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Effect of supplementation of rumen modifiers on growth performance, feed efficiency and nutrient digestibility in growing goats fed Jowar straw based total mixed ration

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Abstract

The present study evaluated the effect of rumen modifiers (probiotic yeasts: *Saccharomyces cerevisiae* and *Yarrowia lipolytica*; bacterial strains: *Propionibacterium freudenreichii* and *Bacillus subtilis*; along with fibrolytic enzymes) supplementation in total mixed ration (TMR) on growth performance, nutrient utilization, and economics in growing Osmanabadi goat kids. Eighteen kids of 4-5 months were divided into three groups: T₀ (control, basal TMR), T₁ (TMR + 5 g probiotic mixture/day/kid + enzymes 300 g/ton), and T₂ (TMR + 10 g probiotic mixture/day/kid + enzymes 450 g/ton) and fed for 84 days. Final body weight and average daily gain in weight were significantly higher ($p < 0.05$) in groups supplemented with rumen modifiers (T₁ and T₂) compared to control, while differences between T₁ and T₂ were non-significant. Average daily DMI was significantly higher ($p < 0.05$) in T₁ than in T₀ and T₂. Average daily TDN and DCP intakes were significantly influenced ($p < 0.05$) by rumen modifier supplementation, with highest values recorded in T₁. Digestibility coefficients of DM, OM, CF, CP, and NDF were significantly higher ($p < 0.05$) in T₁ and T₂ than in T₀, while EE, NFE, ADF, and ADL digestibility showed no significant differences. Feed efficiency parameters showed numerical improvement but no significant differences. Economically, group T₁ showed the lowest cost per kg gain and highest net profit per kg live weight gain. It can be concluded that rumen modifier supplementation improved growth performance, nutrient digestibility, and economic returns in growing Osmanabadi kids fed Jowar straw-based TMR.

Keywords: Probiotics, fibrolytic enzymes, growth performance, nutrient utilization, Osmanabadi goats

Introduction

Animal husbandry is a cornerstone of India's agrarian economy, providing livelihood, nutrition, and employment to millions. The 20th Livestock Census (2019) ^[1] reported 535.78 million livestock (+ 4.6%), including 148.88 million goats (+ 10.1%), highlighting their importance for smallholder farmers and rising demand for meat and milk.

With meat consumption in India projected to nearly double by 2030, improving feed efficiency and productivity is essential (Alexandratos & Bruinsma, 2012) ^[2]. This requires advancements in nutrition, including the use of rumen modifiers such as probiotics and fibrolytic enzymes to enhance growth and feed utilization (Chatterjee *et al.*, 2023) ^[3].

Traditional feeding systems based on grazing and crop residues often fail to meet nutritional requirements (Boudalia *et al.*, 2024) ^[4]. Hence, scientifically formulated diets with feed additives like yeast, bacteria, and enzymes are needed to improve nutrient utilization. Since goat diets are largely fibrous, supplementation with exogenous fibrolytic enzymes (EFE) and yeast probiotics has shown promise in improving digestion and performance (Fróes *et al.*, 2024) ^[5].

Rumen modifiers enhance fermentation, stabilize rumen pH, and improve feed efficiency, contributing to sustainable production (Firkins & Mitchell, 2023) ^[6]. Yeast (*Saccharomyces cerevisiae*) improves rumen function, microbial balance, and feed intake, leading to better growth (Throne *et al.*, 2009) ^[7], while enzymes such as cellulase and xylanase enhance fibre breakdown (Beauchemin *et al.*, 2003) ^[8].

Given the rising demand for efficient and sustainable chevon production, supplementation of rumen modifiers such as yeast, bacteria, and fibrolytic enzymes offers a promising strategy. Therefore, present study was undertaken to evaluate the effects of dietary supplementation of rumen modifiers on growth performance and nutrient utilization, as well as the economics of feeding in growing goats.

Materials and Methods

The present study was conducted at the Livestock Farm Complex, Mumbai Veterinary College, Aarey Colony, and in the Department of Animal Nutrition, Mumbai Veterinary College. Eighteen Osmanabadi goat kids (4-5 months old) were selected based on age and body weight and randomly divided into three groups: T₀ (control), T₁ and T₂, with six animals each. The feeding trial was lasted for 84 days, preceded by a one-week adaptation period during which

animals were maintained on a basal diet. Standard management practices, including deworming and vaccination, were followed uniformly across the groups. The experimental design followed ICAR (2013) [9] recommendations, with animals receiving total mixed ration (TMR) consisting of 50% dry roughage (*Sorghum bicolor*), 20% green fodder (*Brachiaria mutica*), and 30% concentrate mixture (Makka chunni, Soybean meal, Cottonseed cake, Tur chunni and Wheat bran). Treatments included rumen modifiers in treatment groups (T₁ and T₂) and T₀ served as control group which was not supplemented with any rumen modifiers. Probiotics as rumen modifiers included *Saccharomyces cerevisiae*, *Yarrowia lipolytica*, *Propionibacterium freudenreichii* and *Bacillus subtilis*, while enzymes consisted of Exoglucanase, Endoglucanase and Xylanase in quantities mentioned in table 1.

Table 1: Dietary treatments

T ₀ (control)	Served as control and received Jowar straw based TMR as per standard recommendation (ICAR, 2013) [9].
T ₁ (Treatment I)	Received feed as per T ₀ plus, yeast (<i>Saccharomyces cerevisiae</i> , <i>Yarrowia lipolytica</i>) and bacteria (<i>Propionibacterium freudenreichii</i> , <i>Bacillus subtilis</i>) 5 g (1.25×10^9 CFU/g)/day/goat and enzymes (Exoglucanase 80 U/g, Endoglucanase 190 U/g, Xylanase 70 U/g) 300 gram/ton of feed.
T ₂ (Treatment II)	Received feed as per T ₀ plus yeast (<i>Saccharomyces cerevisiae</i> , <i>Yarrowia lipolytica</i>) and bacteria (<i>Propionibacterium freudenreichii</i> , <i>Bacillus subtilis</i>) 10 g (1.25×10^9 CFU/g)/day/goat and enzymes (Exoglucanase 80 U/g, Endoglucanase 190 U/g, Xylanase 70 U/g) 450 gram/ton of feed.

Kids were fed twice daily with free access to clean drinking water. Feed samples were collected fortnightly and analyzed for proximate composition using Horwitz and Latimer (2005) [10] methods and fiber fractions using the Van Soest detergent system (Van Soest *et al.*, 1991) [11].

Growth performance parameters such as fortnightly body weight and daily dry matter intake (DMI) were recorded. Animals were weighed before feeding using a digital balance. Feed intake was calculated by measuring feed offered and refusals. Digestibility trial of 7 days duration was conducted during the final week using the total collection method to determine nutrient digestibility and calculate total digestible nutrients (TDN) and digestible crude protein (DCP). Feed conversion efficiency was evaluated as intake of DM, TDN, and DCP per unit body weight gain.

Economics of feeding was calculated based on feed cost and cost per kg body weight gain. Statistical analysis of all data was performed using a Completely Randomized Design

(CRD) as per Snedecor and Cochran (1994) [12].

Results

Growth performance

Fortnightly body weights of growing goats increased progressively across all groups during the trial, with comparable initial body weights, while final body weights were significantly higher ($p < 0.05$) in T₁ (22.49±0.29 kg) and T₂ (22.18±0.30 kg) compared to T₀ (21.05±0.27 kg). Although average fortnightly body weights did not differ significantly among treatments ($p > 0.05$), a consistent increasing trend was observed throughout the experimental period, with higher overall mean body weights in supplemented groups. Correspondingly, growth performance was improved, as average fortnightly gain and average daily gain (ADG) were significantly higher ($p < 0.05$) in T₁ and T₂ compared to T₀, with T₁ showing the highest values, indicating a positive effect of rumen modifier supplementation on growth performance of Osmanabadi goats (Table 2).

Table 2: Effect of rumen modifier supplementation on growth performance of growing goats

Parameter	T ₀	T ₁	T ₂
Initial average body wt.(kg)	14.44±0.21	14.41±0.29	14.38±0.22
Final average body wt. (kg)	21.05 ^b ±0.27	22.49 ^a ±0.29	22.18 ^a ±0.30
Total gain in weight (kg)	6.61	8.08	7.80
Average fortnightly gain in wt.(g)	1102 ^b ±50	1347 ^a ±61	1300 ^a ±61
Average daily gain wt.(g)	79 ^b ±1.4	96 ^a ±1.7	93 ^a ±1.9

Values are means±SEM. Means bearing different superscripts (a, b) in a row differ significantly ($p < 0.05$).

Feed intake

Average daily dry matter intake (DMI) was significantly higher ($p < 0.05$) in T₁ (733.4±14.6 g) compared to T₀ (668.6±9.7 g) and T₂ (676.6±10.6 g). However, DMI expressed as percentage of body weight and per unit metabolic body size did not differ significantly ($p > 0.05$) among treatments, although numerically higher values were

observed in T₁. Total digestible nutrient (TDN) intake was significantly higher ($p < 0.05$) in T₁ (497.3±9.9 g) compared to T₀ and T₂, while digestible crude protein (DCP) intake was significantly increased ($p < 0.05$) in both T₁ (55.0±1.1 g) and T₂ (52.4±0.8 g) compared to T₀, indicating improved nutrient utilization with rumen modifier supplementation (Table 3).

Table 3: Effect of rumen modifier supplementation on feed intake of growing goats

Parameter	T ₀	T ₁	T ₂
Average daily DM intake (g)	668.6 ^b ±9.7	733.4 ^a ±14.6	676.6 ^b ±10.6
DM intake (%)	3.90±0.06	4.06±0.08	3.88±0.06
DMI per unit metabolic body size (g)	79.3±1.1	84.6±1.7	79.0±1.2
Average daily TDN intake (g)	433.7 ^b ±6.3	497.3 ^a ±9.9	460.3 ^b ±7.1
Average daily DCP intake (g)	47.8 ^b ±0.7	55.0 ^a ±1.1	52.4 ^a ±0.8

Values are means±SEM. Means bearing different superscripts (a, b) in a row differ significantly ($p<0.05$).

Feed Conversion Efficiency of Growing Goats

Feed conversion efficiency improved numerically in rumen modifier supplemented groups, with lower DM, TDN, and DCP required per kg body weight gain in T₁ and T₂ compared to T₀; however, the differences were non-significant ($p>0.05$), indicating only a trend toward improved efficiency (Table 4).

Table 4: Effect of rumen modifier supplementation on feed conversion efficiency of growing goats

Parameter	T ₀	T ₁	T ₂
DM required (kg) per kg gain wt.	8.99±0.13	7.74±0.15	7.35±0.11
TDN required (kg) per kg gain wt.	5.81±0.09	5.25±0.10	5.20±0.08
DCP required (kg) per kg gain wt.	0.61±0.03	0.57±0.03	0.57±0.03

Nutrient Digestibility

Rumen modifier supplementation significantly improved ($p<0.05$) digestibility of DM, OM, CP, and CF, with highest values in T₂ followed by T₁, while EE and NFE remained unaffected. Accordingly, dietary DCP and TDN contents were significantly higher in supplemented groups. Fiber digestibility showed a significant increase ($p<0.05$) in NDF, whereas ADF and ADL were not significantly affected, indicating enhanced fiber utilization mainly through improved NDF digestion (Table 5).

Table 5: Effect of rumen modifier supplementation on nutrient digestibility and nutritive value of diet

Parameter	Group T ₀	Group T ₁	Group T ₂
Dry Matter	62.68 ^c ±0.18	65.90 ^b ±0.18	67.45 ^a ±0.05
Organic Matter	65.47 ^c ±0.24	68.70 ^b ±0.18	69.93 ^a ±0.19
Crude Protein	68.11 ^c ±0.29	71.50 ^b ±0.28	73.75 ^a ±0.14
Ether Extract	74.49±0.28	74.48±0.3	74.52±0.31
Crude Fiber	58.11 ^c ±0.28	62.00 ^b ±0.38	64.65 ^a ±0.24
NFE	72.23±1.38	73.20±0.48	73.90±0.90
TDN%	64.79 ^b ±0.74	66.61 ^a ±0.22	67.86 ^a ±0.48
DCP%	7.14 ^c ±0.03	7.49 ^b ±0.03	7.73 ^a ±0.01
NDF	57.3 ^b ±0.91	61.11 ^a ±0.88	61.01 ^a ±0.61
ADF	52.47±0.79	52.26±0.61	53.38±0.91
ADL	26.71±0.53	27.68±0.48	28.51±0.71

Values are means±SEM. Means bearing different superscripts (a, b) in a row differ significantly ($p<0.05$).

Economics

The cost of TMR remained uniform across groups, with additional expenses in T₁ and T₂ due to rumen modifier supplementation and slightly higher intake, resulting in higher total feeding costs over 84 days compared to control. However, cost per kg live weight gain was lowest in T₁ (Rs. 281.33) compared to T₀ (Rs. 291.41) and T₂ (Rs. 300.10), indicating improved economic efficiency at moderate supplementation. Whereas, net profit per kg gain increased by 8.29% in T₁, while T₂ showed lower returns,

demonstrating that moderate inclusion of rumen modifiers is economically most beneficial.

Discussion

Growth performance

Studies consistently report improved growth performance with rumen modifier supplementation. Lu *et al.* (2023) [13] and Yuangklang *et al.* (2017) [14] observed higher final body weights and ADG with probiotics and fibrolytic enzymes, while Lu *et al.* (2023) [13] and Al-Galiby *et al.* (2023) [15] also reported significant improvements in body weight and gain; similar trends were noted by Maake *et al.* (2021) [16] and Ogbiko *et al.* (2020) [17], supporting the present findings of higher body weights in T₁ and T₂. Likewise, enhanced weight gain and ADG with rumen modifiers have been reported by Mousa *et al.* (2022) [18] and Al-Galiby *et al.* (2023) [15], along with Lu *et al.* (2023) [13] and Jinturkar *et al.* (2009) [19], although Whitley *et al.* (2009) [20] reported variable responses, overall aligning with the present study showing improved growth performance from T₀ to T₂.

Feed intake

Dry matter intake (DMI) responses to rumen modifiers are variable, as studies by Bureenok *et al.* (2023) [21], and McAllister *et al.* (2000) [22] reported significant increases in DMI with fibrolytic enzymes, whereas Al-Galiby *et al.* (2023) [15], and Awawdeh and Obeidat (2011) [23] found no significant effect, indicating that responses depend on diet and supplementation conditions. Similarly, improved TDN intake and utilization observed in the present study align with findings of Mousa *et al.* (2022) [18] and Fróes *et al.* (2024) [5], as well as enhanced fibre digestibility reported by Yuangklang *et al.* (2017) [14] and Pinos-Rodríguez *et al.* (2002) [24], though some studies such as Kumar *et al.* (2023) [25] and Bureenok *et al.* (2023) [21], reported non-significant effects, highlighting variability based on diet composition and strategy.

Feed Conversion Efficiency of Growing Goats

Numerical improvements in feed conversion efficiency (lower DM, TDN, and DCP required per kg gain) in T₁ and T₂ align with previous findings, where Mousa *et al.* (2022) [18] reported significant FCR improvement, while Maake *et al.* (2021) [16] and Ogbiko *et al.* (2020) [17] observed mainly non-significant but favorable trends, including dose-related responses; similarly, Muwalla *et al.* (2007) [26] and Awawdeh and Obeidat (2011) [23] reported no significant effects, indicating variability across studies. Improved energy utilization reflected by lower TDN requirement per kg gain is consistent with findings of Mousa *et al.* (2022) [18], supporting the present results.

Nutrients Digestibility

Rumen modifier supplementation improved nutrient digestibility, as reported by Mousa *et al.* (2022) [18] and Cai *et al.* (2021, 2021a) [27, 28], showing significant increases in DM, OM, and CP digestibility, with supporting evidence from Sutton *et al.* (2003) [29] and Gado *et al.* (2009) [30], although some studies like Muwalla *et al.* (2007) [26] and Reddish and Kung (2007) [31] reported non-significant effects. Improvements in EE, CF, and NFE digestibility have also been reported by Al-Galiby *et al.* (2023) [15], and Mousa *et al.* (2022) [18], though variability exists depending on diet and supplementation. Similarly, enhanced NDF

digestibility observed aligns with findings of Mousa *et al.* (2022) ^[18] and Yuangklang *et al.* (2017) ^[14] while non-significant effects on ADF and ADL are consistent with Eun and Beauchemin (2007) ^[32] and Giraldo *et al.* (2008) ^[33], indicating that enzyme action mainly enhances hemicellulose-rich fractions.

Economics

The present findings align with earlier studies indicating that moderate rumen modifier supplementation improves feed efficiency and economic returns, as reported by Mousa *et al.* (2022) ^[18], showing enhanced digestibility, growth, and approximately 192.14% higher net profit, Okunade *et al.* (2025) ^[34], reporting reduced feed cost per kg gain, and Abd El-Trwab *et al.* (2016) ^[35], demonstrating improved feed efficiency and lower feeding cost, thereby supporting the economic benefits observed in the present study.

Conclusion

The present study demonstrates that supplementation of rumen modifiers comprising probiotics and fibrolytic enzymes in a total mixed ration significantly enhances growth performance and nutrient utilization in growing Osmanabadi goats under intensive production systems. Rumen modifier supplementation resulted in significantly higher ($p < 0.05$) body weight, average daily gain, and overall growth performance in both treatment groups (T_1 and T_2) compared to the control (T_0), confirming their positive role in improving productive efficiency. Among the treatments, T_1 (moderate supplementation) showed superior performance in terms of nutrient intake, particularly TDN and DCP, along with better feed conversion trends and the most favorable economic returns, as reflected by the lowest cost per kg body weight gain and higher net profit. In contrast, T_2 (higher supplementation) resulted in significantly improved nutrient digestibility, including DM, OM, CP, CF, and NDF. However, these improvements did not translate into proportional gains in growth efficiency or economic benefits, suggesting diminishing returns at higher inclusion levels. In conclusion, while both levels of rumen modifier supplementation improved performance, moderate supplementation (T_1) proved to be the most efficient and economically viable strategy. Therefore, incorporation of rumen modifiers at optimal levels in TMR can be recommended as a sustainable nutritional approach to enhance productivity and profitability in intensive goat production systems.

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