

RESEARCH ARTICLE

Physicochemical and Nutritional Changes in Milk Composition of Indigenous Goats During Different Lactation Stages in Swat Valley, Pakistan

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ABSTRACT

Goat milk plays a significant role in nutrition and rural livelihoods in mountainous regions of Pakistan. However, limited data are available regarding compositional changes of milk from local goats across different lactation stages under field conditions in Swat Valley. Understanding these variations is essential for improving feeding strategies and dairy product utilization. A total of 120 clinically healthy local goats were selected from smallholder farms in Swat. Animals were categorized into early (0–40 days), mid (41–80 days), and late lactation (81–120 days), with 40 goats per group. Milk samples were collected weekly and analyzed for fat, protein, lactose, total solids (TS), and solid-not-fat (SNF) using standard milk analyzer machine. Data were analyzed using one-way ANOVA, and differences among means were considered significant at $p < 0.05$. Significant variations ($p < 0.05$) were observed across lactation stages. Fat percentage increased from early ($3.84 \pm 0.41\%$) to late lactation ($4.92 \pm 0.38\%$). Protein content followed a similar increasing trend ($3.21 \pm 0.27\%$ to $3.78 \pm 0.30\%$). Lactose concentration decreased significantly from early ($4.52 \pm 0.19\%$) to late lactation ($4.21 \pm 0.23\%$). Total solids increased progressively from $12.10 \pm 0.62\%$ to $13.74 \pm 0.71\%$. Milk from late lactation contained higher fat and protein levels, suggesting improved suitability for cheese and processed dairy products, while early lactation milk had relatively higher lactose concentration. These findings provide baseline compositional data for indigenous goats in Swat and may assist in developing stage-specific feeding and milk utilization strategies.

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1. Introduction

Goat production is a cornerstone of subsistence and semi-commercial farming systems in mountainous regions of Pakistan, particularly in Swat Valley where small ruminants are better adapted to rugged terrain and seasonal fodder variability than large ruminants. Goat milk contributes significantly to household nutrition, especially for children and elderly populations due to its digestibility and smaller fat globule size compared to cow milk [1,2]. In recent decades, global demand for goat milk and its derivative products has increased, driven by perceived health benefits, hypoallergenic properties, and suitability for artisanal dairy processing [3,4]. This trend emphasizes the need for region-specific data on milk composition, especially from indigenous goat populations that are raised under traditional systems.

Milk composition is a dynamic biological trait influenced by multiple interacting factors including genotype, parity, feeding regime, environmental temperature, health status, and stage of lactation [5,6]. Among these, lactation stage exerts a particularly strong physiological effect due to endocrine regulation and mammary gland metabolism [7]. Early lactation is typically characterized by high milk yield and relatively lower fat and protein concentration, while late lactation often shows reduced yield but increased total solids due to concentration effects and altered mammary epithelial activity [8,9]. Such compositional changes directly influence processing efficiency, especially cheese yield, coagulation properties, and shelf stability of dairy products [10].

Previous studies in Mediterranean and temperate goat breeds have consistently reported increasing fat and protein

content toward late lactation, alongside a gradual decline in lactose concentration [3,11,12]. However, variations may occur depending on nutritional plane and environmental stressors [13]. In South Asian contexts, particularly Pakistan, there remains limited published information regarding lactational changes in milk composition of indigenous goats reared under smallholder conditions. Most available studies focus on exotic or crossbred dairy goats [14], leaving a knowledge gap for local populations in mountainous agro-ecological zones.

Swat Valley presents unique climatic and feeding conditions, with seasonal grazing patterns and limited concentrate supplementation. These factors may influence nutrient partitioning and milk synthesis patterns differently from controlled experimental herds. Establishing baseline compositional data across lactation stages in this region is essential for improving feeding strategies, enhancing dairy product value addition, and supporting evidence-based extension services. Therefore, this study aimed to evaluate variations in fat, protein, lactose, total solids, and SNF in milk of local goats across early, mid, and late lactation stages under field conditions in Swat Valley.

2. Materials and Methods

2.1. Study Area

The study was conducted in Swat Valley, Khyber Pakhtunkhwa, Pakistan, characterized by a temperate climate.

2.2 Experimental Animals and Design

One hundred and twenty clinically healthy local goats were selected from different smallholder farms. Animals were maintained under similar traditional management systems including daytime grazing and seasonal fodder supplementation.

Goats were divided into three groups:

1. Early lactation (0–40 days) (n = 40)
2. Mid lactation (41–80 days) (n = 40)
3. Late lactation (81–120 days) (n = 40)

Parity ranged from 2 to 4 to minimize variability.

2.3 Milk Sampling Procedure

Pool sample of 100 mL of milk was collected during morning and evening milking into sterile containers. Samples were stored at 4°C in insulated ice boxes and transported to the laboratory quickly for analysis.

2.4 Laboratory Analysis

Milk composition was analyzed for Fat (%), Protein (%), Lactose (%), Total solids (%) and Solid Not fats SNF (%) through Milk Lactoscan Bulgarian Analyzer (S60) of the laboratory of the station.

2.5 Statistical Analysis

Data was analyzed using one-way ANOVA under a completely randomized design. Tukey's multiple comparison test was used to separate means. Statistical significance was declared at $p < 0.05$.

2.6 Ethical Approval Statement

All procedures involving animals were conducted according to the ethical guidelines of the Research, and informed consent was obtained from participating farmers.

3. Results and Discussion

3.1 Variation in Milk Fat Across Lactation

Milk fat percentage increased significantly ($p < 0.05$) from early to late lactation (Table 1). This progressive increase is consistent with classical lactation physiology, where declining milk volume toward late lactation results in concentration of milk solids [7,8]. Similar patterns have been documented in European dairy goats [3,11] and in tropical breeds [15].

The elevated fat content during late lactation may also reflect metabolic adjustments associated with negative energy balance resolution after peak lactation. As milk yield declines, the mammary gland shifts from high-volume synthesis to higher solid concentration, partly influenced by changes in acetate and beta-hydroxybutyrate availability for de novo fatty acid synthesis [16]. From a practical perspective, higher fat levels in late lactation milk enhance cheese yield and butterfat recovery, which is economically relevant for small-scale dairy processors [10].

Table 1. Fat Percentage Across Lactation Stages

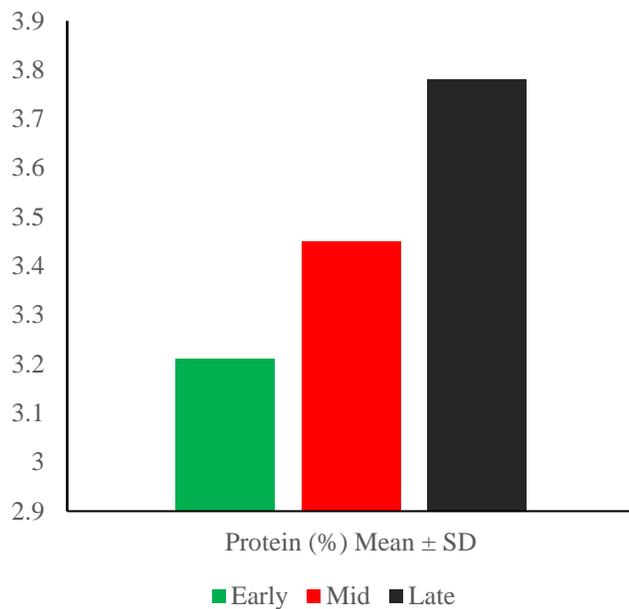
Stage	Fat (%) Mean \pm SD
Early	3.84 \pm 0.41
Mid	4.36 \pm 0.35
Late	4.92 \pm 0.38

3.2 Changes in Protein Concentration

Protein percentage increased significantly across lactation stages (Figure 1). This trend aligns with findings from Jenness [7] and later confirmed in several goat breeds worldwide [3,12,17]. The increase in protein concentration during late lactation may be attributed to reduced secretory activity and increased casein fraction concentration as milk volume decreases [18].

Casein concentration is particularly important because it determines coagulation efficiency and curd firmness during cheese production [10]. Studies have demonstrated that late lactation milk typically yields firmer curd and improved cheese recovery compared to early lactation milk [19]. Under smallholder conditions in Swat, where milk is often processed into traditional dairy products, these compositional shifts may influence product texture and yield.

Figure 1. Protein Percentage Across Lactation Stages



3.3 Lactose Dynamics During Lactation

Unlike fat and protein, lactose content showed a gradual decline from early to late lactation (Table 2). Lactose synthesis is closely linked to milk volume regulation, as it governs osmotic pressure within mammary alveolar cells [20]. Higher lactose levels during early lactation are associated with peak milk production, while declining lactose toward late lactation corresponds with reduced secretory activity [8]. Similar decreasing trends in lactose concentration have been reported in both temperate and tropical goat breeds [11,15]. Nutritional stress and seasonal forage variability can further influence lactose synthesis [13]. In Swat Valley, seasonal grazing fluctuations may contribute to subtle variations in carbohydrate metabolism and glucose availability for lactose production.

Table 2. Lactose Percentage Across Lactation Stages

Stage	Lactose (%) Mean ± SD
Early	4.52 ± 0.19
Mid	4.34 ± 0.21
Late	4.21 ± 0.23

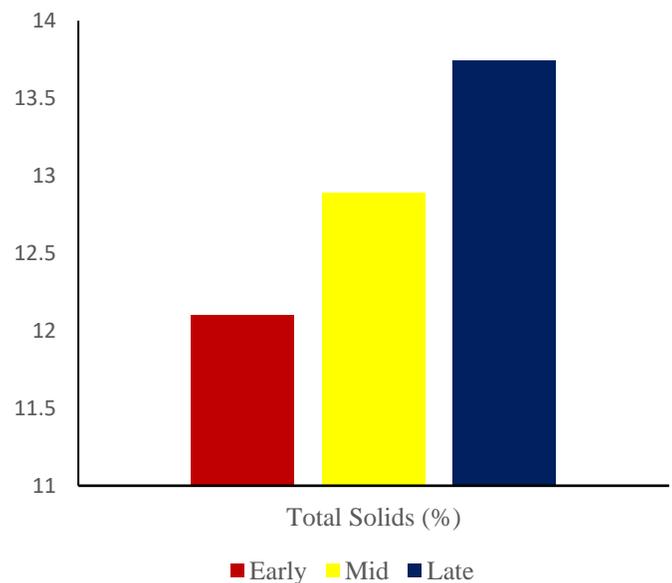
3.4 Total Solids and Solid-Not-Fat (SNF)

Total solids increased progressively from early to late lactation, reflecting cumulative increases in fat and

protein fractions (Figur 2). These findings are in agreement with previous investigations across multiple goat populations [1,3,12]. Higher total solids improve milk density and processing yield, particularly for fermented and coagulated dairy products [10].

SNF also demonstrated a modest but significant increase across lactation. This component includes lactose, proteins, and minerals, and plays a crucial role in determining milk's nutritive value [21]. Increased SNF toward late lactation has been associated with enhanced mineral concentration and protein fraction stability [17].

Figure 2. Total Solids and SNF



3.5 Regional Implications

The compositional trends observed in Swat goats follow established physiological patterns reported internationally, suggesting that lactation biology remains consistent despite differences in management systems. However, absolute values may vary due to environmental conditions, grazing-based feeding, and genetic background [5,13]. These results provide baseline data specific to indigenous goats in Swat Valley and may support targeted feeding interventions aimed at optimizing milk quality during different production phases. Future studies incorporating seasonal effects, parity influence, and nutritional supplementation would further clarify determinants of milk quality under mountain agro-ecological systems.

4. Conclusion

Milk composition of local goats in Swat Valley varies significantly across lactation stages. Late lactation milk contains higher fat, protein, and total solids, enhancing its suitability for cheese production and value-added dairy processing. Early lactation milk contains relatively higher lactose concentration, making it more appropriate for fluid consumption. These baseline findings can support feeding strategies, dairy value chain development, and regional goat production planning. Further research incorporating seasonal and breed variation is recommended.

References

- [1]. Haenlein GFW (2004). Goat milk in human nutrition. *Small Ruminant Research*. 51: 155–163.
- [2]. Park YW, Juárez M, Ramos M, Haenlein GFW (2007). Physico-chemical characteristics of goat and sheep milk. *Small Ruminant Research*. 68: 88–113.
- [3]. Jenness R (1980). Composition and characteristics of goat milk. *Journal of Dairy Science*. 63: 1605–1630.
- [4]. AOAC (2005). *Official Methods of Analysis* (18th ed.). Washington DC.
- [5]. Ciappesoni G et al. (2004). Factors affecting goat milk yield and composition. *Czech Journal of Animal Science*. 49: 465–473.
- [6]. Fox PF, McSweeney PLH (1998). *Dairy Chemistry and Biochemistry*. New York: Springer.
- [7]. Jenness R (1980). Composition and characteristics of goat milk. *Journal of Dairy Science*. 63: 1605–1630.
- [8]. Walstra P, Wouters JTM, Geurts TJ (2006). *Dairy Science and Technology*. Boca Raton: CRC Press.
- [9]. Raynal-Ljutovac K et al. (2008). Composition of goat and sheep milk products. *Small Ruminant Research*. 79: 57–72.
- [10]. Park YW (2017). Goat Milk Chemistry and Nutrition. *Handbook of Milk of Non-Bovine Mammals*.
- [11]. Zeng SS et al. (1997). Milk composition of dairy goats. *Journal of Dairy Science*. 80: 2525–2534.
- [12]. Mayer HK, Fiechter G (2012). Physicochemical characteristics of goat milk. *International Dairy Journal*. 24: 12–18.
- [13]. Morand-Fehr P (2005). Recent developments in goat nutrition. *Small Ruminant Research*. 60: 25–43.
- [14]. Ahmad S et al. (2019). Comparative milk quality of indigenous goats. *Pakistan Journal of Zoology*. 51: 1–8.
- [15]. Rafiq S et al. (2016). Seasonal variation in goat milk composition. *Tropical Animal Health and Production*. 48: 135–142.
- [16]. Chilliard Y et al. (2003). Diet, rumen fermentation and milk fat synthesis. *Journal of Dairy Science*. 86: 1751–1770.
- [17]. Clark S, Sherbon JW (2000). Genetic and environmental influences on goat milk. *Journal of Dairy Science*. 83: 535–545.
- [18]. Pirisi A et al. (2007). Milk protein variation in dairy goats. *Dairy Science & Technology*. 87: 403–413.
- [19]. Guo MR et al. (2001). Effect of lactation stage on cheese yield. *Journal of Dairy Science*. 84: 171–179.
- [20]. Neville MC et al. (2002). Lactose synthesis and milk secretion. *Physiological Reviews*. 82: 1103–1134.
- [21]. FAO (2011). *Guide to Good Dairy Farming Practice*. FAO Animal Production Paper.

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