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# Effect of dietary inclusion of soybean seed remnants on performance of growing goats

M A TANGADE[1], S AAMRUTKAR[1], S V DAHEKAR[1], S R TATHOD[1], M N WANKHADE[1], S P AWANDKAR[1], M R WADE[1] and K Y DESHPANDE[1]✉

*Post Graduate Institute of Veterinary and Animal Sciences, Maharashtra Animal and Fishery Sciences University (MAFSU), Akola 444 104, India*

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ABSTRACT

A 90 days experiment was conducted to evaluate the effect of adding soybean seed remnants (SSR) into the concentrate mixture on performance of growing Berari goats. Eighteen goats of similar age (4–6 months) and body weight (11.40 ± 0.59 kg) were randomly assigned to three dietary groups (n=6): $SSR_0$, $SSR_{20}$ and $SSR_{30}$ containing 0, 20 and 30% levels of SSR in concentrate respectively on DM basis. The fortnightly dry matter intake (DMI) and body weight (BW) changes showed no significant difference among groups. Ether extract (EE) digestibility was significantly higher in $SSR_{20}$ and $SSR_{30}$ groups. Feed conversion efficiency (FCE) was significantly improved in $SSR_{30}$ at day 60, while average daily gain (ADG), feed conversion ratio (FCR), and DM intake remained unaffected. Body condition score (BCS) was significantly improved at days 60 and 90. At day 90, packed cell volume (PCV), serum albumin, glucose, and globulin levels were significantly higher in SSR-supplemented groups. Rumen pH, titratable acidity, total volatile fatty acids (TVFA), and ammonia-N levels remained comparable. The total cost of production decreased linearly with increasing SSR inclusion level. The cost of total mixed ration (Rs/kg) decreased with increasing SSR levels, being lowest in $SSR_{30}$ (Rs 16.58). Thus it is concluded that the partial inclusion of soybean seed remnants in the concentrate mixture of growing goats up to 30% on dry matter basis can be a possible strategy to improve the energy density of diet and economics of goat production.

**Keywords**: Digestibility, Economics, Growing goats, Growth performance, Soybean seed remnants, Total mixed ration

Goats are among the most significant ruminant species for small and marginal farmers, as well as landless labourers, playing a vital role in their socio-economic development. Livestock productivity in the majority of tropical countries remains relatively low, primarily due to the inadequate quantity and poor nutritional quality of available feed resources. Feed cost remains a critical determinant in livestock production economics, accounting for approximately 50%–70% of total production expenses, with dietary protein representing the most expensive input (Flachowsky and Meyer 2015). India is currently facing a substantial deficit in feed resources, with shortages estimated at 28.9% for concentrate feed ingredients, 23.4% for dry crop residues, and 11.24% for green fodder (Roy *et al*. 2019). Furthermore, ICAR-NIANP (2013), in its Vision 2050, has projected deficits by 2025 of 21.3% in crop residues, 40% in green fodder, and 38.1% in concentrate feeds. These challenges combined with the high cost and limited availability of conventional feed resources underscore the necessity for alternate cost-effective feeding strategies with enhanced nutrient density (Novais *et al*. 2015).

Identifying affordable alternatives to conventional feed ingredients is therefore essential to improving the economic viability of livestock systems (Silva 2015). Soybean (*Glycine max*), one of the most widely cultivated legumes globally, serves as a key source of both protein and oil, contributing approximately 65% of the world's protein concentrates used in animal feed and about 25% of global edible oil production (ICAR-IISR 2021). During seed cleaning and size grading processes in seed production and oil extraction industries, raw soybean seeds that do not meet quality standards referred to as soybean seed remnants are separated as byproducts. These remnants possess protein levels comparable to whole soybean seeds but are more economically priced, making them a potential alternative protein source in livestock feeding systems (Kamble 2022). In the agricultural year 2024–25, soybean production in India was estimated at 151.32 lakh tonnes, cultivated over approximately 13.5 million hectares. With an average seed requirement of 75 kg per hectare, the total seed requirement for sowing was estimated to be around 1.012 million metric tonnes (MoA&FW 2024). Most of

Present address: [1]Post Graduate Institute of Veterinary and Animal Sciences, Maharashtra Animal and Fishery Sciences University (MAFSU), Akola 444104, India. ✉Corresponding author email: kuldeepdeshpande@mafsu.ac.in

this seed was produced at seed processing plants, where a significant portion, ranging from 30% to 70%, gets rejected during the production of certified quality seed. These rejections are primarily due to the presence of undersized, damaged, or diseased seeds. While the exact proportion of discarded seed varies based on raw seed quality and processing efficiency, this remnant is commonly utilized as livestock feed, contributing to resource recycling in the agricultural sector (Kamble 2022).

Given their favourable nutrient composition, soybean seed remnants may serve as an effective and economical alternative to conventional protein supplements such as soybean meal. Hence, the aim of this study was to evaluate the efficacy of soybean seed remnants as a substitute for conventional protein sources in the concentrate mixture for goats, with the objective of reducing feed costs without compromising nutritional quality.

## MATERIALS AND METHODS

*Permission of animal ethical committee*: Experimental protocol was approved by the Institutional Animal Ethics Committee; vide meeting held on 15/01/2025 with IEC resolution number of IEC-VCR (2) 2025; Sr.no.13 conducted at Post Graduate Institute of Veterinary and Animal Sciences, Akola.

*Experimental animals*:18 Berari goats (aged 4-6 months, and average body weights 11.40±0.59 kg) were divided randomly into three groups with six goats in each group (equal male to female ratio). All the experimental goats were housed in a shed with individual feeding facilities.

*Feeds and feeding management*: The feeds used in the experiments were green jowar, concentrate mixture, and grams straw as roughages. Concentrate mixture was formulated from locally available feed ingredients, i.e. (maize, deoiled rice bran, soybean meal, mineral mixture, salt and feed grade urea) and offered to control group ($SSR_0$), while $SSR_{20}$ and $SSR_{30}$ groups received a concentrate mixture containing 20 and 30 percent inclusion of soybean seed remnants on dry matter basis, respectively. Percent composition of ingredients in concentrate mixture and cost is given in Table 1. Three iso-caloric and iso-nitrogenous total mixed rations (TMRs) were formulated using green jowar fodder, concentrate mixture, and dry gram straw to meet the nutrient requirements for maintenance and growth of goats, as per ICAR (2013) feeding standards in three different groups comprising of 40 % concentrate mixture, 40% green jowar as green roughages and 20%-gram straw as dry roughages. Feeds were offered daily at 9.00 AM after collection and measurement of residue on each day. The experimental goats were weighed fortnightly and subsequently the quantity of TMR offered was adjusted.

*Nutrient digestibility*: The digestion trial of 7 days (3 days adaptation) was carried out after 90 days of feeding. Daily feed offered, residues left over and faeces voided during this period were recorded. Representative samples of feeds and refusals were weighed, collected and recorded individually for each animal for estimation of intake. Depending upon the daily faecal output, a suitable fraction for daily aliquoting was fixed for the estimation of DM and nitrogen.

*Body condition score*: Body condition scoring was performed periodically in goats at 0, 30, 60 and 90 days respectively using a BCS ranging from 1.0 to 5.0, with 0.5 increments. Mario Villaquiran scale was used to score the goats (Villaquiran *et al*. 2005).

*Chemical analyses*: Proximate analysis of ground feed and faeces of various groups including control was carried out as per the methods of (AOAC 2023) and fibre fractions (Van Soest *et al*. 1991).

*Blood metabolites*: Blood samples were collected from the experimental goats at the start and end of the experiment. The blood glucose (Trinder 1969) and hematological parameters were analyzed on same day. The serum was refrigerated and albumin, globulin, total protein (Doumas *et al.* 1981) and BUN (Kaneko *et al*. 2008) were analyzed afterwards.

*Rumen fermentation parameters*: About 75 ml of rumen liquor was collected two hrs post feeding from all the animals with the help of hand suction pump and Ryle's stomach tube in airtight flask filled with $CO_2$. The rumen liquor was strained through double layer muslin cloth in the flask and used for further analysis.

The pH of rumen liquor was determined by digital pH meter immediately after collection along with titrable acidity (Rosenberger 1983) and total volatile fatty acids (TVFA) in rumen liquor (Barnett and Reid 1957).

The rumen liquor samples were also analysed for ammonia-N using the Conway method (Conway1957). The cost of rearing the goats for complete experiment was calculated by taking into consideration the feed cost, total feed consumed, and other expenses.

*Statistical analyses*: Statistical analysis was performed according to Snedecor and Cochran (1994). Data obtained from different response parameters were subjected to one

Table 1. Percent ingredient composition of concentrate mixture used

| Ingredient | Inclusion level | | |
|---|---|---|---|
| | $SSR_0$ | $SSR_{20}$ | $SSR_{30}$ |
| Maize | 45.30 | 41.10 | 41.00 |
| DORB | 21.00 | 26.00 | 24.60 |
| Soybean meal | 27.00 | 8.60 | 0.00 |
| Soybean seed remnant | 0.00 | 20.00 | 30.00 |
| urea | 0.70 | 0.80 | 0.90 |
| DCP | 0.50 | 0.50 | 0.50 |
| Calcite | 1.50 | 1.50 | 1.50 |
| Trace minerals | 0.30 | 0.30 | 0.30 |
| Vitamin pre- mixture | 0.20 | 0.20 | 0.20 |
| Salt | 1.00 | 1.00 | 1.00 |
| Oil | 2.50 | 0.00 | 0.00 |
| Total | 100.00 | 100.00 | 100.00 |
| Cost (Rs / kg) | 38.74 | 31.17 | 28.62 |

way ANOVA following completely randomized design. The period and interaction effect was calculated for blood parameters and BCS using general linear model in SPSS software version (30.0) (IBM 2024). Means were compared as per Tukey's test.

## RESULTS AND DISCUSSION

*Chemical composition of experimental feeds and SSR*: The chemical composition of the diets provided to the experimental goats is presented in (Table 2). The crude protein (CP) content of soybean seed remnants (SSR) was 37%, which aligns well with the findings of Krička *et al*. (2003), who reported CP values ranging from 39 to 41% in soybeans and their by-products. Similarly, the ether extract (EE) content of SSR in this study (16%) is consistent with the 19% EE reported by Andrade *et al*. (2015) in soybean seeds. The CP content of the concentrate mixtures used in the present study (approximately 21%) is comparable to values reported by Kamble (2022) and Niwińska *et al*. (2020), who documented CP levels of 21.30% and 21.65%, respectively, in concentrate mixtures formulated for growing goats. Additionally, the EE (%) of gram straw (1.30) was in congruence with Upreti *et al*. (2007), who recorded 1.0% EE in their study. The proximate composition of green Jowar fodder used in present study is consonant with Chakravarthi *et al*. (2017). Importantly, the total mixed rations (TMR) formulated across the different dietary treatments maintained similar proximate compositions, confirming that all diets were isocaloric and isonitrogenous. The CP content remained nearly identical across treatments: 12.79% for $SSR_0$, 12.77% for $SSR_{20}$, and 12.76% for $SSR_{30}$. This aligns with the observations of Krička *et al*. (2003) and Olanipekun and Adelakun (2015) who highlighted that soybean is one of the most important protein-rich feed ingredients, that corroborates protein uniformity across treatments. The consistency in CP content across diets reflects a well-balanced formulation and ensures that the protein supply was uniform regardless of SSR inclusion level.

*Nutrient intake*: The inclusion of graded levels of SSR in the concentrate mixture did not significantly affect ($p$>0.05) dry matter intake (DMI) or organic matter intake (OMI) in growing goats. This indicates that SSR can be incorporated into goat diets without negatively impacting feed consumption. These findings are consistent with Kamble (2022), who reported that raw or heat-treated soybean remnants, can be used in small ruminant diets without adverse effects on feed intake. DMI values, expressed both as g/kg metabolic body weight ($W^{0.75}$) and as a percentage of body weight (%BW), showed minimal variation among treatments and across the study period. Similarly, Rahman *et al*. (2014) observed no significant effect on body weight gain despite a reduction in total DMI when goats were supplemented with soy waste. Fortnight DMI (g/d) gradually increased across all treatment groups over the experimental period; however, differences between groups remained statistically non-significant ($p$>0.05) (Fig. 1). This trend suggests that goats adapted well to the diets, regardless of SSR inclusion levels. Kamble (2022) similarly reported that the inclusion of raw or heat-treated soybean remnants in concentrate mixtures did not alter DMI patterns over time. Supporting these findings, Andrade *et al*. (2015) found that different forms of processed soybean

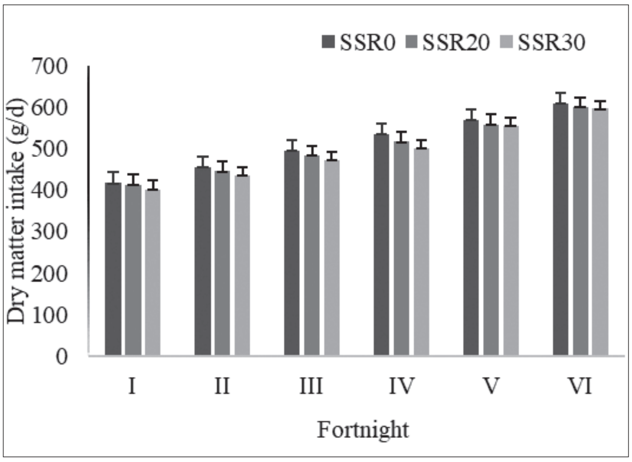


Fig. 1. Effect of feeding graded levels of SSR on fortnightly dry matter intake (g/d) in growing goats

Table 2. Chemical composition of experimental feeds and feed ingredients

| Attribute | DM | CP | CF | EE | TA | NFE | NDF | ADF | Hemic | ADL | Cell |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *Feed ingredient* | | | | | | |
| Gram straw | 91.64 | 5.51 | 41.63 | 1.30 | 9.33 | 42.23 | 64.60 | 46.90 | 17.70 | 10.80 | 36.10 |
| Green Jowar | 26.06 | 8.15 | 33.72 | 1.73 | 8.14 | 48.26 | 57.92 | 35.64 | 22.28 | 7.36 | 28.28 |
| SSR | 90.43 | 37.00 | 6.20 | 16.00 | 8.50 | 32.30 | 13.20 | 7.70 | 5.50 | 0.90 | 2.20 |
| | | | | | *Concentrate mixture* | | | | | | |
| $SSR_0$ | 91.52 | 21.07 | 6.05 | 5.02 | 4.92 | 62.94 | 32.15 | 14.05 | 18.09 | 4.79 | 9.26 |
| $SSR_{20}$ | 92.32 | 21.03 | 6.52 | 5.30 | 6.08 | 61.07 | 31.56 | 14.74 | 16.82 | 4.82 | 9.91 |
| $SSR_{30}$ | 92.21 | 21.00 | 6.33 | 6.73 | 6.24 | 59.70 | 30.29 | 14.29 | 15.99 | 4.69 | 9.60 |
| | | | | | *Total mixed ration (TMR)* | | | | | | |
| $SSR_0$ | 65.36 | 12.79 | 24.23 | 2.96 | 7.09 | 52.93 | 48.95 | 29.26 | 19.69 | 7.02 | 22.24 |
| $SSR_{20}$ | 65.68 | 12.77 | 24.42 | 3.07 | 7.55 | 52.18 | 48.71 | 29.53 | 19.18 | 7.03 | 22.50 |
| $SSR_{30}$ | 65.64 | 12.76 | 24.35 | 3.64 | 7.62 | 51.63 | 48.20 | 29.35 | 18.85 | 6.98 | 22.37 |

Table 3. Average digestibility coefficients, nutritive value of experimental rations and intake of digestible nutrients

| Attribute | Treatment | | | SEM | *p* value |
|---|---|---|---|---|---|
| | $SSR_0$ | $SSR_{20}$ | $SSR_{30}$ | | |
| | *Digestibility of gross nutrients (%)* | | | | |
| DM | 65.81 | 64.76 | 64.12 | 0.508 | 0.415 |
| OM | 68.30 | 67.20 | 66.67 | 0.481 | 0.394 |
| CP | 68.92 | 69.10 | 69.44 | 0.495 | 0.919 |
| EE* | 69.86$^a$ | 74.82$^b$ | 76.78$^b$ | 0.833 | <0.001 |
| NDF | 52.41 | 53.46 | 54.29 | 0.892 | 0.715 |
| ADF | 50.70 | 49.65 | 48.65 | 0.739 | 0.555 |
| Hemicellulose | 59.36 | 57.18 | 54.95 | 0.837 | 0.093 |
| Cellulose | 57.35 | 56.15 | 53.90 | 0.878 | 0.281 |
| | *Nutritive value of experimental rations* | | | | |
| DCP (%) | 9.37 | 9.42 | 9.45 | 0.068 | 0.895 |
| TDN (%) | 66.68 | 66.09 | 65.91 | 0.451 | 0.791 |
| | *Intake of digestible nutrients (g/d)* | | | | |
| DDM | 390.25 | 385.72 | 385.43 | 10.600 | 0.981 |
| DOM | 377.09 | 370.53 | 370.75 | 10.010 | 0.960 |
| DCP | 55.53 | 56.02 | 56.62 | 1.352 | 0.954 |
| TDN | 395.16 | 393.12 | 395.93 | 10.132 | 0.994 |

*abMeans bearing different superscripts in a row differ significantly ($p$<0.05)

in dairy cow diets had no significant impact on DMI. In contrast, Urano *et al*. (2006) reported a linear decline in DMI when raw soybeans were included at increasing levels in lamb diets, highlighting that species-specific responses and the form of soybean product used can influence intake outcomes.

*Nutritive value and plane of nutrition*: Digestible dry matter, organic matter, crude protein and total digestible nutrients expressed as (g/d) and (g/kgW$^{0.75}$) did not differ significantly ($p$>0.05) among treatment groups. The percent nutrient density in terms of DCP and TDN remained similar ($p$>0.05) among the treatment groups (Table 3). These findings indicate that the inclusion of SSR at varying levels in the concentrate mixture did not impair nutrient digestibility in growing goats. Erickson and Barton (1987) similarly reported that incorporating whole soybeans in lamb diets did not significantly impact dry matter digestibility, nitrogen retention, or crude protein digestibility. Furthermore, Kadzere and Jingura (1993) noted that crude protein digestibility could improve with increased soybean inclusion, supporting the hypothesis that SSR is a nutritionally effective and digestible feed resource. The observed similarity in nutrient density across treatments highlights suitability of SSR as a feed ingredient. A previous study by Andrade *et al.* (2015) have demonstrated that different forms of processed soybean in ruminant diet did not significantly alter nutrient digestibility, further supporting the present finding.

*Nutrient digestibility*: No significant difference ($p$>0.05) was observed in the apparent digestibility of nutrients namely DM, OM, CP, CF, NFE, and the fiber fractions (NDF, ADF, hemicellulose, and cellulose) amongst the treatment groups (Table 3). However, it was noteworthy to record significant improvement in EE digestibility in SSR supplemented groups. These results are in accordance with the findings of Erickson and Barton (1987), Andrade *et al*. (2015) and Kamble (2022), who reported that replacing conventional protein sources with soybean seed or processed soybean or raw or heat-treated soybean remnants did not adversely affect nutrient digestibility in ruminants. Significant improvement in ether extract (EE) digestibility with SSR inclusion increased progressively from 69.86±0.95% in $SSR_0$ group to 76.78±0.87% in the $SSR_{30}$ group ($p$<0.001). This improvement suggested that the processing or inherent characteristics of soybean seed remnants may enhance fat utilization. Kadzere and Jingura (1993) also demonstrated that crushed whole soybeans can lead to higher digestibility of fat components.

*BW (kg), average daily gain (g), feed conversion ratio (FCR), feed conversion efficiency (FCE), and average DMI (g)*: Dietary inclusion of graded levels of SSR had no significant effect ($p$>0.05) on body weight (BW), weight gain, average daily gain (ADG), or DMI in growing goats (Table 4). Final BW remained consistent across all groups, indicating nutritional adequacy. These findings align with Carvalho *et al*. (2021) and Kamble (2022), who observed no adverse effects on growth when soybean by-products replaced conventional feeds in small ruminants. Although not statistically significant, a numerical improvement in ADG with increasing SSR levels suggests improved nutrient utilization. Similar trends were reported by Schwulst (1988) and Kim *et al*. (2016), who observed acceptable or improved FCR with soybean-based feed alternatives. Slight improvements in FCR and FCE in the current study further support the potential of SSR to enhance feed utilization, consistent with the findings of Rahman *et al*. (2014) and Thakur *et al*. (2015).

*Blood metabolites*: Hemoglobin (g/dL), WBC ($10^3$/

Table 4. Effect of feeding graded levels of SSR on growth performance of goats

| Attribute | Treatment | | | SEM | $p$ value |
|---|---|---|---|---|---|
| | $SSR_0$ | $SSR_{20}$ | $SSR_{30}$ | | |
| Body Weight(kg) | | | | | |
| Initial | 11.40 | 11.40 | 11.42 | 0.326 | 1.000 |
| Final | 17.52 | 17.60 | 17.96 | 0.332 | 0.866 |
| Total BW gain | 6.13 | 6.20 | 6.54 | 0.098 | 0.189 |
| ADG(g) | 68.03 | 68.86 | 72.61 | 1.084 | 0.189 |
| DMI (g/d) | 513.12 | 502.38 | 493.32 | 13.074 | 0.570 |
| FCR | 7.55 | 7.33 | 6.97 | 0.229 | 0.604 |
| FCE | 13.46 | 13.93 | 14.94 | 0.441 | 0.400 |

Table 5. Effect of feeding graded levels of SSR on blood metabolites of goats

| Attribute | Treatment | | | Period (Days) | | SEM | P | T | P*T |
|---|---|---|---|---|---|---|---|---|---|
| | $SSR_0$ | $SSR_{20}$ | $SSR_{30}$ | 0 | 90 | | | | |
| Hb (g/dL) | 8.75 | 9.03 | 9.22 | 8.78 | 9.22 | 0.119 | 0.071 | 0.277 | 0.925 |
| PCV (%) | 27.72 | 28.20 | 28.88 | $27.62^{x}$ | $28.91^{y}$ | 0.244 | 0.006 | 0.111 | 0.861 |
| WBC ($10^3$/µL) | 12.66 | 12.70 | 12.53 | 12.09 | 13.17 | 0.310 | 0.099 | 0.973 | 0.734 |
| RBC($10^6$/µL) | 12.29 | 12.37 | 13.04 | 12.12 | 13.01 | 0.335 | 0.203 | 0.624 | 0.706 |
| Total protein(g/dL) | 5.65 | 5.79 | 6.04 | 5.69 | 5.97 | 0.103 | 0.185 | 0.303 | 0.939 |
| Albumin (g/dL) | 2.78 | 2.81 | 2.63 | $2.57^{x}$ | $2.91^{y}$ | 0.056 | 0.001 | 0.287 | 0.338 |
| Globulin (g/dL) | $2.87^{a}$ | $2.98^{ab}$ | $3.42^{b}$ | 3.12 | 3.06 | 0.094 | 0.730 | 0.045 | 0.504 |
| A:G ratio | 1.01 | 1.01 | 0.77 | 0.88 | 0.98 | 0.049 | 0.284 | 0.057 | 0.185 |
| BUN (mg/dL) | 27.54 | 28.50 | 27.48 | 28.50 | 27.19 | 0.791 | 0.431 | 0.851 | 0.444 |
| Glucose (mg/dL) | 48.55 | 48.89 | 48.62 | $46.57^{x}$ | $50.80^{y}$ | 0.785 | 0.008 | 0.981 | 0.624 |

$^{a,b}$Means bearing different superscripts in a row differ significantly ($p$<0.05) P: Period, T: Treatment, PxT: Period×Treatment interaction

µL), and RBC ($10^6$/µL) levels were not significantly affected ($p$>0.05) by SSR feeding at both day 0 and day 90, indicating no adverse impact of SSR inclusion on the general hematological profile (Table 5). These findings are consistent with El-Moghazy *et al*. (2020) and Kamble (2022), who reported stable blood indices in ruminants fed soybean by-products. Similarly, Antunović *et al*. (2009) observed no changes in blood parameters, including WBC, with raw or roasted soybean inclusion in lamb diets. PCV (%) increased significantly ($p$=0.006) at day 90 compared to day 0, though treatment and interaction effects were not significant ($p$>0.05). This may indicate enhanced erythropoiesis and physiological adaptation to SSR feeding over time, as earlier reported by Millam *et al*. (2020).

Serum concentrations of total protein, blood urea nitrogen (BUN), and albumin:globulin (A:G) ratio showed no significant differences ($p$>0.05) among treatment groups at both day 0 and day 90. However, albumin (g/dL) and glucose (mg/dL) levels increased significantly ($p$<0.05) at day 90, while globulin (g/dL) was significantly higher in the $SSR_{30}$ group compared to $SSR_0$, with no significant interaction effects (Table 5).These results align with those of Cônsolo *et al*. (2015) and Thakur *et al*. (2015), who reported no significant effect of soybean inclusion (whole raw soybean or as soya pulp) on total protein concentrations in Nellore steers and cows, respectively. Similarly, stable BUN levels were observed by Radivojevic *et al*. (2011) and Erickson and Barton (1987). Similar findings were reported by El-Moghazy *et al.* (2020), who found that glucose concentrations were not significantly different among treatment groups receiving protected soybean meal. The increase in albumin is consistent with Sallam *et al*. (2021), while the rise in globulin levels corresponds with Lima *et al*. (2024), suggesting a possible immunomodulatory

Table 6. Effect dietary feeding graded levels of SSR on rumen fermentation parameters of growing goats

| Attribute | Treatment | | | SEM | $p$ value |
|---|---|---|---|---|---|
| | $SSR_0$ | $SSR_{20}$ | $SSR_{30}$ | | |
| pH | 6.30 | 6.25 | 6.18 | 0.037 | 0.466 |
| TA | 19.17 | 19.33 | 20.17 | 0.944 | 0.909 |
| TVFA (mmol/L) | 105.50 | 104.17 | 102.50 | 0.830 | 0.356 |
| Ammonia-N mg/100 mL | 23.07 | 22.16 | 21.04 | 0.491 | 0.253 |

effect of SSR inclusion. The unchanged A:G ratio supports findings from Sallam*et al*. (2021), indicating no disruption in protein metabolism.

*Rumen fermentation parameters*: The pH, titrable acidity, TVFA and ammonia nitrogen concentration did not differ significantly ($p$>0.05) among the treatment groups (Table 6). Bailoni *et al*. (2004) and Barletta *et al*. (2016), also reported no significant alterations in ruminal pH when soybean meal was replaced with whole soybeans in dairy cows. Similarly, De Almeida *et al.* (2016) had explained that replacing corn grain and soybean meal with whole raw soybean did not significantly affect ruminal pH, supporting the results obtained in the present study. Titrable acidity (TA) exhibited a numerical increase in $SSR_{30}$ compared to $SSR_0$ and $SSR_{20}$, but the differences were statistically non-significant ($p$>0.05) which aligns with the study by Schauff *et al*. (1992), where the addition of whole soybeans did not cause significant changes in the molar proportions of volatile fatty acids (VFA) or ammonia-N concentrations. Bailoni *et al*. (2004), had reported that substituting soybean meal with extruded or toasted soybeans had no adverse effects on VFA concentrations. Furthermore, Harjanti *et al*. (2012) also observed that total VFA concentrations did not differ significantly when soybean curd residue silage was used as a replacement for commercial concentrate in sheep diets. Ammonia-N concentration showed a declining trend with increasing levels of SSR. However, the differences were not statistically significant ($p$>0.05). This trend is in agreement with Erickson and Barton (1987), who observed a reduction in ruminal ammonia-N concentrations as the proportion of whole soybeans in the diet increased. Similarly, Barletta *et al*. (2016) reported that $NH_3$-N concentration was significantly lower in cows fed soybean-based diets compared to control diets.

*Body condition score*: The body condition scores were similar among the treatment groups ($p$=0.807). However, a significant improvement ($p$<0.01) in BCS was noticed at day 60 and 90 as compared to day 0 and day 30. Whereas, the interaction effect was not significant ($p$>0.05), the values were nearing the BCS of healthy goats (2.5–4.0). This indicate that SSR can be included in the diet without negatively impacting body condition scores and average daily gain indicating its better nutritional worth and further warrants its potential to mitigate shortage of costly protein source. The findings are in agreement with Mandale *et al*. (2023), Gholve *et al*. (2021) and Sonawane *et al.* (2019) who observed a linear improvement ($p$<0.05) in BCS from day 0 to day 90. Contrary to these findings Naves *et al*. (2016) also reported no significant effect of the particle size of raw soybeans on body condition in dairy cows. These studies suggest that while soybean-based feeds can maintain body condition, their effects may vary depending on the form and level of inclusion. The monthly body condition scores of experimental goats are depicted in Fig. 2.

*Cost economics*: One of the significant implications of the study was reduction in feed cost and production cost per kg live weight in the treatment groups with dietary inclusion of either 20% or 30% SSR as compared with $SSR_0$ (Table 7). In $SSR_{20}$ and $SSR_{30}$ groups, a reduction in the feed cost and production cost per kg live weight was observed as compared to $SSR_0$ group. The feed cost per kg weight gain was found to be on higher side in the control group when compared with the treatment groups supplemented by SSR. This encourages its utilization in concentrate mixture to replace costly protein source. The results are in harmony with the findings of Wang *et al.* (2004), Carvalho *et al.* (2021) and Kamble (2022) who reported that the incorporation of alternative soybean-based feed sources in the diets would decrease the cost per kg live weight gain and results in high profit when compared with the control group.

It is concluded that the partial inclusion of soybean seed remnants in the concentrate mixture of growing goats up to 30% on dry matter basis can become a valuable strategy to improve the energy density of diet and economics of goat production without any adverse effect on performance, blood metabolite concentration and rumen fermentation parameters.

Table 7. Effect offeeding graded levels of SSR on cost economics of goat rearing

| Attribute | Treatment | | |
|---|---|---|---|
| | $SSR_0$ | $SSR_{20}$ | $SSR_{30}$ |
| Cost of TMR (Rs/kg) | 21.08 | 17.80 | 16.58 |
| Voluntary intake of TMR (kg/goat) | 70.66 | 69.16 | 67.64 |
| Total cost of TMR consumed (Rs)/goat | 1489.43 | 1230.99 | 1121.52 |
| Live weight gain(kg) | 6.12 | 6.20 | 6.54 |
| TMR consumption/kgLW gain (kg) | 11.54 | 11.16 | 10.35 |
| Cost of TMR per kg live weight gain (Rs) | 243.27 | 198.62 | 171.62 |
| Total cost of production (Rs) | 4994.43 | 4735.99 | 4626.52 |

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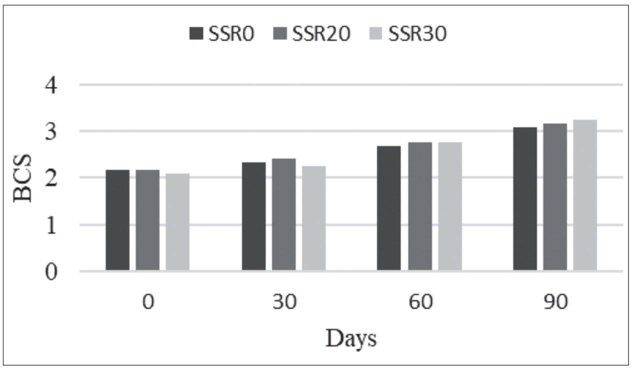


Fig. 2. Effect of feeding graded levels of SSR on body condition score in growing goats

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