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Research Article

Composition of milk: A comparative analysis on goat, cow and buffalo milk from Amreli region of Gujarat

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Abstract

The article describes an exploration into the components of milk and its different characteristics across species found in the Amreli region of Saurashtra. Using MilkoScan™ (indiFOSS) and EUTECH PH meter, the study investigated milk constituents and other properties. Following the analysis of all samples, Principal component analysis (PCA) was employed to examine how the elements in milk relate to each other. This analysis showcased a significant ($P<0.05$) difference in the overall fat, protein and lactose content of goat milk (2.97%, 3.59% and 4.25%) as opposed to cow (5.97%, 3.98% and 4.72%) and buffalo (6.36%, 3.99% and 4.74%) milk, revealing substantially lower values in goat milk. The calculated calorific value of buffalo milk (92.17 Kcal) and cow milk (88.58 Kcal) was significantly ($P<0.05$) higher as compared to goat milk (58.13 Kcal). However, no statistically significant ($P>0.05$) distinctions were identified in the mean ash content across the entire sample set. Interestingly, the electrical conductivity (EC) of goat milk surpasses that of cow milk and buffalo milk. In the Principal Component Analysis (PCA), it was revealed that PC1 explained 63.1% and PC2 explained 17.0% of the total variance. The PCA analysis revealed a positive correlation among %ash, %protein, %SNF, %lactose and Freezing point depression (FPD) across different milk samples. In contrast, properties like milk conductivity showed a negative correlation with redox potential and pH.

Keywords: Calculated calorific, Fat, Goat milk, Principal component analysis (PCA), Protein

Highlights

- The study encompassed the procurement of milk samples from multiple species, and these samples were subjected to analysis employing the MilkoScan™ (indiFOSS) instrument and the EUTECH PH meter.
- The study indicated the variations in the composition of goat milk, cow milk and buffalo milk. Each type of milk exhibits distinct characteristics in terms of fat content, SNF, protein, lactose, calorific value, FP, pH, electrical conductivity, Eh and specific gravity.
- The application of Principal component analysis (PCA) in this study revealed a direct relationship: an increase in soluble constituents such as salt and lactose in milk samples corresponded to higher Freezing point depression (FPD). Moreover, milk conductivity was adversely affected by the quantity of fat present, while the Eh exhibited an increase alongside higher percentages of fat.
- The information provided in this analysis can aid in making informed choices about milk consumption based on individual preferences and nutritional requirements.

INTRODUCTION

The milk production of world is expected to achieve 937.0 million tonnes in 2022 (Food Outlook, 2022). The greater part (81%) of the milk produced worldwide comes from cow, followed by buffaloes (15.0%), goats (2.0%), sheep (1.0%) and camels (0.50%) (FAO, 2023). In India, the amount of milk produced exhibited a yearly increase of 5.29%, with 209.96 million tonnes being produced in 2020-21 and 221.06 million tonnes being produced in 2021-22. Goat milk contributes to 3% of the total milk amount produced in the country, and 2% of all milk volume comes from exotic cows (DAHD, 2022-23). Amreli district is characterized by its vast area, covering 7397 square kilometers and occupying a pivotal position in the south-central region of the Saurashtra Peninsula, making it a highly noteworthy district in Saurashtra. The district is divided administratively into eleven talukas, which are Amreli, Dhari, Rajula, Khamba, Jagrabad, Kunkavav, Babra, Lathi, Lilia, and Savar Kundla. The district head office is based in Amreli. The Gohilwadi breed predominantly thrives in the arid and semi-arid regions of north-western Gujarat, specifically in the districts of Bhavnagar, Amreli, and Junagadh. Gohilwadi goats get their name from Gohilwad, a historical region within Kathiawar and the earlier designation of the Bhavnagar district. These goats serve multiple purposes, being valuable for their

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milk, meat and fiber production. The Rabari and Bharwar communities, also known as Maldharis, have traditionally been the custodians of this breed. Notably, Gohilwadi goats are recognized for their substantial size and their black coat adorned with coarse, long hair. The nasal line exhibits a gentle convex curvature. The ears are tubular and droop downwards, while both male and female individuals possess slightly twisted horns that curve backwards. The daily milk production of this species is approximately 1.7 kilograms, while the average lactation period extends to 227 days (Anonymous, 2013).

Milk is often regarded as an almost perfect human food, serving as the primary source of nourishment for newborn offspring. It boasts high nutritive value, providing essential body-building proteins, bone-forming minerals, energy-rich lactose and milk fat. Additionally, milk delivers crucial fatty acids in an easily digestible and absorbable form (Vishweshwar *et al*., 2005). The goat, being one of the earliest domesticated animals, held significant value in ancient times, especially for its prized milk. Across the world, due to extensive and well-funded promotional efforts, cow milk has gained widespread popularity. However, it's important to acknowledge that goat milk might offer comparable or even superior quality. Goat milk and its derived products are easily digestible due to variations in FA make-up, small FGs, and smaller casein micelles compared to bovine milk (Park *et al*., 2007). Goat milk's immunomodulatory qualities can be linked to substances like peptides and oligosaccharides (Daddaoua *et al*., 2006; Santosh *et al*., 2011). Because goat milk is rich in microelements Se (13.7 ng/mL), it is commonly used to treat dengue fever (Van Dael *et al*., 1992). Moreover, the gentle texture of goat milk curd, along with its composition, might offer advantages to individuals experiencing gastrointestinal issues and ulcers (Bhattarai, 2014). Scientific studies have shown that goat milk possesses anti-carcinogenic properties, as well as significant antimicrobial and antiatherogenic actions (Alférez *et al*., 2001; Ceballos *et al*., 2009; Atanasova and Ivanova, 2010; Johansson, 2011). The unique flavor profile of goat milk and milk products is due to the release of Banch chain fatty acid (4-ethyloctanoic acid), giving rise to gotty aroma (Haenlein, 2004). In reality, 65% of milk consumed globally is sourced from goats, proving its superiority over cow milk in several aspects (Mahmood and Usman, 2010; Kumar and Sharma, 2016).

A review of the literature reveals a lack of studies comparing the nutritive quality and composition of milk from Gohilwadi goat, Gir cow, and Gir buffalo in the Amreli district. To address this knowledge deficiency, the present investigation was conducted to offer insights into the milk's composition and other aspects among these three species. This experiment introduced a pioneering approach by employing PCA tools to delve into the collective trends observed in diverse milk components and properties across different species. The significance of PCA lies in its capacity to reveal complex interrelationships among multiple variables. Its application serves as a valuable aid for research scholars, enabling a comprehensive understanding of the complicated connections among food constituents. This tool not only solves the complex web of relationships within milk components but also holds promise for broader applications across food science disciplines. Its utility extends to providing detailed insights that can inform and guide further research and studies in the area of food analysis and composition.

MATERIALS AND METHODS

Milk collection: The Gohilwadi goat, Gir cow and Jafarawadi milk samples for this study were collected from different taluka of Amreli district, including Savarkundal, Khambha, Babara, Bagsara, Lathi, Lilya and Dhasa. The samples were transferred to the dairy chemistry lab in ice boxes, where they were maintained at 4°C. At the College of Dairy Science, Amreli, milk samples were analyzed.

Compositional analysis of milk samples: The raw milk samples (Goat/Cow/Buffalo) were warmed between 38 to 40°C followed by filtration through muslin cloth. The filtered sample was mixed properly and subjected to compositional analysis through the precalibrated Milkoscan instrument MilkoScan™ (indiFOSS). The milk samples were analyzed using the standard protocol provided by the manufacturer. Other physicochemical attributes of milk, like pH, electrical conductivity (EC) and redox potential (Eh) were analyzed by an EUTECH (PC 510) PH meter.

Specific gravity: The milk's specific gravity is determined using a Lactometer, considering the milk's temperature deviation and applying corrections. The resulting reading is referred to as Correct Lactometer Reading (CLR) and can be calculated using a specific formula.

$$\text{Sp. Gr.} = 1 + \frac{\text{CLR}}{1000}$$

Ash content: The Gravimetric method, as outlined by

AOAC (2000), was employed to determine the ash percentage. A muffle furnace was used for this purpose. Initially, a pre-weighed crucible was utilized to accommodate the milk sample (5 g). The crucible, along with its milk solids content, was subjected to the muffle furnace at a temperature of 55°C for 4±1 hours. Subsequently, the ignited sample was carefully moved to a desiccator containing silica gel as the desiccant. After precisely 1 hour, the crucible was weighed, and the content was computed using the prescribed formula:

$$\% \text{ Ash} = \frac{\text{Weight of ignited sample}}{\text{Weight of milk sample taken}} \text{X } 100$$

Calorific values of milk samples: Using a well-established generalized equation, the calorific/energy values were computed based on the Atwater factor method.

Kcal/100 g = (% protein x 4) + (% fat x 9) + (% lactose x 4)

RESULTS

Table 1 depicts the percent constituents and other properties of milk present in all the milk samples.

The fat content of milk is a crucial factor that determines its taste and nutritional value. Goat milk shows the lowest fat content, with an average of 2.97±0.68%, while cow milk and buffalo milk have significantly (P<0.05) higher fat content, averaging 5.97±1.30% and 6.36±1.11%, respectively. The higher fat content in cow and buffalo milk can contribute to their creamier texture.

SNF represents the non-fat components of milk, which includes proteins, lactose, minerals and vitamins. Buffalo milk and cow milk exhibit significantly (P<0.05) higher SNF percentages compared to goat milk. Cow milk has an average SNF of 9.48±0.10%, while buffalo milk has 9.40±0.26%. Goat milk, on the other hand, contains 8.23±0.23% SNF.

Buffalo milk and cow milk showed significantly (P<0.05) higher TS percentages compared to goat milk. Buffalo milk has an average TS of 15.76±0.50%, cow milk has 15.45±0.55%, while goat milk contains 11.20±0.46% TS.

Protein is an essential nutrient in milk that aids in growth and tissue repair. Buffalo milk and cow milk exhibit significantly (P<0.05) higher protein content compared to goat milk. Buffalo milk has an average protein percentage of 3.99±0.10%, cow milk has 3.98±0.03%, and goat milk contains 3.59±0.09% protein.

Lactose is the primary carbohydrate in milk and contributes to its sweetness. Goat milk shows the lowest lactose content, with an average of 4.25±0.11%, while cow milk and buffalo milk contain significantly (P<0.05) higher lactose percentages, averaging 4.72±0.39% and 4.74±0.12%, respectively.

Ash represents the inorganic mineral content in milk. The ash content of all three types of milk is relatively similar, with no significant (P>0.05) differences observed. Goat milk has an average ash content of 0.73±0.03%, cow milk contains 0.74±0.01%, and buffalo milk has 0.77±0.03% ash.

The Veith ratio is an important parameter used to assess the added water in milk, and a change in FP indicates possible adulteration. In our study, this ratio

Table 1. Constituent and other parameters of milk from goat, cow and buffalo

Sl. No.	Parameter	Goat milk	Cow milk	Buffalo milk
1	% Fat	2.97 ± 0.68^a	5.97 ± 1.30^b	6.36 ± 1.11^b
2	% SNF	8.23 ± 0.23^a	9.48 ± 0.10^b	9.40 ± 0.26^b
3	% TS	11.20 ± 0.46^a	15.45 ± 0.55^b	15.76 ± 0.50^b
4	% Protein	3.59 ± 0.09^a	3.98 ± 0.03^b	3.99 ± 0.10^b
5	% Lactose	4.25 ± 0.11^a	4.72 ± 0.39^b	4.74 ± 0.12^b
6	% Ash	0.73 ± 0.03^a	0.74 ± 0.01^a	0.77 ± 0.03^a
7	Veith ratio	11.7:9.8:2	12.9:10.8:2	12.4:10.4:2
8	Calorific value (Kcal/100 g)	58.13 ± 3.04^a	88.58 ± 4.91^b	92.17 ± 4.11^c
9	FP (°C)	-0.493 ± 0.014^b	-0.582 ± 0.016^a	-0.581 ± 0.018^a
10	pH	6.67 ± 0.02^a	6.79 ± 0.05^a	6.81 ± 0.02^b
11	Electrical conductivity (millimho)	5.97 ± 0.20^b	4.54 ± 0.52^{ab}	4.21 ± 0.55^a
12	Eh (volt)	0.13 ± 0.01^a	0.21 ± 0.19^a	0.31 ± 0.18^b
13	Specific gravity	1.028 ± 0.001^a	1.027 ± 0.001^a	1.029 ± 0.001^a

Data are presented as mean ± S.E.; $^{a\text{-}b}$ means with different superscripts are significantly different (P<0.05) from each other in a row for pure milk was calculated as 11.7:9.8:2 for goat milk, 12.9:10.8:2 for cow milk, and 12.4:10.4:2 for buffalo milk.

Calorific value measures the energy content of milk per 100 grams. Buffalo milk shows the highest calorific value at 92.17±4.11 Kcal/100 g, followed by cow milk at 88.58±4.91 Kcal/100 g, and goat milk has the lowest value of 58.13±3.04 Kcal/100 g.

The freezing point of milk is influenced by its soluble constituents. Cow milk and buffalo milk have higher freezing points compared to goat milk, indicating a higher resistance to freezing. Both cow and buffalo milk have the significantly ($P<0.05$) highest FP of -0.582±0.016°C and -0.581±0.018°C, while goat milk has the lowest FP of -0.493±0.014°C.

The pH of milk can provide insights into its acidity level. Goat milk exhibits a slightly lower pH of 6.67±0.02 compared to cow milk (6.79±0.05) and buffalo milk (6.81±0.02).

Electrical conductivity is a measure of the milk's ability to conduct electricity, influenced by its mineral content. Goat milk has the highest electrical conductivity at 5.97±0.20 millimho, followed by cow milk at 4.54±0.52 millimho, and buffalo milk with the lowest value of 4.21±0.55 millimho.

Eh measures the oxidative-reductive properties of milk. Buffalo milk exhibits the significantly $P<0.05$) highest Eh value of 0.31±0.18 volt, followed by cow milk at 0.21±0.19 volt and goat milk with the lowest value of 0.13±0.01 volt.

The specific gravity of milk can provide valuable information about its composition and can be used to detect any potential adulteration or dilution. All three types of milk show similar specific gravity values, with no significant differences observed.

DISCUSSION

Milk fat: Milk fat is a valuable constituent because milk pricing policy also depends on the fat content in milk. Hence, it is the most valuable component of milk from an economic point of view. Earlier researchers confirmed that fat content in milk is directly affected by species, breed, season, feed, etc (Walstra, 1999). It can be observed from Table 1 that raw goat possessed significantly lower ($P<0.05$) fat content than other milk samples. Sabahelkhier *et al.* (2012) reported that the average lipid content in goat, cow and buffalo milk was 3.90%, 3.75% and 7.70%, respectively. Mishra *et al.* (2022) observed mean value of fat as 3.87%, 4.59% and 7.50% in goat, cow and buffalo, respectively. Our study showed the average lower percent fat obtained in milk of goat than earlier worker.

Solid-not-fat (SNF%): The SNF is milk solids that do not include fat. These solids are often known as "serum solids." The SNF is mostly made up of proteins, lactose and minerals. The SNF fraction of milk is incredibly important nutritionally since it includes protein, lactose, critical vitamins and minerals, and it is also crucial for milk processing and handling. In the present study, it was observed that %SNF level was significantly ($P<0.05$) higher in cow and buffalo milk compared to goat milk. The SNF was found to be 8.9% in goat milk and 9.0% in cow milk (Anamika *et al.*, 2021). Mishra *et al.* (2022) observed the average value of SNF as 7.01%, 7.61% and 8.58% in goat, cow and buffalo, respectively. The SNF content in goat milk was 4.48 percent examined by Ashwini *et al.* (2017). Kapadiya *et al.* (2016) studied the comprehensive composition of unprocessed goat milk, cow milk and buffalo milk from the Anand region of Gujarat and reported the average SNF content was 8.57%, 8.54% and 9.48%, respectively.

Total solid (TS%): TS refers to the combined amount of SNF and lipid in milk. The average TS contents in the milk of different types of goats varied from 12.00 to 13.73 percent (Mahmood and Usman, 2010). In our analysis, TS level was significantly ($P<0.05$) higher both in cow and buffalo milk in comparison to goat milk. The research carried out by Kapadiya *et al.* (2016) revealed average TS values of 12.76%, 13.79% and 18.45% for goat, cow and buffalo, respectively. Mishra *et al.* (2022) reported that the average TS content in goat, cow and buffalo milk was 13.25%, 13.05% and 17.52%, respectively.

Protein: Protein is made up of L-α amino acids, linked to each other by amide linkage or peptide bond. Milk is the natural secretion for young mammals and contains two major proteins: casein and whey protein. A compositional difference has been observed between different species, and the largest variation has been observed in protein in individual species (Kazimierska and Kalinowska, 2021). The level of protein was found to be significantly ($P<0.05$) lower in case of goat milk than milk of cow as well as buffalo. The average protein percentage was found to be 3.17% in cow (Dora *et al.*, 2020). The protein present in cow's milk was reported by Rao and Ramamurthy (1973) to be 3.4 percent. The research carried out by Mishra *et al.* (2022) revealed average protein values of 3.02%, 3.44% and 4.46% for goat, cow and buffalo, respectively. In general, the protein content of milk tends to exhibit a positive correlation with the percentage of fat present (Mathur *et al.*, 2005).

Lactose: The reducing sugar, i.e. lactose, is found in milk. It is composed of two monosaccharide (glucose and galactose) unit joint through O-glycosidic linkage. It was seen from Table 1 that overall lactose in goat milk was significantly ($P<0.05$) lower than milk of cow and buffalo milk. Singh and Sengar (1990) observed that the percent lactose in different breeds of goat varied from 4.28% to 4.40%. Kapadiya *et al.* (2016) studied the composition of goat milk, cow milk and buffalo milk from the Anand region of Gujarat and reported the average lactose content was 4.16%, 4.76% and 4.86%, respectively. Average lactose values were documented as 4.09%, 4.88% and 5.02% for goat, cow and buffalo, respectively, according to a study by Mishra *et al.* (2022). The observed variation in lactose content could potentially be attributed to differences in breed, feeding practices and environmental conditions (Pandya and Ghodke, 2007; Ahmad *et al.*, 2008).

Ash content: Elements like sodium, potassium, calcium, magnesium phosphates, citrates, chlorides, sulphates, carbonates, and bicarbonates are the key constituents of the milk salts system. Due to the loss of sodium, potassium, and citrate during ashing, the ash content of milk does not provide a precise reflection of the salt system in milk (Fox and Mcsweeney, 2015). In the present study, it was observed that there was a non-significant ($P>0.05$) amount of ash content examined in all the milk samples. The average ash content was higher in buffalo milk, followed by cow and goat milk. The ash content of bovine milk is relatively constant at 0.7-0.8 percent (Fox and McSweeney, 2015). The total amount of minerals present in goat milk varied from 0.70% to 0.85%, which is higher than milk from bovine (Anamika *et al.*, 2021). As per the study of Mishra *et al.* (2022), the overall ash content was observed to be lower in the case of cow milk (0.58) than in goat milk (0.77) and buffalo milk (0.83). The fluctuations in ash content, as noted, could stem from multiple factors such as breed, individual characteristics of animals, lactation stage, feed composition, udder infections, and seasonal variations (Fox and McSweeney, 2015).

Veith ratio: The composition of normal milk exhibits a well-defined correlation between its lactose, protein, and ash content. This ratio of these constituents, expressed in percentages, is commonly referred to as the "Veith ratio." In our study, this ratio was calculated as 11.7:9.8:2 for goat milk, 12.9:10.8:2 for cow milk, and 12.4:10.4:2 for buffalo milk. Specifically, for Indian cow milk, the Veith ratio was observed as 12.4:8.6:2. On the other hand, for buffalo milk, the corresponding Veith ratio was recorded as 12.4:9.7:2 (Mathur *et al.*, 2005).

Calorific values: The calculated or predicted average calorific value is dependent on the amount of fat, protein and lactose content present in milk samples. It can be seen from the table that the average calculated calorific value of goat milk is significantly ($P<0.05$) lower than cow milk and buffalo milk. In the investigation conducted by Anjaneyulu *et al.* (1985), the mean calorific values were identified as 72.0, 67.0 and117.0 for goat, cow and buffalo, respectively. The lower value of energy in goat milk is due to the presence of lower amount of fat, protein and lactose.

Freezing point (FP): Milk's freezing point is analyzed in significant part to determine how much water is present and to confirm that the milk has been adulterated with water (Zagorska and Ciprovica, 2013). According to Buchberger (2000), a variety of factors, such as breed, age, lactation stage, health condition, milk production, amount of feed and its quality, season, region, milking length, and others, have an impact on milk's freezing point. Lactose and salt content are major constituents affecting the FP of milk (Fox and McSweeney, 2015). In this study, it can be seen that the freezing point (FP) value of cow milk and buffalo milk was significantly ($P<0.05$) higher than that of goat milk, which indicates the lower level of soluble constituents like lactose and minerals present in goat milk. The FP milk obtained from goat ranged from -0.540 to -0.570°C reported by Park *et al.* (2007). Darshana (2014) reported the average FP of goat, cow, and buffalo milk was -0.501°C, -0.540°C and -0.558°C, respectively. The FP of milk obtained from cow varied from -0.497°C to -0.589°C (Sunil, 2014). Sunil (2014) found that the range of FP of buffalo milk was varied from -0.540°C to -0.616°C.

pH: pH is calculated using the negative logarithm of the [H+] in the system. In the present investigation, the pH of milk from buffalo was significantly ($P<0.05$) higher than that of goat and cow milk; however, a non-significant ($P>0.05$) value was obtained between goat milk and cow milk. The range of pH for cow milk was observed to vary from 6.49 to 6.91, with an average of 6.65 (Sunil, 2014). The pH obtained for buffalo milk ranged from 6.48 to 6.88 (average 6.68) (Sunil, 2014). Darshana (2014) reported pH of goat milk, cow milk and buffalo milk as 6.98, 6.67 and 6.70, respectively.

Electrical conductivity (EC): Milk may transmit electrical current because it includes a variety of ions, particularly chlorides. In this investigation, goat milk possessed significantly ($P<0.05$) higher EC than buffalo milk; however, the EC of cow milk was at par. It can be assumed that reason behind higher EC of goat milk due to lower amount of fat content which impedes the flow of electric current. The EC of milk from goat, cow and buffalo were 5.342, 4.68, and 4.96 millimho, correspondingly (Darshana, 2014). Aneja *et al.* (2002) reported EC of milk obtained from cow ranged from 4.0 to 5.5 millimho. Park *et al.* (2007) noted that the range of EC of milk obtained from cow varied from 4.0 to 5.0 millimho. The EC of buffalo milk fell between 2.93 and 3.57 millimho (Sunil, 2014).

Redox potential (Eh): A system's total reducing or oxidizing capability is described by its redox potential (expressed as mV) (Fox and McSweeney, 2015). The positive value of Eh shows the oxidizing properties and the negative value reveals reducing properties. Various factors, such as dissolved oxygen, ascorbic acid, riboflavin, lactose, cys-cys transformation, and pH value, have an impact on the redox potential (Mathur *et al*., 2005). It can be examined from Table 1 that Eh of buffalo milk is significantly higher ($P<0.05$) than other samples. The average Eh value of goat milk was lower than cow and buffalo milk. It was seen that as the fat content in milk rose, the Eh of milk also significantly increased (Pastushenko, 2000). Generally, it was observed that Eh varied from +0.20 to +0.30 volts in fresh milk due to dissolved oxygen (Mathur *et al*., 2005).

Specific gravity: The presence of constituents in milk directly determines its specific gravity. In this study, it was observed that the specific gravity of buffalo milk was higher, followed by goat milk and cow milk. However, there was a non-significance ($P>0.05$) difference observed in the average value. The specific gravity (Sp. gr.) of goat milk was observed to range from 1.025 to 1.029 (Bhosale, 2009). Wasiksiri *et al.* (2010) found a mean value of 1.030 for goat milk samples. According to Han *et al.* (2012), the average specific gravity value of buffalo milk was 1.0317-1.0380. In buffalo milk, Padghan *et al.* (2008) found a mean specific gravity of 1.031±0.001. Sindhu (1998) observed that buffalo milk has a greater specific gravity of 1.0323 at 20°C than cow milk, which has a specific gravity of 1.0317 at 20°C. In cow milk, Park *et al.* (2007) found that the specific gravity range varied from 1.0231 to 1.0398. Mahmood and Usman (2010) examined the specific gravity of goat, cow, and buffalo milk were 1.030, 1.029, and 1.033, respectively.

PCA (Principal component analysis) output: The eigenanalysis of the correlation matrix was summarized in Table 2, whereas Fig. 1 and Fig. 2 offered graphical depictions of the score and loading plot within the context of PCA.

Table 2. Eigen analysis of the Correlation Matrix

Eigenvalue	7.56	2.03	0.95	0.73	0.28	0.20	0.13	0.05	0.02	0.00
Proportion	0.631	0.170	0.079	0.061	0.024	0.017	0.011	0.005	0.002	0.000
Cumulative	0.631	0.801	0.880	0.941	0.965	0.982	0.993	0.998	1.000	1.000

Variable	**PC1**	**PC2**
Fat	0.336	-0.206
SNF	0.319	0.234
TS	0.355	-0.084
Protein	0.309	0.323
Lactose	0.316	0.290
FPD	0.328	0.155
Ash	0.212	0.312
pH	0.256	-0.320
Conductivity (mS)	-0.227	0.386
Eh (mV)	0.266	-0.157
Calorific value	0.347	-0.147
Sp.gr.	-0.040	0.538

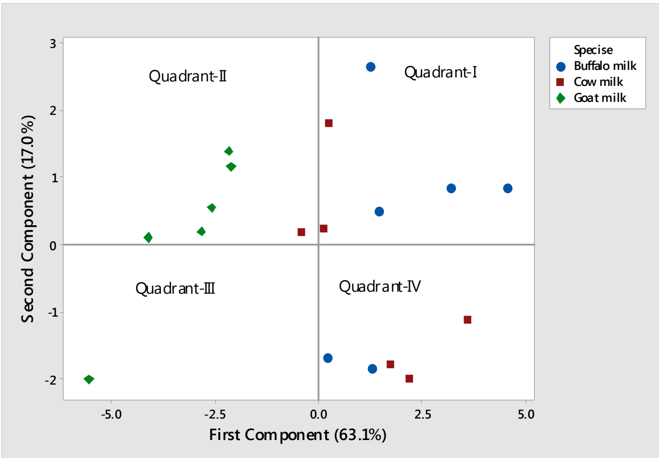

Fig. 1. Represents the score plot in PCA

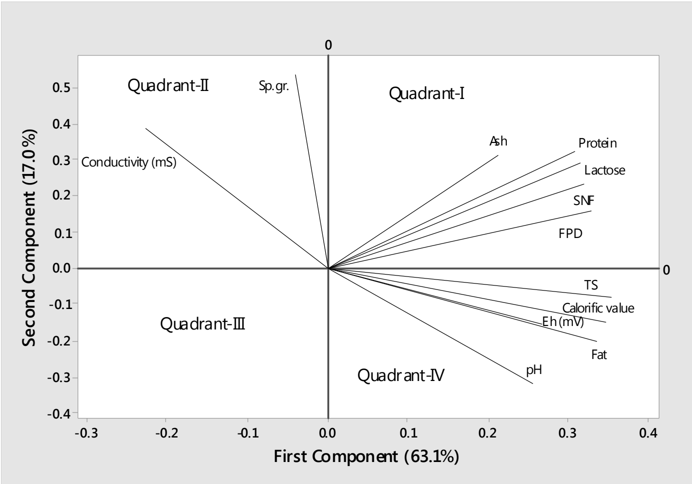

Fig. 2. Represents the loading plot in PCA

Based on the PCA, we can observe that PC1 explains the majority of the total variance (63.1%) and is influenced by various variables related to the composition of the milk being analyzed (e.g., fat, protein, lactose, etc.). PC2 explains the second-largest portion of variance (17%) and seems to be related to other aspects of the substance's properties (e.g., conductivity, pH, ash etc.). The score plot (Fig. 1) clearly demonstrates that the goat milk sample occupies quadrant-II, whereas cow milk and buffalo milk are distributed in quadrant-I and IV, respectively. This positioning indicates that goat milk can be easily distinguished from cow and buffalo milk based on their constituents and other properties. Upon reviewing the loading plot (Fig. 2), it's clear that certain analyzed factors such as % TS, calorific value, and % fat (Quadrant IV) demonstrated a positive correlation among them. Conversely, when considering other milk properties, both the Eh and pH exhibited a negative correlation with conductivity. Furthermore, the analysis revealed that as the percentage of fat increased across all samples, there was a simultaneous increase in Eh. In Quadrant II of the loading plot (Fig. 2), there's a clear indication of a direct correlation among lactose, % ash, % protein, % SNF, and freezing point depression (FPD).

From the above analysis, it can be seen that the overall value obtained for constituent (fat, SNF, protein, lactose, ash) and other properties of goat milk (pH, Eh, FPD) were lower than cow milk and buffalo milk. The EC of goat milk was higher, followed by cow milk and buffalo milk. This investigation's outcomes clearly indicate that both cow and buffalo milk excels as a valuable sources of macronutrients, displaying substantially higher levels of fat, protein, lactose, and minerals in comparison to goat milk. The experiment revealed that the average data obtained for most constituents and properties of raw milk samples were mostly consistent with the work carried out by other researchers. The results of PCA provide insights into both the percentage variance and the interrelationships among milk constituents and other properties. Notably, goat milk can be readily distinguished based on its unique composition. The loading plot (Fig. 2) revealed interesting correlations within milk properties. Quadrant IV showcased a positive relationship among % TS, calorific value, and % fat, while distinct negative correlations emerged between Eh, pH, and conductivity. Remarkably, as fat percentage increased, Eh showed a consistent rise. Additionally, Quadrant II highlighted a direct correlation among lactose, % ash, % protein, % SNF, and Freezing point depression (FPD), offering valuable insights into these interconnected elements within milk constituents.

Conflict of interest: The author declares no conflicts of interest pertaining to this research study.

Author's contribution: ASH: Tested the milk samples, wrote the first version of the article, performed chemical analysis of milk, meticulously collected and organized the data, and played a pivotal role in crafting the original draft of the article; TH: Provided invaluable expertise in designing the research plan, offered continuous guidance throughout the study, and conducted the final editing to ensure the article's quality; AJT: Conducted thorough statistical analysis, curated the data with precision, and contributed significantly to the data-related aspects of the research; KKA: Played a key role in interpreting the data for the article, evaluated the entire study comprehensively, and contributed to the overall quality of the research.

Data availability statement: All the data supporting the research findings have been presented in this paper. The corresponding author is willing to provide the raw data upon reasonable request.

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