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NUTRITIONAL AND PHYSIO-CHEMICAL COMPARISON OF FRESH, RAW AND COMMERCIAL MILK

Original Research

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ABSTRACT

Background: Milk is a vital source of nutrition for individuals of all age groups, including infants, children, adults, and the elderly. It is globally recognized for its rich nutrient profile, offering proteins, fats, carbohydrates, vitamins, and minerals. However, milk adulteration, particularly with water, has become a widespread issue, reducing its nutritional quality and posing significant health risks. Understanding variations in milk quality among different suppliers is crucial to ensuring safe consumption and guiding better production practices.

Objective: This study aimed to evaluate the quality, safety, and nutritional composition of fresh raw milk from farms, shops, milkmen, and packaged brands available in local markets, identifying variations and contamination levels to promote consumer awareness and inform better handling practices.

Methods: Milk samples were collected from farms, shops, milkmen, and packaged brands through random sampling in the Multan region. A total of 20 milk samples were analyzed, five from each source. Sterilized glass bottles were used for sample collection, followed by transportation in iceboxes to maintain freshness. Nutritional analyses included protein, fat, lactose, and moisture content using standard methods such as the Kjeldahl and Gerber techniques. Physio-chemical properties, including specific gravity, acidity, total solids, and solids-not-fat, were measured using lactometers, pH meters, and titration methods. Data were statistically analyzed using one-way ANOVA to assess significant differences among groups.

Results: The study revealed significant variations in milk quality. Packaged milk showed the lowest moisture content (80.4%), while milkman samples had the highest (92.0%). Protein levels ranged from 2.2% in milkman samples to 3.4% in farm milk. Fat content was lowest in milkman samples (2.1%) and highest in farm milk (4.3%). Lactose ranged from 3.2% in milkman samples to 5.5% in packaged milk. Solid-not-fat content varied between 7.7% and 8.5%, while total solids ranged from 11.6% to 14.4%. Specific gravity ranged from 1.02 to 1.03, and acidity levels were between 0.09% and 0.15%. Packaged milk was the safest option with minimal contamination, while farm milk exhibited superior nutritional quality compared to milk from shops and milkmen, which were heavily contaminated.

Conclusion: Packaged milk was found to be safer for consumption, but farm milk exhibited better nutritional quality. Milk from shops and milkmen was heavily contaminated, underscoring the need for improved hygiene practices. These findings emphasize the importance of awareness among consumers, farmers, and suppliers regarding milk quality, adulteration, and safe handling practices to ensure better public health outcomes.

Keywords: Acidity, Adulteration, Consumer Awareness, Food Safety, Milk Quality, Nutritional Value, Raw Milk.

INTRODUCTION

Milk is an essential component of a balanced diet, providing vital nutrients necessary for human health and well-being across all age groups. Its nutritional value stems from its composition, which includes carbohydrates, fats, proteins, vitamins, and minerals, all of which contribute to its role as a staple food. Milk is primarily composed of water, accounting for approximately 87% of its content, while the remaining 13% comprises milk solids, including lactose, fats, proteins, vitamins, and minerals (1, 2). Lactose, the primary carbohydrate in milk, forms from the combination of D-galactose and D-glucose molecules, with its levels varying slightly among different breeds. Similarly, the fat content of milk is variable, depending on factors such as type and source, but generally comprises about 3.4%, with a significant proportion of saturated fatty acids. Proteins in milk are predominantly casein and whey, which serve essential functions in growth and repair (3). Casein makes up about 82% of milk protein, while whey accounts for 18%, and their composition can fluctuate due to factors like lactation stages and breed (4, 5). Milk is also an abundant source of both fat-soluble and water-soluble vitamins. These vitamins play crucial roles in metabolism, immune response, vision, and bone health (6, 7). Vitamin D aids in calcium absorption, while B-complex vitamins support enzymatic functions and energy metabolism. Minerals like calcium and phosphorus are integral to bone development and other physiological processes, making milk a comprehensive nutritional package (8). The easily digestible nature of milk further enhances its value, making it particularly suited for infants and toddlers during their developmental years, while also supporting the nutritional needs of adults and elderly individuals (9, 10).

However, the consumption of milk also raises concerns related to food safety and quality. The global emphasis on food safety necessitates that milk be free from harmful contaminants and adulterants, which could pose risks to human health (11). Factors such as poor animal handling, unsanitary milking practices, and inadequate storage conditions can lead to compromised milk quality. Modern technology has facilitated better monitoring and analysis of milk to identify potential risks, including physical, biological, and chemical contaminants (12). The presence of harmful substances like antibiotic residues, aflatoxins, and dioxins, as well as the addition of adulterants such as water, starch, and harmful chemicals, highlights the ongoing challenges in maintaining milk safety. Adulteration practices, including the use of melamine to falsely elevate protein content or the addition of detergents to enhance texture, can lead to severe health consequences, such as kidney failure or other systemic illnesses (13). Ensuring the safety of milk involves stringent hygiene standards during production, proper processing, and controlled storage conditions to eliminate harmful elements and maintain its nutritive value (14). Milk's role in human nutrition has evolved over thousands of years, yet its importance remains indisputable. It serves as a primary source of essential nutrients for growth, development, and overall health, underscoring its relevance across all stages of life (15). However, the challenges associated with its safety and quality demand a multifaceted approach, involving rigorous quality control measures and public awareness to mitigate risks and ensure consumer trust. The objective of studying fresh, raw, and commercial milk lies in comparing their nutritional and physio-chemical properties, identifying potential health risks, and establishing evidence-based standards to promote safe and high-quality milk consumption for all.

METHODS

The study was conducted in the Multan region, with milk samples analyzed in the laboratory of the Department of Food Science and Technology at the TIMES Institute, Multan. A random sampling approach was employed to ensure the unbiased selection of milk samples from diverse sources, including farms, shops, milkmen, and packaged milk brands available in the local market. Care was taken to exclude spoiled milk samples or those past their expiration date. The samples were purchased from various locations within Multan city, reflecting a wide range of milk supply chains. Fresh raw milk was sourced from farms and milkmen, while packaged milk was collected from retail outlets. Samples were stored in sterilized glass bottles to maintain integrity and prevent contamination. Prior to collection, all glass bottles were thoroughly sterilized and labeled with the date and time of sampling to ensure traceability. The temperature of each milk sample was checked at the time of collection to verify its freshness. During transportation to the laboratory, samples were placed in an icebox to maintain a controlled temperature and prevent spoilage. In total, 20 milk samples were collected, comprising five samples from each source category: farms, packaged brands, shops, and milkmen.

Nutritional analyses were performed on the collected samples using standardized laboratory procedures, adapted slightly for the study's objectives. The protein content of the milk was determined using the Kjeldahl method, which involved digestion, distillation, and titration to quantify total protein. Fat content was measured through the Gerber method, using sulfuric acid, isoamyl alcohol, and centrifugation to separate and measure the fat layer. Moisture content was evaluated with a lactometer, ensuring precise mixing and measurement. Lactose content was assessed via a titrimetric method, employing Fehling solutions and methylene blue as an indicator for accurate determination. Physio-chemical analyses of the milk samples were also conducted to evaluate their quality parameters. Total soluble solids and solids-not-fat were determined based on lactometer readings and calculated formulas. The pH of the milk samples was measured using a calibrated pH meter, while titratable acidity was assessed by titrating the milk sample with sodium hydroxide and using phenolphthalein as an indicator. Specific gravity was calculated using the pycnometer method, which involved weighing the pycnometer filled with water and comparing it to the weight when filled with milk.

The data collected from the nutritional and physio-chemical analyses were subjected to statistical evaluation. One-way ANOVA was applied to analyze differences among the groups, followed by Tukey's HSD test to identify specific pairwise differences. Statistical significance was categorized into highly significant, significant, or non-significant levels, and the analyses were performed using the software 'Statistic' version 8.1.

RESULTS

The study analyzed the nutritional and physio-chemical properties of milk samples collected from farms, shops, milkmen, and packaged brands in Multan. General appearance, aroma, color, taste, and consistency were evaluated to assess the sensory attributes of the samples. It was observed that 40% of the raw milk samples from shops, milkmen, and farms had a dirty appearance, with visible impurities such as straws and particles, while packaged milk showed a clear and acceptable appearance. Aroma analysis revealed that 20% of milkman samples emitted a bad odor due to contamination and improper storage. In terms of color, 80% of the samples were white, while 20% exhibited a yellowish hue, potentially indicative of adulteration. Taste evaluation revealed that 20% of milkman samples were bitter, likely due to summer heat and improper storage, while other sources displayed acceptable taste. Consistency testing revealed that 70% of samples were watery, particularly from shops and milkmen, suggesting adulteration practices like dilution with water.

Nutritional analysis showed significant variability in protein, fat, moisture, and lactose content. Protein levels ranged from 2.20% to 3.36%, with the highest protein content observed in farm milk (3.33%) and the lowest in packaged milk (2.96%). Fat content ranged from 2.12% to 4.36%, with farm milk showing the highest fat percentage (3.94%) and milkman samples having the lowest (2.50%), reflecting practices like skimming. Moisture content varied significantly, ranging from 80.46% to 92.0%. Milkman samples contained the highest moisture levels (89.80%), indicating potential adulteration, while packaged milk samples had lower moisture levels (81.68%), closer to standard values. Lactose levels ranged from 3.23% to 5.33%, with packaged milk showing the highest average lactose content (5.31%) and milkman samples the lowest (3.56%), likely due to water adulteration reducing total solids.

Physio-chemical analysis revealed significant variation in total solids, solids-not-fat (SNF), specific gravity, acidity, and pH levels. Total solids ranged between 11.62% and 14.17%, with the highest levels in farm milk (14.17%) and the lowest in milkman samples (12.67%), indicating dilution. SNF values ranged from 7.78% to 8.51%, lower than the standard 9%, with packaged milk showing higher averages (8.40%) compared to milkman samples (8.07%). Specific gravity ranged from 1.02 to 1.031, with farm milk having a higher density, reflecting better quality compared to diluted milk from shops and milkmen. Acidity varied significantly, ranging from 0.08% to 0.20%, with higher levels in milkman samples (0.17%), indicating bacterial contamination. pH levels ranged from 5.93 to 6.70, with some milkman samples showing alarmingly low pH values, indicative of poor quality and potential spoilage. These findings underscore the quality disparities between fresh raw milk and packaged milk, highlighting issues of adulteration and inadequate storage.

The chart illustrates the average nutritional content—protein, fat, and lactose percentages—across different milk sources: packaged milk, farms, milkmen, and shops. Farm milk exhibited the highest protein content at 3.33%, followed by shop milk at 2.98%, packaged milk at 2.96%, and milkman samples at 2.92%. In terms of fat content, farm milk again had the highest value at 3.94%, while packaged milk and shop milk showed comparable levels at 3.30% and 2.94%, respectively, with milkman samples significantly lower at 2.50%. Lactose content was highest in packaged milk at 5.31%, followed by farm milk at 4.96%, shop milk at 3.88%, and milkman samples at 3.56%. These results highlight the superior nutritional quality of farm milk and packaged milk, while milkman samples showed consistently lower values, indicating potential issues such as dilution or adulteration.

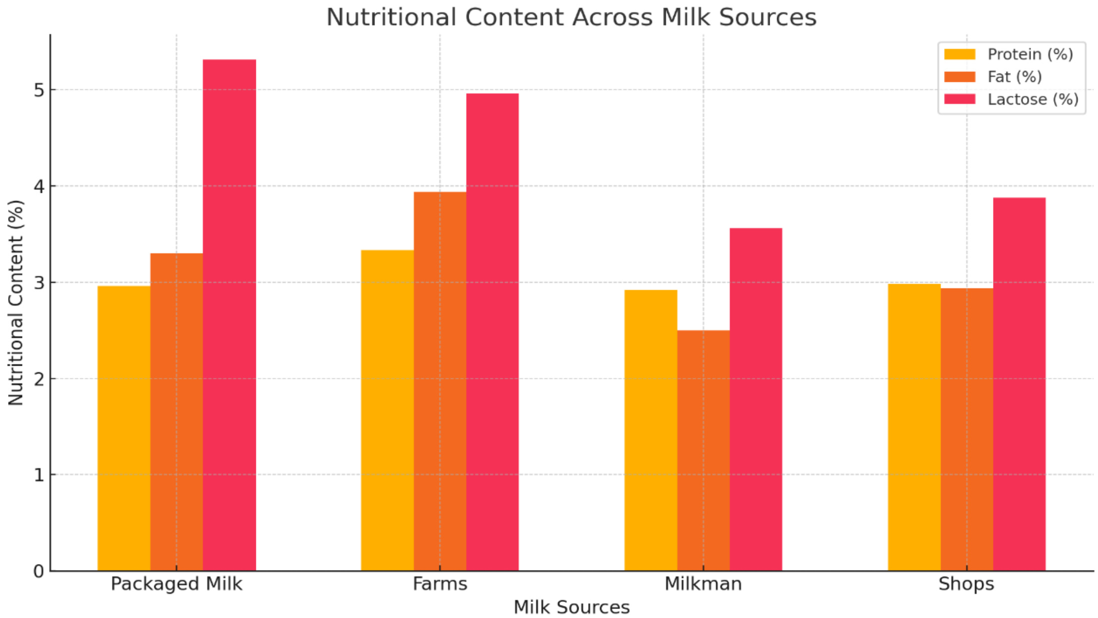

Figure 1 Nutritional Content Across Milk Sources

The chart compares the moisture and total solids percentages across milk sources: packaged milk, farms, milkmen, and shops. Moisture content was highest in milkman samples at 89.80%, followed by shop milk at 86.93%, farm milk at 85.56%, and packaged milk at 81.69%. Conversely, total solids were highest in farm milk at 14.17%, with shop milk at 13.17%, packaged milk at 13.04%, and milkman samples at the lowest value of 12.67%. These findings highlight a clear inverse relationship, with higher moisture content in milkman samples correlating with lower total solids, suggesting dilution, whereas farm milk exhibited the best balance of low moisture and high total solids, indicative of better quality.

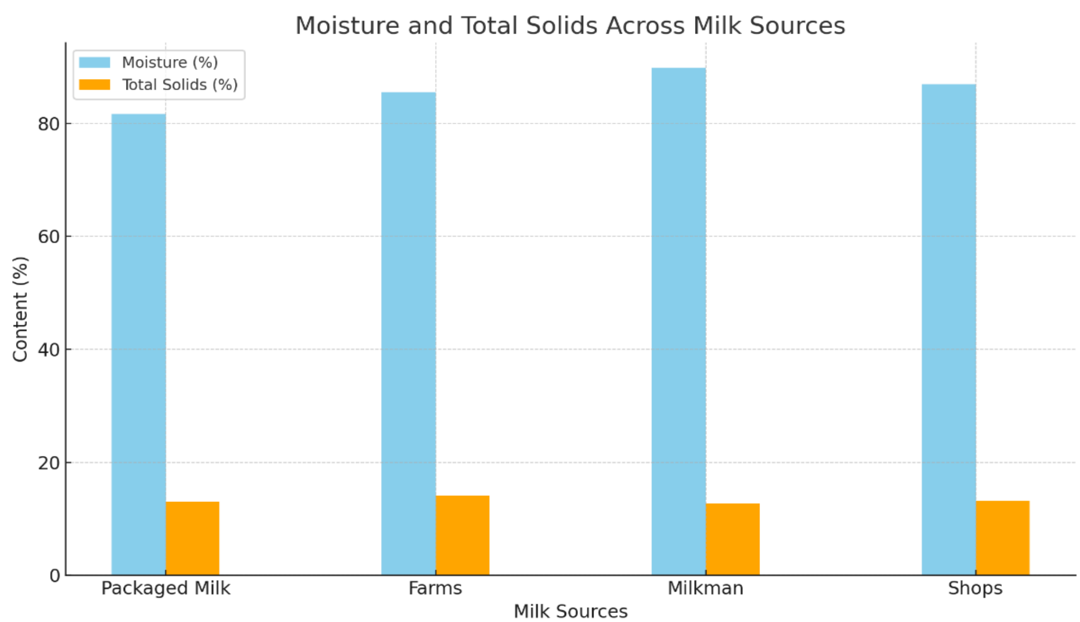

Figure 2 Moisture And Total Solids Across Milk Sources

Table 1 Nutritional analyses of milk collected from different sources

Samples	Moisture %	Protein%	Fat %	Lactose %
BA	80.4±0.43i	3.07±0.15a-e	36±0.046de	5.23±0.05ab
BB	82.30±0.71hi	2.20±0.10g	17±0.17d-g	5.37±0.05ab
BC	84.83±0.74e-g	2.50±0.10fg	53±0.20cd	5.17±0.07abc
BD	80.00±0.50i	3.26±0.20ab	3.29±0.12de	5.33±0.13ab
BE	81.83±0.74hi	2.80±0.10c-f	3.17±0.14d-g	5.50±0.10a
FA	84.67±0.76fg	3.36±0.04a	4.37±0.15a	4.90±0.10bc
FB	85.33±0.51d-g	3.19±0.17a-c	4.17±0.12ab	5.13±0.05abc
FC	86.87±0.31c-f	3.40±0.20a	3.87±0.14bc	4.90±0.10bc
FD	83.65±0.31gh	3.37±0.066a	3.40±0.20de	4.73±0.20c
FE	87.16±0.76c-e	3.13±0.12a-d	3.90±0.20bc	5.07±0.15abc
MA	91.10±0.59a	3.10±0.10a-e	2.33±0.15hi	3.47±0.15fg
MB	88.12±0.58bc	2.80±0.14b-f	2.77±0.17gh	3.23±0.15g
MC	87.46±0.90c	2.80±0.15b-f	3.01±0.01ef	3.60±0.26efg
MD	92.00±0.50a	2.53±0.15fg	2.33±0.15hi	4.03±0.15de
ME	90.33±0.74ab	2.73±0.20d-f	2.12±0.12i	3.50±0.36fg
SA	86.47±1.35c-f	3.053±0.08b-e	3.02±0.06efg	4.06±0.15de
SB	86.37±1.02c-f	2.84±0.11a-e	3.21±0.10d-f	3.48±0.12fg
SC	87.03±1.33c-e	3.26±0.04ab	2.73±0.10fg	4.23±0.15d
SD	87.43±1.02cd	2.70±0.20ef	3.30±0.08de	3.76±0.15d-f
SE	85.33±0.80d-g	3.17±0.15a-d	3.200±0.10d-f	3.86±0.15def

The table summarizes the nutritional analysis of milk samples collected from different sources, highlighting variations in moisture, protein, fat, and lactose content. Moisture content ranged from 80.00% in sample BD to 92.00% in sample MD, with milkman samples generally having higher moisture levels, such as MA at 91.10%, indicating potential dilution. Protein content varied significantly, with the highest observed in sample FC at 3.40% and the lowest in sample BB at 2.20%, showing that farm milk consistently had higher protein levels compared to other sources. Fat content showed a wide range, from a low of 2.12% in sample ME to a high of 4.37% in sample FA, with packaged milk and milkman samples generally having lower fat levels. Lactose content ranged from 3.23% in sample MB to 5.50% in sample BE, with packaged milk showing the highest lactose levels, while milkman samples had reduced lactose, likely due to adulteration. These findings underscore significant disparities in milk quality and composition across different sources.

Table 2: Physio-chemical analyses of milk collected from different sources

Samples	TS %	SNF %	SG %	Acidity	pH %
BA	13.07±0.05ef	8.40±0.07ab	1.031±0.003ab	0.12±0.005ij	6.70±0.10a
BB	12.91±0.03fg	8.34±0.09a-d	1.032±0.004a	0.14±0.005f-i	6.60±0.25ab
BC	12.66±0.15gh	8.50±0.05a	1.031±0.003ab	0.13±0.005h-j	6.62±0.10ab
BD	13.41±0.08b-d	8.49±0.04a	1.029±0.003ab	0.15±0.001e-g	6.60±0.25ab
BE	13.0±0.12ef	8.51±0.03a	1.031±0.002ab	0.12±0.001j	6.56±0.30a-c
FA	14.13±0.06a	8.30±0.05a-e	1.030±0.003ab	0.14±0.005d-f	6.30±0.10a-e
FB	14.13±0.06a	8.36±0.02a-c	1.029±0.006ab	0.14±0.006de	6.30±0.10a-e
FC	13.54±0.05bc	8.24±0.08a-f	1.027±0.003ab	0.13±0.004h-j	6.40±0.10a-d
FD	13.31±0.05c-e	8.35±0.05a-c	1.031±0.003ab	0.17±0.006cd	6.43±0.15a-d
FE	13.67±0.16b	8.24±0.04a-f	1.028±0.003ab	0.13±0.003g-i	6.30±0.10a-e
MA	12.67±0.12g	8.07±0.05d-f	1.025±0.003ab	0.18±0.005bc	6.06±0.15de
MB	13.03±0.04ef	7.98±0.01fg	1.026±0.001ab	0.16±0.005de	6.20±0.10b-e
MC	11.62±0.15i	8.12±0.09c-f	1.024±0.002ab	0.20±0.006a	6.14±0.05c
MD	12.36±0.20h	7.78±0.20g	1.023±0.002ab	0.18±0.003ab	5.90±0.11e
ME	13.30±0.10c-e	8.05±0.16e-g	1.023±0.001b	0.16±0.009c-e	6.10±0.10de
SA	13.17±0.07d-f	8.33±0.04a-d	1.024±0.001ab	0.09±0.003k	6.30±0.10a-e
SB	13.28±0.07cde	8.00±0.10fg	1.027±0.002ab	0.13±0.005h-j	6.00±0.10de
SC	13.03±0.03ef	8.21±0.07b-f	1.026±0.004ab	0.13±0.004g-j	6.21±0.07b-e
SD	12.91±0.06fg	8.13±0.07b-f	1.027±0.002ab	0.08±0.008k	6.24±0.06b-e
SE	13.07±0.02ef	8.14±0.06b-f	1.027±0.002ab	0.14±0.005f-h	6.33±0.06a-e

The table presents the physio-chemical analysis of milk samples from various sources, focusing on total solids (TS), solids-not-fat (SNF), specific gravity (SG), acidity, and pH. Total solids ranged from 11.62% in sample MC to 14.13% in samples FA and FB, with farm milk consistently showing higher TS values, while milkman samples exhibited lower levels, indicating possible dilution. SNF content varied from 7.78% in sample MD to 8.51% in sample BE, with packaged milk showing the highest averages at 8.50% and milkman samples having the lowest at 8.07%. Specific gravity ranged narrowly from 1.023 in samples MD and ME to 1.032 in sample BB, with packaged milk and farm milk showing more stable values, suggesting better quality. Acidity levels varied significantly, from a low of 0.08% in sample SD to a high of 0.20% in sample MC, with milkman samples generally having higher acidity, indicating bacterial activity. The pH values ranged from 5.90 in sample MD, reflecting spoilage, to 6.70 in sample BA, with packaged milk maintaining more stable and acceptable pH levels, while milkman samples showed lower values, reflecting poorer quality. These findings highlight significant disparities in milk quality, with farm and packaged milk generally performing better compared to milkman samples.

DISCUSSION

The findings of this study provided comprehensive insights into the nutritional and physio-chemical differences among milk samples collected from various sources, including farms, shops, milkmen, and packaged brands (16). The study demonstrated clear disparities in milk quality, reflecting the impact of adulteration, storage practices, and processing methods on nutritional integrity and overall acceptability (17). Farm milk exhibited the highest quality in terms of protein, fat, total solids, and specific gravity, whereas milkman samples showed significant indicators of adulteration, such as elevated moisture content, reduced total solids, and lower lactose percentages (18). A notable strength of this research was the incorporation of diverse milk sources, allowing for a robust comparison across various supply chains. The evaluation of key nutritional components, including protein, fat, and lactose, alongside physio-chemical properties such as acidity, pH, and specific gravity, enabled a comprehensive assessment of milk quality. Packaged milk showed stability and acceptable ranges for most parameters, which can be attributed to pasteurization and standardized processing (19, 20). However, the slightly reduced protein and fat levels in packaged milk indicated nutrient loss during heat treatments such as UHT processing. In contrast, milkman samples demonstrated significant quality deficiencies, highlighting the prevalence of dilution and bacterial contamination due to inadequate storage and transportation practices. Farm milk consistently maintained superior quality, reflecting its minimal processing and immediate sourcing (21).

The study also addressed key limitations. The sample size, although representative, was relatively small, which may limit the generalizability of the findings to broader populations. Seasonal variations were not explored, yet environmental factors such as temperature may significantly influence milk quality and stability (22). Additionally, the lack of advanced microbiological analyses restricted the ability to correlate bacterial contamination with specific nutritional and physio-chemical variations. Future research could address these limitations by expanding the sample size, incorporating seasonal analyses, and performing microbiological testing to provide a more nuanced understanding of milk quality (23). The first study, conducted by Khawar S. Khan et al. (2022), evaluated the feasibility and quality outcomes of decentralized solar milk pasteurization and chilling technologies (24). This study compared milk processed through solar-powered methods to commercially available open and packaged milk. The results showed that solar-processed milk had superior nutritional quality, including higher fat (5.4%), protein (3.9%), and total solids (14.5%), as well as better sensory attributes like taste, color, and aroma. Furthermore, solar-processed milk demonstrated enhanced shelf life and cost efficiency, offering a sustainable alternative for milk processing in regions with limited access to conventional infrastructure. This study highlighted the potential of on-farm solar milk processing technologies to improve the nutritional and economic outcomes of the dairy industry, especially in developing countries (24).

Another study, conducted by M. S. Ahamed et al. (2020), focused on milk quality indicators from open markets and dairy industries in Bangladesh (25). This study found that raw milk from open markets often exhibited higher fat content (up to 4.2%) but was frequently adulterated with water, sugar, and soda, resulting in compromised solids-not-fat (SNF) values. Conversely, pasteurized milk from branded dairy industries had lower fat content (3.55%) but maintained consistent microbial safety, as it lacked harmful pathogens such as Salmonella and Vibrio cholerae that were prevalent in open-market milk. These findings underscored the safety and nutritional trade-offs between raw and processed milk, emphasizing the importance of regulated processing for consumer safety (25). Overall, the study provided valuable evidence highlighting quality differences across milk sources. The findings emphasized the importance of improved storage, transportation, and regulatory measures to curb adulteration and ensure milk safety. While packaged milk displayed better safety profiles, farm milk demonstrated superior nutritional quality, reinforcing its relevance for consumers seeking nutrient-dense options. Enhanced monitoring of local vendors and stricter enforcement of quality standards remain crucial to safeguarding public health and nutritional adequacy in milk consumption.

CONCLUSION

In conclusion, this study highlighted the significant challenges faced by the common person in accessing pure milk, especially in a developing country like Pakistan. While branded milk offers safety through pasteurization and UHT processing, it often lacks the nutritional density of raw milk and may contain additives like stabilizers and sugar to extend shelf life. Conversely, raw milk, particularly from shops and milkmen, suffers from poor handling practices, lack of refrigeration, and frequent adulteration, compromising its quality and safety. These issues underscore the urgent need for improved infrastructure, stricter regulations, and awareness campaigns to address malpractices and ensure access to safe, nutrient-rich milk for all segments of society. Eliminating these gaps is crucial for enhancing public health and ensuring equitable access to quality milk.

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AUTHOR CONTRIBUTIONS

Author	Contribution
Anum Arif	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Sabiha Abbas*	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Muhammad Sibt-e-Abbas	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Shabbir Ahmed	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Usman	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Sania Ilyas	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

REFERENCES

1. Zebib H, Abate D, Woldegiorgis AZJH. Nutritional quality and adulterants of cow raw milk, pasteurized and cottage cheese collected along value chain from three regions of Ethiopia. 2023;9(5).

2. Limbu DS, Bantawa K, Devkota M, Ghimire MJHJoS, Technology. Microbiological quality and adulteration of pasteurized and raw milk marketed in Dharan, Nepal. 2020:37-44.

3. Fagnani R, Nero LA, Rosolem CPJJoDR. Why knowledge is the best way to reduce the risks associated with raw milk and raw milk products. 2021;88(2):238-43.

4. Haldar L, Raghu H, Ray PRJA, Livestock Production, 1 AAfSFSV. Milk and milk product safety and quality assurance for achieving better public health outcomes. 2022:217-59.

5. Kiambi S, Fèvre EM, Alarcon P, Gitahi N, Masinde J, Kang'ethe E, et al. Assessment of milk quality and food safety challenges in the complex nairobi dairy value Chain. 2022;9:892739.

6. Ferreira MM, Marins-Gonçalves L, De Souza DJFC. An integrative review of analytical techniques used in food authentication: A detailed description for milk and dairy products. 2024:140206.

7. Patil GB, Wani SP, Bafna PS, Bagul VS, Kalaskar MG, Mutha REJF, et al. Milk adulteration: From detection to health impact. 2024:100339.

8. Zebib H, Zewdu AJMC. Nutritional Quality, Level of Chemical Contaminants and Adulterants in Milk and Dairy Products in Ethiopia: A Review. 2020;13(1):64-72.

9. Techane TJIJDM. Effect of adulterants on quality and safety of cow milk: A Review. 2023;8(1):277-87.

10. Parajuli L, Paudel S, Khadka R, Maharjan R, Shrestha AJNJoB. Analysis of microbiological quality and adulteration of raw milk samples from different areas of Kathmandu Valley. 2023;11(2):37-42.

11. Ionescu A-D, Cîrîc AI, Begea MJAS. A review of milk frauds and adulterations from a technological perspective. 2023;13(17):9821.

12. YARED AA. QUALITY ASSESSMENT OF RAW AND PASTEURIZED MILK AMONG DAIRY PRODUCT VENDORS, ADDIS ABABA, ETHIOPIA 2024.

13. Choudhary A, Gupta N, Hameed F, Choton SJIJoCS. An overview of food adulteration: Concept, sources, impact, challenges and detection. 2020;8(1):2564-73.

14. dos Santos Rosario IL, Vieira CP, Salgado MJG, Monteiro NB, Alzate KG, de Araújo GC, et al. Assessment of plain yoghurt quality parameters affected by milk adulteration: Implications for culture kinetics, physicochemical properties, and sensory perception. 2024;77(3):827-42.

15. Yadav AK, Gattupalli M, Dashora K, Kumar VJFAM. Key milk adulterants in India and their detection techniques: A review. 2023;16(3):499-514.

16. Ibrahim T, Wattoo FH, Wattoo MHS, Hamid SJPJoHS. Assessment of Fresh Milk Quality Through Quality Parameters: Assessment of Fresh Milk Quality. 2023:21-5.

17. Gemechu AT, Tola YB, Dejenie TK, Grace DR, Aleka FB, Ejeta TTJJoFP. Assessment of butter adulteration practices and associated food safety issues along the supply chain in traditional communities in the central highlands and southwest midlands of Ethiopia. 2021;84(5):885-95.

18. Yu M, Li B, Hong T, Li Z, Ru X, Bian W, et al. Advancements in nutritional composition of milk and species identification. 2024;8:fyae039.

19. Ouma JA. Milk Quality Assessment for Adulteration and Organic Contaminants in Juja and Githurai Markets, Kiambu County: JKUAT-COPAS; 2023.

20. GIRI A. PHYSIOCHEMICAL CHARACTERIZATION, ADULTERATION PROFILE AND SENSORY EVALUATION OF DIFFERENT POWDERED MILK SAMPLES FOUND IN POKHARA METROPOLITAN CITY, KASKI, NEPAL. 2024.

21. Shawky E, Nahar L, Nassief SM, Sarker SD, Ibrahim RSJTiFS, Technology. Dairy products authentication with biomarkers: A comprehensive critical review. 2024:104445.

22. Montgomery H, Haughey SA, Elliott CTJGFS. Recent food safety and fraud issues within the dairy supply chain (2015–2019). 2020;26:100447.

23. Maitiniyazi S, Canavari MJJoDS. Exploring Chinese consumers' attitudes toward traceable dairy products: A focus group study. 2020;103(12):11257-67.

24. Khan KS, Munir A, Raza A, Latif Y, Hensel OJAEiA. Improving Milk Value Chains: A Case Study for Qualitative-Economic Feasibility of Decentralized Solar Milk Pasteurization and Chilling Processes. 2022;38(2):409-19.

25. Ahamed M, Sadia M, Haque K. Comparative Quality Analysis of Milk Collected from Open Markets and Dairy Industries in Bangladesh %J Food Science and Quality Management. 2020.

