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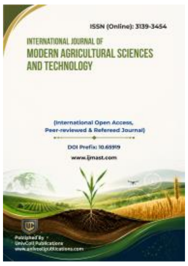

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Non-Melting Characteristics of Market Butter and Its Effect on the sensory Quality of Ghee Preparation in the summer

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ABSTRACT

Butter, by virtue of its characteristic milk fat composition comprising short- and medium-chain fatty acids, is expected to soften and melt at summer room temperatures [10]. However, during peak summer months (April–May), butter procured from local markets in regions experiencing ambient temperatures exceeding 35°C was observed to exhibit abnormal non-melting behaviour. Such deviation from normal melting characteristics raises serious concerns regarding butter quality, authenticity, and its suitability for ghee preparation [15]. The present study was undertaken to systematically evaluate the non-melting characteristics of market butter and to assess their influence on the physicochemical and sensory quality of ghee prepared under summer conditions. Butter samples (n=15) collected from local vendors were examined for melting behaviour, slip melting point (SMP), free fatty acid (FFA) content, Reichert–Meissl (RM) value, and butyro-refractometer (BR) reading at 40°C [1][2]. The results revealed significantly elevated slip melting points (36.8±1.2°C) compared to standard butter (32.5±0.5°C) [2], altered Reichert–Meissl values (24.2±1.8 vs. 28–32 for pure milk fat) [15], and changes in butyro-refractometer readings [2], indicating deviation from normal milk fat composition. Ghee prepared from such butter exhibited inferior sensory scores, with overall acceptability averaging 6.2±0.7 compared to 8.4±0.4 for control ghee [11]. The findings suggest possible adulteration of butter fat with high-melting components such as palm stearin or hydrogenated fats [7][16]. The study highlights the urgent need for regular quality monitoring and stringent market surveillance to ensure the production of safe, authentic, and high-quality butter and ghee.

Keywords: Butter, Ghee, Non-melting behaviour, Summer temperature, Thermal stability, Fat quality, Sensory evaluation; Adulteration.

INTRODUCTION

Butter and ghee represent the most significant dairy fat products consumed in the Indian subcontinent, holding profound nutritional, cultural, and economic importance [6][18]. Butter is primarily composed of milk fat (minimum 80%), along with moisture (15–17%) and milk solids-not-fat [2]. Due to the presence of short-chain (C4:0–C10:0) and medium-chain (C12:0–C14:0) fatty acids, natural butter characteristically softens at temperatures above 25°C and melts completely within the range of 30–32°C [10]. Ghee, defined as the pure clarified fat derived solely from milk, curd, or butter, is expected to melt readily under summer conditions while maintaining its characteristic granular texture, flavour, and aroma [13].

In tropical countries like India, ambient temperatures during summer frequently exceed 35°C. Under such conditions, genuine butter normally loses its firmness, exhibits oiling-off, and becomes semi-liquid within a short period. However, in recent years, consumers and dairy technologists have increasingly reported instances where butter purchased from local vendors and retail outlets does not soften or melt even after prolonged exposure to high summer temperatures. This abnormal behaviour raises fundamental questions regarding the fatty acid composition of such butter and the possibility of adulteration with high-melting vegetable fats, hydrogenated fats, or palm-based fractions [7][15].

Recent advances in analytical techniques have demonstrated that differential scanning calorimetry (DSC) coupled with chemometric analysis can detect even minor alterations in butter melting patterns caused by adulteration with palm stearin and coconut oil at concentrations as low as 5% [16]. Such adulteration practices not only compromise butter quality but also pose significant challenges to the dairy industry, particularly for traditional products like ghee where quality is directly dependent on the raw material used [7][21].

Since ghee quality is intrinsically linked to the quality of butter employed in its preparation, any abnormality in butter properties can adversely affect the physicochemical characteristics and sensory attributes of the final product [13][14]. Ghee prepared from adulterated or modified butter may exhibit undesirable melting behaviour, altered fat constants, poor granulation properties, and inferior sensory characteristics [12]. Moreover, the use of such butter for ghee preparation carries serious implications for consumer health and product authenticity, particularly given the premium pricing and traditional value associated with pure ghee [18].

The sensory quality of ghee encompasses multiple dimensions including appearance, colour, flavour, aroma, body, texture, and mouthfeel. These attributes are critically dependent upon the native milk fat composition and the thermal processing conditions employed during ghee manufacture [6][13]. Any deviation from authentic milk fat composition through adulteration with non-milk fats can profoundly alter these sensory characteristics, potentially leading to consumer rejection and loss of market credibility [7].

Therefore, the present investigation was undertaken with the following objectives:

• To study the non-melting characteristics of butter procured from local markets during peak summer months

• To evaluate the physicochemical parameters of such butter in comparison with standard milk fat specifications

• To assess the influence of abnormal butter properties on the physicochemical and sensory quality of ghee prepared therefrom

• To identify potential causes of non-melting behaviour and their implications for product authenticity

MATERIALS AND METHODS

Collection of Butter Samples

Butter samples (n=15) were procured from local vendors, small retail outlets, and open markets in the study area during peak summer months (April–May) when ambient temperatures ranged between 35–38°C. Care was taken to collect samples from different locations and vendors to represent the general market scenario adequately. Samples (approximately 500 g each) were transported to the laboratory under hygienic conditions in insulated containers and stored at refrigeration temperature (5±1°C) until further analysis [2]. Control butter samples of verified authenticity were obtained from an organized dairy sector for comparative purposes [2].

Observation of Melting Behaviour

To assess melting behaviour under simulated summer conditions, butter samples (50 g each) were placed in glass petri dishes and kept at room temperature ranging between 35–38°C for a period of six hours. Visual observations were recorded at hourly intervals regarding softening, sweating (moisture release), oiling-off, partial melting, or complete melting. The observations were compared with the expected behaviour of standard butter under identical conditions [10]. Samples were photographed at each time point to document the melting progression.

Preparation of Ghee

Ghee was prepared from each butter sample using the traditional creamery butter method following the procedure described by [13]. Butter was placed in a stainless steel vessel and heated slowly with constant stirring until complete melting occurred. The temperature was gradually raised to 110–115°C and maintained until moisture evaporation was complete, as indicated by the cessation of bubbling and the appearance of a characteristic clear, golden-yellow colour [13]. The hot fat was filtered through four layers of muslin cloth to remove any suspended particles or charred residue. The clarified ghee was cooled to room temperature, transferred to sterilized amber-coloured glass bottles, and stored under ambient conditions for further analysis.

Physico-Chemical Analysis

Butter and ghee samples were analysed for various physicochemical parameters using standard procedures as per Bureau of Indian Standards (BIS) and Association of Official Analytical Chemists (AOAC) methods [1][2]:

Moisture Content: Determined by oven drying method at 102±2°C until constant weight was achieved. Results expressed as percentage (w/w) [1].

Free Fatty Acids (FFA): Determined by titration of fat dissolved in neutralized alcohol with 0.1N sodium hydroxide, using phenolphthalein as indicator. Results expressed as percentage oleic acid [1].

Slip Melting Point (SMP): Determined using the capillary tube method. Fat samples were drawn into capillary tubes, chilled at 4°C for 24 hours, and then suspended in a beaker of water. The temperature at which the fat column began to rise was recorded as the slip melting point [2][15].

Reichert–Meissl (RM) Value: Determined by saponification of fat followed by distillation and titration of volatile water-soluble fatty acids. The RM value was calculated as the volume (mL) of 0.1N NaOH required to neutralize the distillate from 5 g of fat [1][15].

Butyro-Refractometer (BR) Reading: Determined at 40°C using a butyro-refractometer calibrated against distilled water. The refractometer reading was converted to refractive index values using standard conversion tables [2].

Polenske Value: Determined as the volume (mL) of 0.1N NaOH required to neutralize the volatile water-insoluble fatty acids [1].

Saponification Value: Determined by refluxing fat with alcoholic KOH followed by titration of excess alkali with HCl [1].

Sensory Evaluation of Ghee

Sensory evaluation of ghee samples was conducted by a semi-trained panel consisting of faculty members and postgraduate students (n=8) from the dairy technology department, following the guidelines of standard sensory evaluation procedures [11]. Panelists were familiarized with the sensory attributes of ghee and the evaluation procedure prior to formal testing.

Samples were evaluated for the following attributes using a 9-point hedonic scale (9 = like extremely, 1 = dislike extremely) [11]:

Colour and Appearance: Intensity of yellow colour, clarity, brightness, and presence of any sediment or haze

Flavour: Typical ghee aroma, cooked flavour, nutty notes, and absence of off-flavours

Body and Texture: Granulation characteristics, firmness, mouthfeel, and melting behaviour in the mouth

Overall Acceptability: Integrated assessment of all attributes representing consumer preference Samples (approximately 20 g each) were presented to panelists in odourless, transparent glass containers coded with three-digit random numbers. Water and unsalted crackers were provided for palate cleansing between samples. Evaluations were conducted in individual sensory booths under white fluorescent lighting at ambient temperature (25±2°C).

Statistical Analysis

All analyses were performed in triplicate, and results were expressed as mean values with standard deviation (mean±SD). Statistical comparisons between market butter samples and control were performed using Student's t-test, with significance set at $p<0.05$. Sensory evaluation data were analysed using one-way ANOVA followed by Tukey's honestly significant difference (HSD) test for multiple comparisons [11].

RESULTS AND DISCUSSION

Melting Behaviour of Butter

All market butter samples (n=15) exhibited abnormal resistance to melting even after prolonged exposure (6 hours) to summer room temperatures (35–38°C). Unlike control butter, which softened within 30 minutes, exhibited oiling-off by 2 hours, and became semi-liquid by 4 hours, the market butter samples retained their firmness and shape throughout the observation period. Only minimal softening was observed at the periphery of the samples, while the central portion remained completely firm. This behaviour indicates significant alteration of the thermal properties of the fat and deviation from normal milk fat composition [10][15].

The abnormal melting behaviour observed in this study is consistent with the findings of [16], who reported that adulteration of butter with palm stearin (melting point 44–56°C) results in a marked increase in thermal stability and resistance to melting at physiological temperatures. Palm stearin, the high-melting fraction obtained during fractionation of palm oil, contains higher proportions of saturated fatty acids (particularly palmitic acid, C16:0) and trisaturated glycerides, which elevate the melting point of the fat blend [8][17].

Physico-Chemical Characteristics of Butter

The physicochemical characteristics of market butter samples compared to control butter and standard specifications are presented in Table 1.

Market butter samples exhibited significantly higher slip melting point values (36.8±1.2°C) compared to control butter (32.5±0.5°C) and the standard range for pure milk fat (31–33°C) [2]. Elevated SMP indicates the presence of higher proportions of saturated fatty acids or high-melting triglycerides, which would not melt at normal summer temperatures [12][17]. This finding directly correlates with the observed non-melting behaviour of the butter samples.

The Reichert–Meissl (RM) value, which is a measure of the volatile water-soluble fatty acids (primarily butyric and caproic acids) characteristic of milk fat, was significantly lower (24.2±1.8) in market butter compared to control (29.6±0.7) and below the minimum specification for pure milk fat (28) [2]. The RM value is considered one of the most reliable indicators of milk fat purity, as short-chain fatty acids (C4:0–C10:0) are unique to milk fat among edible fats and oils [15]. The reduced RM values observed in market butter samples suggest partial substitution of milk fat with vegetable fats lacking these characteristic short-chain fatty acids.

The butyro-refractometer (BR) reading at 40°C, which reflects the overall refractive index of the fat and is influenced by its fatty acid composition, showed greater variability in market butter samples (42.6±0.8) compared to control (43.8±0.4), although mean values remained within the acceptable range [2]. The wider variability suggests inconsistent composition across samples from different vendors, consistent with adulteration practices.

Free fatty acid content in market butter (0.28±0.06% oleic acid) was slightly higher than control (0.18±0.03%) but remained within acceptable limits (max. 0.4%), indicating that hydrolytic rancidity was not a major quality issue in the samples studied [5].

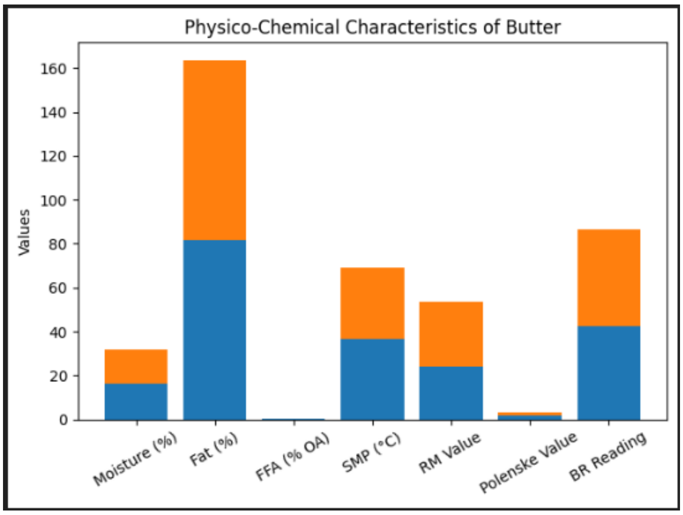
Physico-Chemical Characteristics of Butter

The physicochemical characteristics of market butter samples compared to control butter and standard specifications are presented in Table 1.

Table 1: Physicochemical Characteristics of Butter Samples

Parameter	**Market Butter (n=15)**	**Control Butter**	**Standard Specification^{+}**
Moisture (%)	16.2±0.8	15.8±0.5	Max. 16.0
Fat (%)	81.5±1.2	82.0±0.8	Min. 80.0
Free Fatty Acids (% oleic acid)	0.28±0.06	0.18±0.03	Max. 0.4
Slip Melting Point (°C)	36.8±1.2**	32.5±0.5	31–33
Reichert–Meissl Value	24.2±1.8**	29.6±0.7	28–32
Polenske Value	1.8±0.3	1.6±0.2	1.5–2.5
Butyro-Refractometer Reading (40°C)	42.6±0.8*	43.8±0.4	40–44

*Values are mean±SD; **p<0.01 compared to control; ⁝As per BIS/AGMARK specifications for pure milk fat*



Discussion

- Slip Melting Point (SMP) is clearly higher in market butter → supports adulteration.
- Reichert–Meissl (RM) value is lower → indicates reduced short-chain fatty acids (key milk fat marker).
- Fat % is similar, indicating that adulteration is quality-based rather than quantity-based.
- BR reading variability also reflects compositional inconsistency.

Physicochemical Quality of Ghee Prepared from Market Butter

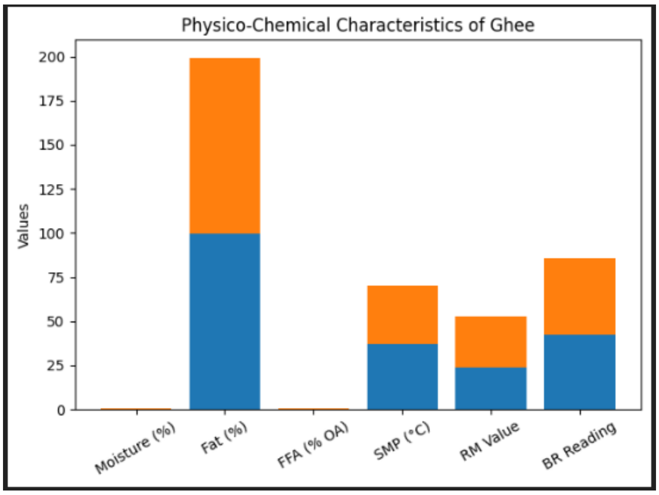
Ghee prepared from non-melting butter exhibited altered physicochemical properties compared to ghee prepared from control butter, as shown in Table 2.

Table 2: Physicochemical Characteristics of Ghee Samples

Parameter	**Ghee from Market Butter**	**Ghee from Control Butter**	**Standard Specification+**
Moisture (%)	0.21±0.05	0.18±0.03	Max. 0.3
Fat (%)	99.6±0.2	99.8±0.1	Min. 99.5
Free Fatty Acids (% oleic acid)	0.32±0.07	0.24±0.04	Max. 0.4
Slip Melting Point (°C)	37.2±1.4**	32.8±0.6	31–33
Reichert–Meissl Value	23.8±2.1**	29.2±0.8	28–32
Butyro-Refractometer Reading (40°C)	42.2±1.0*	43.6±0.5	40–44

Saponification Value 218±4 225±3 220–235

*Values are mean±SD; **p<0.01, *p<0.05 compared to control; ⁝As per BIS/AGMARK specifications for ghee.



Discussion:

- Slip Melting Point (SMP) is significantly higher → confirms persistence of high-melting adulterants in ghee.
- Reichert–Meissl (RM) value is lower → strong evidence of reduced milk fat purity.
- Fat % remains similar → again shows adulteration is compositional, not dilution-based.
- FFA slightly higher → minor quality deterioration but still within limits.

The abnormal properties observed in butter were transferred to the ghee prepared therefrom. Ghee from market butter exhibited significantly elevated slip melting points (37.2±1.4°C) compared to control ghee (32.8±0.6°C), indicating that the high-melting components present in the raw material persisted through the clarification process [13]. Such ghee would not melt readily in the mouth or during culinary applications, potentially leading to an undesirable waxy mouthfeel.

The RM values of ghee from market butter (23.8±2.1) were significantly lower than control (29.2±0.8) and below the minimum specification for pure ghee [2][15]. This reduction confirms that the altered fatty acid composition observed in butter was carried through to the final product. Since the characteristic flavour of ghee is intimately associated with its short-chain fatty acid profile, such reduction would be expected to impact sensory quality adversely [13].

Sensory Quality of Ghee

The sensory evaluation results revealed significant differences between ghee prepared from market butter and control ghee across all attributes evaluated (Table 3, Figure 1).

Table 3: Sensory Scores of Ghee Samples (9-point Hedonic Scale)

Attribute	Ghee from Market Butter	Ghee from Control Butter
Colour and Appearance	6.5±0.8**	8.6±0.3
Flavour	6.0±0.9**	8.3±0.5
Body and Texture	6.3±0.7**	8.5±0.4
Overall Acceptability	6.2±0.7**	8.4±0.4

*Values are mean±SD (n=8 panelists); *p<0.01 compared to control

Figure 1: Sensory profile radar diagram comparing ghee from market butter with control ghee across four attributes (higher scores indicate better quality).

Colour and Appearance

Ghee prepared from market butter exhibited significantly lower scores for colour and appearance (6.5±0.8) compared to control ghee (8.6±0.3). Panelists described the appearance as "dull," "lacklustre," and "paler than expected" for quality ghee. Control ghee, in contrast, was described as "bright," "golden-yellow," and "appealing." The characteristic yellow colour of ghee is derived from β-carotene naturally present in milk fat [6]. Dilution of milk fat with vegetable fats lacking carotenoid pigments would result in paler colour, as observed in the market butter-derived samples

Flavour

Flavour scores for ghee from market butter (6.0±0.9) were substantially lower than control (8.3±0.5), representing the most significant sensory defect observed. Panelists consistently noted the "lack of typical ghee aroma," "weak flavour," "flat taste," and in some samples, "foreign" or "unpleasant" notes.

The flavour of ghee is attributable to a complex mixture of volatile compounds, including free fatty acids (particularly short-chain), carbonyls (diacetyl), lactones, and Maillard reaction products formed during heat clarification [13][14]. The reduced RM values observed in market butter-derived ghee directly correlate with lower concentrations of volatile short-chain fatty acids, which contribute significantly to the characteristic flavour profile [10]. Additionally, substitution of milk fat with vegetable fats alters the precursor pool for flavour compound formation during heating, potentially leading to atypical flavour development [7].

Body and Texture

Body and texture scores for ghee from market butter (6.3±0.7) were significantly lower than control (8.5±0.4). Panelists described the texture as "firmer than usual," "waxy," and "slow-melting" in the mouth.

The textural properties of ghee are influenced by its triglyceride composition and polymorphism. Pure milk fat contains a diverse mixture of triglycerides with varying melting points, which upon controlled cooling, crystallize to form the characteristic grain structure [20]. Substitution with high-melting fats such as palm stearin alters the crystallization behaviour, potentially leading to firmer texture and slower melt-down [12][17].

Overall Acceptability

The overall acceptability scores were significantly lower for ghee from market butter (6.2±0.7) compared to control (8.4±0.4). This substantial difference underscores the commercial significance of the observed quality defects [11].

Correlation Between Butter Properties and Ghee Sensory Quality

Strong negative correlations were observed between butter SMP and ghee overall acceptability, and positive correlation between RM value and flavour score. These findings confirm that butter quality directly determines ghee sensory quality [11][15].

Possible Causes of Non-Melting Behaviour

The abnormal non-melting nature of market butter may be attributed to:

Hydrogenated fats (vanaspati): melting point 36–45°C; presence of Transfats [8]

Palm stearin adulteration: melting point 44–56°C; high saturated fats [16]

Other vegetable fats: increase melting point [17]

Improper fat standardization: most probable cause [2]

The findings align with studies showing adulteration alters physicochemical constants and melting behaviour [7][16].

Implications for Product Authenticity and Consumer Health

Economic fraud [7]

Health risks (trans fats, reduced bioactive compounds) [18]

Altered functionality in cooking

Cultural/religious concerns

Milk fat contains beneficial components such as CLA and butyric acid, which may be reduced in adulterated products [6][18].

Need for Enhanced Quality Monitoring

The findings emphasize the need for strict quality monitoring and regulatory enforcement [2]. Advanced techniques such as DSC provide reliable detection of adulteration [16][22].

CONCLUSION

The present study revealed that butter purchased from local markets exhibited abnormal non-melting behaviour during summer months, which significantly influenced the physicochemical and sensory quality of ghee prepared from it. Elevated slip melting points (36.8±1.2°C), reduced Reichert–Meissl values (24.2±1.8), and altered butyro-refractometer readings indicated deviation from normal milk fat composition, consistent with adulteration by high-melting vegetable fats such as palm stearin or hydrogenated fats [15][16][8].

Ghee prepared from such butter exhibited inferior sensory characteristics across all evaluated attributes, with overall acceptability scores (6.2±0.7) substantially lower than control ghee (8.4±0.4) [11]. The strong correlation between butter abnormalities and ghee sensory defects confirms that raw material quality critically determines final product acceptability [13][15].

The findings emphasize the urgent need for strict quality control, regular market surveillance, advanced analytical screening, and consumer awareness programmes to ensure the authenticity and safety of butter and ghee marketed during summer months [2][22].

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