Research Article

Optimizing Breed-Specific Feeding Strategies to Enhance Goat Production in the Wet Climate Regions

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Abstract | The increasing scarcity of grazing land and the rising density of livestock pose significant challenges to goat production, particularly for small-scale farmers who depend on these animals for their livelihoods. This study extends existing research on alternative feeding systems by investigating the global relevance of feeding strategies—stall-feeding, semi-grazing, and grazing—on the performance and profitability of three Pakistani goat breeds: Makhi Cheeni, Barbari, and non-descript. A total of 243 goats were systematically assigned to treatment groups, ensuring nutritional balance through calculated nutritional and chemical compositions of *Pennisetum purpureum* and concentrated feeds. The study assessed performance metrics, including weight gain, body condition score (BCS), and blood parameters, aiming to identify globally applicable, breed-specific feeding strategies for optimal production in the Pothohar Valley, a region characterized by its wet climate. Results demonstrated that Makhi Cheeni and non-descript goats achieved the highest weight gains under stall-feeding (1.50 and 1.20 kg/week, respectively), with outcomes statistically comparable to those in the semi-intensive system ($p > 0.05$). Grazing produced the lowest weight gains for these breeds (1.08 and 0.81 kg/week, $p < 0.05$). In contrast, Barbari goats showed no significant difference in weight gain across the feeding systems. Moreover, Makhi Cheeni goats recorded the highest BCS under stall-feeding (2.83), whereas grazing led to the lowest BCS (2.37, $p < 0.05$). Blood analysis indicated lower total cholesterol levels in Makhi Cheeni goats under semi-intensive grazing systems compared to stall-feeding ($p < 0.01$), pointing to possible dietary insufficiencies. This research highlights the importance of breed-specific feeding strategies, with Makhi Cheeni goats particularly benefiting from stall feeding in terms of growth, health, and cholesterol metabolism. The findings not only address local challenges but also offer insights that could be valuable for improving goat production systems globally.

Keywords | Goat breeds, Feeding systems, Weight gain, Body condition Score, Hematological parameters, Sustainable goat farming.

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INTRODUCTION

Small ruminants, particularly goats, are integral to rural economies not only in South Asia but also in many other parts of the world, providing sustenance, economic stability, and income (Devendra, 2005; FAO, 2018). Their adaptability to diverse climates and prolific breeding capabilities make them a crucial livestock choice in regions such as the Pothohar Valley in Pakistan, where agriculture faces significant challenges. The Pothohar Valley (32°58′N; 72°15′E), situated between the Indus and Jhelum rivers, offers a distinctive landscape with fertile slopes and adequate rainfall, creating optimal conditions for natural browsing and grazing. However, traditional grazing practices are increasingly unsustainable due to shrinking land resources and escalating stocking densities (Shinde and Sejian, 2013). This situation mirrors a broader global challenge, where similar constraints necessitate innovative feeding strategies across various regions.

In this context, it becomes vital to explore feeding systems that not only cater to local needs but also offer insights that could be applied globally. The three primary goat feeding systems—extensive, semi-intensive, and intensive (stall-fed)—each present unique opportunities and challenges. Extensive grazing, while resource-efficient, is becoming less viable globally as land availability diminishes. Semi-intensive systems, blending grazing with supplemental feeding, show promise but require careful management of resources and costs. Intensive stall-fed systems, though offering higher productivity, demand substantial investment and raise animal welfare concerns. Understanding these systems and their implications for various goat breeds can provide valuable lessons applicable beyond the Pothohar Valley.

Pakistan boasts an incredible diversity of goats, with over 34 breeds, including the popular Kamori, Dera Deen Pannah, Teddy, and Beetal (Kaleri et al., 2023). Even within the Beetal breed, genetic variations have spawned strains like Makhi Cheeni, Faisalabadi, and Rahim Yar Khan, each with distinct udder size, milk yield, and other crucial characteristics (Kinkpe et al., 2023). Body weight at weaning, a critical indicator of animal welfare, productivity, and profitability, further highlights the need for breed-specific feeding strategies (Dawood et al., 2020). These breed-specific strategies are not only critical for local agricultural sustainability but also offer models that could be adapted to improve goat farming practices in other regions facing similar challenges.

This study seeks to address a significant knowledge gap by evaluating the interaction between goat breed, feeding method, and the regional environment in the Pothohar Valley. By comparing the performance of Makhi Cheeni, Barbari, and non-descript goats under grazing, supplemented grazing, and complete stall-feeding systems, this research aims to identify the most effective feeding strategies for each breed. The findings of this study, while rooted in the specific context of the Pothohar Valley, have the potential to inform global practices, offering evidence-based recommendations that could enhance goat farming efficiency and sustainability worldwide.

MATERIALS AND METHODS

Ethical and Animal Rights Statement

This study was approved by the ethical and animal welfare committee of the Faculty of Animal Husbandry and Veterinary Sciences (FAHVS), The University of Agriculture, Peshawar, Pakistan. All necessary measures were taken to minimize the animals' pain and discomfort during the experiment.

Location and General Management Practices

This study was conducted at JS Goat Farm, Rawat, Rawalpindi, Pakistan, which houses a diverse population of goat breeds.

Three breeds, Makhi Cheeni (a Beetal strain), Barbari, and non-descript goats, were selected for comparison across three distinct feeding systems: stall feeding, semi-intensive grazing, and open grazing. Healthy goat kids (22-30 kg body weight, 130-150 days old, body condition score 1.7-3) were selected for the study from JS Goat Farm. All kids underwent a two-week adaptation phase before the trial began, during which they were individually tagged and housed in clean, regularly disinfected pens with *ad libitum* clean water. Strict veterinary protocols ensured timely vaccinations, medication, and deworming. During the trial, each group followed assigned feeding routes: stall feeding, semi-intensive grazing, and open grazing. On rainy days, all groups received a limited evening supplement of alfalfa and concentrate to meet baseline feed requirements (Tables 1 and 2). Ambient temperature and relative humidity were recorded three times daily using the HTC-2 digital Temperature scale. Detailed records of all expenses (feed, labor) were maintained for each kid to determine the most profitable group for farmers.

Study Animals Grouping and Feeding Regime

A total of 243 post-weaned goats (81 from each breed: Makhi Cheeni, Barbari, and non-descript were randomly assigned to nine groups (27 per group) representing three distinct feeding regimens: stall feeding (SF), semi-intensive grazing (SI), and open grazing (G), based on established protocols by Wahed and Owen (1986), Hossain et al. (2022) and Benthien et al. (2018), respectively (Figure

1). Each feeding regimen was further subdivided by breed, resulting in three subgroups per regimen (e.g., SF-Makhi Cheeni, SF-Barbari, SF-non-descript). Additionally, each group included nine adult mothers from the corresponding breed to care for the kids. This balanced design, with breed and feeding system factors represented equally, enabled the evaluation of their interactive effects on performance parameters.

Table 1: Nutritional composition of Alfalfa (% on dry weight basis)

Parameters	Percentage (%)
Moisture	8.22
Crude Protein	19.80
Crude Fat	3.90
Crude Fiber	25.37
Ash	10.73
Neutral Detergent Fiber	45.34
Acid Detergent Fiber	33.21
Metabolizable Energy (ME)	2661.19

Metabolizable Energy = 37% x Protein + 81.8 x % Fat + 35.5 x % NFE (Pauzenga, 1985).

Table 2: Chemical composition of concentrated feed

Ingredients	Quantity (kg)
Rice polish	10
Wheat bran	10
Corn	35
Canola meal	12
Maize Gluton 30%	17
Soya bean	7
Molasses	9
Total	100
Nutritional composition	
Total DM%	90.63
Total Crude Protein%	18.56
Total Crude Fiber%	5.81
Total Ash %	4.51
Total TDN%	81.30
Digestible Energy Mcal/kg	3.33
Metabolizable energy Mcal/kg	2.89
Total DP%	13.74

DM: Dry matter; TDN: Total Digestible Nutrients; DP: Digestible Protein

Three distinct feeding systems were employed in this study. In stall feeding (SFA, SFB, SFC), goats received three daily meals: two 500g portions of alfalfa and one 300g concentrate feed, spaced five hours apart. For semi-intensive grazing (SIA, SIB, SIC), goats grazed for 4-6 hours before receiving 300g concentrate feed at the farm. The open grazing groups (GA, GB, GC) freely grazed throughout the day in areas where Moringa (*Moringa oleifera*) leaves, (Australian Keekar), siris (*Albizia lebbeck*), and (*Mulberry*) plants were present. All groups had unrestricted access to clean water. Additionally, during the night confinement, the goats had *ad libitum* access to blocks composed of salt and trace minerals, as well as clean water.

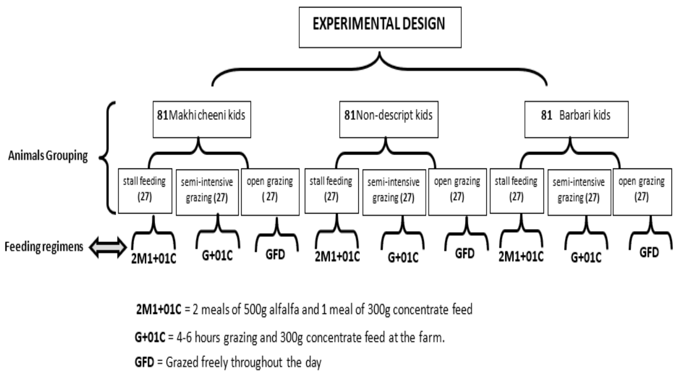

Figure 1: Experimental design

Study Parameters

This research evaluated the impact of different feeding systems on growth, body condition, hematological parameters, and health outcomes.

Body Weight Gain

Weekly weight gain (kg) and daily growth rate (g) were monitored for eight weeks, following the methodologies of (Prasad et al., 1988; Younas et al., 2014).

$$Weight\ gain(\%) = \frac{Final\ weight\ (kg) - Initial\ weight\ (kg)}{Final\ weight\ (kg)} \times 100$$

Body Condition Scoring (BCS)

The evaluation of BCS was performed on a weekly basis using palpation of the lumbar region of the goats, based on a scale of 1 to 5 units, where 1 = very thin and 5 = very fat, as described by Hervieu et al. (1991). Details of score descriptions are provided in Table 3.

Haematological Parameters

Blood samples were collected from the jugular vein twice at the beginning and end of the study. Hematological measurements of white blood cells (WBCs), red blood cells (RBCs), glucose, total protein, and total cholesterol were analyzed according to Abbas et al. (2020) using URIT 3000Plus Hematology Analyzer Merck (made in Japan).

Statistical Analysis

All the data were recorded on Microsoft Excel®, and analyses were performed using R 4.3.2 software (R Core Team, 2023). The means were compared using an analysis of variance. This was supplemented by a Student Newman-Keuls test for comparison of means in the event of significant differences ($p < 0.05$) observed between feeding systems using the agricolae package (de Mendiburu, 2023).

Table 3: Body Condition Score Determination

Score	Appearance
1	Very thin, very prominent hip bones, and no fat deposits.
1.5	Relatively equal to the BCS value of 1
2	It looks thin and the pelvis is protruding.
2.5	Relatively equal to the BCS value of 2
3	Relatively normal, the bones do not look thin, and there is an accumulation of fat.
3.5	Relatively equal to the BCS value of 3
4	Looks fat, bones do not look prominent, fat accumulation tends to increase.
4.5	Relatively equal to the BCS value of 4
5	Very fat, excess fat accumulated

RESULTS

Effect of feeding systems on the growth performance of goat breeds

Analyzing weight gain data across these three feeding systems revealed distinct breed-specific responses. Makhi Cheeni goats exhibited the highest weight gain (33.75 kg) under the stall-feeding system over the eight-week study period. This weight gain was statistically similar ($p > 0.05$) to that observed in the semi-intensive system (Table 4). However, goats under the grazing system displayed the lowest weight gain compared to the other two systems ($p < 0.05$).

Similar trends in weight gain were observed for Barbari and non-descript goats (Figures 2b and 2c). Stall feeding resulted in the highest weight gain, followed by the semi-intensive system. The grazing system again yielded the lowest weight gain for both breeds ($p < 0.05$).

As displayed by Table 4, feeding systems significantly impacted body weight gain (BWG) across breeds. Makhi Cheeni goats exhibited the highest BWG under stall feeding (1.50 kg/week), which was statistically similar ($p > 0.05$) to the semi-intensive system (1.32 kg/week). Conversely, grazing resulted in the lowest BWG for Makhi Cheeni (1.08 kg/week) and differed significantly ($p < 0.05$) from the other two systems.

A similar pattern emerged for non-descript goats. Stall feeding led to the highest BWG (1.20 kg/week), followed by the semi-intensive system (1.13 kg/week), with no significant difference ($p > 0.05$) observed between them. Grazing produced the lowest BWG (0.81 kg/week) in non-descript goats, statistically distinct ($p < 0.05$) from the other feeding systems.

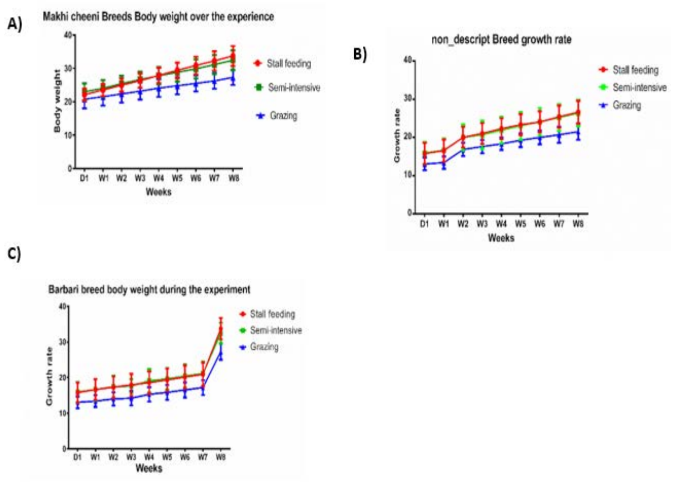

Figure 2: Growth curve during the experiment
A- Makhi cheeni ; B- Barbari ; C- Non-descript

Barbari goats, however, displayed no statistically significant difference ($p > 0.05$) in BWG across feeding systems.

Regarding the BCS, the current study revealed that feeding systems significantly influenced BCS across Makhi Cheeni goats (Table 1). Stall feeding resulted in the highest BCS (2.83), followed closely by the semi-intensive system (2.79). Grazing produced the lowest BCS in Makhi Cheeni (2.37), with a statistically significant difference ($p < 0.05$) compared to the other two systems.

In contrast, Barbari and non-descript goats exhibited no statistically significant difference ($p > 0.05$) in BCS across feeding systems.

The disease incidence and mortality were non-significant across all groups. No mortality was recorded during the trial.

Blood-related characteristics of goats under various feeding systems

Analysis of blood metabolite parameters in Makhi Cheeni goats revealed statistically significant differences ($p > 0.01$) across feeding systems (Table 5). Total cholesterol levels in Makhi Cheeni goats fed under the stall-feeding system (84 mg/dL) fell within the normal range, suggesting adequate cholesterol metabolism. This might indicate a more balanced diet or efficient cholesterol utilization in stall-fed goats. However, total cholesterol levels in goats under the semi-intensive and grazing systems fell below the normal

Table 4: Effect of feeding systems on the growth performance of goat during the experiment

Breeds	Periods	Parameters	Stall feeding	Semi-intensive	Grazing	p-value
Makhi cheeni	Week 1	BW d1	22.10 ± 1.82	22.98 ± 2.52	20.75 ± 2.76	0.298
		BW W1	23.51±1.87	24.01±2.51	21.53±2.71	0.199
		BWG1	1.41^{a}±0.11	1.03^{b}±0.12	0.78^{c}±0.21	<0.001***
		BCS1	2.66±0.40	2.83±0.25	2.50±0.31	0.255
Barbari		BW d1	15.78±2.81	15.95±2.85	13.05±1.67	0.113
		BW W1	16.55±2.91	16.63±3.01	13.40±1.64	0.079
		BWG1	0.350±0.52	0.76±0.15	0.350±0.52	0.193
		BCS1	2.42±0.38	2.46±0.40	2.41±0.38	0.977
Non-descript		BW d1	15.78±2.81	15.95±2.85	13.05±1.67	0.113
		BW W1	16.55±2.91	16.63±3.02	13.40±1.64	0.079
		BWG1	1.10^{a}±0.13	1.05^{b}±0.24	0.62^{c}±0.19	0.001**
		BCS1	2.50±0.32	2.42±0.38	2.67±0.41	0.505
Makhi cheeni	Week 2	BW W2	24.95±2.00	25.42±2.35	22.32±2.58	0.074
		BWG2	1.43^{a}±0.15	1.40^{a}±0.42	0.78^{c}±0.29	0.004**
		BCS2	2.67±0.41	2.79±0.25	2.50±0.31	0.335
Barbari		BW W2	17.30±2.99	17.43±3.04	14.02±1.82	0.073
		BWG2	0.75±0.15	0.80±0.08	0.62±0.28	0.269
		BCS2	2.42±0.38	2.46±0.40	2.41±0.38	0.977
Non-descript		BW W2	20.02±2.72	19.98±3.39	16.83±1.75	0.097
		BWG2	1.07^{a}±0.15	0.98^{ab}±0.28	0.72^{b}±0.23	0.043*
		BCS2	2.50±0.32	2.42±0.38	2.67±0.40	0.505
Makhi cheeni	Week 3	BW W3	26.33^{a}±2.12	26.65^{a}±2.39	23.17^{ab}±2.53	0.039*
		BWG3	1.38^{a}±0.20	1.23^{a}±0.22	0.85^{b}±0.35	0.009**
		BCS3	2.67±0.41	2.79±0.24	2.50±0.31	0.335
Barbari		BW W3	17.97±3.09	17.63±1.97	14.23±2.02	0.079
		BWG3	0.67±0.14	0.80±0.25	0.62±0.24	0.342
		BCS3	2.42±0.38	2.45±0.40	2.42±0.38	0.977
Non-descript		BW W3	21.02±2.73	20.70±3.69	17.60±1.69	0.101
		BWG3	1.00±0.20	0.71±0.32	0.77±0.16	0.126
		BCS3	2.50±0.32	2.42±0.38	2.67±0.41	0.505
Makhi cheeni	Week 4	BW W4	27.87^{a}±2.28	27.80^{ab}±2.60	24.08^{b}±2.60	0.029*
		BWG4	1.53^{a}±0.21	1.15^{ab}±0.33	0.92^{b}±0.45	0.024*
		BCS3	2.92±0.41	2.87±0.34	2.50±0.31	0.119
Barbari		BW W4	18.56±3.08	19.10±3.27	15.31±2.02	0.074
		BWG4	0.60±0.27	0.86±0.08	0.68±0.22	0.113
		BCS4	2.62±0.61	2.67±0.46	2.42±0.38	0.650
Non-descript		BW W4	22.28^{a}±2.78	21.88^{a}±3.48	18.32^{ab}±1.65	0.046*
		BWG3	1.27±0.20	1.18±0.64	0.72±0.28	0.080
		BCS3	2.58±0.34	2.80±0.50	2.67±0.41	0.654
Makhi cheeni	Week 5	BW W5	29.42^{a}±2.34	28.83^{a}±2.82	24.80^{b}±2.60	0.015*
		BWG5	1.55^{a}±0.18	1.03^{b}±0.43	0.72^{b}±0.32	0.002**
		BCS5	2.75±0.45	2.83±0.30	2.33±0.26	0.053
Barbari		BW W5	19.37±3.17	19.65±3.02	15.86±2.08	0.060
		BWG5	0.80±0.11	0.55 ±0.36	0.55±0.20	0.162
		BCS5	2.33±0.38	2.54±0.43	2.67±0.46	0.413

Non-descript		BW W5	23.33^a±2.80	23.05^a±3.58	19.25^{ab}±1.78	0.042*
		BWG5	1.05±0.36	1.17±0.50	0.93±0.24	0.582
		BCS5	2.58±0.34	2.66±0.41	2.50±0.32	0.727
Makhi cheeni	Week 6	BW W6	30.86^a±2.62	29.83^a±2.86	25.5^b±2.41	0.007**
		BWG6	1.45^a±0.32	1.00^{ab}±0.50	0.71^b±0.32	0.018*
		BCS6	2.96^a±0.40	2.83^a±0.30	2.33^b±0.25	0.011*
Barbari		BW W6	20.15±3.24	20.43±3.24	16.55±2.09	0.064
		BWG6	0.78±0.10	0.78±0.23	0.68±0.04	0.419
		BCS6	2.58±0.41	2.75±0.35	2.29±0.40	0.152
Non-descript		BW W6	24.06^a±2.83	24.08^a±3.58	19.98^{ab}±1.80	0.036*
		BWG6	0.73±0.32	1.03±0.26	0.73±0.12	0.092
		BCS6	2.62±0.26	2.71±0.37	2.46±0.37	0.440
Makhi cheeni	Week 7	BW W7	32.25^a±2.84	31.13^a±2.85	26.23^b±2.38	0.003**
		BWG7	1.38^a±0.31	1.30^a±0.38	0.72^b±0.07	0.002**
		BCS7	3.00^a±0.39	2.83^a±0.26	2.37^b±0.26	0.009**
Barbari		BW W7	20.93±3.31	21.13±3.32	17.20±2.05	0.062
		BWG7	0.78±0.13	0.70±0.17	0.65±0.05	0.220
		BCS7	2.54±0.33	2.83±0.40	5.66±8.13	0.464
Non-descript		BW W7	25.38^a±2.91	25.22^a±3.50	20.68^b±2.14	0.021*
		BWG7	1.31±0.33	1.13±0.39	0.70±0.37	0.029*
		BCS7	2.62±0.26	2.75±0.32	2.46±0.37	0.310
Makhi cheeni	Week 8	BW W8	33.75^a±2.99	32.45^a±2.96	27.32^b±2.32	0.003**
		BWG8	1.50^a±0.19	1.32^{ab}±0.13	1.08^b±0.25	0.008**
		BCS8	2.83^a±0.56	2.79^b±0.24	2.37^c±0.26	0.001**
Barbari		BW W8	21.67±3.54	21.83±3.43	17.77±2.05	0.063
		BWG8	0.73±0.26	0.70±0.14	0.57±0.17	0.342
		BCS8	2.54±0.33	2.87±0.41	2.37±0.34	0.084
Non-descript		BW W8	26.58^a±3.00	26.35^a±3.43	21.50^b±2.12	0.013*
		BWG8	1.20^a±0.13	1.13^a±0.29	0.81^b±0.21	0.021*
		BCS3	2.66±0.26	2.75±0.32	2.45±0.37	0.291

BW : Body weight ; BWG : Body weight gain ; BCS: Body condition scores
*Significant and $p<0.05$; **: Highly significant and $p<0.01$; ***: Very highly significant and $p<0.001$
a,b,c: Means with unlike superscripts in the same row differ significantly ($p<0.05$).

Table 5: Mean square for the effect of feeding systems on blood metabolites of goat groups

Breeds	Parameters	Stall feeding	Semi-intensive	Grazing	p-value
Makhi cheeni	WBCs (×10^4/µL)	1.62±1.00	1.82±0.42	2.11 ± 1.12	0.657
	RBCs (×10^6/µL)	1.47± 0.47	1.56± 0.54	1.57± 0.53	0.926
	Glucose (mg/dL)	64.33±7.84	57.50±6.06	59.33±10.48	0.364
	TC (mg/dL)	84.00^a±9.14	72.67^b±7.09	73.67^b±7.20	0.008**
	TP (g/dL)	6.82±0.43	6.87±0.43	6.68±0.39	0.686
Barbari	WBCs (×10^4/µL)	2.03±0.43	2.17±0.49	1.81±0.46	0.426
	RBCs (×10^6/µL)	1.18±0.52	0.98±0.45	0.97±0.52	0.714
	Glucose (mg/dL)	67.33±12.78	65.00±7.72	62.66±12.19	0.772
	TC (mg/dL)	82.33±11.12	85.00±6.87	86.00±7.48	0.756
	TP (g/dL)	6.63±0.33	6.84±0.47	7.02±0.36	0.258
Non-descript	WBCs (×10^4/µL)	1.63±0.22	1.89±3.93	1.87±3.52	0.319

	RBCs ($\times10^6$/μL)	1.66±0.44	1.51±0.30	1.66±0.50	0.77
	Glucose (mg/dL)	62.33±7.23	62.33±7.22	65.33±7.45	0.627
	TC (mg/dL)	78.83±11.69	85.50±9.40	79.83±11.37	0.533
	TP (g/dL)	7.12±0.52	6.69±0.45	6.67±0.62	0.288

WBCs: White blood cell; RBCs: Red blood cell; TC: Total cholesterol; TP: Total protein

Normal range: WBCs (/μL): 0.6-1.4 (×104/μL); RBCs: 8-18.5 (×106/μL); Glucose (mg/dL): 50-75 (mg/dL); TC (mg/dL): 80-130; TP(g/dL): 6.4-7.0

**: Highly significant and *p<0.01;* a,b: Means with unlike superscripts in the same row differ significantly *(p<0.05)*.

range, implying potential deficiencies in cholesterol precursors or limitations in cholesterol synthesis. This could be due to dietary limitations in essential fatty acids or cholesterol precursors present in higher amounts in stall-feed compared to forage in semi-intensive and grazing systems. White blood cell (WBC) count, red blood cell (RBC) count, and total protein (TP) levels in Makhi Cheeni goats did not exhibit statistically significant differences (p > 0.05) across feeding systems, even though their values were above the normal range.

Similar to BCS, Barbari and non-descript goats displayed no statistically significant differences (p > 0.05) in blood metabolite parameters across feeding systems.

DISCUSSION

Small ruminants are considered an essential part of livestock farming, serving as a source of income for landless farmers (Ghafar et al., 2020). In recent years, there has been a continuous reduction in the grazing land area and an increase in stocking density per hectare in different regions of the country, posing a severe threat to goat farmers (Shinde and Sejian, 2013). So, there is a need to investigate an alternate feeding system to rear goats specifically for meat purposes.

The study found that stall feeding resulted in the highest weight gain for Makhi Cheeni and non-descript goats, with semi-intensive systems achieving statistically similar results. Grazing produced the lowest weight gain in these breeds. This aligns with the research of Gruffat et al. (2020), who found that stall-fed lambs had higher average daily gain compared to pasture-fed lambs. Stall and semi-intensive systems likely provide more consistent, higher-quality feed compared to grazing, leading to improved weight gain Pathan et al. (2017). However, the lack of significant difference between stall and semi-intensive systems suggests that for these breeds, providing access to some level of forage alongside a controlled diet may be sufficient for optimal growth. This is partially supported by Miah and Alim (2009) findings, where Black Bengal goats in an intensive system (similar to stall feeding) didn't show a statistically significant difference in weight gain compared to a semi-intensive system. However, it's important to note that Barbari goats in this study did not exhibit a clear preference for any feeding system. This could be due to breed-specific factors like digestive efficiency or foraging behaviour, requiring further investigation. Additionally, Alshamiry et al. (2023) found significant differences in weight gain between various feeding groups, highlighting the influence of specific feed composition on weight gain even within controlled systems.

The current findings revealed a significant influence of feeding systems on BCS for Makhi Cheeni goats. Stall and semi-intensive feeding led to higher BCS compared to grazing, aligning with the study of Karthik et al. (2021) and Costa et al. (2013). Controlled feed intake in these systems likely provides consistent, high-quality nutrients, reflected in better body condition (Su et al., 2022).

In contrast, Barbari and non-descript goats exhibited no significant difference in BCS across feeding systems. This could be due to breed-specific factors like digestive efficiency or foraging behavior that influence their ability to utilize variable forage quality in grazing systems (Chebli et al., 2022). These breeds might be more adaptable to such conditions compared to Makhi Cheeni. Research by Patil et al. (2014) highlights potential variations, reporting a body weight gain difference (linked to BCS) between stall-fed and grazing goats, though breed information was not specified. While previous studies compared stall feeding to grazing, this broadens the scope by incorporating a semi-intensive system, offering a more nuanced understanding of weight gain across different feeding intensities. Concerning the Makhi Cheeni breed, the consistently high BCS aligns with findings from Devi et al. (2020) and Ahmad et al. (2023), suggesting potential adaptability to both intensive and extensive systems. However, insights from Shoshe et al. (2019), Mehedi Hasan (2021) and Meza-Herrera et al. (2023) propose that optimizing BCS may be achieved in semi-intensive systems through targeted supplementation or controlled concentrate intake. Research from Seid et al. (2020) supports the benefits of grazing systems with concentrate supplementation for this breed, urging further investigation into their specific nutritional needs and exploring browsing-focused approaches. In view of these findings, it is important to consider specific breeds. The ability of Makhi Cheeni goats to adapt suggests they may have a wider range of diets, while Barbari goats may benefit from specific grazing or forage-based methods. Semi-intensive systems have shown the potential to improve body condition scores, particularly through targeted supplementation. Careful assessment and incorporation of local feed resources, considering economic feasibility, are recommended.

Concentration supplementation can be beneficial in grazing systems, particularly for Makhi Cheeni. Optimization of the grazing-concentrate ratio based on breed-specific needs and environmental factors is essential. Integrating locally available feedstuffs is critical for effective management, urging researchers and practitioners to explore potential forages and concentrates aligning with breed-specific nutritional requirements, promoting a sustainable and efficient goat husbandry approach.

In the present study, feeding systems revealed a significant effect (P>0.05) on blood metabolite profiles, particularly in Makhi Cheeni goats. Stall-fed Makhi Cheeni exhibited normal cholesterol levels, suggesting efficient metabolism potentially due to a balanced diet and efficient utilization within this system, as described by the study of Sharma et al. (2023). The study conducted by Sharma et al. (2023) reported noteworthy variations in metabolite levels among bucks of the Black Bengal breed goats. Conversely, goats under semi-intensive and grazing systems showed lower cholesterol levels, potentially linked to dietary limitations in essential fatty acids typically found in higher quantities within concentrate feeds compared to forage. This aligns with established ruminant nutrition research by (Moate et al., 2004) and (Lourenço et al., 2008), highlighting the importance of dietary fatty acids for cholesterol synthesis. Other research reported similar findings, identifying significant differences in haematological and biochemical parameters between goat breeds in the same feeding system in Northern Nigeria (Njidda et al., 2013). Additionally, studies have observed variations in specific blood parameters, such as packed cell volume and haemoglobin values, across different breeds (Pradhan, 2016).

Moreover, Barbari and non-descript goats displayed no significant differences in blood metabolite parameters across feeding systems, including white blood cells (WBC), blood glucose, and total protein. This suggests potential breed-specific adaptations for nutrient utilization from forage. These breeds might be more adept at extracting essential components and maintaining physiological balance even with variations in dietary intake compared to Makhi Cheeni goats. Consistent results regarding total protein values were also noted in a study by Kouri et al. (2018).

CONCLUSION

This study demonstrates breed-specific responses to feeding systems for optimal goat production. Makhi Cheeni goats thrived under stall feeding, achieving superior weight gain, body condition score, and potentially efficient cholesterol metabolism. Barbari goats displayed no significant difference across feeding systems, suggesting potential adaptability. Non-descript goats exhibited weight gain benefits from stall and semi-intensive feeding compared to grazing. These findings highlight the importance of breed selection and targeted feeding strategies for maximizing production efficiency and economic viability, particularly in scenarios with limited grazing land. Semi-intensive systems, offering a balance between controlled feed and forage access, warrant further exploration for economically sustainable goat production, especially for breeds like Makhi Cheeni. Integrating locally available feedstuffs and optimizing grazing-concentrate ratios based on breed-specific needs is crucial for practical implementation. This research informs targeted feeding practices to enhance goat production for small-scale farmers facing challenges due to declining grazing land availability.

NOVELTY STATEMENT

This study uniquely provides a breed-specific analysis of alternative feeding strategies for goats in the Pothohar Valley, Pakistan. Unlike previous research, it evaluates the performance, health, and profitability of three distinct goat breeds under different feeding regimes. The findings, particularly the benefits of stall-feeding for Makhi Cheeni goats, offer new insights that can inform more effective and globally relevant goat production practices, addressing both local and international challenges in the field.

AUTHORS CONTRIBUTIONS

Muhammad Abdul Basit designed and conducted the research and wrote the draft manuscript.
Abdur Rahman designed and supervised the study.
Lionel Kinkpe: Performed the statistical analysis, wrote the draft and finalized the manuscript.
Boko Michel Orounladji, Gadah Albasher, Hafiz Qadeer Ahmed, and Elodie Dimon contributed to the Statistical Analysis
Muhammad Subbayyal Akram and Syed Muhammad Suhail read and finalized the manuscript.

IRB APPROVAL

The Advanced Studies and Research Board (ASRB) (No.1035/ASRB/UAP, dated 11/02/2023) approved the study.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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AVAILABILITY OF DATA AND MATERIALS

The datasets used or analyzed during the current study are available from the corresponding author on request.

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