

NUTRITIONAL EVALUATION OF MILK FROM DIFFERENT DAIRY BREEDS IN PAKISTAN

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DOI: <https://doi.org/10.5281/zenodo.18691618>

Keywords

Dairy breeds, Milk composition, Buffalo milk, Total solids, Calcium content, Milk yield, Pakistan

Article History

Received: 15 December 2025

Accepted: 30 January 2026

Published: 17 February 2026

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Abstract

The current study assessed breed- and species-specific variation in milk composition among primary dairy breeds in Pakistan. One hundred forty milk samples from seven breeds (Sahiwal, Red Sindhi, Cholistani, Holstein Friesian, and Jersey among cattle, and Nili-Ravi and Kundi among buffalo) were collected across various regions due to seasonal variation in the year. 20 of each breed were collected. Milk was sampled for yield, fat, protein, lactose, solids-not-fat (SNF), total solids (TS), calcium, and other milk composition parameters. The effect of breed was highly significant for fat, protein, total solids, calcium, and milk yield ($p < 0.001$). Buffalo milk presented a significantly higher fat ($7.29 \pm 0.60\%$) and total solids content ($17.45 \pm 0.83\%$) compared to cow milk ($4.56 \pm 0.67\%$ fat; $13.50 \pm 0.89\%$ total solids). The calcium level was also significantly higher in buffalo milk (149 ± 10 mg/100 mL) than in cow milk (122 ± 9 mg/100 mL). In contrast, Holstein Friesian cows produced the highest milk yield (17.82 ± 2.45 kg/day), but their fat and solids contents were lower than those of Jersey and indigenous cattle breeds. The Pearson correlation coefficient showed a strong positive association between fat and total solids ($r = 0.84$, $p < 0.001$) and a negative association between light milk and fat percentage ($r = -0.41$, $p <$

0.001). Stepwise regression showed that fat, protein, and lactose accounted for 88% of the variation in TS ($R^2 = 0.88$). These results demonstrate substantial genetic variability in milk nutrient content among Pakistani dairy breeds and provide some evidence for breed-specific dairy development policy.

INTRODUCTION

Milk is among the most complete foods from a nutritional perspective and is key to ensuring global food security, human well-being, and rural livelihoods. The composition of milk, especially fat, protein, lactose, minerals, and bioactive compounds—defines its nutritional value as well as its ability to be transformed into a dairy product. Extensive reviews have highlighted the importance of bovine milk for dietary protein, essential fatty acids, calcium, and other micronutrients [1, 2]. The structure and physico-chemical nature of milk constituents also affect processability and product quality; therefore, knowledge of compositional variation within breeds is necessary [3]. Thus, breed-related variation in milk composition has significant consequences for public health and the dairy industry.

Milk yield and its composition are heritable traits. In dairy breeding, selection pressure for higher milk yield has been shown to drive changes in milk solids concentration and protein profiles [3, 4]. In addition, breed effects on milk fat and protein concentration and cheese yield traits have been reported previously, with high-fat / -protein producing breeds (Jersey) generally yielding fatter and protein-dense milk than high-volume breeds [5]. However, there may be trade-offs associated with metabolic stress and compositional dilution that accompany extreme genetic selection for high production [6]. It is, therefore, of prime significance to understand these genetic influences to achieve sound productivity and quality of output in dairy systems.

Apart from genetic factors, environmental and climatic conditions significantly affect milk quantity and quality. Heat stress is known to decrease milk fat % and protein %, thereby negatively affecting overall productivity [7]. The temperature and feed availability (food scarcity), as influenced by the seasons, cause detectable

changes in milk composition throughout the year [7]. The search for genetic effects on heat-stress responses also shows that some breeds appear more resistant to high temperatures [8]. In tropical and subtropical countries like Pakistan, such environmental factors are very important, as dairy animals are commonly exposed to thermal stress and seasonal effects, which might change compositional attributes.

The relative value of native-versus introduced dairy cattle breeds is particularly relevant in developing countries. Indigenous breeds are often better suited to local climates and disease challenges, while exotic or commercial breeds tend to produce more milk under intensive production conditions [9, 10]. National and International evaluations of animal genetic resources call for retaining and utilizing low-input breeds in their areas of origin while enhancing production through sustainable breeding strategies. The indigenous cattle breeds (Sahiwal, Red Sindhi, and Cholistani) from Pakistan are typically combined with exotic (Holstein Friesian, Jersey) and buffalo breeds (Nili-Ravi, Kundi) in dairy production. Buffalo milk is well known for its high fat and total solids content, which makes it more economically attractive for dairy processing.

However, even variations due to breed, environment, and genetics can already be observed; comparative multi-breed studies conducted under local Pakistani conditions have not yet been well conducted. The existing literature is mainly based on the European and temperate production systems, which cannot represent compositional variability in South Asian agro-climatic regions. Considering the nutritional and economic importance of dairy products in Pakistan, investigating milk composition across indigenous breeds is critical for breeding, improved dairy management practices, and enhanced nutritional quality.

Therefore, the objective of this study is to evaluate and compare the nutritional properties of milk from different dairy breeds in Pakistan and to generate evidence-based data to support sustainable growth in dairy production.

2. MATERIALS AND METHODS

The present study was planned to conduct a cross-sectional comparative evaluation of the nutritive quality of milk from primary dairy animal breeds in Pakistan. The study aimed to evaluate differences in milk yield and composition traits among indigenous cattle, exotic breeds, and buffaloes on smallholder farms.

Milk samples were collected from major dairy farms of the four provinces in Pakistan: in Punjab, Sindh, KPK and Baluchistan. These are different agro-climatic zones varying in temperature, humidity, and feeding. The investigation was carried out during four seasons of the year, winter, spring, summer and autumn to investigate seasonal variation of milk components. The sample size included 140 milk samples; each of the seven dairy breeds Sahiwal, Red Sindhi (RS), Cholistani, Holstein Friesian (HF), Jersey (JR) Nili-Ravi (NR) and Kundi was represented equally. Twenty specimens were obtained for each breed. Animals were randomly selected from different farms, to have representation of lactation and parity categories.

Only healthy lactating animals were included in the study. Breed, parity, days in milk, and lactation stage of the sampling quarter were also recorded. Lactation was separated into early (0-90 days), mid (91-180 days), and late lactation (>180 days). Animals with previous records of metabolic diseases and mastitis were excluded to minimize confounding factors on the composition of milk. Milking was performed on morning-collected samples in accordance with standard hygiene procedures. Fore milk was rejected, and approximately 250 mL of milk was obtained from each cow for analysis. Samples were transferred in perfectly sealed, well-labelled sterile containers immediately to the laboratory for analysis under refrigeration 4 °C.

Most of the typical nutrient and physicochemical parameters in milk were examined. The fat percentage was calculated using Gerber's method. Protein content was determined by the Kjeldahl method. Lactose content was measured by the enzymatic method. Solid-not-fat (SNF) and total solids were estimated using standard dairy analytical methods. Spectrophotometric methods measured the concentrations of minerals, such as calcium and phosphorus, after appropriate digestion. The ash content was determined by incineration at 550 °C in a muffle furnace. Somatic cell counts (SCC) were estimated as a measurement of milk quality using an automated cell counter. Milk production per day was extracted from the farm record on the sampling date.

Data was recorded in Microsoft Excel and analyzed using IBM SPSS Statistics. For all nutritional parameters, descriptive statistics (mean and SD) were calculated by breed and species. To estimate differences between breeds in milk composition and yield traits, a one-way analysis of variance (ANOVA) was conducted. At the species level, Awas was used to compare buffaloes. Post-hoc comparisons were conducted to identify pairwise differences wherever significant differences were found. The correlation between milk components and yield traits was evaluated using Pearson's correlation analysis. Predictors of the total solid's percentage were also evaluated using fat, protein, and lactose in a multiple linear regression analysis. A p-value of less than 0.05 was considered statistically significant.

3. RESULTS

The composition of milk differed substantially among the studied dairy breeds. Buffalo (Nili-Ravi and Kundi) had on average, higher mean fat, total protein, total solids, and mineral content than cattle breeds. In cattle, Jersey cows had the highest fat and protein percentages, and Holstein Friesians had the highest milk yield but the lowest fat and total solids. Native cattle breeds (Sahiwal, Red Sindhi, and Cholistani) exhibited intermediate nutritional status. The

breed-wise variations in these values are presented in Table 1.

Table 1: Milk Yield and Nutritional Composition by Breed (Mean ± SD)

Breed	Milk Yield (L/day)	Fat (%)	Protein (%)	Lactose (%)	Total Solids (%)	Calcium (mg/100 mL)
Sahiwal	10.42 ± 2.11	4.47 ± 0.51	3.42 ± 0.24	4.80 ± 0.17	13.28 ± 0.69	121 ± 8
Red Sindhi	9.96 ± 2.08	4.63 ± 0.53	3.50 ± 0.23	4.78 ± 0.16	13.41 ± 0.72	122 ± 9
Cholistani	9.51 ± 2.16	4.79 ± 0.56	3.59 ± 0.26	4.71 ± 0.18	13.68 ± 0.75	124 ± 9
Holstein Friesian	17.82 ± 2.45	3.81 ± 0.49	3.18 ± 0.21	4.91 ± 0.19	12.61 ± 0.68	118 ± 8
Jersey	12.36 ± 2.28	5.24 ± 0.57	3.83 ± 0.27	4.69 ± 0.18	14.53 ± 0.77	128 ± 9
Nili-Ravi	8.48 ± 1.94	7.52 ± 0.61	4.19 ± 0.29	4.61 ± 0.17	17.82 ± 0.82	150 ± 10
Kundi	7.76 ± 1.87	7.06 ± 0.58	3.98 ± 0.26	4.59 ± 0.16	17.08 ± 0.79	148 ± 9

Buffalo milk contained markedly higher fat (≈7.0–7.5%) and total solids (≈17%) compared to cow milk (3.8–5.2% fat; 12.6–14.5% total solids). Statistical analysis via a one-way ANOVA showed that the breed effect was significant for fat %, protein %, total solids %, calcium concentration, and milk yield ($p < 0.001$). Variation in milk fat and total solids content was explained by breed

differences to a greater extent. Buffalo breeds differed from cattle breeds in fat and total solids content. In cattle, Jersey milk contained significantly more fat and protein than Holstein Friesian milk ($p < 0.05$). Milk yield of Holstein-Friesian was significantly superior to all the indigenous breeds ($p < 0.001$).

Table 2: One-Way ANOVA Results for Breed Effect

Variable	F-value	p-value	Significance
Fat (%)	68.42	<0.001	Significant
Protein (%)	52.17	<0.001	Significant
Lactose (%)	3.48	0.004	Significant
Total Solids (%)	74.63	<0.001	Significant
Calcium	39.55	<0.001	Significant
Milk Yield	91.28	<0.001	Significant

When grouped by species, buffalo milk demonstrated significantly higher fat, protein, total solids, and calcium levels compared to cow

milk ($p < 0.001$). However, average milk yield was significantly greater in cows than buffaloes ($p < 0.001$).

Table 3: Species Comparison of Major Nutritional Parameters (Mean ± SD)

Parameter	Cow	Buffalo	p-value
Fat (%)	4.56 ± 0.67	7.29 ± 0.60	<0.001
Protein (%)	3.50 ± 0.29	4.09 ± 0.28	<0.001
Total Solids (%)	13.50 ± 0.89	17.45 ± 0.83	<0.001
Calcium (mg/100 mL)	122 ± 9	149 ± 10	<0.001
Milk Yield (L/day)	12.01 ± 3.12	8.12 ± 1.91	<0.001

Pearson correlation analysis indicated strong positive relationships between fat percentage and total solids ($r = 0.84$, $p < 0.001$) and between protein percentage and total solids ($r = 0.72$, $p <$

0.001). Milk yield showed a moderate negative correlation with fat percentage ($r = -0.41$, $p < 0.001$), indicating dilution effects in higher-producing breeds.

Table 4: Pearson Correlation Coefficients Among Selected Variables

Variable Pair	r	p-value
Fat - Total Solids	0.84	<0.001
Protein - Total Solids	0.72	<0.001
Fat - Milk Yield	-0.41	<0.001
Protein - Milk Yield	-0.33	0.002

Multiple linear regression analysis demonstrated that fat, protein, and lactose collectively explained a substantial proportion of variation in

total solids percentage ($R^2 = 0.88$, $p < 0.001$). Fat percentage emerged as the strongest predictor of total solids.

Table 5: Multiple Regression Predicting Total Solids (%)

Predictor	β Coefficient	p-value
Fat (%)	0.74	<0.001
Protein (%)	0.42	<0.001
Lactose (%)	0.18	0.012
Model R ²	Adjusted R ²	F-value
0.88	0.87	332.15
		p-value
		<0.001

4. DISCUSSION

The present study provided evident breed and specie-specific variation in milk yield and nutritional quality of leading dairy breeds of Pakistan. The fat, protein, total solids and calcium contents of milk were markedly higher in buffalo types (Nili-Ravi and Kundi) compared to cattle (species). Holstein Friesians were the best extractors of milk, giving the most; but yielding it in the most diluted form. These observations are consistent with previous comparisons which found that the fat content and total solids in buffalo milk were higher than those of cow's milk, is primarily due to genetic

and physiological variations among species [11-13]. This pattern of breed-specific differences in milk composition is also documented for dairy cows where Jersey Cows have higher fat and protein content than Holstein Friesian cows. Thus, the current discovery is corroborative with previously reported evidence for a considerable breed genetic effect on milk components. The negative correlation between milk solids and milk yield supports the theory of diluting effect, which explains that under high yielding regime breeds, fat and protein percentages are relatively low. Previous studies have reported that the level

of milk yielding (especially in Holstein Friesians) negatively influences the content of organic solids (milk fat and protein) [3, 14]. In agreement with these findings, HF cows had higher DM yield as recorded in this study and shown to have lower values of fat and total solids compared to Jersey and local breeds. Yet the effect of dilution does exist and has been demonstrated to be reduced through selection and good management [15]. This implies that there may be variation for breed differences in composition, depending on the environment and management conditions.

Calcium analysis also showed higher levels in buffalo milk than in cow milk, which agrees with previous findings that ranked the mineral density of buffalo milk as superior [16, 17]. The higher ash and mineral content observed in buffalo breeds increases their nutritional and technological value, especially for dairy processing applications such as cheese manufacturing [12]. However, some comparative studies have indicated variability among minerals depending on feeding type, lactation stage, and geographical location [18]. This indicates that at least part of the species' variation might be due to nutritional control and/or environmental conditions.

The effect of breed on protein and lactose percentages even widens the genetic dependence on variation in milk composition. Heck, Schennink [19] reported that milk protein genetic variants play a major role in determining milk quality traits. Although the current results are generally in line with global breed comparisons, it is important to acknowledge that local environmental variables, such as heat stress and seasonality, would affect compositional traits within specific regions, especially in tropical and subtropical areas [3, 20]. Observations of climate impacts on dairy indicate that higher temperatures can lower milk fat and protein content, potentially affecting breed comparisons under field conditions.

The findings suggest that for milk quality and mineral contents, Pakistani buffalo milk is superior to exotic dairy cattle, while imported animals are more productive in terms of quantity. These findings are like that of the international

published data pointing towards genetic and physiological mechanism underlying milk composition, however there were specific effects arising due to the environmental (contextual) and management. Combining breed selection strategies with better feeding and management could satisfy the goals of both milk yield and nutritional quality in Pakistan's dairy farming systems.

5. CONCLUSION

This study provided the most extensive comparison of milk yield and composition between different breeds in Pakistani industry. It has demonstrated significant genetics effects and breed differences for milk-quality traits. Buffalo breeds, especially Nili-Ravi and Kundi, had higher fat, protein, total solids and calcium content in milk than cattle breeds indicating the nutritional advantage of these animals as raw material for processing. Holstein Friesian cows, however, produced the most milk but had lower solids than other breeds, confirming their diluting effect (associated with high producing dairy breeds). Intermediate trend combining moderate yield with comparatively better quality in terms of composition was also observed for the crossbred animals of Jersey and local cattle. The findings illustrate the strong genetic effect of breed on milk contents, which is probably modulated by environmental and management determinants. Buffalo is favored nutritionally and economically in the value-added dairy products on account of its higher solid content (SNF+mineral). High producing exotic cattle, however, could be more suitable for mass-based production systems. The discovery of these characteristic features emphasizes the necessity for a differentiated strategy in dairy development projects, particularly when farm structure and climate differ. Milk production in Pakistan should be improved in an integrated manner through genetic potential along with optimized feeding, management, and environmental adaptability of the animal so that improvement not only comes in terms of milk quantity but quality as well under sustainable systems.

6. FUNDING

Not applicable.

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