digestibility, live weight, and feed efficiency (Atta-Elmnan *et al*., 2012). The phytochemicals present in fenugreek seeds, such as phenolics, alkaloids, flavonoids, and saponins, are

crucial in promoting animal growth by enhancing antioxidant activity, improving digestive health, modulating the immune response, and providing anti-inflammatory and anti-parasitic effects (Dhull *et al*., 2021). Fenugreek affects rumen microbiota by reducing populations of protozoa, fungi, and methanogenic through its saponins, tannins, and flavonoids. Saponins disrupt protozoal cell membranes, lowering H_2 availability for methanogens and thereby decreasing CH_4 production (Tapio *et al*., 2017; Hassan *et al*., 2020). Tannins further inhibit methanogen-protozoa interactions and suppress fiber-degrading bacteria such as Fibrobacter succinogenes and Butyrivibrio fibrisolvens, reducing hydrogen release and methane synthesis (Niu *et al*., 2021; Ibidhi and Salem, 2022). Fenugreek flavonoids exhibit antibacterial effects on gram-positive microbes, altering rumen microbial balance and fermentation patterns (Oskoueian *et al*., 2013). Fenugreek supplementation can shift rumen fermentation toward greater propionate production, as shown by increased propionic acid at low fenugreek concentrations *in vitro* (Goel *et al*., 2008). This shift lowers the acetate:propionate ratio, providing an alternative hydrogen sink that can reduce methanogenesis (Ku-Vera *et al*., 2020). The effect is likely mediated by fenugreek saponins, which may suppress Gram-positive, acetate-producing microbes while favoring conditions that enhance propionate yield (Ugbogu *et al*., 2019; Jayanegara *et al*., 2020). In a rumen simulation using Alfalfa substrate, fenugreek increased the metabolic rate of dry matter but decreased total VFAs and gas (CH_4, NH_3, CO_2), indicating more substrate channeled to microbial biomass (Naseri *et al*., 2013). The multifunctional potential of fenugreek seeds motivated researchers to investigate their impact on livestock performance, nutrient utilization, and voluntary intake. This multifunctional potential of fenugreek seeds has prompted researchers to explore their influence on the performance, nutrient utilization, and voluntary intake of livestock. However, limited information is available on supplementing fenugreek seeds in growing kids to enhance nutrient digestibility and overall performance.

Black Bengal goats are famous for their dwarf stature, improved fertility, and succulent meat and skin (Hossain, 2021). Native to Bangladesh and the Indian subcontinent, the Black Bengal goat is well-known for its remarkable ability to use locally available feed resources efficiently and its adaptability to different agro-climatic conditions (Hossain, 2021). However, challenges often arise in meeting the nutritional requirements of growing kids, which are crucial for achieving optimal growth rates and overall performance (Darcan and Silanikove, 2018). The dietary supplementation of fenugreek seeds may offer a solution to address these nutritional challenges and potentially enhance the growth and productivity of Black Bengal goat kids. This study hypothesized that fenugreek seed supplementation enhances voluntary intake, nutrient utilization, and growth performance in Black Bengal goat kids. This study hypothesized that fenugreek seed supplementation improves the voluntary intake, nutrient utilization, and growth performance of Black Bengal goat kids.

Materials and Methods

Ethical approval

Ethical approval was not required for this study, as the research was conducted in accordance with the institutional guidelines applicable to this type of study.

Location of the experiment

The present study was conducted in the goat farm at the Eastern Regional Station (ERS) of the Indian Council of Agricultural Research (ICAR)-National Dairy Research Institute (NDRI), located in Kalyani, West Bengal, India. The animal farm is situated at an altitude of 9.75 meters (31.9 feet) above mean sea level, at 22°58´30´´ N latitude and 88°26´04´´ E longitude. During the summer, the maximum ambient temperature reaches 39°C-40°C; in winter, the minimum temperature drops to 6°C-7°C, and average annual precipitation is 1500 mm.

Duration of experiment and experimental animals

The experiment commenced on November 2021, and continued till February 2022 (120 days), with an initial 15-day adaptation period for experimental animals before experimentation. A total of 18 post-weaned female Black Bengal goat kids, aged 3-4 months, were selected and randomly divided into three homogeneous groups while maintaining average body weight to enable a more precise assessment of growth differences during the experiment. All the experimental kids were housed individually in a well-ventilated goat shed with a concrete floor and side drainage for waste disposal, ensuring proper cleanliness, hygiene, and a healthy environment throughout the experimental period. Before the trial, all kids were dewormed and vaccinated against PPR, goat pox, and enterotoxemia.

Experimental feeds and feeding of kids

Fenugreek seeds were obtained from a local market and were sorted to eliminate any impurities. The experimental animals were maintained under individual feeding, receiving roughage (chaffed para grass, maize, and oat) twice a day and a concentrate ration once a day under stall feeding conditions, to meet their maintenance and growth requirements. The kids were given a concentrate mixture consisting of 14% digestible crude protein and 65% total digestible nutrients. The fenugreek seed was thoroughly mixed into the concentrate mixture provided in the diets. The amount of feed given was measured using a digital weighing balance to determine the dry matter intake by the animals. The diets of the experimental animals in different groups are as follows:

- Standard diet without supplementation of fenugreek seed (0% fenugreek seed)
- Standard diet with supplementation of fenugreek seed

at 2% of the dry matter of the concentrate ration
- Standard diet with supplementation of fenugreek seed at 4% of the dry matter of the concentrate ration

Growth and digestion trial

Clean and fresh drinking water was provided to each animal ad libitum twice daily, at 10:00 am and 16:00 pm. The amount of concentrate and green fodder supplied, as well as the residual feed, was measured daily to calculate daily feed consumption. Each kid's body weight was recorded every fortnight for 120 days. The average daily gain (ADG) was calculated fortnightly by subtracting the previous fortnight's body weight from the current fortnight's body weight and dividing the difference by the number of days. The feed conversion ratio (FCR) was determined based on the total dry matter (DM) and crude protein (CP) intake per unit of average daily gain. Following the growth trial, a 7-day digestibility trial was conducted, during which daily feeds and residual feed were noted to determine net feed intake. Fecal matter excreted over 24-hour periods was recorded, and daily representative samples were collected to determine chemical composition for calculating nutrient utilization after supplementation with fenugreek seeds.

Analysis of samples

Extraction of phytochemical constituents from fenugreek seeds

The extraction of phytochemicals such as total phenolics, flavonoids, saponins, and alkaloids from *Trigonella foenum-graecum* seed samples was conducted monthly throughout the entire experimental period and was assessed using a standard method (Soni and Sosa, 2013).

Proximate composition and fiber fractions

Collected samples of feed, feed residue, and feces were examined in triplicate to determine their chemical composition, including dry matter, crude protein, organic matter, ether extract, and total ash, following the method outlined by AOAC (2005). Additionally, the portions of cell wall components such as neutral detergent fiber (NDF), acid detergent fiber (ADF), total carbohydrate, and hemicellulose were assessed and computed based on the procedure established by Van Soest *et al*. (1991). All the chemical compositions of the primary feeds are presented in Table 1.

Table 1: Chemical composition of feeds, fodder and fenugreek seeds provided to Black Bengal goats (on dry matter basis)

Nutrients (%)	Fodder	Concentrate	Fenugreek seeds
Dry matter	24.04	90.24	90.85
Crude protein	11.93	20.60	28.62
Crude fiber	27.11	11.20	6.40
Ether extract	2.10	3.10	5.22
Total ash	9.15	3.32	4.09
Organic matter	90.84	96.68	95.91
Neutral detergent fiber	58.93	28.76	37.52
Acid detergent fiber	32.37	14.71	14.06
Hemicellulose	26.56	14.05	23.46
Total carbohydrate	73.29	72.98	62.07

Economics calculation

The economics were calculated by taking into consideration the cost of the concentrate mixture, green fodder, fenugreek seeds, and labor wages. The labor wages were calculated at the rate of INR (Indian Rupees) 150 per animal for 120 days for cleaning and feeding only. The net profit in the 0%, 2%, and 4% fenugreek seed supplementation groups was estimated by subtracting the total cost (feed+labor+misc) from the return from the sale of goats at the market (INR 350/kg live weight). The net profit was computed on a live weight basis, and the evaluation of net profit in the treatment groups was conducted by comparing them to the control group in both monetary and percentage terms.

Statistical analysis

Statistical analysis was done using the IBM SPSS ver. 26 software, in which data regarding nutrient intake, the availability of digestible nutrients, and growth performance metrics such as body weight, average daily gain, feed conversion ratio, and feed conversion efficiency were analyzed using one-way ANOVA with repeated measures. Data were presented as mean±SE. Duncan's new multiple ranges with the least significant difference were used for post-hoc comparison at a 95% confidence level.

Results

Evaluation of phytochemicals of fenugreek seeds

The total phenolic (mean±SE) content of *Trigonella foenum-graecum* seed was 7.98±1.75 mg/g as tannic acid equivalent (TAE). The quantitative content of alkaloids, flavonoids, and saponins was 0.022±0.004 mg/g, 0.41±0.07 mg/g, and 0.27±0.06 mg/g, respectively.

Dry matter and crude protein intake

The effects of fenugreek seed supplementation on nutrient intake in Black Bengal kids during the experimental period are presented in Table 2. There were no significant differences observed in total fodder intake, dry matter intake through green fodder, total dry matter intake (TDMI), and crude protein intake through green fodder among the different fenugreek supplementation groups (0%, 2%, and 4%). However, there was a significant increase in total concentrate intake ($P<0.01$), dry matter intake through concentrate ($P<0.01$), crude protein intake through concentrate ($P<0.05$), and total crude protein intake ($P<0.05$) in the groups supplemented with fenugreek seeds at the 4% level that exhibited the highest intake, followed by the group with 2% fenugreek seed supplementation, while the 0% fenugreek seed supplementation group had the lowest intake.

There was a significant decrease ($P<0.01$) in dry matter intake per kg $W^{0.75}$ and crude protein intake per kg $W^{0.75}$ as the level of Fenugreek seed supplementation increased. The 0% fenugreek seed supplementation group exhibited the highest dry matter intake per kg $W^{0.75}$ and crude protein intake per kg $W^{0.75}$, while the

group supplemented with 4% fenugreek seeds showed the lowest intake per kg $W^{0.75}$.

Nutrient utilization during the digestibility trial

The nutrient digestibility (%) in various experimental groups is depicted in Table 3. Black Bengal kids supplemented with fenugreek seeds at both 2% and 4% levels exhibited higher dry matter (P<0.05), crude protein (P<0.01), ether extract (P<0.05), organic matter (P<0.01), and total carbohydrate (P<0.01) digestibility compared to the 0% supplementation group. However, among the treatment groups (2 and 4%), the digestibility of nutrients was similar. Significant differences were also observed in the digestibility of crude fiber *viz.* neutral detergent fiber (P<0.05), acid detergent fiber (P<0.05), and hemicellulose (P<0.01) among the treatment groups; where the fenugreek seed supplemented group (2 and 4%) had greater digestibility of fiber than the 0% fenugreek seed supplementation group.

Nutrient intake during the digestibility trial

The impact of fenugreek seed supplementation on nutrient intake in Black Bengal kids under different groups is presented in Table 4. There were no significant

Table 2: Effect of fenugreek seeds supplementation on nutrient intake

Attributes	Rate of supplementation			P-value
	0%	2%	4%	
Number	6	6	6	-
Total fodder intake (g/kid/day)	914.69±4.74	916.56±4.63	917.92±4.65	NS
Total concentrate intake (g/kid/day)	108.40±0.30 ^{a}	110.73±0.47 ^{b}	115.50±0.54 ^{c}	P<0.01
Dry matter intake through green fodder (g/kid/day)	217.18±1.93	217.63±1.88	217.96±1.89	NS
Dry matter intake through concentrate (g/kid/day)	97.87±0.20 ^{a}	99.85±0.45 ^{b}	101.95±0.52 ^{c}	P<0.01
Total dry matter intake (g/kid/day)	315.06±1.07	317.48±1.28	319.91±1.51	NS
Total dry matter intake (g/kg $W^{0.75}$)	70.95±0.48 ^{a}	70.07±0.33 ^{b}	69.01±0.31 ^{c}	P<0.01
Crude protein intake through green fodder (g/kid/day)	28.68±0.26	28.73±0.25	28.78±0.25	NS
Crude protein intake through concentrate (g/kid/day)	20.14±0.80 ^{A}	20.54±0.92 ^{B}	20.97±0.10 ^{C}	P<0.05
Total crude protein intake (g/kid/day)	48.82±0.12 ^{A}	49.27±0.22 ^{B}	49.75±0.24 ^{C}	P<0.05
Crude protein intake (g/kg $W^{0.75}$)	11.01±0.07 ^{a}	10.89±0.05 ^{b}	10.75±0.04 ^{c}	P<0.01

$^{A, B, C}$ P<0.05, $^{a, b, c}$ P<0.01, NS: Non-significant (P>0.05), and row-wise means having different superscripts within a category differed significantly

Table 3: Effect of fenugreek seeds supplementation on nutrients digestibility

Attributes (%)	Rate of supplementation			P-value
	0%	2%	4%	
Dry matter	61.59±1.60 ^{A}	65.71±1.40 ^{B}	66.71±1.34 ^{B}	P<0.05
Crude protein	60.30±1.83 ^{a}	66.59±1.32 ^{b}	67.51±1.02 ^{b}	P<0.01
Ether extract	64.78±2.27 ^{A}	71.38±2.03 ^{B}	71.30±1.57 ^{B}	P<0.05
Organic matter	63.44±1.51 ^{a}	68.39±1.29 ^{b}	69.15±1.25 ^{b}	P<0.01
Neutral detergent fiber	53.09±2.02 ^{A}	59.01±1.84 ^{B}	59.34±1.84 ^{B}	P<0.05
Acid detergent fiber	45.12±2.55 ^{A}	51.92±2.40 ^{B}	52.49±2.05 ^{B}	P<0.05
Hemicellulose	64.27±1.49 ^{a}	69.44±1.40 ^{b}	69.62±1.35 ^{b}	P<0.01
Total carbohydrate	62.26±1.65 ^{a}	67.65±1.36 ^{b}	68.17±1.29 ^{b}	P<0.01

$^{A, B}$ P<0.05, $^{a, b}$ P<0.01, NS: Non-significant (P>0.05), and row-wise means having different superscripts within a category differed significantly

Table 4: Nutrient intake in different groups during the digestibility trial of 7 days

Attributes	Rate of supplementation			P-value
	0%	2%	4%	
Fodder intake (g/kid/day)	876.33±25.22	881.67±43.07	882.33±37.12	NS
Concentrate intake (g/kid/day)	134.40±1.15 ^{a}	142.20±1.28 ^{b}	151.20±1.32 ^{c}	P<0.01
Dry matter intake from fodder (g/kid/day)	223.84±5.75	230.05±9.59	230.24±9.08	NS
Dry matter intake from concentrate (g/kid/day)	120.96±1.11 ^{a}	127.98±1.31 ^{b}	136.08±1.37 ^{c}	P<0.01
Total dry matter intake (g/kid/day)	344.80±5.75	358.03±9.59	366.32±9.08	NS
Crude protein intake from Fodder (g/kid/day)	29.86±0.98 ^{a}	30.33±1.20 ^{b}	30.59±1.50 ^{b}	P<0.01
Crude protein intake from concentrate (g/kid/day)	24.79±0.31 ^{a}	26.23±0.26 ^{b}	27.89±0.38 ^{b}	P<0.01
Total crude protein intake (g/kid/day)	54.66±0.98 ^{a}	56.57±1.41 ^{ab}	58.48±1.19 ^{c}	P<0.01
Digestible crude protein intake (g/kid/day)	33.19±1.33 ^{a}	37.94±1.39 ^{b}	39.83±1.62 ^{b}	P<0.01
Digestible crude protein intake % of diet (kid/day)	9.57±0.32 ^{a}	10.55±0.20 ^{b}	10.79±0.24 ^{b}	P<0.01
Total digestible nutrients intake (g/kid/day)	200.44±7.45 ^{a}	228.45±8.98 ^{b}	234.91±9.43 ^{b}	P<0.01
Total digestible nutrients % of diet (kid/day)	57.79±1.63 ^{a}	63.32±1.03 ^{b}	63.56±1.28 ^{b}	P<0.01

NS: Non-significant (P>0.05), and row-wise means having different superscripts ($^{a, b, c}$) within a category differed significantly

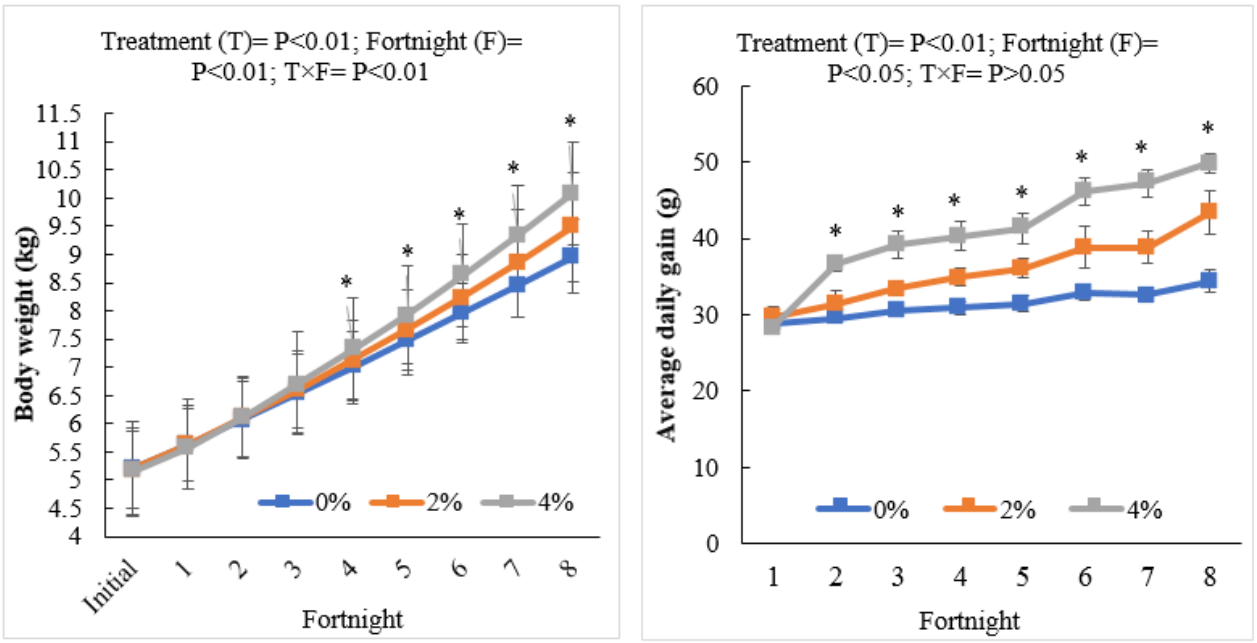

Fig. 1: Effect of fenugreek seeds supplementation on body weight and average daily gain in Black Bengal kids. * P<0.05

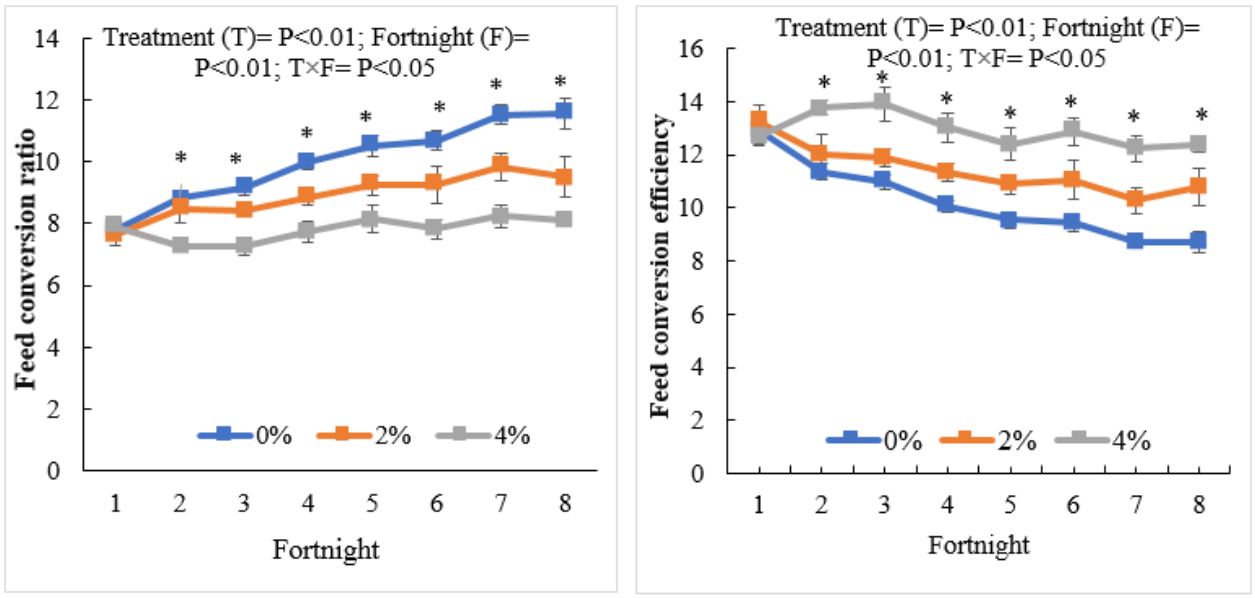

Fig. 2: Effect of Fenugreek seeds supplementation on feed conversion ratio and feed conversion efficiency. * P<0.05

differences in total fodder intake, dry matter intake from fodder, and total dry matter intake among the different fenugreek seed supplementation groups (0%, 2%, and 4%). However, the groups supplemented with fenugreek seeds (2% and 4%) showed higher (P<0.01) concentrate intake, dry matter intake from concentrate, crude protein intake, digestible crude protein intake, digestible crude protein intake % of diet, total digestible nutrients intake, and total digestible nutrients % of diet compared to the 0% fenugreek seed supplementation group during the digestibility trial.

Body weight and average daily gain

The effect of fenugreek seed supplementation on body weight and average daily gain in Black Bengal kids is represented in Fig. 1. There were significant differences in body weight and average daily gain among the supplementation groups over the experimental period. Black Bengal kids supplemented with fenugreek seeds at both 2% and 4% levels exhibited higher body weights and average daily gain compared to the 0% fenugreek seed supplementation group. Additionally, the body weight and average daily gain increased as the level of fenugreek seed supplementation increased (0%<2%<4%). The overall mean body weight and average daily gain of the 4% group were 5.69% and 30.81% higher than those of the 0% group, while in the 2% group, they were 2.56% and 14.07% higher than those of the 0% group, respectively.

Table 5: Economic analysis of fenugreek seed supplementation

Parameters	Rate of supplementation		
	0%	2%	4%
Cost of concentrate mixture (₹/kg)	32.60	32.60	32.60
Cost of fodder (₹/kg)	2.00	2.00	2.00
Cost of concentrate intake (₹/animal for 120 days)	424.19±0.73	433.19±1.24	451.83±1.53
Cost of green fodder intake (₹/animal for 120 days)	219.53±1.27	219.98±1.31	220.30±0.96
Cost of FG intake (₹/animal for 120 days) FG@ ₹ 60/kg	-	14.37	29.36
Total feed cost (₹/animal for 120 days)	643.72±1.35	667.53±2.08	701.49±1.98
Return from sale of goats (@ ₹ 350/kg live weight)	3136.58±22.98	3319.17±41.82	3528.58±35.00
Cost of labour & Misc. (₹/animal for 120 days)	150	150	150
Total cost (₹) (feed+labour+misc.)	793.72±1.35	817.53±2.08	851.49±1.98
BW gain in 120 days (kg)	3.77±0.02	4.3±0.12	4.93±0.08
Total cost (₹)/kg BW gain (feed+labour+misc.)	210.57±1.25	190.8±4.88	172.9±3.03
Net profit (₹/animal for 120 days)	2342.87±22.05	2501.63±40.03	2677.10±36.10
Net profit (₹/kg live weight)	261.41±0.55	263.74±0.90	265.49±0.96
Net profit (compared with 0%))	-	158.77±44.31	334.23±40.72
Net profit (compared with 0%)	-	6.51±1.78	13.29±1.56
1 USD=89.26 Indian Rupees (₹)			

Feed conversion ratio and feed conversion efficiency

The research findings of fenugreek seed supplementation on the feed conversion ratio and feed conversion efficiency of Black Bengal kids are displayed in Fig. 2. The 0% fenugreek seed supplementation group exhibited the highest feed conversion ratio values, while the groups supplemented with fenugreek seeds at both 2% and 4% levels showed lower feed conversion ratio values; which indicates that supplemented groups required less feed to gain body weight. The overall mean feed conversion ratio of the 4% and 2% groups were 29.19% and 13.37%, respectively, lower ($P<0.05$) than that of the 0% group. The significant ($P<0.01$) interaction effect between treatment (T) and fortnight (F) (T×F) suggests that the impact of treatment on feed conversion ratio varied across fortnights.

Similar to the feed conversion ratio, the feed conversion efficiency values also displayed significant differences ($P<0.01$) among the experimental groups and fortnights. The groups supplemented with fenugreek seeds at both levels (2% and 4%) demonstrated higher feed conversion efficiency values compared to the 0% group. The overall mean feed conversion efficiency of the 4% and 2% groups were 26.44% and 11.94%, respectively, higher ($P<0.05$) than that of the 0% group. The interaction ($P<0.01$) effect (T×F) suggests that the supplementation effect on feed conversion efficiency varies over time.

Economics

The economic evaluation of feeding management practices during the experimental period across three groups is presented in Table 5. The results indicated that the treatment group was more economical and beneficial. Although the treatment group required a higher cost for fodder and concentrate supplemented with fenugreek seeds, due to higher intake compared to the control group, the total cost per kg of body weight gain was lower in the treatment groups. Fenugreek seed supplementation at a 4% level resulted in a higher net profit compared to the 2% and 0% groups. Additionally, the 4% supplementation level showed a better net profit, both in monetary terms and percentage, than the 2% and 0% levels.

Discussion

Evaluation of phytochemicals of fenugreek seeds

The total phenolic content of *Trigonella foenum-graecum* seed was higher than the reported level of 1.05 mg/g by Kochhar *et al.* (2006), 2.9 mg/g by Mahmoud *et al*. (2012), and 6.16 mg/g by Abdouli *et al.* (2014) and lower than the reported level of 10.30 mg/g by Yasothai (2021). The total alkaloid contents in *Trigonella foenum-graecum* seed were similar as those reported by Mahmood and Yahya (2017). The total flavonoid contents in *Trigonella foenum-graecum* seed were lower than the reported level of 1.36 to 2.74 mg/g by Singh *et al.* (1994), and 2.61 mg/g by Mabrouki *et al*. (2015), and higher than the reported level of 0.31 mg/g by Abdouli *et al.* (2014), and 0.08 to 0.32 mg/g by Mahmood and Yahya (2017). The total saponin content in fenugreek seed was higher than the reported level of 0.07 to 0.17 mg/g by Mahmood and Yahya (2017). The variation in phytochemical contents might be attributed to the extraction method involved and region-wise cultivation of fenugreek seeds.

Dry matter and crude protein intake of Black Bengal kids

The present study indicated an increase in dry matter intake and crude protein intake among groups offered a diet supplemented with fenugreek seeds comapred to offered a control diet. The findings of this study are in line with the observations of the study of Al-Sherwany (2015), in which Hamdani ewes were fed with 0.6 and

1.2 g/kg live body weight of crushed fenugreek seed in the diet and it was reported that 1.2 g/kg live body weight of crushed fenugreek seed in the diet increased dry matter intake. Fenugreek seed supplementation in goats led to a significant increase in dry matter intake (Salama *et al*., 2015; Gaikwad *et al*., 2019), growth performance (Salama *et al*., 2015), and feed consumption (AL-Hameed, 2019) in the treatment group compared to the control group. Atta Elmnan *et al*. (2014) observed an increase in dry matter intake and crude protein intake in lactating Nubian goats when supplemented with 5%, 10%, and 15% fenugreek seed with the best results at the 15% level. Abu EL-Kassim *et al*. (2018) noted a significant increase in feed intake in Ossimi ewes, and Ismail (2000) found that dry matter intake increased in Barki lambs that were treated with fenugreek seeds compared to the group that did not receive fenugreek seed supplementation. On the contrary, Hasin *et al*. (2019) found that the supplementation of fenugreek seeds to goats resulted in similar feed intake between the control and treatment groups. Similarly, supplementing fenugreek seeds at various levels in the diets of Awassi lambs did not improve feed intake among all experimental groups (Al-Wazeer, 2017). In the current study, both dry matter intake and crude protein intake per kg $W^{0.75}$ were lower in the fenugreek-supplemented group compared to the control group. In contrast, Sharma *et al*. (2024) reported that fenugreek seed supplementation in indigenous goat kids resulted in similar dry matter and crude protein intake per kg $W^{0.75}$ between the control and treatment groups.

The potential galactopoietic impact of fenugreek has been postulated to be associated with an elevation in feed consumption, which is ascribed to the presence of saponins (Tomar *et al*., 1996). Furthermore, it has been suggested that the increases in feed consumption resulting from fenugreek supplementation may be attributed to its influence on the hypothalamus, whereby it stimulates hunger centers within the brain and increases the desire to eat (Abo El-Nor, 2007). This increase in concentrate intake and dry matter intake through fenugreek seed supplementation could be attributed to the potential palatability of the seeds, influencing the kids to consume a greater amount of concentrate feed.

Nutrient intake and utilization during the digestibility trial

The roughage intake was similar between the groups, but the concentrate intake of the kids was higher in the fenugreek seed supplementation group during the digestibility trial. The digestibility of dry matter (DM), crude protein (CP), ether extract (EE), organic matter (OM), total ash (TA), hemicellulose, total carbohydrate (T-CHO), acid detergent fiber (ADF), and neutral detergent fiber (NDF) in both the 2 and 4% fenugreek seed supplementation groups was significantly higher than that in the control group. The enhanced nutrient utilization observed in the group receiving fenugreek seed supplementation may be attributed to fenugreek seeds facilitating increased cellular glucose uptake (Pradeep *et al*., 2019), leading to greater availability of energy and consequently, promoting more efficient metabolism for improved nutrient utilization (Zuk-Golaszewska and Wierzbowska, 2017) within the treatment groups. The better digestibility of various nutrients in the present study could be due to the changes in the types and numbers of more active microorganisms that break down cellulose in the goat's rumen when fenugreek seeds are added to their diet as a medicinal supplement (Mir and Kumar, 2012).

The present results agree with the findings of Atta Elmnan *et al*. (2014), who reported a significant increase in dry matter, organic matter, and crude protein digestibility in lactating Nubian goats supplemented with different levels of fenugreek seeds. Similar results were found by Mir and Kumar (2012) in male nondescript goats fed fenugreek seeds at a dose rate of 3% of dry matter intake, where there is was significantly increased digestibility of dry matter, organic matter, crude protein, crude fiber, total carbohydrate, neutral detergent fiber, acid detergent fiber, and hemicellulose and in digestibility coefficients of dry matter, organic matter, crude protein, ether extract, neutral detergent fiber, hemicellulose, and total carbohydrate in the experiment group as compared to the control group. El-Foly *et al*. (2005) found that the addition of fenugreek seeds to the diet of sheep greatly improved the digestion of organic matter and nitrogen-free extracts. Similarly, fenugreek seed supplementation in the diet of goat kids significantly increased the digestibility of dry matter, organic matter, crude protein, ether extract and neutral detergent fiber in the treatment group compared to the control group (Salama *et al*., 2015).

The increased digestibility in fenugreek seed supplementation may be attributed to the saponins in the seeds, which stimulate anaerobic fermentation of organic matter, thereby improving the efficiency of nutrient utilization (Abo El-Nor, 2007). In contrast, Al-Wazeer (2017) reported that there were no significant differences in the digestibility of dry matter, organic matter, crude protein, acid detergent fiber, and neutral detergent fiber between the treatment and control groups in goats. Conversely, Hidayet and Mustafa (2025) in lambs reported that the inclusion of fenugreek seed at different levels (5, 10, and 15%) in the diet did not cause any significant variation in the digestibility of dry matter, organic matter, crude protein, and ether extract. Furthermore, fenugreek seed supplementation was found to enhance the population of bacteria in the rumen of lactating cows (Ali *et al*., 2005), leading to increased concentrate intake, higher crude protein intake, and enhanced intake of digestible nutrients. The enhanced digestibility of dry matter, protein, fat, organic matter, and various fiber fractions suggests that fenugreek seeds contain bioactive components that support improved nutrient utilization and absorption in the digestive tract. These findings of the present study suggest the potential benefits of incorporating fenugreek seeds in the diet of Black Bengal kids to improve their nutrient intake and

growth performance.

Body weight and average daily gain

In the present experiment, the fortnightly body weight and average daily gain across the experimental period consistently showed that the groups supplemented with fenugreek seeds (2% and 4%) had improved growth compared to the 0% group. The increased body weight and average daily gain in kids fed with supplemented Fenugreek seed could be attributed to the increased availability of different nutrients, as observed in this study and earlier works (Hasin *et al*., 2019). Salama *et al*. (2015) found that the addition of 2% of fenugreek seed in the total mixed ration of the diet improved the growth performance of male Baladi kids. Nallathambi *et al.* (2016) reported that supplementation of fenugreek seed at 10 g/day to lactating ewes resulted in a better growth rate of lambs. Additionally, Mousa *et al.* (2024) reported that replacing cottonseed meal with different levels (50%, 75%, and 100%) of fenugreek seed meal (FSM) in the diets of Ossimi lambs affected growth performance. Lambs fed the FSM50 diet achieved the highest total weight gain, while those receiving FSM75 and FSM100 had lower gains compared to the control (FSM0). On the contrary, Al-Wazeer (2017) reported that supplementations of 0, 2.5, 5, and 7.5 g/head/day of fenugreek seed in Awassi lambs resulted in no significant difference between the groups.

Elevated body weight is more likely a consequence of increased dietary consumption of fenugreek seeds. Furthermore, fenugreek seeds contain trigonelline, an active compound with potent appetite-stimulating properties, leading to heightened feed intake and subsequently increased body weight (Kamel, 2008). Similarly, Srinivasan (2005) has documented that fenugreek augments the synthesis of bile acids within the liver and their excretion in bile, resulting in improved fat digestion and absorption. This enhanced digestion could further contribute to increased feed intake, body weight, and average daily gain. The observed rise in body weight and average daily gain in the group receiving fenugreek supplementation may be attributed to the presence of Diocin, a growth hormone (GH) secretagogue structurally similar to estrogen. Diocin stimulates growth hormone secretion by binding to pituitary cell receptors that recognize GH-releasing hormone (GH-RH), thereby resulting in an increase in body weight and average daily gain (Graham *et al*., 2008). This demonstrates the potential of fenugreek seed supplementation to enhance the overall growth performance of Black Bengal kids.

Feed conversion ratio and feed conversion efficiency

The inclusion of fenugreek seed supplementation in the diets of goat kids has been found to enhance the sensory qualities of the feed, resulting in improved flavor and aroma (Akbag *et al*., 2022). This sensory improvement contributes to increased activity in digestive secretions and hormones related to feed intake regulation (Wani and Kumar, 2018). Consequently, goat kids consuming fenugreek seeds exhibit elevated feed intake, leading to enhanced nutrient digestion within the animal's digestive system. Fenugreek seeds are rich in a diverse array of bioactive compounds, many of which possess antioxidant and antimicrobial properties (Akbag *et al*., 2022), and these bioactive compounds play a crucial role in safeguarding against potential pathogenic invaders within the gastrointestinal tract (Yao *et al*., 2020). As a result, a greater proportion of digested nutrients is directed toward body growth in kids that receive fenugreek seed supplementation hence, there is an improved feed conversion ratio and feed conversion efficiency in the 2% and 4% groups compared to the 0% group kids.

Similar findings, where a significant difference in feed conversion ratio and feed conversion efficiency between the fenugreek seed-supplemented and without fenugreek seed-supplemented groups in goats were reported by Al-Sherwany (2015) and Gaikwad *et al.* (2019). On the other hand, Al-Wazeer (2017) reported no significant differences in feed conversion ratio and feed conversion efficiency among the goat experimental groups.

The results of the present study indicate that Fenugreek seed supplementation had a positive impact on both feed conversion ratio and feed conversion efficiency in Black Bengal kids during the 120-day experimental period. The supplementation, particularly at 2% and 4% levels, was associated with improved feed conversion efficiency, suggesting enhanced utilization of feed for weight gain. These findings suggest that fenugreek seed supplementation might offer benefits in terms of optimizing the efficiency of feed utilization and growth in Black Bengal kids.

Economics

The enhanced growth performance and improved feed efficiency observed in the treatment groups translated directly into significant economic advantages, highlighting the positive impact of dietary supplementation on overall profitability in the present study. Fenugreek seed supplementation at 2% and 4% levels yielded higher net profit compared to the 0% (control) group, with the 4% level providing the greatest net profit both in absolute monetary terms and as a percentage, surpassing the 0% and 2% inclusion levels. Similar findings were reported by Salama *et al.* (2015) in Baladi male kids, where 2% fenugreek seed supplementation resulted in lower feed cost per kg of gain and higher net profit compared with the control. Additionally, Mousa *et al.* (2024) found that replacing cottonseed meal (CSM) with fenugreek seed meal (FSM) in Ossimi lamb diets reduced feed costs. The 50% substitution level (FSM50) produced the highest relative net revenue at 131% compared with the control. The improvement in economic efficiency with FSM was primarily linked to its lower cost relative to CSM and the greater total weight gain achieved with FSM inclusion.

Limitations

The limitation of the present study is the absence of measurements of key microbial metabolites, particularly rumen short-chain fatty acids (SCFAs) such as acetate, propionate, and butyrate. These SCFAs are the primary energy source for ruminants, and their production profile directly reflects the efficiency of rumen fermentation and nutrient utilization. The saponins and fiber content in fenugreek seeds likely altered the rumen microbial ecosystem, which would, in turn, influence the concentration and molar proportions of these SCFAs. Therefore, future studies should incorporate the analysis of rumen fermentation parameters to provide a more complete mechanistic understanding of how fenugreek supplementation enhances goat productivity.

In this study, the supplementation of fenugreek seeds to the diet increased the feed intake of Black Bengal kids. Moreover, the supplementation of fenugreek seeds at both 2% and 4% of the dry matter of the concentrate ration led to improved nutrient digestibility, enhanced body weight, average daily gain, feed conversion ratio, and feed conversion efficiency. However, the best outcomes were observed in the group receiving fenugreek seed at 4% of the dry matter of the concentrate ration. Therefore, supplementation of fenugreek seeds in the diets of growing Black Bengal goat kids could prove valuable for enhancing nutrient utilization and promoting the growth performance of these animals.

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Conflict of interest

The authors declare that they have no conflict of interest.

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References

Abdouli, H; Missaoui, H; Jellali, S; Tibaoui, G; Tayachi, L; Yaich, H; Jabri, J; Abid, K; Malek, A; Rekhis, J and Kamoun, M (2014). Comparison of two fenugreek seed genotypes: bitterness value, secondary metabolites contents and biological activities. J. New Sci., 7: 19-27.

Abo El-Nor, SAH (2007). Effect of some medicinal plants seeds in the rations on the productive performance of lactating buffaloes. Int. J. Dairy Sci., 2: 348-355.

Abu EL-Kassim, MA; Abd El-Hafez, GA; Mousa, SM and Hassan, EH (2018). Effect of dietary onion, garlic and fenugreek seeds powder on feed intake, blood metabolites and rumen fermentation in Ossimi ewes. Assiut J. Agri. Sci., 49: 38-48.

Akbag, HI; Savaş, T and Karagul Yuceer, Y (2022). The effect of fenugreek seed (*Trigonella foenum-graecum*) supplementation on the performance and milk yield characteristics of dairy goats. Arch. Anim. Breed., 65: 385-395.

AL-Hameed, SA (2019). Effect of dietary grounded fenugreek (*Trigonella foenum graecum* L.) seeds and ginger (*zingiber officinal*) rhizomes powder on performance and some blood traits of layer hens. Plant Arch., 19: 4287-4293.

Ali, MF; Saleh, MS; Eweedah, NM and Mohmoud, SA (2005). Effect of using chamomile (*Mtricaria chamomilla*) flowers as feed additives on performance of growing lambs under desert farming systems. Egypt. J. Nutr. Feeds., 8: 127-137.

Al-Sherwany, DAO (2015). Feeding effects of fenugreek seeds on intake, milk yield, chemical composition of milk and some biochemical parameters in Hamdani ewes. Al-Anbar J. Vet. Sci., 8: 49-54.

Al-Wazeer, AAM (2017). Effect of fenugreek seeds supplementation on growth performance, digestion coefficient, rumen fermentation and some blood metabolites of Awassi lambs. Kufa J. Vet. Med. Sci., 8: 8-18.

AOAC (2005). *Official methods of analysis*. (18th Edn.), Association of official analytical chemists. Washington, D.C., P: 2590.

Atta Elmnan; Balgees, A and Mangara, JL (2012). Effect of fenugreek (Trigonella foenum-graecum) seed dietary levels on lipid profile and body weight gain of rats. Pak. J. Nutr., 11: 1004-1008.

Atta Elmnan, AB; Rewais, FA; Fadel Elseed, AMA; Mahala, AG and Amasiab, EO (2014). Effect of supplementation of fenugreek (*Trigonella foenum-graecum* L.) seeds on feed intake, digestibility, N-balance and rumen environment of Nubian goats. Int. J. Dev. Sustain., 2: 1214-1223.

Darcan, NK and Silanikove, N (2018). The advantages of goats for future adaptation to climate change: A conceptual overview. Small Rumin. Res., 163: 34-38.

Dhull, SB; Punia, S; Kumar, R; Kumar, M; Nain, KB; Jangra, K and Chudamani, C (2021). Solid state fermentation of fenugreek (*Trigonella foenum-graecum*): implications on bioactive compounds, mineral content and in vitro bioavailability. J. Food Sci. Technol., 58: 1927-1936.

El-Foly, AH; Abd El-Baki, SM; Nowar, ME; Shehata, SA and Ibrahim, MK (2005). Effect of fenugreek seeds and vegetable oil addition on digestibility and nitrogen and energy utilization of sheep. Egypt. Zagazig J. Agric. Res., 10: 1271-1289.

Gaikwad, BS; Patil, RA; Padghan, PV and Shinde, SS (2019). Effect of fenugreek (*Trigonella foenum-gracum* L.) seed powder as natural feed additive on performance and blood parameters of broiler chicks. Int. J. Curr. Microbiol. Appl. Sci., 8: 1137-1146.

Goel, G; Makkar, HPS and Becker, K (2008). Changes in microbial community structure, methanogenesis and rumen

fermentation in response to saponin-rich fractions from different plant materials. J. Appl. Microbiol., 105: 770-777.

Graham, MR; Baker, JS; Evans, P; Kicman, A; Cowan, D; Hullin, D; Thomas, N and Davies, B (2008). Physical effects of short-term recombinant human growth hormone administration in abstinent steroid dependency. Horm. Res. Paediatr., 69: 343-354.

Hasin, D; Pampori, ZA; Ahmad Sheikh, A; Aarif, O; Bhat, IA and Abdullah, M (2019). Milk production and hormonal profile as affected by fenugreek supplementation in lactating goats of Kashmir valley. Biol. Rhythm Res., 52: 986-993.

Hassan, FU; Ebeid, HM; Tang, ZH; Li, MW; Peng, LJ; Peng, KP; Liang, X and Yang, CJ (2020). A mixed phytogenic modulates the rumen bacteria composition and milk fatty acid profile of water buffaloes. Front. Vet. Sci., 7: 1-16.

Hidayet, H and Mustafa, K (2025). Impact of diet supplementation with fenugreek seeds on digestibility and some rumen and blood parameters in lambs. YYU J. Agr. Sci., 35: 381-391.

Hossain, ME (2021). Performance of black Bengal goat: a 50-year review. Trop. Anim. Health Prod., 53: 1-15.

Ibidhi, R and Ben Salem, HB (2022). Effect of daily or intermittent addition of fenugreek (*Trigonella foenum-graecum* L.) seeds to concentrate on intake, digestion, and growth performance of Barbarine lamb. Small Rumin. Res., 216: 1-16.

Ismail, SA (2000). Effect of fenugreek seeds (*Trigonella foenum-graecum* L.) as feed additive on sheep performance in the northwestern coast of Egypt. Proceedings of the 3rd All Africa Conference on Animal Agriculture and 11th Conference of the Egyptian Society of Animal Production, Alexandria, Egypt. PP: 321-325.

Jayanegara, A; Yogianto, Y; Wina, E; Sudarman, A; Kondo, M; Obitsu, T and Kreuzer, M (2020). Combination effects of plant extracts rich in tannins and saponins as feed additives for mitigating *in vitro* ruminal methane and ammonia formation. Animals., 10: 1-14.

Kamel, C (2008). Natural plant extracts: Classical remedies bring modern animal production solutions. Cah. Options Mediterr., 54: 31-38.

Kochhar, A; Nagi, M and Sachdeva, R (2006). Proximate composition, available carbohydrates, dietary fibre and anti-nutritional factors of selected traditional medicinal plants. J. Hum. Ecol., 19: 195-199.

Ku-Vera, JC; Jimenez-Ocampo, R; Valencia-Salazar, SS; Montoya-Flores, MD; Molina-Botero, IC; Arango, J; Gomez-Bravo, CA; Aguilar-Perez, CF and Solorio-Sanchez, FJ (2020). Role of secondary plant metabolites on enteric methane mitigation in ruminants. Front. Vet. Sci., 7: 1-14.

Mabrouki, S; Omri, B; Abdouli, H and Tayachi, L (2015). Chemical, functional and nutritional characteristics of raw, autoclaved and germinated fenugreek seeds. J. New Sci., 16: 541-551.

Mahmoud, NY; Salem, RH and Mater, AA (2012). Nutritional and biological assessment of wheat biscuits supplemented by fenugreek plant to improve diet of anemic rats. Acad. J Nutr., 1: 1-9.

Mahmood, NM and Yahya, KI (2017). Nutrient and phytochemical of fenugreek (*Trigonella foenum graecum*) seeds. Int. J. Sci. Basic Appl. Res., 36: 203-213.

Mir, IA and Kumar, R (2012). Effect of feeding fenugreek seeds (*Trigonella foenum-graecum*) as feed additive on nutrient utilization in goats. Indian J. Anim. Nutr., 29: 256-261.

Mousa, GA; Kholif, AE; Hassaan, NA; El-Garhy, GM and Hassan, OG (2024). Effect of replacing cottonseed meal with fenugreek seed meal on feed intake, digestibility, growth, blood parameters and economics of fattening lambs. Small Rumin. Res., 236: 107305.

Nallathambi, B; Purushothaman, MR; Nagarajan, M and Natarajan, A (2016). Supplementation of fenugreek seeds to lactating ewes and effect on growth performance of preweaned twin lambs. J. Anim. Res., 6: 543-545.

Naseri, V; Hozhabri, F and Kafilzadeh, F (2013). Assessment of *in vitro* digestibility and fermentation parameters of alfalfa hay-based diet following direct incorporation of fenugreek seed (*Trigonella foenum-graecum*) and asparagus root (*Asparagus officinalis*). J. Anim. Physiol. Anim. Nutr., 97: 773-784.

Niknam, R; Kiani, H; Mousavi, ZE and Mousavi, M (2021). Extraction, detection, and characterization of various chemical components of *Trigonella foenum-graecum* L. (fenugreek) known as a valuable seed in agriculture. In: Naeem, M; Aftab, T and Khan, MMA (Eds.), *Fenugreek: Biology and applications*. (1st Edn.), Springer Singapore. PP: 189-217.

Niu, HX; Xu, ZJ; Yang, HE; McAllister, TA; Acharya, S and Wang, YX (2021). *In vitro* ruminal fermentation of fenugreek (*Trigonella foenum-graecum* L.) produced less methane than that of alfalfa (*Medicago sativa*). Anim. Biosci., 34: 584-593.

Oskoueian, E; Abdullah, N and Oskoueian, A (2013). Effects of flavonoids on rumen fermentation activity, methane production, and microbial population. Biomed. Res. Int., 2013: 1-8.

Pradeep, SR; Barman, S and Srinivasan, K (2019). Attenuation of diabetic nephropathy by dietary fenugreek (*Trigonella foenum-graecum*) seeds and onion (*Allium cepa*) via suppression of glucose transporters and renin-angiotensin system. Nutrition. 67: 1-37.

Salama, R; Fouda, SM; El-Sysy, MAI and Gomaa, AS (2015). Effect of adding fenugreek seeds to goat rations and age at weaning on the fattening performance and carcass characteristics of Baladi male kids. Egypt. J. Nutr. Feeds., 18: 55-63.

Sharma, S; Kurechiya, N; Patil, AK; Jain, RK; Keshri, A; Aich, R and Rawat, K (2024). Effect of dietary supplementation of fenugreek (*Trigonella foenum-graecum*) seeds on feed intake, nutrient utilization and haemato-biochemical profile of indigenous goat kids. Rumin. Sci., 13: 121-125.

Singh, J; Gupta, K and Arora, SK (1994). Changes in the anti-nutritional factors of developing seeds and pod walls of fenugreek (*Trigonella foenum graecum* L.). Plant Foods Hum. Nutr., 46: 77-84.

Soni, A and Sosa, S (2013). Phytochemical analysis and free radical scavenging potential of herbal and medicinal plant extracts. J. Pharmacogn. Phytochem., 2: 22-29.

Srinivasan, K (2005). Spices as influencers of body metabolism: an overview of three decades of research. Food Res. Int., 38: 77-86.

Tapio, I; Snelling, TJ; Strozzi, F and Wallace, RJ (2017). The ruminal microbiome associated with methane emissions from ruminant livestock. J. Anim. Sci. Biotechnol., 8: 1-11.

Tomar, KS; Singh, VP and Yadav, RS (1996). Effect of feeding maithy (*Trigonella foenum-graecum*) and chandrasoor (*Lepidium sativum* L.) seeds on milk and blood constituents of Murrah buffaloes. Indian J. Anim. Sci., 66: 1192-1193.

Ugbogu, EA; Elghandour, M; Ikpeazu, VO; Buendia, GR;

Molina, OM; Arunsi, UO; Emmanuel, O and Salem, AZM (2019). The potential impacts of dietary plant natural products on the sustainable mitigation of methane emission from livestock farming. J. Clean. Prod., 213: 915-925.

Van Soest, PV; Robertson, JB and Lewis, BA (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3597.

Wani, SA and Kumar, P (2018). Fenugreek: A review on its nutraceutical properties and utilization in various food products. J. Saudi Soc. Agric. Sci., 17: 97-106.

Yao, D; Zhang, B; Zhu, J; Zhang, Q; Hu, Y; Wang, S and Xiao, J (2020). Advances on application of fenugreek seeds as functional foods: Pharmacology, clinical application, products, patents and market. Crit. Rev. Food Sci. Nutr., 60: 2342-2352.

Yasothai, R (2021). Chemical composition of fenugreek (*Trigonella foenum-graecum L.*) seed and galactomannan depleted fenugreek residue. Pharma Innovation. 10: 944-947.

Zuk-Gołaszewska, K and Wierzbowska, J (2017). Fenugreek: productivity, nutritional value and uses. J. Elem., 22: 1067-1080.