



Research Article

Comparative Quality Profiling of Butter and Ghee Produced by Different Manufacturers in Bangladesh

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ABSTRACT

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Milk fat products, notably butter and ghee, are widely used because of their rich flavor, nutritional properties, and cultural significance. However, they have not been subjected to sufficiently rigorous, brand-level chemical evaluation, which is necessary to assess nutritional quality, purity, shelf life, and the risk of adulteration. This study evaluated the quality of commercial butter and ghee products from various Bangladeshi manufacturers by measuring key fat-quality parameters. Five samples of butter and six samples of ghee commercially available in the market were analyzed for acid value, peroxide value, iodine value, saponification value, Reichert-Meissl (RM) value, Polenske value, and Kirschner value using standardized Association of Official Analytical Chemists (AOAC) International and Bureau of Indian Standards (BIS) protocols. All measurements were performed in triplicate. Statistical significance was evaluated by a one-way ANOVA ($P \leq 0.05$) using a Completely Randomized Design, and mean variation was ascertained using the Least Significant Difference (LSD) test at a 5% level of significance. The findings showed that most of the commercial dairy lipid brands complied with the national standards. For both butter and ghee, the acid value ranged from 0.46 to 0.75, peroxide value from 0.63 to 0.82, iodine value from 28.35 to 35.86, saponification value from 227.91 to 231.63, RM value from 25.36 to 28.28, Polenske value from 0.64 to 0.87, and Kirschner value from 16.917 to 21.43. Based on a multi-parametric quality index integrating both freshness and purity, Butter-3 was identified as the best choice among commercial butter samples, and Ghee-4 ranked the highest among commercial ghee samples. In conclusion, this study provides a biochemically sound comparison of commercially packaged dairy fats to guide consumers and support regulatory compliance in Bangladesh.

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Introduction

Milk fat is a highly complex lipid matrix composed of approximately 98% triglycerides, along with minor fractions of diacylglycerols, monoacylglycerols, free fatty acids, phospholipids, cholesterol, and fat-soluble vitamins (Jensen, 2002). In South Asian countries, including Bangladesh, milk fat is primarily consumed in concentrated forms such as butter and ghee. Butter is a water-in-oil emulsion containing approximately 80% milk fat, 16% water, and 2% milk solids-not-fat (MSNF), produced by churning pasteurized cream (Patel *et al.*, 2015). In contrast, ghee is a clarified, anhydrous milk fat product containing more than 99.5% milk fat, prepared by heating butter or cream to evaporate moisture and separate caramelized milk solids (Hae-Soo *et al.*, 2013; Kumar *et al.*, 2019; Ray, 2019). Both products are staple culinary items widely utilized in domestic cooking,

baking, confectionery, and traditional Ayurvedic medicine due to their distinctive flavor, high smoke point, and nutritional benefits (Ray, 2019; Chi *et al.*, 2024).

From a nutritional perspective, dairy lipids contain functional components such as conjugated linoleic acid and fat-soluble vitamins (A, D, E, and K), which possess anti-inflammatory, anti-obesity, and immune-modulating properties (Sindhuja *et al.*, 2020). Moreover, emerging epidemiological evidence demonstrates that whole-fat dairy consumption is not associated with an increased risk of cardiovascular disease or type 2 diabetes, prompting a reassessment of traditional dietary restrictions (Astrup *et al.*, 2019).

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Since butter and ghee are highly valued dairy fats, they are extremely vulnerable to economic adulteration in developing countries like Bangladesh (Kumar *et al.*, 2019; Ahmed *et al.*, 2020). Adulterants typically include vegetable oils (such as palm, soybean, or coconut oils) and animal body fats (for example, tallow or lard) (Trbović *et al.*, 2017; Chi *et al.*, 2024). The addition of non-milk fat and other adulterants to butter and ghee can modify their fatty acid composition and lipid profiles, alter their nutritional quality, and potentially pose health risks to consumers (Naviglio *et al.*, 2017; Mahama *et al.*, 2020; Begum and Jain, 2024). For instance, edible oils contaminated with mineral oils are carcinogenic and hepatotoxic (Xia *et al.*, 2021). Similarly, consuming edible oils adulterated with cottonseed oil can lead to adverse health effects, including obesity, diabetes, and cancer, due to its high polyunsaturated fatty acid (PUFA) content (Yang *et al.*, 2021). Likewise, the consumption of butter adulterated with egg yolk, which is added to white butter to give a yellow color to enhance consumer attraction, can result in human salmonellosis (Lake *et al.*, 2015; Gemechu *et al.*, 2021).

Bangladesh standards specify that butter oil and ghee should contain a maximum acid value (mg KOH/g) of 1.9 and a maximum peroxide value (meq O₂/kg) of 0.8, with an iodine value ranging from 26 to 35, minimum saponification and Reichert-Meissl (RM) values of 218.0 and 23.0, respectively, and a maximum Polenske value of 2.8 (BSTI, 2023). While prior studies in Bangladesh have examined isolated milk fat quality or dairy properties (Kumar *et al.*, 2019; Ahmed *et al.*, 2020), there is a lack of comprehensive, brand-specific comparative studies that simultaneously evaluate both purity and freshness using a robust statistical framework. Thus, the specific objectives of this study were set to evaluate the freshness and adulteration levels of leading commercial butter and ghee brands in Bangladesh and establish a comprehensive quality ranking system to identify the highest-performing brands in terms of both freshness and purity. This involved measuring the acid and peroxide values as indicators of freshness, followed by determining the iodine, saponification, Reichert-Meissl (RM), Polenske, and Kirschner values for adulteration analysis, and subsequently ranking the tested butter and ghee samples by assigning an overall quality score to each product.

Materials and Methods

Sample Collection and Preparation

Dairy fat samples, comprising five major butter brands (Butter-1, Butter-2, Butter-3, Butter-4, and Butter-5) and six prominent ghee brands (Ghee-1, Ghee-2, Ghee-

3, Ghee-4, Ghee-5, and Ghee-6), were procured between November 2024 and February 2025 from different retail outlets across various geographic regions in Bangladesh, such as Mymensingh, Dhaka, Chittagong, and Sirajgonj, to reflect regional market diversity. Each source was sampled in triplicate. Butter samples were collected in "Frozen" condition, kept on ice during transport to the laboratory, and stored in a deep freezer at -20°C to maintain their physical and structural integrity. In contrast, ghee samples were collected in "On Shelf" condition, transported to the laboratory within 24 hours under light-protected conditions, and kept in a cool, dry, and dark cupboard to avoid light-induced auto-oxidation.

Milk Fat Constants: Freshness Indicator Analyses

Acid value was determined by weighing 5-10 g of well-mixed sample into an Erlenmeyer flask, adding 50-100 mL of an alcohol-ether mixture and phenolphthalein, and titrating with 0.1 N alcoholic KOH until a faint pink color persisted for 10 seconds. Peroxide value was determined by weighing 5.00 ± 0.05 g of sample, dissolving it in 30 mL acetic acid-chloroform solution, adding 0.5 mL saturated KI, and allowing it to stand for 1 minute. Then, after adding 30 mL water, the liberated iodine was titrated with 0.1 N sodium thiosulfate until the yellow color was almost gone, followed by addition of starch and titration until the blue color disappeared. Both determinations were performed according to AOAC (1995).

Milk Fat Constants: Adulteration Indicator Analyses

Iodine value was measured by the Wijs method (AOAC, 1995). The melted and filtered sample was weighed into a clean, dry flask, dissolved in 15 mL cyclohexane-acetic acid solvent (1:1, v/v), treated with 25 mL Wijs solution, and kept in the dark at $25 \pm 5^\circ\text{C}$ for 1 or 2 hours. After addition of 20 mL KI solution and 150 mL water, the liberated iodine was titrated with 0.1 N sodium thiosulfate using starch as indicator. Saponification value was determined by accurately weighing approximately 5 g of filtered sample, adding 50 mL alcoholic KOH, and boiling under reflux for approximately 30 minutes until the fat was completely saponified. After cooling, the solution was titrated with 0.5 N HCl using phenolphthalein, with a blank determination performed simultaneously (AOAC, 1995). Reichert-Meissl (RM) value, Polenske value, and Kirschner value were measured by steam distillation of saponified fat (BIS, 1966; AOAC, 1995). RM and Polenske values were determined by weighing 5 ± 0.1 g sample, adding 20 mL glycerol-soda solution, and heating until completely saponified. The contents were dissolved in 135 ± 1 mL of recently boiled water, followed by the addition of 6 mL H₂SO₄ (1 + 4) and 15

pieces of silicon carbide. The mixture was steam-distilled to collect 110 mL of distillate in 30 ± 2 min. After cooling and filtration, 100 mL of the filtrate was titrated with 0.1 N NaOH using phenolphthalein for RM value determination. For Polenske value measurement, the insoluble acids were washed from the filter with three 15 mL portions of water, dissolved with three 15 mL portions of neutral alcohol, and the combined alcoholic washings were titrated with 0.1 N NaOH. Kirschner value, in contrast, was determined by adding 0.5 g finely powdered silver sulphate to the neutralized solution, allowing it to stand in the dark for 1 hour with occasional shaking, and filtering in the dark. A 100 mL portion of the filtrate was transferred to a dry Polenske flask, mixed with 35 mL cold distilled water recently boiled for 15 minutes, 10 mL dilute H_2SO_4 , and 0.1 g pumice powder or two glass beads, and distilled to 110 mL in 19-21 min. After mixing and filtration, 100 mL of the filtrate was titrated with barium hydroxide solution.

Statistical Analysis

The study followed a Completely Randomized Design (CRD) in which eleven commercial dairy fat samples from different sources were analyzed in triplicate. One-way ANOVA was performed to find out the significance level at $P \leq 0.05$ using STATA 10. The data were presented as mean $\pm$ standard error (SE), and where ANOVA indicated significant differences ($P \leq 0.05$), the Least Significant Difference (LSD) test was also performed at the 5% significance level to determine the inter-group performance.

Results

Freshness and Adulteration Profiles of Commercial Butter

All measured freshness indicator parameters for the butter samples differed significantly ($P \leq 0.05$) among the five sources (Table 1).

Table 1. Freshness indicator analysis of collected butter samples.

Butter Samples	Acid Value	Peroxide Value
Butter-1	$0.46^b \pm 0.03$	$0.67^b \pm 0.07$
Butter-2	$0.51^b \pm 0.07$	$0.63^b \pm 0.04$
Butter-3	$0.53^b \pm 0.03$	$0.66^b \pm 0.06$
Butter-4	$0.81^a \pm 0.05$	$0.84^a \pm 0.04$
Butter-5	$0.59^b \pm 0.01$	$0.74^{ab} \pm 0.04$

Values are shown as mean $\pm$ SE, which are significantly different ($P \leq 0.05$). The small letters a and b indicate comparison among different samples according to LSD.

The acid values of butter, reflecting hydrolytic stability, showed highly significant differences ($P \leq 0.01$), with Butter-4 exhibiting the highest value, indicative of reduced freshness, and Butter-1 exhibiting the lowest (Table 1). Peroxide values, representing primary oxidation, also differed significantly ($P \leq 0.05$), with

Butter-4 showing the highest oxidative degradation (Table 1).

The milk fat constants measured to assess the adulteration status of the butter samples are presented in Table 2.

Table 2. Assessment of adulteration indicators in collected butter samples.

Butter Samples	Iodine Value	Saponification Value	RM Value	Polenske Value	Kirschner Value
Butter-1	$30.50^a \pm 0.40$	$227.91^c \pm 0.57$	25.53 ± 0.31	$0.73^{abc} \pm 0.03$	17.807 ± 0.45
Butter-2	$30.78^a \pm 0.49$	$229.54^{abc} \pm 0.44$	26.94 ± 0.34	$0.67^{bc} \pm 0.03$	17.013 ± 0.07
Butter-3	$29.54^{ab} \pm 0.33$	$230.96^a \pm 0.60$	26.28 ± 0.35	$0.787^a \pm 0.01$	17.987 ± 0.57
Butter-4	$30.42^a \pm 0.43$	$228.65^{bc} \pm 0.66$	25.36 ± 0.33	$0.64^c \pm 0.05$	16.917 ± 0.25
Butter-5	$28.35^b \pm 0.36$	$230.18^{ab} \pm 0.19$	25.96 ± 0.03	$0.75^{ab} \pm 0.03$	17.803 ± 0.40

Values are shown as mean $\pm$ SE. The small letters a, b, and c indicate comparison among significantly different ($P \leq 0.05$) samples according to LSD.

Iodine values, measuring the degree of fat unsaturation, varied significantly ($P \leq 0.05$), with Butter-2 showing the highest unsaturation and Butter-5 exhibiting the lowest (Table 2). Saponification values also differed significantly ($P \leq 0.05$), with Butter-3 showing the highest value, suggesting a higher abundance of low molecular weight short-chain fatty acids (Table 2). In contrast, Table 2 shows that the RM and Kirschner

values of the butter samples showed no statistically significant differences among the brands ($P > 0.05$), indicating a relatively consistent ruminant fat origin. The Polenske values, on the other hand, differed significantly ($P \leq 0.05$), with Butter-3 showing the highest concentration of water-insoluble volatile fatty acids (Table 2).

Freshness and Adulteration Status of Commercial Ghee

All measured freshness indicators in the tested ghee samples varied significantly ($P \leq 0.05$) among the six sources (Table 3).

Table 3. Analysis of freshness indicators in the collected ghee samples.

Ghee Samples	Acid Value	Peroxide Value
Ghee-1	0.46 ^c ± 0.04	0.68 ^b ± 0.01
Ghee-2	0.56 ^{bc} ± 0.02	0.55 ^c ± 0.04
Ghee-3	0.55 ^{bc} ± 0.06	0.68 ^b ± 0.03
Ghee-4	0.55 ^{bc} ± 0.04	0.68 ^b ± 0.01
Ghee-5	0.75 ^a ± 0.03	0.71 ^{ab} ± 0.05
Ghee-6	0.69 ^{ab} ± 0.07	0.82 ^a ± 0.06

Values are shown as mean ± SE, which are significantly different ($P \leq 0.05$). The small letters a and b indicate comparison among different samples according to LSD.

For commercial ghee samples, the acid and peroxide values showed highly significant ($P \leq 0.01$) brand-to-brand variations (Table 3), indicating differing levels of freshness and oxidative stability. Ghee-5 and Ghee-6 exhibited higher hydrolytic and oxidative degradation,

whereas Ghee-1 and Ghee-2 demonstrated superior freshness profiles.

The measured milk fat constants used to assess the adulteration status of the ghee samples are summarized in Table 4.

Table 4. Assessment of adulteration indicators in tested ghee samples.

Ghee Samples	Iodine Value	Saponification Value	RM Value	Polenske Value	Kirschner Value
Ghee-1	32.37 ^{cd} ± 0.40	230.56 ± 0.43	26.98 ± 0.50	0.74 ^b ± 0.03	20.53 ± 0.29
Ghee-2	33.28 ^{bc} ± 0.35	231.63 ± 0.28	28.28 ± 0.29	0.71 ^b ± 0.01	21.43 ± 0.28
Ghee-3	32.28 ^{cd} ± 0.35	230.61 ± 0.39	27.89 ± 0.47	0.71 ^b ± 0.03	20.88 ± 0.54
Ghee-4	31.87 ^d ± 0.50	231.05 ± 0.38	27.34 ± 0.32	0.78 ^{ab} ± 0.04	20.94 ± 0.30
Ghee-5	35.86 ^a ± 0.42	229.85 ± 0.48	27.05 ± 0.54	0.87 ^a ± 0.03	20.52 ± 0.44
Ghee-6	34.28 ^b ± 0.33	230.77 ± 0.72	26.98 ± 0.51	0.72 ^b ± 0.03	20.33 ± 0.26

Values are shown as mean ± SE. The small letters a, b, c, and d indicate comparison among significantly different ($P \leq 0.05$) samples according to LSD.

Iodine values among ghee brands showed highly significant variations ($P \leq 0.01$), with Ghee-5 exhibiting the highest unsaturation (Table 4). On the contrary, Table 4 indicates that saponification values, RM values, and Kirschner values showed no statistically significant variations ($P > 0.05$), reflecting a stable core ruminant lipid composition. Polenske values, however, differed significantly ($P \leq 0.05$), with Ghee-5 exhibiting the highest concentration of water-insoluble volatile fatty acids (Table 4).

Overall Quality Ranking of Commercial Brands

To provide a consolidated quality index, a multi-parametric ranking system was designed to evaluate the tested brands based on freshness and purity indicators. For butter, the LSD test superscripts were assigned as follows: a = 1, b = 2 for acid, peroxide, and iodine values (where lower is better), and a = 3, b = 2, c = 1 for saponification and Polenske values (where higher is better), as well as corresponding intermediate values. These scores were then combined to determine the overall quality ranking of the collected butter samples, as shown in Table 5.

Table 5. Ranking of the tested butter samples.

Butter Samples	Ranking of Butter							Total Sum	Overall Ranking
	Related to Freshness			Related to Adulteration					
	Acid Value	Peroxide Value	Sum	Iodine Value	Saponification Value	Polenske Value	Sum		
Butter-1	2	2	4	1	1	2	4	8	4 th
Butter-2	2	2	4	1	2	1.5	4.5	8.5	3 rd
Butter-3	2	2	4	1.5	3	3	7.5	11.5	1 st
Butter-4	1	1	2	1	1.5	1	3.5	5.5	5 th
Butter-5	2	1.5	3.5	2	2.5	2.5	7	10.5	2 nd

For ghee, a similar multi-point scoring system was applied as: a = 1, b = 2, c = 3, d = 4 for acid, peroxide, and iodine values (where lower values are considered preferable), and as a = 2, b = 1 for Polenske value (where higher values are preferred), along with

corresponding intermediate values. The total scores were then consolidated to establish the overall quality ranking of the tested ghee samples, as detailed in Table 6.

Table 6. Ranking of the collected ghee samples.

Ghee Samples	Ranking of Ghee						Total Sum	Overall Ranking
	Related to Freshness			Related to Adulteration				
	Acid Value	Peroxide Value	Sum	Iodine Value	Polenske Value	Sum		
Ghee-1	3	2	5	3.5	1	4.5	9.5	2 nd
Ghee-2	2.5	3	5.5	2.5	1	3.5	9	3 rd
Ghee-3	2.5	2	4.5	3.5	1	4.5	9	3 rd
Ghee-4	2.5	2	4.5	4	1.5	5.5	10	1 st
Ghee-5	1	1.5	2.5	1	2	3	5.5	4 th
Ghee-6	1.5	1	2.5	2	1	3	5.5	4 th

Discussion

The milk fat constants measured in this study confirm that most butter and ghee products fall within the expected ranges for dairy fat according to BSTI (2023), but with notable brand-to-brand variation.

The acid values of the butter brands ranged from 0.46 to 0.81 mg KOH/g (Table 1). While all five brands complied with the historical maximum national threshold of 1.9 mg KOH/g (BSTI, 2023), Butter-4 displayed a mean acid value of 0.81 mg KOH/g. The elevated acid value in Butter-4 indicates a possible compromise in the cold chain during retail storage or transport, or advanced storage age. For ghee, the acid values ranged from 0.46 to 0.75 mg KOH/g (Table 3). Even though all brands complied with the BSTI (2023) standard, Ghee-5 (0.75 mg KOH/g) and Ghee-6 (0.69 mg KOH/g) displayed elevated acid values. Such an increase in acid value suggests that the butter used for clarifying may have already undergone hydrolysis, or that moisture was not completely removed during boiling, since the acid value serves as an indicator of hydrolytic rancidity (Jirankalgikar and De, 2014). Similar patterns were reported by previous studies in Bangladesh (Kumar *et al.*, 2019; Ahmed *et al.*, 2020).

The peroxide values of the commercial butter brands ranged from 0.63 to 0.84 meq O₂/kg (Table 1), while those of the ghee samples ranged from 0.55 to 0.82 meq O₂/kg (Table 3). According to BSTI (2023) standards, the maximum permissible peroxide value is 0.8 meq O₂/kg. Subject to this threshold, Butter-4 (0.84 meq O₂/kg) and Ghee-6 (0.82 meq O₂/kg) were slightly above the compliance level, possibly due to poor storage or extended shelf time (Gosewade *et al.*, 2017). The majority of the measured peroxide values in this study are consistent with those previously reported in Bangladesh (Kumar *et al.*, 2019).

While all commercial butter brands conformed to the national standard with iodine values ranging from 28.35 to 30.78 (Table 2), Ghee-5 exhibited an iodine value of 35.86 (Table 4), which slightly exceeded the upper BSTI (2023) limit of 35. This elevation, combined with Ghee-5's relatively low saponification value (229.85) (Table 4) and comparatively elevated Polenske value (0.87) (Table 4), suggests potential adulteration with unsaturated oils since higher iodine values in the samples indicate a greater degree of unsaturation in the fatty acid bonds (Kumar *et al.*, 2019).

The saponification value of all butter and ghee samples in this study met the national requirement (BSTI, 2023), with values ranging from 227.91 to 230.96 for butter (Table 2) and 229.85 to 231.63 for ghee (Table 4). Similar trends were also studied by Ahmed *et al.* (2020), as opposed to the study carried out by Kumar *et al.* (2019), where all of the samples failed to meet the national standards. This suggests the dominance of low molecular weight short- and medium-chain fatty acids characteristic of milk fat because a lower saponification value indicates a reduced content of medium-chain fatty acids and a higher average molecular weight of the samples (Seneviratne and Dissanayake, 2005; Özcan and Chalchat, 2007).

In this study, the RM values of all butter samples were between 25.36 and 26.94 (Table 2), while those of ghee samples ranged from 26.98 to 28.28 (Table 4), complying with the BSTI (2023) standard of RM value $\geq$ 23.0. This indicates a consistent fat profile of bovine origin, since adulteration with vegetable oil or animal body fat reduces the RM value (Ahmed *et al.*, 2020).

The Kirschner values ranged from 16.917 to 17.987 for butter (Table 2) and 20.33 to 21.43 for ghee (Table 4). Although the BSTI (2023) standards do not specify any required Kirschner value threshold, the relatively lower Kirschner values for the butter samples warrant additional investigation.

The Polenske values of the tested butter (0.64 to 0.787) (Table 2) and ghee (0.71 to 0.87) (Table 4) brands were in alignment with the BSTI (2023) maximum limit of 2.8. However, the comparatively lower Polenske values observed in this study may reflect breed-related variation, differences in the regional diet of dairy animals, or minor adulteration, and therefore should be investigated in future studies.

According to the multi-parametric quality ranking, Butter-3 ranked highest (total score 11.5) (Table 5) among all the collected commercial butter brands. It combined excellent freshness compliance (low acid and peroxide values) with high saponification (230.96) and Polenske (0.787) values (Table 2), indicating both high oxidative stability and a rich short-chain fatty acid profile. Butter-5 secured the second rank (score 10.5) (Table 5), aided by its highly favorable low iodine value (28.35) (Table 2). Conversely, Butter-4 ranked last (score 5.5) (Table 5) due to its non-compliance with the BSTI (2023) oxidation limit and high hydrolytic rancidity (Table 1).

For ghee brands, Ghee-4 ranked first (total score 10.0) (Table 6), primarily driven by its low iodine value (31.87) (Table 4) and high Polenske score (0.78) (Table 4). Ghee-1 followed closely in second place (score 9.5) (Table 6), thanks to its superior freshness profile (acid value of 0.46) (Table 3). Ghee-5 and Ghee-6 shared the lowest rank (4th, score 5.5) (Table 6). Ghee-5 was penalized for potential unsaturated oil adulteration (high iodine value of 35.86) (Table 4), whereas Ghee-6 was penalized for increased oxidative rancidity (peroxide value of 0.82) (Table 3) exceeding the BSTI (2023) threshold.

Overall, the commercial butter and ghee samples evaluated in this study generally complied with national quality standards (BSTI, 2023), indicating robust industry compliance and a low risk of gross adulteration in the formal market. Nevertheless, brands exhibiting slightly elevated acid and peroxide values, such as Butter-4 and Ghee-6, require closer regulatory oversight to optimize packaging, processing temperatures, and retail shelf conditions. Further studies integrating gas chromatography (GC) for fatty acid profiling are recommended to expand on these findings.

Conclusion

This study evaluated the quality of commercial butter and ghee brands in Bangladesh in terms of freshness and purity. Most commercial products complied with the national standards. However, notable quality degradation and potential adulteration were identified in specific brands. For example, non-compliance with the national peroxide value limit was detected in Butter-4 and Ghee-6, indicating oxidation and rancidification. In addition, Ghee-5 exhibited a slightly elevated iodine value compared to the national quality threshold, suggesting possible economic adulteration with unsaturated vegetable oils. Saponification and RM values met standard requirements across all samples, ruling out gross substitution of milk fat. Based on the multi-parametric ranking system, Butter-3 and Ghee-4 are the highest-quality choices for consumers. In summary, the results indicate that while some manufacturers maintain high-quality standards, others may require better quality assurance. Therefore, adoption of systematic quality testing and stricter regulatory oversight is recommended to ensure that all commercial butter and ghee meet safety and compositional standards.

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Authors' Contribution

N.M.: Collection of samples, performing the lab experiments, and collection and analysis of data. **M.M.R.:** Collection of samples and writing of the manuscript. **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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