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Research Article

Quality and Consumer Acceptability of Cottage Cheese Prepared from the Blend of Cow and Goat Milk

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Abstract | This research delves into studying how mixing cow and goat milk affects the physical, chemical, microbiological and taste aspects of cottage cheese. Different concentrations (%) of cow and goat milk were mixed such as (CG1 (100:0) served as control, CG2 (90:10), CG3 (80:20), CG4 (70:30), CG5 (60:40), CG6 (50:50) and CG7 (0:100)) to prepare milk blends. The analysis of physical and chemical properties showed notable differences in composition among the milk blends, with goat milk has higher fat content (4±0.003%) while cow milk has more lactose (4.6±0.1%). The pasteurized milk was gently heated followed by addition of addition of acid coagulant. After setting whey was separated and the cottage cheese was stored at 5±1°C. The time for coagulation and cheese yield varied based on the blend composition, with goat milk speeding up coagulation (19.69±1.2 sec) but reducing cheese yield (20.75±1.6%). During storage, the protein and fat content of cottage cheese varied significantly across blends; higher goat milk content resulted in lower protein (15.13±0.3%) and higher fat levels (23.6±0.3%). Microbial analysis indicated that goat milk and blends with higher concentrations of it exhibited more microbial growth compared to cow milk (7.46±0.01 log CFU g^{-1} and 7.14±0.06 log CFU g^{-1} respectively). However, blends with up to 30% goat milk had minimal impact on microbial growth. Sensory evaluation highlighted that blends containing 20-30% goat milk were most favored by judges as they were similar to cow milk cheeses in terms of color, aroma, flavor and texture (8.97, 8.89, 8.44, and 7.48 respectively). Mixing 20-30% goat milk with 70-80% cow milk results in a cottage cheese blend that is balanced in terms of nutrition and aligns with consumer preferences. However, it is important to note that the applicability of these findings may vary based on regional sensory preferences, highlighting the need for additional research involving diverse populations. This research offers valuable information for dairy companies looking to expand their range of cheeses prepared from different species like cow and goat while ensuring both quality and consumer satisfaction.

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Introduction

Cottage cheese is a versatile and nutrient-dense dairy product that holds great importance in our diet. Not only has a rich source of protein, but it also provided essential vitamins and minerals necessary for maintaining a healthy body (Abdul-Hakim *et al*, 2023). Generally, cottage cheese comprises moisture, fat, protein, lactose and minerals (55-70%, 22-27%, 17-18%, 2.0-2.5%, 1.5- 2.0%, respectively). Furthermore, cottage cheese contains biologically active amino acids, peptides, and lactic acid bacteria that have probiotic benefits. These probiotic bacteria promote gut health, aid in digestion, and boost the immune system (Linares *et al*., 2017; Ho *et al*., 2016). Additionally, cottage cheese has a unique texture and flavor that contributes to the overall quality of this dairy food. Therefore, incorporating cottage cheese into our diet can provide numerous health benefits and contribute to a well-balanced and nutritious eating plan (Linares *et al*., 2017).

In 2020, the global production of cottage cheese reached approximately 2.89 million metric tons, with the United States being the largest producer. The revenue generated annually from cottage cheese sales worldwide amounted to around $4.5 billion (Setyawardani *et al*., 2023). In Pakistan, cottage cheese production has been steadily increasing, reaching an estimated 150,000 metric tons in 2020. The annual revenue generated from cottage cheese sales in Pakistan is approximately $120 million. These statistics highlight the significant role of cottage cheese in both the global and Pakistani dairy industries, showcasing its popularity and economic significance in the market (Hayat and Meena, 2023).

Cow milk is mostly utilized for the production of cottage cheese due to its suitable chemical composition yielding cheese of soft uniform consistency (Chakraborty *et al*., 2021). Cow milk is low in fat, high in protein and lactose (Rasheed *et al*., 2016; Boikhutso, 2010). The chemical composition of goat milk which is rarely used in cheese production refers to the specific makeup and concentration of various substances present in the milk (Noël *et al*., 2008). These substances include proteins, fats, carbohydrates, vitamins, minerals, and other compounds. Goat milk typically contains a higher proportion of certain compounds compared to cow milk, such as smaller fat globules (Clark and Gracia, 2017), a higher concentration of short- and medium-chain fatty acids, and higher levels of vitamins A and D. It also has a higher concentration of certain minerals like calcium, phosphorus, potassium, and magnesium compared to cow milk (Dunshea *et al*., 2019).

Mixing cow and goat milk for cottage cheese production offers numerous benefits that enhance the taste, texture, and nutritional value of the final product (Prazeres *et al*., 2012). However, among milk from different species, cow milk is mostly used for consumption and dairy product manufacturing (Kodrik *et al*., 2011). Cow milk has a mild, creamy taste, while goat milk has a slightly tangy and more robust flavor (Sharmila *et al*., 2018; Moatsou and Park, 2017). By mixing these two milks, the resulting cottage cheese will have a balanced and complex taste that appeals to a wide range of palates (Gallardo-Escamilla *et al*., 2005). Additionally, mixing cow and goat milk for cottage cheese production can improve the texture of the cheese. Goat milk has smaller fat globules compared to cow milk, which can result in a smoother and creamier texture (Clark and Gracia, 2017; Prazeres *et al*., 2012).

Physicochemical properties play a crucial role in determining the sensory characteristics of cottage cheese (Gallardo-Escamilla *et al*., 2005). For example, the moisture content of cottage cheese can affect its texture, with higher moisture levels resulting in a softer and creamier texture (Kindstedt, 2014). Additionally, the pH level of cottage cheese can impact its flavor, as a higher pH can lead to a more acidic and tangy taste. Furthermore, the presence of specific chemical compounds in cottage cheese, such as volatile organic compounds, can contribute to its aroma (Štefániková *et al*., 2020). These physicochemical properties interact with each other and with the various components of cottage cheese, such as proteins, lipids, and carbohydrates, to create the overall sensory experience of cottage cheese. Moreover, microbial analyses play a vital role in cottage cheese production, as they help ensure product safety, extend shelf life, and maintain desirable sensory characteristics (Ali *et al*., 2022).

Keeping in view the need to combine cow and goat milk, current study is conducted (1) to identify a formulation of cow and goat milk blends for producing cottage cheese that meets the acceptance standards of consumers who are accustomed to cottage cheese made solely from cow milk. (2) to determine different concentration of cow and goat milk on coagulation time and yield percentage of cottage cheese, (3) to measure physicochemical properties and microbial growth during shelf-life of cottage cheese, and (4) to evaluate sensory characteristics and consumer acceptance of cottage cheese produced from different concentration of cow and goat milk.

Materials and Methods

Milk collection and cheese preparation

Whole cow and goat milk were obtained from the dairy farm of the University of Agriculture, Peshawar and brought to the laboratory of Food Science and Technology and the milk was then pasteurized at 85±1°C for 19±1 sec. The pasteurized milk was cooled to 32°C and different concentrations of cow and goat milk were combined to obtain the following concentration: CG1 (100:0) served as control, CG2 (90:10), CG3 (80:20), CG4 (70:30), CG5 (60:40), CG6 (50:50) and CG7 (0:100). After preparing different concentrations of cow and goat milk, samples were taken to determine composition of the milk using Lactoscan (Milkotronic, Bulgaria) followed by addition of 2% starter culture of mesophilic bacteria (Raleigh, North Carolina, USA). Acid coagulant (vinegar) was added with constant and gentle stirring. After coagulation, the curd was allowed to settle for 5 min and whey was removed using clean muslin cloth. The curd was pressed (0.025 MPa) for 20 min at 23±1°C to obtained cottage cheese. The cheese so obtained was divided into cubes of 5.8 X 5.8 X 2 cm and stored in polythene bags at 5±1°C for 15 days. The samples were analyzed for physicochemical, microbiological and organoleptic characteristics at 0, 5,10, and 15 days intervals.

Physicochemical analyses

Coagulation time: Coagulation time is defined as the interval between addition of coagulant and appearance of curd and is measured in second (Derra *et al*., 2018).

Percent yield: To calculate percent yield of the cottage cheese, the following formula was used as specified by Darwish *et al*. (2024).

$$Percent\ Yield = \frac{weight\ of\ cheese}{weight\ of\ milk} \times 100$$

Chemical analyses

The chemical composition of cottage cheese (protein, fat, ash, moisture, and acidity) was determined based on the standardized procedures of the AOAC (2005). To determine pH value of the homogenized cottage cheese samples, a digital pH meter (HANS-12, Hanna Instruments, USA) was used (Barukčić *et al*., 2020).

Microbiological analyses

Microbiological quality of cottage cheese during the storage period of 15 days at 5±1°C was determined in terms of (a) viable cell counts of aerobic bacteria (ISO, 2013), (b) Enterobacteriaceae (ISO, 2004) and (c) yeast and molds (ISO, 2008).

Sensory analyses

Sensory analyses of the cottage cheese were carried out in terms of color, aroma, taste, texture, and overall acceptability. The analyses were done by 30 panelists (15 females and 15 males) from the faculty of nutrition sciences, the University of Agriculture, Peshawar, who already consume cottage cheese as part of their diet. Moreover, all the panelists were trained on organoleptic characteristics of cottage cheese made from cow milk available in the local market. The age of the judges ranged from 25 to 50 years. The samples of cottage cheese (20 g) were placed in coded disposable plastic cups and served to the panelist at room temperature along with water to rinse mouth during the analyses. The judges gave score according to 9-point hedonic scale where 9 is very like and 1 is very dislike (Darwish *et al*., 2024).

Statistical analyses

The collected data was analyzed through one-way ANOVA using Statistix 10 (Analytical Software 2105 Miller Landing Rd Tallahassee, USA) statistical software. The means were compared using LSD at a significance level of P≤0.05. All the experiments were performed three times and the results were expressed as mean ± SD.

Results and Discussion

Composition of blended milk

After blending cow and goat milk in various concentrations, composition of the blended milk was determined in regard of TSS, acidity, fat, lactose, moisture, protein and ash content as shown in Table 1. All of the concentrations exhibited a significant difference (*P≤0.05*) in TSS content, with the highest TSS observed in CG1 (13±0.7%) and the lowest in

CG7 (12.03±0.4%). The first four blends from CG1 to CG4 and the last three blends from CG5 to CG7 exhibited a nonsignificant variation in acidity and protein content. Nevertheless, there was a significant variation in acidity and protein content between the mentioned groups. Likewise, no significant variation was observed in the fat content of the first six blends from CG1 to CG6, but CG7 exhibited higher fat content (4±0.03%), significantly higher than the mentioned six milk blends. As opposed to acidity and fat content, a significant variation was noticed in the lactose content of all the seven blends, with the highest lactose content observed in CG7 (4.35±0.03%) and the lowest in CG1 (4±0.1%). Both the moisture and ash content of CG7 were significantly higher than the first five blends from CG1 to CG5, however, there was no significant variation observed between CG7 and CG6.

Table 1: *Compositional parameters of cottage cheese (TSS (%), Acidity (%), Fat (%), Lactose (%), Moisture (%), Protein (%), and Ash (%)) determined for blends of cow and goat milk at varying concentrations: CG1 (100:0), CG2 (90:10), CG3 (80:20), CG4 (70:30), CG5 (60:40), CG6 (50:50), and CG7 (0:100).*

Milk Blends	TSS (%)	Acidity (%)	Fat (%)	Lactose (%)	Moisture (%)	Protein (%)	Ash (%)
CG1 (100:00)	13.66±0.7 a	0.17±0.01 b	3.87±0.07 b	4.6±0.1 a	87.0±2.2 b	3.37±0.04 a	0.70±0.008 b
CG2 (90:10)	12.90±0.2 b	0.17±0.01 b	3.83±0.03 b	4.57±0.08 b	87.3±2.1 b	3.35±0.03 a	0.7±0.01 b
CG3 (80:20)	12.43±0.5 c	0.17±0.04 b	3.84±0.03 b	4.51±0.03 c	87.0±3.2 b	3.33±0.07 a	0.7±0.03 b
CG4 (70:30)	12.17±0.1 d	0.17±0.01 b	3.83±0.06 b	4.47±0.09 d	87.3±4.8 b	3.33±0.02 a	0.7±0.006 b
CG5 (60:40)	12.23±0.09 e	0.18±0.03 a	3.85±0.04 b	4.40±0.11 e	87.2±2.5 b	3.2±0.04 b	0.73±0.02 b
CG6 (50:50)	12.50±0.3 f	0.18±0.02 a	3.87±0.06 b	4.38±0.07 f	87.4±3.4 ab	3.2±0.03 b	0.75±0.03 ab
CG7 (00:100)	12.03±0.4 g	0.18±0.03 a	4±0.03 a	4.35±0.03 g	88.0±2.6 a	3.2±0.01 b	0.8±0.01 a

The significant variation in TSS amongst different milk blends (CG1 to CG7) elucidates the effect of milk composition on this key variable. The maximum TSS content in CG1 and minimum in CG7 specifies that the amount of cow and goat milk in the blend plays an indispensable role in controlling the overall solubility of solids due to difference in moisture content (Boikhutso, 2010). Cow milk has a higher TSS content as compared to goat milk owing to differences in protein and lactose concentrations (Collard and McCormick, 2021). Consequently, a blend with a greater proportion of cow milk, such as CG1, will naturally show high level of TSS (Turkmen, 2017). These results are aligned with existing literature on the composition of milk and TSS content, which indicate that rise in moisture content leads to lowered TSS in the milk (Collard and McCormick, 2021; Clark and García, 2017). The nonsignificant variation in acidity and protein content among CG1 to CG4 and CG5 to CG7 propose a negligible difference exist in acidity and protein content of cow and goat milk which is also apparent from previous studies of (Chen *et al*., 2022; Roy *et al*., 2020; Mahmood and Sumaira, 2010). While CG1 to CG6 maintain relatively constant fat levels, CG7 shows a remarkable deviation, suggesting a possible tipping point in fat composition (Clark and García, 2017). Factors such as lipid compatibility, triglyceride composition, and fatty acid profiles, species, breed, animal diet, geographical area, and milking time may affect the observed variation in fat content across different milks (Akshit *et al*., 2024; dos Santos *et al*., 2023; Filipczak-Fiutak *et al*., 2021; Boikhutso, 2010). In addition, some studies have proposed an inverse relation between fat and protein content where increase in the fat content leads to decrease in the protein content of the milk (Van Boekel, 1994). The significant differences in lactose content across all seven blends indicate the visible carbohydrate composition of cow and goat milk and their effects in blended formulations (Álvarez-Rosales *et al*., 2019). Lactose, which is the primary carbohydrate in milk, directly affects nutritional characteristics, sweetness, TSS and solubility (Hettinga, 2019). The higher TSS content in CG1 compared to CG7 shows higher lactose in cow milk, which is consistent with previous results (Collard and McCormick, 2021; Clark and García, 2017). Lactose is not given much importance during cheese manufacturing as it is generally degraded to lactic acid, however, in cottage cheese some amount of lactose remained as these are often referred to as fresh (Boikhutso, 2010). Significant variations in moisture and ash content between CG7 and CG1 to CG5 indicate differences in water and mineral content resulting from different blend compositions. The lower TSS and lactose content in goat milk followed (Table 1) by lower protein clearly indicate highest moisture and ash content in CG7 (Roy *et al*., 2020). These results are aligned with previous studies conducted on cow and goat milk composition (Álvarez-Rosales *et al*., 2019; Clark and García, 2017). These differences may affect product nutritional value, texture, and flavor (Guetouache *et al*., 2014), necessitating careful consideration during product development and quality control processes.

Coagulation time and cheese yield

The coagulation time and percent yield of cottage cheese made from blend of cow and goat milk in different concentration varies depending on the amount of milk used (Table 2). It is clear from the results that the coagulation time for cow milk (29.28±1.4 sec) is significantly higher as compared to other blended milk and goat milk (19.69±1.2 sec). As the amount of goat milk is increased, the coagulation time tends to decrease. Additionally, cheese made from cow and goat milk in different concentrations showed higher coagulation time compared to goat milk alone. Likewise, the percent cheese yield for cow milk (27.10±1.9%) is also higher than that for cheese made from goat milk (20.75±1.6%). The percent cheese yield tends to reduce with increasing concentration of goat milk from CG2 to CG6, as shown in Table 2.

Table 2: *Coagulation time (sec) and Cheese yield (%) for cottage cheese made from blends of cow and goat milk at varying concentrations: CG1 (100:0), CG2 (90:10), CG3 (80:20), CG4 (70:30), CG5 (60:40), CG6 (50:50), and CG7 (0:100).*

Milk Blends	Coagulation Time (Sec)	Percent Yield
CG1 (100:00)	29.28±1.4 a	27.10±1.9 a
CG2 (90:10)	26.91±1.1 b	25.47±0.8 b
CG3 (80:20)	25.07±1.3 c	23.11±1.6 c
CG4 (70:30)	23.38±1.3 d	22.15±1.8 d
CG5 (60:40)	23.39±1.5 e	21.67±1.5 e
CG6 (50:50)	21.91±1.1 f	20.97±1.2 f
CG7 (00:100)	19.69±1.2 g	20.75±1.6 g

The findings of this study on the coagulation time and percentage yield of cottage cheese made from various blends of cow and goat milk provide important insight into the effect of milk concentration on cheesemaking parameters. The increase in coagulation time of cow milk compared to goat milk shows that there are inherent differences in the composition or characteristics of the two types of milk from two different species, (Table 1) that affect the coagulation process (Vacca *et al*., 2020; Puledda *et al*., 2017; Sadia *et al*., 2015). The longer coagulation time of cow milk can be ascribed to factors such as higher concentrations of certain proteins, casein micelle structure (Clark and Sherbon, 2000), differences in the size and composition of fat globules (Troch *et al*., 2017; Fekadu *et al*., 2005). As the concentration of goat milk is increased in the blend, the coagulation time tends to reduce. This trend shows that goat milk with higher fat content facilitates faster coagulation than cow milk (Clark and Sherbon, 2000). It can be inferred that the presence of certain enzymes or proteins in goat milk enhances the coagulation process, leading to faster formation of curd (Stocco *et al*., 2018). Cheese made from blended milk shows higher coagulation time compared to goat milk alone indicates that the addition of cow milk may introduce factors that interfere with or slow down the coagulation process such as decrease in calcium ion and increase in size of casein micelle (Park *et al*., 2007; George and Ace, 1984). This could be due to the dilution of certain coagulation-promoting components present in goat milk or the presence of inhibitory substances in cow milk (Park, 1994). Similarly, the higher percentage yield of cheese from cow milk than goat milk indicates the difference in the cheese-making potential of these two types of milk (Vacca *et al*., 2020). Cow milk contains a higher proportion of large fat globules that contribute to curd formation and retention, leading to a higher cheese yield per unit volume of milk (Fekadu *et al*., 2005). The decrease in percent cheese yield with increasing amount of goat milk in the mixture further proposes that goat milk may not be as effective in producing cheese as compared to cow milk. This is attributed lower total solids and protein content of goat milk, which may result in reduced curd formation or reduced curd retention during cheesemaking (Sadia *et al*., 2015).

Composition of cottage cheese

The protein content of cow and goat milk blend cottage cheese varies significantly depending on the amount of each milk type. Throughout the storage period of 15 days, cheese made from cow milk showed a higher protein content compared to goat milk (Figure 1A). Moreover, with an increase in the concentration of goat milk, the protein content tends to decrease; however, the variation remained statistically no significant for CG1, CG2, CG3, CG4, and CG5. Increasing the concentration of goat milk above 40% significantly reduces protein content. This trend was noticed in all intervals during the storage period. Likewise, the fat content of the cottage cheese also varied during the 15-day storage duration (Figure 1B). Cottage cheese with higher concentration of goat milk tended to have lower fat content as compared to higher concentration of cow milk. Initially, CG1 and CG2 showed significantly higher fat content and maintained this trend throughout the storage duration. In contrast to protein and fat content, ash content reduced with an increasing concentration of cow milk (Figure 1C). Goat milk alone showed significantly higher ash content compared to cow milk and other blends. Nonetheless, blending cow and goat milk exhibited a slight impact on ash content during the storage duration. Likewise, moisture content also showed a decreasing trend with an increase in the concentration of cow milk (Figure 1D). Cow milk alone showed significantly lower moisture content compared to goat milk. Titratable acidity and pH of the cottage cheese samples during the storage period of 15 days is represented in Figure 2A, B. On day 1, lowest TA and highest pH values were observed for CG1 followed by CG2 and consecutive samples, while highest TA and lowest pH values were observed in CG7. Throughout storage period this trend continues in all samples till day 15.

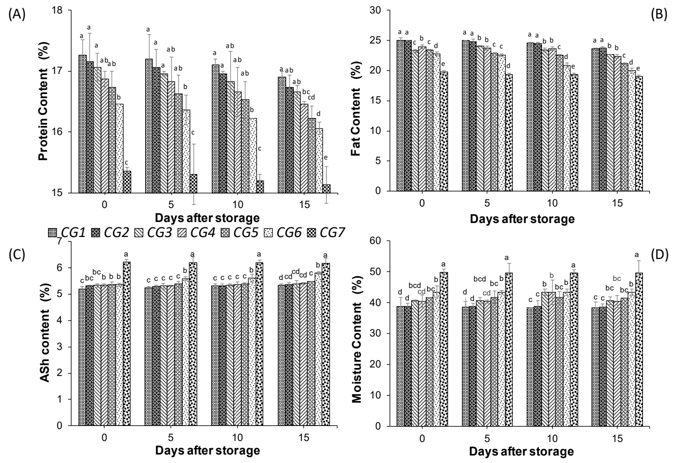

Figure 1: *Effect of cow and goat milk blend in different concentrations CG1 (100:0), CG2 (90:10), CG3 (80:20), CG4 (70:30), CG5 (60:40), CG6 (50:50), CG7 (0:100) on (A) Protein content, (B) Fat content, (C) Ash content, and (D) Moisture content of cottage cheese during 15 days storage at 5±1°C. Vertical bars represent standard error of means for three replicates. Different letters show significant difference among mean values using LSD at (P ≤ 0.05).*

The results of this study elucidate the compositional changes in cheese using different proportions of cow and goat milk mixtures during a 15-day storage period. This study observed changes in protein, fat, ash, and moisture content, providing useful insight into the effects of milk type concentration on the quality and nutritional properties of cottage cheese (Figure 1). One of the key findings was the notable effect of milk type concentration on the protein content of cottage cheese (Abd El-Gawad and Ahmed, 2011). Cheese made from cow milk consistently presents higher protein content than goat milk. This finding is consistentwith previous research showing that cow milk generally has a higher protein content

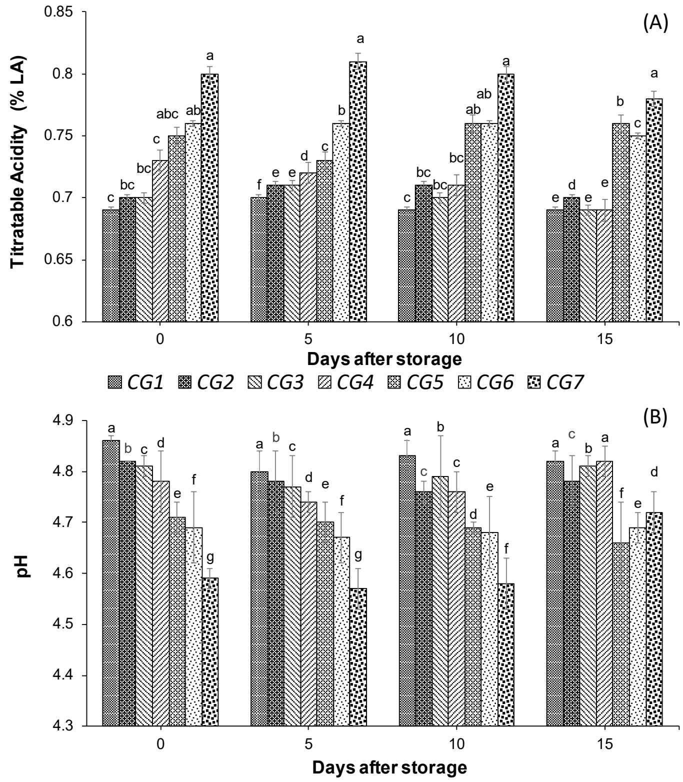

Figure 2: *Effect of cow and goat milk blend in different concentrations CG1 (100:0), CG2 (90:10), CG3 (80:20), CG4 (70:30), CG5 (60:40), CG6 (50:50), CG7 (0:100) on (A) Acidity and (B) pH of cottage cheese during 15 days storage at 5±1°C. Vertical bars represent standard error of means for three replicates. Different letters show significant difference among mean values using LSD at (P ≤ 0.05).*

than goat milk (Ali *et al*., 2021; Sadia *et al*., 2015). However, as the concentration of goat milk increased, there was a tendency for protein content to decrease (Sadia *et al*., 2015), although this decrease was not statistically significant for some proportions of cow and goat milk blends (Table 1). In particular, a significant decrease in protein content was observed when goat milk content exceeded 40%. This decrease in protein content can be attributed to many of factors, including differences in the protein composition of cow and goat milk (Mahmood and Sumaira, 2010), as well as possible interactions between proteins during cheese formation and storage (Guinee, 2016). Similarly, the fat content of cottage cheese varies depending on the concentration of cow and goat milk blends (Clark and García, 2017). Cheese made with a higher concentration of goat milk have lower fat content than those with a higher concentration of cow milk (Sadia *et al*., 2015). Intriguingly, cottage cheese samples with low concentration of goat milk such as CG1 and CG2, initially showed significantly higher fat content and maintained this trend throughout the storage duration (Figure 1). This shows that the composition of the milk blend can affect the fat content of cottage cheese (Bland *et al*., 2015), which may have potential effects on organoleptic characteristics as well (Martin *et al*., 2016). This research also examined the ash content of cottage cheese, which represents the mineral content of milk (Manuelian *et al*., 2017). Goat milk alone has significantly higher ash content than cow milk, possibly due to differences in mineral composition between the two types of milk (Clark and García, 2017; Sadia *et al*., 2015). However, mixing of cow and goat milk showed minimal effect on ash content during the storage period. Nevertheless, it is noteworthy that the ash content decreased with increasing concentration of cow milk, indicating a weak effect on the mineral content of cheese (Boukria *et al*., 2020). The moisture content of cottage cheese showed a decreasing trend with increasing concentration of cow milk (Akshit *et al*., 2024). Cow milk alone has a significantly lower moisture content than goat milk, which is aligned with the higher total solids and protein content found in cow milk (Collard and McCormick, 2021; Roy *et al*., 2020; Álvarez-Rosales *et al*., 2019). This elucidates the importance of milk type selection in determining the moisture and overall texture of cottage cheese. Higher pH and lower acidity are prerequisite for paste stability, which can be made possible using thermophilic starter culture (Batty *et al*., 2019). In this study a significant difference was observed in pH and acidity based on the concentration of cow and goat milk in the blends. Earlier, Sadia *et al*. (2015) has reported higher pH and consequently lower acidity in cottage cheese made from cow milk. pH is generally believed to be the most important indicator of cheese quality during production and storage (Johnson, 2017; Razzaq, 2003). Previously, pH of cottage cheese has been reported in the range of 3.7-4.6, however, in our case maximum pH observed in cheese sample made from cow milk was 4.86 which reduced to 4.82 after 15 days of storage. This might be due to the type of coagulant used in cheese making (Yasar and Guzeler, 2011). Moreover, difference in ash content and acidity of milk also affect pH and TA of cheese (Sadia *et al*., 2015) reported that pH and acidity of the cheese is affected by the type of coagulant used and the source of milk (Birhanu *et al*., 2013). In addition to affecting coagulation, pH also affects organoleptic characteristics and microbial population of cottage cheese (Possas *et al*., 2021; Sadia *et al*., 2015). TA is considered as better predictor of taste and aroma than pH and varies depending on the type of cheese (Tyl and Sadler, 2017).

Microbial quality

As illustrated in Figure 3A, the total viable cell count ranged from 5.43 to 5.51 log CFU g^{-1}. Cheese made from cow milk and milk with a higher concentration of cow milk exhibited a lower total viable count; however, the differences were not statistically significant. From day 5 onwards, CG7 and CG6 showed significantly higher total viable counts, at 6.86 and 6.82 log CFU g^{-1}, respectively. On the last day of storage, the lowest viable count was observed in CG1, CG2, and CG3, at 7.14, 7.16, and 7.164 log CFU g^{-1} respectively. A similar trend was also observed for Enterobacteriaceae and yeasts and molds, as depicted in Figure 3B, C. Cheese made from cow milk and a higher concentration of cow milk showed lower levels of Enterobacteriaceae and yeasts and molds. Initially, on day 0, no Enterobacteriaceae and yeasts and molds were detected in any of the samples. However, from day 5 onwards, the growth of Enterobacteriaceae and yeasts and molds began, reaching 2.29 and 2.54 log CFU g^{-1} in CG1, significantly lower than the other six samples. CG2, CG3, and CG4 showed statistically similar results, significantly higher than CG5, CG6, and CG7 for Enterobacteriaceae. In contrast to Enterobacteriaceae, CG1, CG2, and CG3 showed similar results for yeasts and molds, lower than the other remaining samples. Overall, cheese made from goat milk and blends containing a higher concentration of goat milk showed more microbial growth compared to cow milk. However, mixing goat milk in concentrations up to 30% has little to no impact on microbial growth.

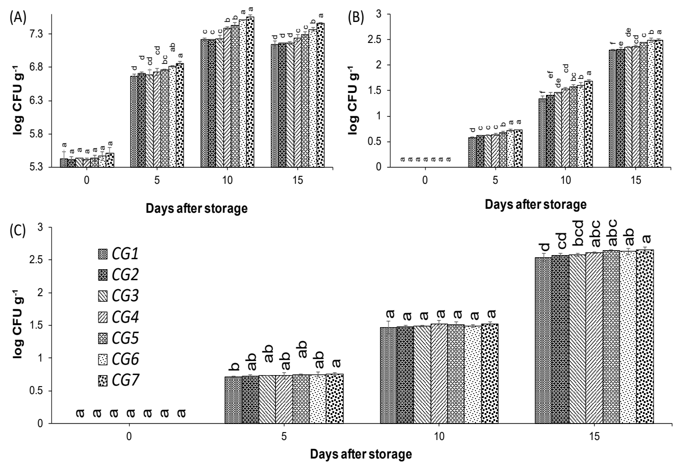

Figure 3: *Effect of cow and goat milk blend in different concentrations CG1 (100:0), CG2 (90:10), CG3 (80:20), CG4 (70:30), CG5 (60:40), CG6 (50:50), CG7 (0:100) on (A) Total viable cell count, (B) Enterobacteriaceae, and (C) Ash content Yeasts and Molds of cottage cheese during 15 days storage at 5±1°C. Vertical bars represent standard error of means for three replicates. Different letters show significant difference among mean values using LSD at ($P \leq 0.05$).*

The results presented in the microbial quality analysis of cottage cheese samples provide valuable insight into the impacts of milk type and concentration on microbial growth during storage. The total viable cell count is an important indicator of the microbial load in cheese and reflects the overall microbial population present (Barukčić *et al*., 2020). In current study, despite differences in milk type and concentration, variations in total viable count were not statistically significant (Auldist *et al*., 1996). This suggests that factors other than milk type and concentration may have influenced the microbial population, such as environmental conditions, processing methods, or starter cultures used during cheese production (Mayo *et al*., 2021). However, it is remarkable that at the end of the storage period, some samples exhibited significantly higher total viable counts which can be attributed to presence of lactic acid bacteria that are responsible for flavor development in cheese (Tadjine *et al*., 2020). Similar findings were also reported by Barukčić *et al*. (2020). This can be attributed to various factors, including the proliferation of certain microbial species under specific storage conditions or the presence of spoilage microorganisms (Hamad, 2012). The presence of Enterobacteriaceae and yeasts and molds in cheese samples is of particular concern because these microorganisms may indicate contamination or spoilage (Laslo and György, 2018; Papaioannou *et al*., 2007). The absence of these microorganisms in the initial samples suggests good hygienic practices during cheese production (Prates *et al*., 2017). However, their emergence during storage highlights the importance of proper handling and storage conditions to prevent microbial proliferation. Interestingly, cheeses made from cow milk and higher cow milk blends exhibit lower levels of Enterobacteriaceae and yeasts and molds than goat milk-based cheeses. This may be attributed to inherent differences in the chemical and microbial composition of cow and goat milk (Collard and McCormick, 2021; Quigley *et al*., 2013; Turkmen, 2017). Low microbial counts in cow milk-based cheeses may also be associated with the presence of natural antiseptic like microbiota, favorable pH and water activity, higher lactose, amino acids and peptides (Łepecka *et al*., 2022; Barukčić *et al*., 2020). Differences in microbial growth between different samples highlight the complex interactions between milk composition and the microbial environment in cheese (Mayo *et al*., 2021). Although addition of up to 30% goat milk had no significant effect on microbial growth, further investigation into the threshold effects of milk adulteration on microbial quality is needed (Figure 3). The microbial quality analysis of cheese samples revealed intricate relationships between milk type, concentration, and microbial growth during storage. While cow milk-based cheeses demonstrated lower microbial counts compared to goat milk-based cheeses (Tadjine *et al*., 2020), the addition of goat milk at moderate concentrations had minimal effects on microbial quality.

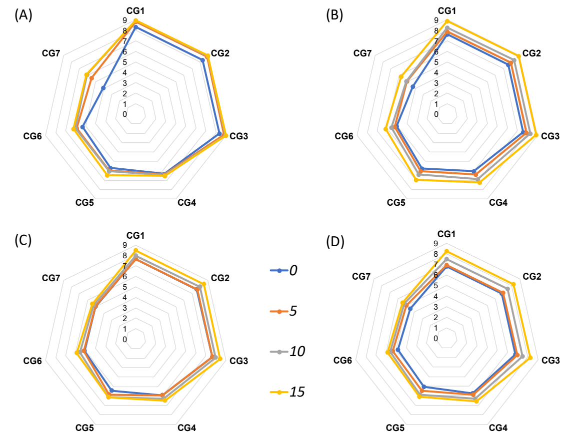

Figure 4: *Effect of cow and goat milk blend in different concentrations CG1 (100:0), CG2 (90:10), CG3 (80:20), CG4 (70:30), CG5 (60:40), CG6 (50:50), CG7 (0:100) on (A) Color, (B) Aroma, (C) Taste, and (D) Texture of cottage cheese during 15 days storage at 5±1°C.*

Organoleptic characteristics of cottage cheese

The results of organoleptic analyses are displayed in Figure 4. Initially, CG1, CG2, and CG3 received significantly higher scores of 8.33, 8.32, and 8.32, respectively, for color and maintained this trend throughout the storage period. As the storage period increased, the scores rose and reached 8.98, 8.99, and 8.97, respectively, on day 15. Overall, CG1, CG2, and CG3 were deemed more acceptable to the judges compared to cheese made from blends of cow and goat milk or goat milk alone. Similarly, to color, the score for aroma increased from day 0 to day 15 as the cheese ripened. However, in terms of aroma, the difference among CG1, CG2, and CG3 was slightly significant but still higher than CG4, CG5, CG6, and CG7. On day 10, CG1 received the highest score of 8.93, followed by CG2 (8.9) and CG3 (8.89). Cheese made from CG4, CG5, CG6, and CG7 received significantly lower scores compared to the former three samples. Likewise, in terms of taste and texture, CG1, CG2, and CG3 received more favorable results compared to other samples. When the overall acceptability of the cottage cheese samples was analyzed, CG1, CG2, and CG3 emerged as the most acceptable cheese samples, indicating that adding 20% goat milk to 80% cow milk remained acceptable, similar to cheese made from cow milk alone.

The organoleptic properties of food products play an important role in determining its overall quality and consumer acceptance (Ahmad *et al*., 2023). Figures 4, 5 show the results of the organoleptic analyses where color is one of the primary attributes influencing consumer perception of food products (Huang and Lu, 2015). In this study, cottage cheese samples prepared from blends CG1, CG2, and CG3 obtained significantly higher scores for color than the other samples. This can be attributed to the higher fat content in cow milk than goat milk (Clark and García, 2017; Sadia *et al*., 2015), This trend remained consistent throughout the storage period (Figure 4A), indicating that the addition of goat milk positively affected the color characteristics of the cheese due to its smaller sized fat globules (Park *et al*., 2017) which gives shiny surface to the cheese by scattering light (Chakraborty *et al*., 2021). Aroma is another important aspect of sensory evaluation, which contributes significantly to the overall dining experience (Ouyang *et al*., 2018). The results indicated that the aroma scores of the cottage cheese samples increased as the cheese ripened during the storage period. However, CG1, CG2, and CG3 consistently received higher aroma scores than samples made from goat milk alone. This might be due to higher proportion of fatty acids such as caproic, capric and caprylic which give tangy aroma to the cheese made from goat milk alone or blends containing higher concentration of goat milk (Park *et al*., 2017). Moreover, with increase in storage duration different reactions take place including lipolysis and proteolysis which also results in production of such compounds that affect aroma of the cheese (Park, 2001; Jin and Park, 1995). Similarly, the results showed that CG1, CG2, and CG3 consistently received more favorable scores for taste and texture than the other samples. This means that the addition of goat milk in concentration below 30% resulted in cottage cheese with superior flavor and texture characteristics, possibly due to the higher proportion of fat in goat milk (Clark and García, 2017) that which gives it characteristic tangy taste and smooth texture (Park *et al*., 2017). Higher lactose content in cow milk could also the reason for higher sensory score (Collard and McCormick, 2021). Higher protein content can also the reason for good texture as they form firmer protein network (Chakraborty *et al*., 2021). Overall acceptability serves as a composite measure that reflects consumers' overall perception of the product. The results show that addition of 20% goat milk to 80% cow milk maintains or improves the overall acceptability of cottage cheese (Figure 5), which is comparable to cheese made from cow milk alone that can be attributed to different composition of milk from two different species (Collard and McCormick, 2021; Roy *et al*., 2020; Clark and García, 2017). The results of this study show that adding goat milk to cottage cheese production can have a positive effect on its organoleptic properties, including color, aroma, flavor, texture, and overall acceptability.

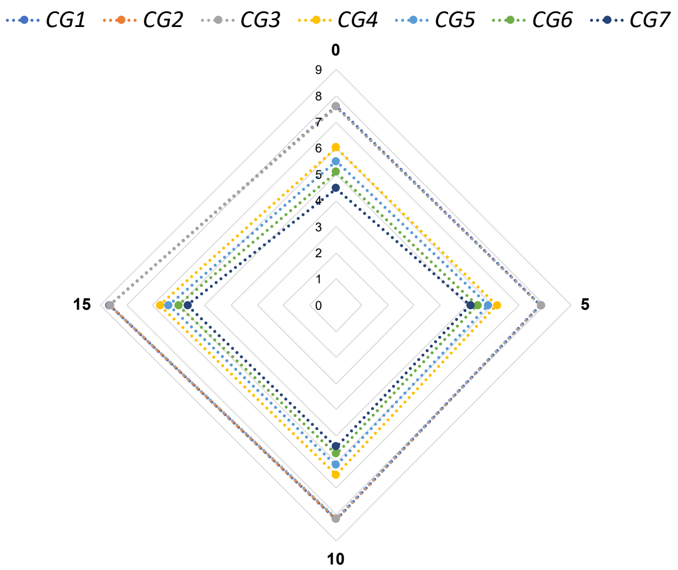

Figure 5: *Effect of cow and goat milk blend in different concentrations CG1 (100:0), CG2 (90:10), CG3 (80:20), CG4 (70:30), CG5 (60:40), CG6 (50:50), CG7 (0:100) on Overall Acceptability of cottage cheese during 15 days storage at 5±1°C.*

Conclusions and Recommendations

Blending 20 to 30% goat milk with 70 to 80% cow milk produces nutritionally balanced cottage cheese that meets consumer preferences who are accustomed to cottage cheese made solely from cow milk. This blend maintains quality characteristics and organoleptic experience similar to cow milk cheese. However, generalizability of the results beyond the study country (Pakistan) is limited due to possible regional variations in organoleptic preferences. Further research with diverse populations is needed to validate global applicability of these findings. In addition, it is recommended to conduct further studies analyzing various minerals, such as calcium, present in cottage cheese.

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This study has been carried out as the requirement for M.Sc. (Hons) degree of the first author. Artificial Intelligences (ChatGPT version 3.5) has been employed to correct grammatical mistakes and to enhance readability of the manuscript.

Novelty Statement

This study has not only assessed physicochemical and organoleptic characteristics of cottage cheese made from cow and goat milk in varying concentrations but also provide exact concentrations to prepare a cheese which utilizes both cow and goat milk with greater consumer acceptability. This is the novelty of this research.

Author's Contribution

AI conceptualized, designed and carried out the study. IMQ and MSH supervised, carried out formal analysis and validated the results. AI and AA specified methodology, curated the data and prepared the first draft. HJ, FA, and SM assisted in resource allocation and investigation, proof read and formatted the manuscript for submission.

Conflict of interest
There is no conflict of interests among authors of this research paper.

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