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Research Article

Quality Assessment of Open-Market Milk Compared to Commercially Branded Milk in Mymensingh City, Bangladesh

Md. Moshiur Rahman[1], Nazmul Mia[1], Mohammad Ashiqul Islam[2] and Muhammad Javidul Haque Bhuiyan[1]✉

[1]Department of Biochemistry and Molecular Biology, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

[2]Department of Dairy Science, Faculty of Animal Husbandry, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

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Correspondence
Muhammad Javidul Haque Bhuiyan
✉: mjhbhuiyan@bau.edu.bd

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Abstract

Milk is a vital nutrient source, but in Bangladesh, its quality is often compromised by dilution and adulteration. Regular, systematic monitoring of open-market milk quality is vital for protecting public health. This study compared the physicochemical properties, nutrient composition, and common adulterants in raw milk from local vendors to commercial pasteurized/Ultra-High-Temperature (UHT) treated brands available in Mymensingh City. Twenty-four samples (five local sources and three brands, triplicate each) were analyzed for specific gravity (SG), pH, titratable acidity (TA), alcohol stability, moisture, total solids (TS), solids-not-fat (SNF), ash, fat, protein, and carbohydrate, using standard methods. Qualitative tests for added sugar, formalin, and added urea were also performed. Data were statistically analyzed by one-way ANOVA ($P \le 0.05$) using a Completely Randomized Design followed by Duncan's Multiple Range Test. Results showed statistically significant ($P \le 0.05$) differences between the samples across all parameters. Branded milk, particularly Brand-1, had higher density and solids content (e.g., specific gravity ≈1.030, total solids ≈13.0%) and correspondingly lower moisture (≈87%) than local samples (SG ≈1.027-1.028; TS ≤ 11.2%). Four of the five open-market samples were heavily diluted: the sample from Churkhai had the highest moisture (≈90.6%) and lowest TS (9.44%), SNF (6.77%), ash (0.03%, indicating severe dilution), fat (2.67%), protein (3.18%), and carbohydrate (3.57%). In contrast, Brand-1 showed the lowest moisture (86.97%), and the highest TS (13.03%) and SNF (9.50%). The alcohol stability test was negative for all samples. Adulterant screening found no formalin or urea in any sample; only a single replicate of the Sutiakhali local sample was positive for added sugar. In conclusion, open-market milk in Mymensingh City was significantly poorer in nutritional composition than commercial milk. The predominant fraud is massive water dilution, not toxic chemicals. These findings underscore the need for stricter regulation and routine quality monitoring in the informal milk market.

Introduction

Milk is valued as a complete food due to its balanced content of carbohydrates, fats, proteins, minerals, and vitamins (Miller *et al.*, 2006). Globally, dairy products contribute a significant fraction of daily nutrition (González-Montaña *et al.*, 2012). In Bangladesh, demand for milk has grown rapidly, with per capita availability of around 239 ml/day, which still falls short of the 250 ml/day target even though national production nearly doubled from 2015-16 to 2024-25 (DLS, 2024). This supply shortage, along with an indigenous and informal dairy sector, has led to widespread quality issues. Only about 9-10% of milk produced enters formal processing by commercial brand companies, whereas the rest is handled by local vendors (goalas) in open markets (Khan *et al.*, 2008). In this decentralized system, poor cold-chain management and economic incentives encourage adulteration: vendors commonly add water and other inexpensive fillers (such as starch, cane sugar, etc.) to increase volume (Kamthania *et al.*, 2014; Azad and Ahmed, 2016; Vallejo *et al.*, 2018; Islam *et al.*, 2019). Such practices reduce nutritional value and can endanger health, since some additives (e.g., formaldehyde, melamine) are toxic (Azad and Ahmed, 2016; Ionescu *et al.*, 2023). For example, melamine added to mimic protein can cause kidney failure in infants, and excess formalin can damage the gastrointestinal tract and cause organ failure and cancer (Wilbur *et al.*, 1999; Alam, 2014; Domingo *et al.*, 2014). Moreover, urea, which is used to

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boost nitrogen content, can overburden the kidneys and result in swollen limbs and impaired vision (Kandpal *et al.*, 2012). Even simple dilution undermines food security by depriving consumers of protein and fat (Ionescu *et al.*, 2023). Bangladesh standards mandate that pasteurized/UHT milk contain at least 3.5% fat and 8.0% SNF (BSTI, 2023). Branded processors are legally obligated to meet these levels. In practice, however, many small vendors remain unaware of these requirements. Studies in Bangladesh and South Asia have repeatedly detected widespread dilution in raw milk and occasional chemical adulterants to exploit the demand-supply gap and low level of consumer awareness (Kamthania *et al.*, 2014; Islam *et al.*, 2019; Karmaker *et al.*, 2019).

Routine and systematic quality assessment of market milk is essential regarding public health concerns. By systematically measuring quality parameters, we aimed to quantify the scale of dilution and adulteration in Mymensingh City's milk supply, providing data critical for food safety and informing policies to ensure quality. Thus, the objectives of this experiment were set to compare physicochemical quality and nutritional composition between open-market raw milk and commercial branded milk in Mymensingh City. This involved measuring specific gravity (SG), pH, titratable acidity (TA), and heat stability (alcohol test) as initial quality indicators, followed by full proximate analysis (moisture, total solids (TS), solids-not-fat (SNF), ash, fat, protein, and carbohydrate). This study also screened for common adulterants, namely added sugar, formalin, and added urea.

Materials and Methods

Study Area and Sampling

Sampling was done between May and August 2025 from eight milk sources in Mymensingh City. Raw milk samples were obtained from five hiddenly selected vendors from five different locations, such as Dudh Mahal, Sutiakhali, Churkhai, Khagdohor, and Gohailkandi, while pasteurized/UHT milk samples were taken from three commercial milk brands (Brand-1, Brand-2, and Brand-3). Each source was sampled in triplicate, which provided a total of 24 samples. Local vendors' milk was collected aseptically in sterile containers; packaged brands (pasteurized or UHT) were obtained from local shops. Samples were kept on ice during transport. In the laboratory, milk was mixed gently before analysis to ensure homogeneity.

Physicochemical Analyses

Specific gravity (SG) was measured with a lactometer (Aggarwala and Sharma, 1961). Milk pH was measured with a calibrated digital pH meter (Milwaukee pH56 PRO) after calibration with pH 4.01 and 7.01 buffers. Titratable acidity (% lactic acid) was determined by titrating 10 mL of milk with 0.1 N NaOH using phenolphthalein indicator, according to AOAC (1995). Alcohol stability was tested by mixing equal volumes of milk and 68% ethanol; the absence of flocculation (no clumping) after 10 min indicated stability (negative test) as per standard protocols (BIS, 1960).

Compositional Analysis

Moisture and total solids (TS) contents (%) were measured by oven-drying a known weight of milk at 105 °C (AOAC, 1995). Fat content (%) was measured by the Babcock method (AOAC, 1995). SNF (%) was calculated according to AOAC (1995), and Ash (%) was measured by incinerating a dried aliquot at 550 °C (AOAC, 1995). Crude protein (%) was measured according to the Kjeldahl method using conversion as N × 6.38 (AOAC, 1995). Milk carbohydrate content (%) was calculated by difference according to the standard protocol (FAO, 2003).

Adulteration Tests

Each sample was tested qualitatively for common adulterants. Added sugar was detected by the resorcinol test as described by BIS (1960). The presence of formalin was detected by whether a purple ring was formed as a positive indicator when treated with concentrated H_2SO_4 with a few drops of ferric chloride (BIS, 1961). Urea was detected with para-dimethylaminobenzaldehyde (DMAB) reagent, which gives a distinct yellow color (beyond the faint inherent urea level) in the presence of added urea (BIS, 1960). The results were recorded as Positive or Negative.

Statistical Analysis

The experiment was conducted with a Completely Randomized Design (CRD) where eight samples from different sources were taken in triplicate. One-way ANOVA was done to find out the significance level at $P \leq 0.05$ using IBM SPSS (version 25.0). The data were displayed as mean ± standard deviation (SD). Where ANOVA indicated significant differences ($P \leq 0.05$), Duncan's Multiple Range Test (DMRT) was also performed at the 5% significance level to determine the inter-group performance.

Results

Physicochemical Properties

All measured physicochemical parameters differed significantly ($P \leq 0.05$) among the eight sources (Table 1).

Table 1. Physicochemical analysis of collected local and commercial milk samples.

Milk Samples	Specific Gravity	pH	% Acidity
Dudh Mahal	$1.028^{c} \pm 0.000$	$6.62^{cd} \pm 0.006$	$0.162^{a} \pm 0.003$
Sutiakhali	$1.028^{cd} \pm 0.000$	$6.65^{a} \pm 0.006$	$0.152^{c} \pm 0.003$
Churkhai	$1.028^{cd} \pm 0.000$	$6.62^{bcd} \pm 0.015$	$0.160^{ab} \pm 0.005$
Khagdohor	$1.028^{cd} \pm 0.000$	$6.61^{d} \pm 0.006$	$0.163^{a} \pm 0.003$
Gohailkandi	$1.027^{d} \pm 0.000$	$6.61^{d} \pm 0.006$	$0.163^{a} \pm 0.003$
Brand-1	$1.03^{a} \pm 0.001$	$6.64^{a} \pm 0.006$	$0.153^{c} \pm 0.003$
Brand-2	$1.029^{b} \pm 0.000$	$6.64^{ab} \pm 0.015$	$0.155^{bc} \pm 0.005$
Brand-3	$1.03^{ab} \pm 0.000$	$6.63^{abc} \pm 0.012$	$0.157^{abc} \pm 0.003$

Values are shown as mean ± SD, which are significantly different (P ≤ 0.05). The small letters a, b, c, and d indicate comparison among different samples according to DMRT.

Specific gravity (SG) differed significantly (P ≤ 0.01) among samples, ranging from 1.027 to 1.030. The commercial brands, particularly Brand-1 (1.030 ± 0.001) and Brand-3 (1.030 ± 0.000), had the highest SG values, while local samples were slightly lower (e.g., Gohailkandi 1.027 ± 0.000). Table 1 indicates that according to DMRT, the best performing milk sample was commercial Brand-1, whereas local milks clustered at lower values (c-d).

Milk pH values of different sources ranged from 6.61 to 6.65, which showed significant differences (P ≤ 0.01) among all samples (Table 1). The Sutiakhali sample had the highest mean pH value (6.65 ± 0.006), which was significantly above some local milks (Khagdohor, Gohailkandi, both 6.61 ± 0.006).

Titratable acidity (%) also varied (0.152-0.163%; P ≤ 0.01) as shown in Table 1. The lowest acidity was in Sutiakhali (0.152 ± 0.003%) and Brand-1 (0.153 ± 0.003%), whereas Dudh Mahal, Khagdohor, and Gohailkandi had higher acidity (0.162-0.163%).

Notably, the alcohol stability test yielded negative results for all samples, as no visible coagulation was observed.

Compositional (Proximate) Analysis

The proximate composition revealed stark contrasts, as evidenced by Table 2.

Moisture content (%) was the highest in local milk samples and the lowest in Brand-1 (Table 2). Milk from Churkhai had the highest moisture (90.56^{a} ± 0.03%), significantly above all others. In contrast, Brand-1 had only 86.97^{e} ± 0.39% moisture. As expected, total solids (TS) content (%), the inverse of moisture, showed the opposite pattern (Table 2). Brand-1 TS was 13.03^{a} ± 0.39% (significantly highest), far above Churkhai TS at 9.44^{e} ± 0.03%. Khagdohor (10.58%) and Gohailkandi (10.21%) local samples also had low TS. These differences were highly significant (P ≤ 0.01).

Table 2. Assessment of milk composition in selected milk samples.

Milk Samples	% Moisture	% TS	% Fat	% SNF	% Protein	% Ash	% Carb
Dudh Mahal	$88.84^{c} \pm 0.11$	$11.16^{c} \pm 0.11$	$3.07^{b} \pm 0.12$	$8.09^{bc} \pm 0.05$	$3.56^{b} \pm 0.01$	$0.58^{abc} \pm 0.06$	$3.95^{c} \pm 0.01$
Sutiakhali	$89.34^{b} \pm 0.05$	$10.66^{d} \pm 0.05$	$2.83^{c} \pm 0.06$	$7.83^{cd} \pm 0.01$	$3.47^{c} \pm 0.01$	$0.48^{bcd} \pm 0.02$	$3.88^{d} \pm 0.01$
Churkhai	$90.56^{a} \pm 0.03$	$9.44^{e} \pm 0.03$	$2.67^{d} \pm 0.06$	$6.77^{e} \pm 0.05$	$3.18^{g} \pm 0.05$	$0.03^{d} \pm 0.02$	$3.57^{ef} \pm 0.00$
Khagdohor	$89.42^{b} \pm 0.62$	$10.58^{d} \pm 0.62$	$3.10^{b} \pm 0.10$	$7.48^{d} \pm 0.57$	$3.26^{f} \pm 0.01$	$0.6^{abc} \pm 0.57$	$3.61^{e} \pm 0.00$
Gohailkandi	$89.79^{b} \pm 0.17$	$10.21^{d} \pm 0.17$	$2.77^{cd} \pm 0.06$	$7.44^{d} \pm 0.22$	$3.10^{h} \pm 0.01$	$0.79^{ab} \pm 0.22$	$3.56^{f} \pm 0.00$
Brand-1	$86.97^{e} \pm 0.39$	$13.03^{a} \pm 0.39$	$3.53^{a} \pm 0.06$	$9.50^{a} \pm 0.41$	$3.81^{a} \pm 0.02$	$1.04^{a} \pm 0.31$	$4.65^{a} \pm 0.08$
Brand-2	$88.02^{d} \pm 0.07$	$11.98^{b} \pm 0.07$	$3.57^{a} \pm 0.06$	$8.42^{b} \pm 0.08$	$3.40^{d} \pm 0.01$	$0.42^{bcd} \pm 0.08$	$4.61^{a} \pm 0.00$
Brand-3	$88.47^{cd} \pm 0.06$	$11.53^{bc} \pm 0.06$	$3.53^{a} \pm 0.06$	$8.00^{bc} \pm 0.10$	$3.30^{e} \pm 0.01$	$0.28^{cd} \pm 0.09$	$4.41^{b} \pm 0.02$

Values are shown as mean ± SD, which are significantly different (P ≤ 0.05). The small letters a, b, c, d, e, f, g, and h indicate comparison among different samples according to DMRT. TS= Total Solids, SNF= Solids-Not-Fat, Carb= Carbohydrate.

The solids-not-fat (SNF) fraction, a key nutritional indicator, varied dramatically (P ≤ 0.01) (Table 2). All branded milk (Brand-1: 9.50^{a} ± 0.41%) had ≥ 8.0% SNF content. However, among local samples, SNF was very low, such as Churkhai 6.77^{e} ± 0.05%, Gohailkandi 7.44^{d} ± 0.22%, and Khagdohor 7.48^{d} ± 0.57%. The Dudh Mahal and Sutiakhali samples were slightly better (8.09^{bc}% and 7.83^{cd}%) but still below most branded levels.

Ash content (mineral solids) also differed (P ≤ 0.01, Table 2). Brand-1 had the highest ash content (1.04^{a} ± 0.31%). Critically, the Churkhai sample had a perilously low ash content of 0.03^{d} ± 0.02%. Most of the other local and branded samples had low ash content (0.28-0.60%).

Fat content also showed significant variation (P ≤ 0.01) (Table 2). The three branded milks clustered around 3.53-3.57% fat. Local samples were lower. For instance, the Dudh Mahal sample had ≈3.07%, while the Churkhai sample was only 2.67^{d} ± 0.06%, being significantly the lowest. Khagdohor (3.10^{b}%) and Sutiakhali (2.83^{c}%) were intermediate.

Protein content significantly (P ≤ 0.01) differed from 3.10% (Gohailkandi) to 3.81% (Brand-1) (Table 2). Brand-1 led (3.81^{a} ± 0.02%), whereas Gohailkandi (3.10^{h} ± 0.01%), Churkhai (3.18^{g} ± 0.05%), and Khagdohor (3.26^{f} ± 0.01%) were the lowest, all significantly below branded levels.

Finally, carbohydrate content varied as well (Table 2). The commercial brands had the highest carbohydrate content (4.41%-4.65%). In contrast, Gohailkandi (3.56^{f} ± 0.00%), Churkhai (3.57^{ef} ± 0.00%), and Khagdohor (3.61^{e} ± 0.00%) were the lowest. These differences were highly significant (P ≤ 0.01).

Adulteration Screening

In this study, no sample showed positive results for formalin or urea in any replicate. Thus, none of the milk contained formalin or added urea. The added sugar test was negative in four local samples and all three brands. However, the Sutiakhali local sample gave one out of three replicates positive for sugar.

Comparison of Milk Quality Parameters Between Open-Market and Branded Samples

For a comparative analysis of quality parameters in open-market and branded milk samples, the averaged values of all local market samples were grouped into an "open-market" category and compared to the branded milk samples' group, as illustrated in Figure 1. On average, open-market milk had lower specific gravity (1.028) than branded milk (1.030) and a marginally lower pH (6.62 vs. 6.64). The titratable acidity was correspondingly higher in the open-market samples (0.16% vs. 0.155%).

Moreover, branded milk exhibited higher overall solids and nutritional content. The average moisture content of open-market milk was 89.59%, versus 87.82% in branded milk, indicating lower total solids in the open-market group (10.41% vs. 12.18%). Branded milk also had higher mean fat (3.54% vs. 2.89%), protein (3.50% vs. 3.31%), and carbohydrate (4.56% vs. 3.71%) contents than the open-market samples.

Discussion

Milk quality assessment in Mymensingh City revealed that the open-market raw milk was significantly inferior to the commercially branded milk in nutritional and physicochemical aspects. The consistently lower specific gravity and higher moisture of local samples unequivocally indicated heavy dilution with water. The standard SG lower limit for undiluted cow milk is around 1.030 (Fox *et al.*, 2015); all five open-market samples fell below this threshold (1.027-1.028), while brands met or exceeded it. Similar patterns were reported by previous studies in Bangladesh (Karmaker *et al.*, 2019; Ali *et al.*, 2023; Khandakar *et al.*, 2024) and also by other global studies (Yenew *et al.*, 2022; Desye *et al.*, 2023), showing that informal milk supply chains often involve systematic water addition.

Local milks had markedly reduced total solids, SNF, fat, protein, and carbohydrate. Most of the local samples were considerably below typical standards (≈12% SNF, minimum 3.5% fat and 8.0% SNF) (Miller *et al.*, 2006; Fox *et al.*, 2015; BSTI, 2023). For example, the Churkhai sample was the most diluted, which showed lower TS content (9.44%), fat content (2.67%), and SNF content (6.77%), well below the acceptable limits. Similar findings were observed in other studies of street-vended milk (Mansour *et al.*, 2012; Karmaker *et al.*, 2019), that could confirm water as the dominant adulterant. The trace ash content in Churkhai milk (0.03%) is especially alarming, since ash content is relatively stable at approximately 0.7% (Cerbulis and Farrell, 1976; Young *et al.*, 1986). This could stand only for pure water substitution. Such dilution with water is consistent with previous reports of water-adulterated milk in Bangladesh (Chanda *et al.*, 2013).

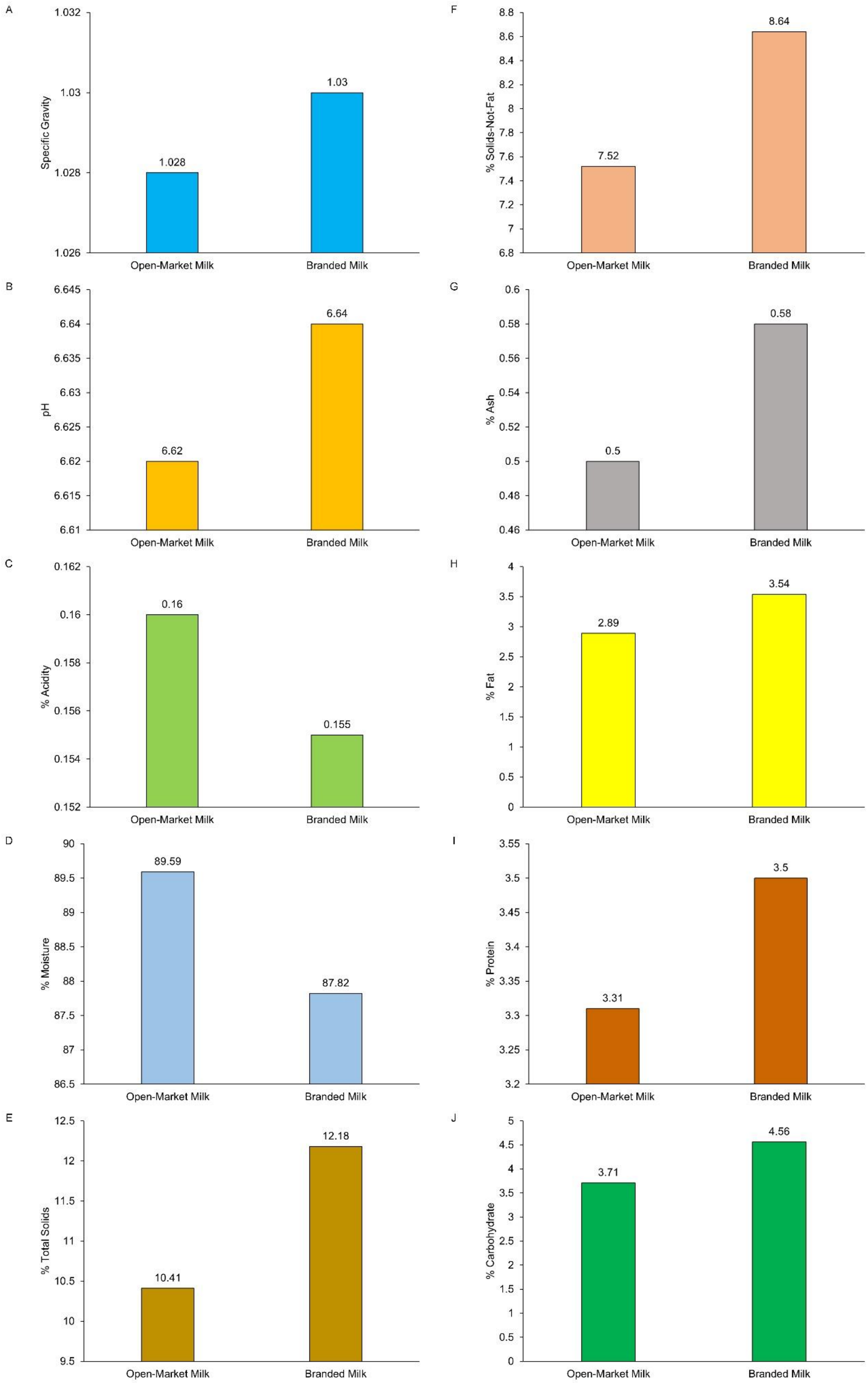

Figure 1: Comparison between the parameters of open-market milk and branded milk samples based on the obtained average values. A, B, C, D, E, F, G, H, I, and J indicate Specific Gravity, pH, % Acidity, % Moisture, % Total Solids, % Solids-Not-Fat, % Ash, % Fat, % Protein, and % Carbohydrate, respectively.

In terms of pH measurements, all values in this study fell within the normal 6.5-6.7 range (Fox *et al.*, 2015), indicating that none of the milk was spoiled or adulterated by alkaline substances. Moreover, although local milks tended toward slightly higher acidity, all samples remained within or near acceptable freshness limits (0.14-0.16%) (Fox *et al.*, 2015). In addition, the universally negative alcohol stability test indicated heat stability and no overt souring in all the tested samples of this study.

All branded milk easily met or exceeded the local standards of minimum 3.5% fat and 8.0% SNF content (BSTI, 2023). For instance, the commercial Brand-1 milk consistently showed the best quality with the highest TS (13.03%), SNF (9.50%), protein (3.81%), carbohydrate (4.65%), and high fat content (3.53%) with the lowest moisture content (86.97%). This indicates that industrial processing and standardization at least meet the nutritional range due to legal obligation. In contrast, milk from local open markets delivered far less nutrition. For example, the Churkhai sample contained only 2.67% fat and 3.18% protein, along with the highest moisture content (90.56%). As an important balanced food source, such nutrient depletion in local vendors' milk could be accounted as an important marker for one of the highest rates of malnutrition in the world that Bangladesh faces (Islam *et al.*, 2019; FAO, 2025).

No formalin or urea was detected in any of the analyzed samples. Similar trends were also studied by Hossain *et al.* (2016), Uddin *et al.* (2016), Rahman *et al.* (2017), M. El-Kholy *et al.* (2018), Moonajilin *et al.* (2018), Karmaker *et al.* (2019), Lal *et al.* (2021), and Nasir and Gemede (2024). This suggests that the toxic chemical adulterants are not widespread in Mymensingh City's milk market. The only sign of chemical masking was an intermittent positive sugar test in one replicate of the milk sample from Sutiakhali. Vendors sometimes use cane sugar to boost density in diluted milk (Kamthania *et al.*, 2014; Islam *et al.*, 2019). The single positive result (out of three replications) implies occasional, possibly opportunistic use. Similar sporadic sugar adulteration has been reported in Bangladesh (Chanda *et al.*, 2013; Karmaker *et al.*, 2019).

Overall, the results affirm that open-market vendors in Mymensingh City primarily commit economic fraud by water dilution, rather than using more sophisticated additives. The combined deficit in TS, SNF, fat, protein, and carbohydrates in most of the local samples means consumers are consuming heavily diluted milk with lower nutritional value. Branded milk samples, by contrast, maintained adequate quality. These findings have practical consequences, as noted by Ionescu *et al.* (2023), who suggested that producers routinely alter the water content of milk to increase milk volume and obtain a higher payment for the adulterated milk with decreased nutritional value.

Conclusion

This study demonstrates that open-market milk sold in Mymensingh City is significantly compromised compared to branded milk. The primary issue is massive dilution with water, leading to sharply lower solids-not-fat, protein, and other nutrients in open-market milk. Commercial brands exhibited higher specific gravity and nutrient levels, reflecting proper standardization. No toxic adulterants (formalin, urea) were found, and added sugar was detected only sporadically. In summary, the consumers of open-market milk in Mymensingh City are at risk of severe nutritional shortfalls. Therefore, public awareness campaigns, stringent quality control, and legal action by law enforcement authorities are urgently needed to protect public health.

Authors Contribution

M.M.R.: Collection of samples, performing the lab experiments, collection and analysis of data, and writing of the manuscript. N.M.: Collection of samples. M.A.I.: Design and co-supervision of the experiments. M.J.H.B.: Supervision of the experiments and review of the manuscript.

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