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RESEARCH PAPER

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Physicochemical profiling and quality evaluation of commercial mustard oils brands in Bangladesh: Indicators of stability and consumer safety

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ABSTRACT

This study evaluated the physicochemical quality and stability of five commercially available mustard oil brands in Bangladesh, including four refined oils (Brand-1,2,3,4) and one traditionally processed Local Ghani oil. Eight quality indicators free fatty acid (FFA) content, acid value (AV), moisture, iodine value (IV), peroxide value (PV), saponification value (SV), refractive index, and viscosity were assessed to characterize hydrolytic stability, oxidative status, and compositional attributes. Significant inter-brand differences ($p < 0.05$) were observed for all parameters except viscosity. FFA and AV ranged from (0.69-1.40) % and (1.92-2.81) mg KOH/g, respectively, with Local Ghani oil consistently exhibiting the highest values, indicating greater hydrolytic degradation. Refined oils showed lower moisture content (0.06-0.08%) and reduced peroxide values (4.61-5.30) meq O_2/kg compared to Local Ghani oil (5.90 meq O_2/kg), reflecting improved oxidative stability. Iodine values varied from (91.08 to 101.01) g I_2/100 g, with refined oils, particularly Brand-4 and Brand-2, exhibiting higher degrees of unsaturation. Overall, refined mustard oils demonstrated superior physicochemical uniformity and stability, whereas traditionally processed oil showed comparatively poorer quality indicators, underscoring the need for strengthened quality control and evidence-based regulatory oversight to ensure consumer safety.

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INTRODUCTION

Edible oils are indispensable in human diets worldwide, providing essential fatty acids, fat-soluble vitamins, and a concentrated energy source, while serving as the primary medium for cooking in many cultures. The quality and stability of these oils influence not only nutritional value but also oxidative stability, shelf life, and safety upon consumption (Gharby *et al.*, 2025). In Bangladesh, mustard oil is widely used edible oil due to its characteristic flavour, favourable fatty acid profile, and cultural acceptance (Kabir *et al.*, 2025). Ensuring the integrity and safety of mustard oils is vital for public health and food security. A 2024 study in Bangladesh found that while many samples of edible fats and oils met acceptable physicochemical parameters, some oils had acid and peroxide values above recommended limits (Islam *et al.*, 2024). Previous studies on local edible oils including mustard, soybean, and palm have reported key physicochemical characteristics and vitamin E content to assess quality across brands (Islam *et al.*, 2024). Studies have reported inconsistencies in physicochemical attributes, including acid value, peroxide value, iodine value, and moisture content, reflecting irregular processing, inadequate refining, and suboptimal storage practices (Yeasmin *et al.*, 2024). For instance, a survey of twelve brands including mustard oil revealed considerable variation in peroxide and iodine values, indicating non-uniform quality (Talukder *et al.*, 2018). Fatty acid analyses using gas chromatography show that mustard oil contains a high proportion of unsaturated fatty acids (MUFA and PUFA), making it nutritionally valuable but more prone to oxidation if improperly processed or stored (Chowdhury *et al.*, 2007). Thermal and storage stability are also concerns: heating significantly increases oxidation and degradation markers, affecting both nutritional and safety aspects (Wazed *et al.*, 2023). Previous studies in Bangladesh have investigated particular quality indicators of edible oils, encompassing physicochemical qualities, vitamin E concentration, fatty acid composition, and the impacts of heating and storage. These investigations have furnished critical baseline data concerning the quality and stability of mustard oil. Nevertheless, the majority of studies concentrated on particular metrics or a restricted selection of brands (Islam *et al.*, 2024; Talukder *et al.*, 2018; Chowdhury *et al.*, 2007; Wazed *et al.*, 2023). Notwithstanding these efforts, significant knowledge deficiencies persist. Few existing research have concurrently assessed physicochemical quality and oxidative stability, and recent comparison data on commercially available mustard oil brands in Bangladesh is scarce. Consequently, inter-brand variability and adherence to BSTI and Codex quality criteria are inadequately defined. Additionally, a 2024 study on edible oils did not particularly examine mustard oil or its oxidative stability (Islam *et al.*, 2024). The absence of full information hinders evidence-based consumer counsel, quality control initiatives, and regulatory decision-making. Due to the prevalent use of mustard oil in Bangladesh, accurate information regarding its quality and oxidative stability is crucial for consumer safety and regulatory supervision. A thorough and methodical evaluation of commercially available mustard oil brands is essential to fill these knowledge gaps and furnish current evidence for consumers, regulators, and industry stakeholders. This study evaluates commercial mustard oil brands in Bangladesh, focusing on physicochemical properties and oxidative stability. Major brands will be sampled and analysed with standard methods, benchmarked against BSTI (Bangladesh Standards and Testing Institution) and Codex standards to identify quality and safety variances. This systematic evaluation aims to provide insights for consumers, regulators, and industry stakeholders, establishing a foundation for future monitoring and quality assessment.

MATERIALS AND METHODS

Sample collection

Five mustard oil samples were selected to represent the Bangladeshi retail market, including four widely marketed commercial brands (Brand-1,2,3,4) and one traditionally produced Local Ghani oil. For each brand, samples were collected from three different supermarkets and sourced from three separate production batches to capture market and batch-to-batch variability. All oils were purchased in sealed, intact retail packaging and confirmed to be within their declared shelf life. Upon collection, samples were labelled with brand name, batch number, and purchase date, then stored in a cool, dry, and dark environment to prevent oxidative or thermal degradation. Before analysis, oil was gently homogenized to ensure uniformity.

Experimental design

This study employed a cross-sectional analytical design to compare the physicochemical quality of five widely marketed mustard oil brands in Bangladesh. All assessments followed validated AOAC (Association of Official Analytical Chemists) protocols to ensure methodological accuracy and international comparability. Key quality indicators including FFA (Free Fatty Acid), acid value, moisture content, iodine value, peroxide value, saponification value, refractive index, and viscosity were quantified to evaluate stability and authenticity. Each parameter was measured in triplicate under controlled laboratory conditions in the department of Food Technology and Nutritional Science of Mawlana Bhashani Science and Technology University, Santosh-1902, Tangail City, Dhaka, Bangladesh to minimize variability and enhance reliability. All physicochemical parameters were subsequently measured in triplicate, providing robust analytical precision and improved reliability in inter-brand comparisons as well as a robust framework for detecting inter-brand differences and establishing objective indicators of consumer safety (Fig. 1).

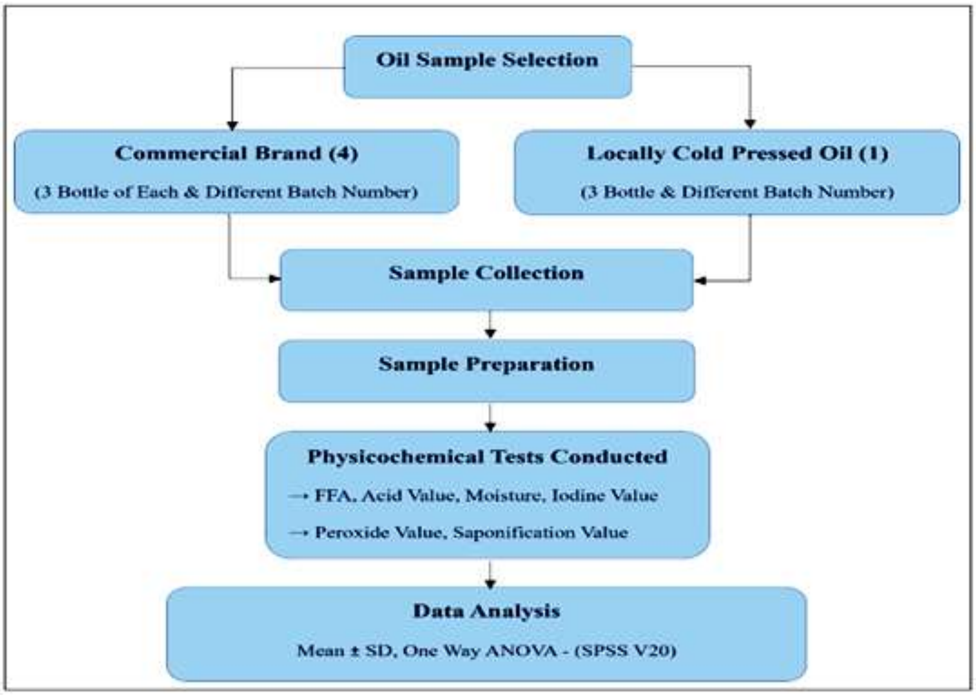

Fig. 1. Experimental workflow of the study

Chemicals and reagents

All chemicals and solvents used in this study were of analytical grade, ensuring high purity and compliance with BSTI (Bangladesh Standards and Testing Institution), AOAC (Association of Official Analytical Chemists), and AOCS (American Oil Chemists' Society) analytical requirements. The reagents employed included potassium hydroxide (KOH) standard solutions (0.1 N and 0.5 N), hydrochloric acid (HCl, 0.5 N), sodium thiosulfate ($Na_2S_2O_3$; 0.01 N and 0.1 N), neutralized ethanol and ethanol ether mixtures, glacial acetic acid, chloroform, saturated potassium iodide (KI) solution, Wijs solution, phenolphthalein indicator (1-2%), and starch indicator (1-2%). Distilled water was used for all reagent preparation, dilution, and washing steps. Moisture content determination required no additional reagents, as the oven-drying method utilized only the oil sample.

All reagents were freshly prepared or standardized before use, and all analyses were conducted under controlled laboratory conditions to maintain methodological accuracy, reproducibility, and alignment with international testing standards.

Determination of physicochemical parameters

Free fatty acid and acid value (mg KOH/g)

Free fatty acid and acid value were determined according to (AOAC, 2023). Oil samples (5 g) were titrated with standardized ethanolic KOH using phenolphthalein as an indicator. Acid value (AV) was calculated as:

$$AV = \frac{V \times N \times 56.1}{W} \qquad (1)$$

Where V= volume of KOH solution used (mL), N= normality of KOH solution (mol/L), W= mass of oil sample (g).

Free fatty acid (%FFA) was expressed as oleic acid equivalent and calculated as:

$$FFA(\%) = \frac{AV \times MW_{\text{oleic}}}{56.1} = \frac{AV \times 282}{56.1} \qquad (2)$$

Where MW_{oleic}= molecular weight of oleic acid (282 g/mol).

Moisture content (%)

Moisture content was determined by oven drying at 105 °C until constant weight, following (AOAC, 2023). Moisture (%) was calculated as:

$$\text{Moisture } (\%) = \frac{W_i - W_f}{W_i} \times 100 \qquad (3)$$

Where W_i= initial weight of oil (g), W_f= weight after drying (g).

Iodine value (g I2/100 g)

Iodine value was determined using the Wijs method (AOAC, 2023). Oil samples reacted with Wijs solution, and liberated iodine was titrated with sodium thiosulfate:

$$IV = \frac{(B-S) \times N \times 12.69}{W} \qquad (4)$$

Where B= mL $Na_2S_2O_3$ used for blank, S= mL $Na_2S_2O_3$ used for sample, N= normality of $Na_2S_2O_3$ solution (mol/L), W= weight of oil sample (g).

Peroxide value (meq O2/kg)

Peroxide value was measured following (AOAC, 2023). Peroxides in the oil liberate iodine from KI in acidic medium, which was titrated with sodium thiosulfate:

$$PV = \frac{(S-B) \times N \times 1000}{W} \qquad (5)$$

Where S= mL $Na_2S_2O_3$ used for sample, B= mL $Na_2S_2O_3$ used for blank, N= normality of $Na_2S_2O_3$ solution (mol/L), W= weight of oil sample (g).

Saponification value (mg KOH/g)

Saponification value was determined according to (AOAC, 2023). Oil samples were refluxed with excess alcoholic KOH, and unreacted KOH was back-titrated with HCl:

$$SV = \frac{(B-S) \times N \times 56.1}{W} \qquad (6)$$

Where B= volume of HCl used for blank (mL), S= volume of HCl used for sample (mL), N= normality of HCl (mol/L), W= weight of oil sample (g).

Refractive index (40 °C)

Refractive index was measured at 40 °C using a digital Abbe-type refractometer (Atago DR-A1, Japan) with temperature-controlled prism.

Viscosity (mPa·s)

Dynamic viscosity was measured at 40 °C using a Brookfield DV-II+ Pro rotational viscometer (USA) with appropriate spindle and rpm.

Viscosity values were expressed in mPa·s as the average of three replicate measurements under controlled temperature.(Sahasrabudhe *et al.*, 2017)0

Statistical analysis

All experiments were performed in triplicate, and data are presented as mean ± SD. One-way ANOVA was used to compare the five commercial oil brands ($p < 0.05$) using SPSS v20.0.

RESULTS

The physicochemical properties of five commercial mustard oil brands exhibited clear and consistent inter-brand variation across all measured quality parameters (Table 1).

Table 1. Physicochemical characteristics of commercial mustard oil brands

Parameter	Local Ghani	Brand-1	Brand-2	Brand-3	Brand-4
Free fatty acid (%)	1.40 ± 0.02^{e}	1.23 ± 0.01^{d}	1.04 ± 0.01^{b}	1.13 ± 0.01^{c}	0.69 ± 0.01^{a}
Acid value (mg KOH/g)	2.81 ± 0.03^{e}	2.20 ± 0.02^{c}	2.06 ± 0.01^{b}	2.29 ± 0.01^{d}	1.92 ± 0.02^{a}
Moisture (%)	0.12 ± 0.01^{b}	0.07 ± 0.01^{a}	0.06 ± 0.01^{a}	0.08 ± 0.01^{a}	0.06 ± 0.00^{a}
Iodine value (g I2/100 g)	91.08 ± 0.12^{a}	98.98 ± 0.10^{c}	100.93 ± 0.12^{d}	98.49 ± 0.07^{b}	101.01 ± 0.10^{d}
Peroxide value (meq O2/kg)	5.90 ± 0.04^{d}	5.24 ± 0.04^{c}	5.30 ± 0.02^{c}	5.10 ± 0.04^{b}	4.61 ± 0.01^{a}
Saponification value (mg KOH/g)	171.80 ± 0.30^{a}	175.16 ± 0.20^{c}	176.10 ± 0.10^{d}	174.41 ± 0.10^{b}	176.10 ± 0.10^{d}
Refractive index (40 °C)	1.4680 ± 0.0001^{b}	1.4616 ± 0.0001^{a}	1.4619 ± 0.0001^{a}	1.4617 ± 0.0001^{a}	1.4617 ± 0.0001^{a}
Viscosity (mPa·s)	20.11 ± 0.06^{a}	20.41 ± 0.06^{c}	20.84 ± 0.04^{d}	20.23 ± 0.07^{ab}	20.39 ± 0.03^{bc}

*Values are expressed as mean ± SD (n = 3). Means within the same row followed by different superscript letters differ significantly according to one-way ANOVA followed by Tukey's HSD post-hoc test ($p < 0.05$).

One-way ANOVA revealed statistically significant differences ($p < 0.05$) for free fatty acid content, acid value, moisture, iodine value, peroxide value, saponification value, refractive index, and viscosity. These parameters collectively reflect differences in hydrolytic stability, oxidative status, fatty acid composition, and processing efficiency among brands, highlighting distinct quality profiles between traditionally processed and industrially refined mustard oils.

Physicochemical characteristics of commercial mustard oil brands

Free fatty acid (FFA) content (Table 1) ranged from (0.69% to 1.40%), with Local Ghani oil exhibiting the highest value and Brand-4 oil the lowest. The mean values showed close agreement across brands, indicating stable central tendency and low dispersion within replicates. Local Ghani oil displayed significantly higher FFA compared to all branded oils, whereas Brand-4 and Brand-2 oils consistently showed lower levels. The observed variation reflects differences in raw material handling, storage practices, and refining efficiency, which influence the extent of triglyceride hydrolysis during processing and post-processing stages. Acid value (AV) followed a pattern comparable to FFA, ranging from (1.92 to 2.81) mg KOH/g. Local Ghani oil recorded the highest AV, while Brand-4 oil showed the lowest value among all samples. The concordance between FFA and AV trends reinforces their reliability as complementary indicators of hydrolytic quality. Narrow standard deviations across all brands suggest good analytical precision and sample homogeneity. Moisture content was low across all samples (0.06-0.12%), with Local Ghani oil exhibiting a significantly higher value, while all refined brands showed statistically comparable and consistently lower moisture levels. Although absolute moisture levels were modest, inter-brand variation highlights differences in drying, clarification, and moisture-control efficiency during oil production. Iodine value (IV), reflecting the degree of unsaturation, varied significantly from (91.08 to 101.01) g I2/100 g. Refined oils generally exhibited higher iodine values than Local Ghani oil, with Brand-2 and Brand-2 oils recording the highest values. The close clustering of mean and median IV values within each brand indicates consistent fatty acid profiles, while the overall range suggests meaningful compositional differences among brands. Peroxide value (PV) ranged from (4.61 to 5.90) meq O2/kg, with significant inter-brand differences. Local Ghani oil showed the highest PV, whereas Brand-4 oil exhibited the lowest value. Despite these differences, PV values for all brands remained within acceptable limits for edible oils, indicating varying but controlled levels of primary oxidation across samples. Saponification value (SV) also differed significantly, ranging from (171.80 to 176.10) mg KOH/g. Higher SVs were observed in Brand-2 and Brand-4 oils, while Local Ghani oil exhibited the lowest value.

The limited dispersion within brands suggests uniform triglyceride composition at the brand level, whereas inter-brand variation reflects differences in fatty acid chain-length distribution. Refractive index measured at 40 °C showed statistically significant but narrow variation (1.4616-1.4680). Refractive index values exhibited statistically significant yet numerically narrow variation, with Local Ghani oil showing a slightly higher value compared to all refined brands, which clustered closely. Local Ghani oil displayed a slightly higher refractive index compared to refined brands, while all branded oils clustered closely, indicating comparable optical properties and compositional consistency. Viscosity values ranged from 20.11 to 20.84 mPa·s and differed significantly among brands ($p < 0.05$). Brand-2 oil exhibited the highest viscosity, while Local Ghani, Brand-3, Brand-4, and Brand-1 oils showed partially overlapping values, indicating moderate variation in flow behaviour across brands despite differences in other physicochemical parameters. Overall, the results demonstrate distinct inter-brand differences in hydrolytic quality, oxidative status, and compositional indicators, with refined oils exhibiting greater uniformity across multiple parameters.

DISCUSSION

This study identified significant variations in the physicochemical quality among five commercial mustard oil brands. Traditional Local Ghani oil showed higher levels of hydrolytic and oxidative degradation, while refined brands like Brand-4, Brand-2, and Brand-1 exhibited better stability and compositional uniformity.

Hydrolytic and oxidative stability: Role of FFA, AV, moisture, and PV

The elevated free fatty acid (FFA) and acid value (AV) in traditionally processed Local Ghani oil compared to refined commercial brands are likely due to inadequate removal of free glycerides, residual moisture, and possible enzymatic activity during extraction. High FFA/AV indicates hydrolytic rancidity, signifying the breakdown of triglycerides into free fatty acids and glycerol, usually promoted by residual water or lipase activity (Flores *et al.*, 2021). Similarly, the peroxide value (PV) a widely accepted index of primary oxidation (hydroperoxide formation) was highest in Local Ghani oil, indicating that this oil experienced more oxidative stress, possibly from prolonged storage, exposure to oxygen or light, or less effective refining. In contrast, refined brands displayed lower PV, suggesting better oxidative stability. These findings are consistent with general observations in edible oil research: refined or properly processed oils tend to have lower FFA and PV relative to crude or locally pressed oils (Bishnoi *et al.*, 2024; Maszewska *et al.*, 2018). The role of moisture was significantly higher in Local Ghani is particularly important. Even small amounts of water can facilitate hydrolysis, leading to increased FFA, and can also influence oxidation processes by affecting the solubility and mobility of oxygen and pro-oxidant catalysts namely metal and ions (Bao *et al.*, 2023). Although water at very low levels such as a few hundred ppm may have limited effect, higher moisture content as seen in less refined oils can meaningfully accelerate degradation pathways (Bao *et al.*, 2023; Emebu *et al.*, 2022). Hence, the combined high FFA, AV, moisture, and PV in Local Ghani oil suggests that traditional processing perhaps cold pressing without rigorous drying and refining leads to inferior stability compared to industrial refining.

Unsaturation, molecular composition, and nutritional implications: Iodine and saponification values

The higher iodine value (IV) in refined brands like Brand-2 and Brand-4 indicates greater unsaturation, which is beneficial for cardiovascular health by replacing saturated fats. Studies support the consumption of unsaturated oils for their lipid-lowering and cardioprotective properties (Gaeini *et al.*, 2021). However, and this is a well-recognized trade-off a higher degree of unsaturation also renders oils more prone to oxidative degradation, especially under suboptimal storage or repeated heating (Gharby *et al.*, 2025). In our study, refined oils displayed lower peroxide value (PV) and acid value (AV) despite having higher iodine value (IV), suggesting effective processing and storage methods. These methods, which include limited oxygen exposure and potential antioxidant additions, preserve oxidative stability, supporting reviews that indicate oxidative stability depends on unsaturation, processing, antioxidant content, and storage conditions (Ma *et al.*, 2023). Saponification value (SV) further complements this picture. Higher saponification value (SV) in refined oils indicates a more uniform triglyceride molecular weight distribution, suggesting controlled refining and consistent feedstock. Conversely, the lower SV in Local Ghani oil implies a wider range of fatty acid chain lengths, potentially due to traditional extraction methods, indicating significant differences in molecular composition that may affect stability and nutritional quality.

Implications in light of food-safety, nutritional and shelf-life perspectives

From a food-safety and shelf-life vantage, oils with high FFA and PV are undesirable, hydrolytic and oxidative rancidity not only degrade nutritive value but also generate volatile and non-volatile oxidation products such as aldehydes and ketones that may cause off-flavours, unpleasant Odors, and potentially toxic effects if consumed over time (Ma *et al.*, 2023; Zhuang *et al.*, 2022). High degradation markers in Local Ghani raise concerns regarding its storage stability, sensory quality, and safety for prolonged use. While higher unsaturation in refined oils may benefit cardiovascular health, a balance between unsaturation and oxidative stability is crucial. This study demonstrates that refined oils can maintain low peroxide and acid values despite higher unsaturation; suggesting proper processing and storage can preserve nutritional benefits without compromising stability. Overall, the findings align with existing literature emphasizing that refining and controlled processing yield oils with better stability and consistent fatty acid composition, unlike traditionally processed oils which may face greater degradation and variability (Bishnoi *et al.*, 2024; Maszewska at al., 2018; Herculano *et al.*, 2021).

Unexpected or noteworthy findings

Overall trends showed expected processing differences, but notable patterns emerged. Local Ghani oil exhibited consistent physicochemical values across replicates, suggesting greater batch uniformity than commonly assumed for traditionally processed oils and challenging the perception of high compositional variability in artisanal products. Additionally, some refined brands exhibited high iodine values alongside low peroxide and FFA levels, indicating that increased unsaturation did not lead to faster oxidation, a decoupling also noted in controlled stability studies of refined oils (Martín-Torres *et al.*, 2023), implying that effective refining, antioxidant retention, and appropriate packaging can offset susceptibility to oxidation.

Mechanistic insights or underlying causes

Differences among mustard oils arise from interactions between lipid composition, moisture, oxidation chemistry, and refining intensity. The elevated FFA and AV in Local Ghani oil reflect moisture-facilitated triglyceride hydrolysis, where residual water enhances lipase activity and accelerates cleavage into free fatty acids (Bishnoi *et al.*, 2024). Traditional cold-pressing preserves more moisture and enzymes compared to industrial refining, which minimizes water levels and hydrolytic degradation. The variation in peroxide value (PV) arises from differences in fatty acid unsaturation and the presence of antioxidants. Refined oils, despite higher iodine values, exhibit low PV due to the removal of metal pro-oxidants and retention of some natural antioxidants, indicating that oxidative stability is influenced by both fatty acid composition and processing methods (Abdel-Razek *et al.*, 2023). Tocopherols and phenolics provide antioxidative protection, whereas trace metals (e.g., Fe^{2+}, Cu^{2+}) accelerate radical generation. Differences in these constituents shaped by seed quality and refining extent, likely contributed to brand-specific PV and AV patterns. Lower SV in Local Ghani indicates a more heterogeneous triglyceride matrix, potentially including longer-chain or non-triglyceride components, which affects viscosity, oxidative behaviour, and overall stability.

Practical implications and recommendations

High FFA, AV, and PV in Local Ghani oil indicate greater hydrolytic and oxidative deterioration, which may lead to formation of aldehydes and other off-flavour oxidation products during regular consumption. Refined brands, with lower degradation markers but higher unsaturation, offer both stability and cardiovascular benefits.

The data highlight the importance of moisture control, removal of pro-oxidants, and uniform triglyceride composition achieved through industrial refining, which collectively enhance oxidative stability (Martín-Torres *et al.*, 2023). Traditional producers could significantly improve product quality by incorporating better drying, light protection, and modest antioxidant fortification Variable quality across brands underscores the need for enforced limits for FFA, PV, and moisture aligned with Codex standards (CAC, 2020). Clear labelling on processing methods and storage recommendations would strengthen consumer decision-making and market accountability.

Strengths and limitations

This study assesses mustard oil quality through physicochemical indicators, distinguishing between traditional and refined products. It links quality differences to processing methods, emphasizing implications for consumer safety and industry practices. Limitations include few replicates, fatty acid profiling, lack of analysis on minor bioactive compounds, and a focus on a single regional market. Nonetheless, it provides a comprehensive overview of quality patterns in commercially available mustard oils.

CONCLUSION

This study provides a comprehensive evaluation of commercial mustard oils in Bangladesh, revealing clear differences between traditionally processed and industrially refined brands. Traditional oils exhibited higher free fatty acids, acid and peroxide values, and moisture content, indicating greater susceptibility to hydrolytic and oxidative degradation, whereas refined oils demonstrated superior stability and uniform triglyceride composition despite higher unsaturation. Mechanistically, these differences reflect the interplay of residual moisture, fatty acid unsaturation, minor antioxidants or pro-oxidants, and refining processes. From a practical perspective, refined oils offer greater nutritional reliability and shelf-life, while traditionally processed oils require careful handling to mitigate degradation. Overall, the findings highlight key indicators of oil stability and consumer safety, providing actionable guidance for consumers, producers, and regulators.

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