

GHEE RESIDUE: COMPOSITION, NUTRITIONAL SIGNIFICANCE, FUNCTIONAL PROPERTIES AND EMERGING OPPORTUNITIES FOR VALUE ADDITION IN FOOD SYSTEMS – A REVIEW

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1. Introduction

The dairy industry generates a variety of by-products during the manufacture of value-added milk products. Efficient utilization of these by-products has become increasingly important due to economic, environmental, and sustainability considerations. Among traditional dairy products, ghee occupies a prominent position in India owing to its characteristic flavor, long shelf life, and cultural significance (De, 2001; Aneja et al., 2002). During the manufacture of ghee, a brownish sediment known as ghee residue is generated as a by-product. Although traditionally regarded as a low-value material, ghee residue possesses considerable nutritional and functional potential because it contains concentrated milk proteins, residual milk fat, lactose, phospholipids, minerals, and flavor compounds generated during thermal processing (Patel and Upadhyay, 2015).

Recent emphasis on circular bioeconomy and sustainable dairy processing has renewed scientific interest in valorization of dairy by-products. Similar to whey, buttermilk, and skim milk solids, ghee residue has attracted attention as a potential ingredient for development of value-added foods and functional products (Yadav et al., 2011; Sarkar, 2015). The pleasant caramelized flavor and high nutrient density of ghee residue make it suitable for incorporation into confectionery, bakery, snack, and nutraceutical products.

2. Formation of Ghee Residue

Ghee residue is formed during clarification of butter or cream when moisture evaporates and non-fat milk solids become concentrated. During heating, milk proteins denature, lactose undergoes caramelization and Maillard reactions, and phospholipids become concentrated within the sediment fraction (Rangappa and Achaya, 1974). The quantity of residue generated depends upon the method of ghee manufacture, heating conditions, quality of raw material, and source of milk (Aneja et al., 2002).

Traditional desi methods generally yield larger quantities of residue than direct cream methods because greater quantities of milk solids are

retained in the product (De, 2001). Depending upon processing conditions, ghee residue may account for approximately 3–8% of the milk solids present in the starting material (Patel and Upadhyay, 2015).

3. Composition of Ghee Residue

The nutritional composition of ghee residue varies considerably depending on the source of milk and method of manufacture. However, most studies indicate that it contains substantial amounts of protein and fat, making it a nutritionally dense dairy by-product (Prajapati and Nair, 2008).

Table 1. Typical Composition of Ghee Residue

Component	Range (%)
Moisture	3–8
Fat	30–60
Protein	20–35
Lactose	8–15
Ash	3–8

The relatively high protein content arises from concentration of casein and denatured whey proteins during thermal clarification. Residual milk fat contributes desirable flavor and energy value, while phospholipids and minerals enhance nutritional quality (Walstra et al., 2006).

4. Nutritional Significance

The nutritional importance of ghee residue has often been underestimated. Owing to concentration of milk solids during heating, the residue contains higher concentrations of proteins and minerals than many conventional cereal-based foods (Prajapati and Nair, 2008).

Milk proteins present in ghee residue possess high biological value and provide essential amino acids required for growth and tissue repair. Residual milk fat contributes energy, fat-soluble vitamins, and flavor-enhancing compounds. Furthermore, concentrated minerals such as calcium and phosphorus support skeletal development and metabolic functions (Walstra et al., 2006).

The thermal reactions occurring during ghee manufacture generate Maillard reaction products, which contribute characteristic flavor and may exhibit antioxidant properties. Similar observations

have been reported for thermally processed dairy products where controlled browning contributes desirable sensory attributes and antioxidant activity (Sarkar, 2015).

5. Functional Properties

The functionality of ghee residue is largely determined by interactions among proteins, lipids, phospholipids, and Maillard reaction products.

Water Absorption Capacity: Denatured milk proteins present in the residue exhibit substantial water-binding capacity, contributing to improved texture and moisture retention in food systems (Walstra et al., 2006).

Fat Absorption Capacity: The presence of residual milk fat and protein complexes enhances flavor retention and mouthfeel, making ghee residue suitable for bakery and confectionery applications (Patel and Upadhyay, 2015).

Emulsification Properties: Milk phospholipids concentrated during ghee manufacture contribute emulsification properties that can improve stability of food emulsions (Aneja et al., 2002).

Flavor Enhancement: One of the most important functional characteristics of ghee residue is its intense caramelized flavor generated through Maillard reactions and lactose degradation during heating (Rangappa and Achaya, 1974).

6. Utilization in Traditional Dairy and Confectionery Products

Traditional communities have utilized ghee residue for generations in preparation of sweet and savory foods. Direct consumption of residue mixed with sugar or jaggery remains common in several regions of India (Rajorhia, 2002).

Ghee residue has been incorporated into products such as Burfi, Pedha, Laddu, Halwa, Sweet fillings and Traditional cereal-based foods

Incorporation of ghee residue not only enhances nutritional quality but also imparts characteristic roasted and caramelized flavor notes that improve consumer acceptance (Rajorhia, 2002; Sarkar, 2015). Studies have demonstrated that incorporation levels of 5–20% can improve flavor and texture characteristics of confectionery products without adversely affecting consumer acceptability (Patel and Upadhyay, 2015).

7. Applications in Bakery Products

The bakery industry represents one of the most promising sectors for utilization of ghee residue. Bakery products such as cookies, cakes, biscuits, muffins, and bread can benefit from the flavor-enhancing and moisture-retaining properties of ghee residue (Yadav et al., 2011). In cookies and biscuits, incorporation of residue contributes

desirable flavor, improved nutritional quality, and enhanced browning characteristics. The protein fraction also contributes to improved texture and nutritional value (Prajapati and Nair, 2008).

Similarly, incorporation of ghee residue in cakes has been reported to improve softness, moisture retention, and sensory acceptability owing to its fat-protein matrix and flavor compounds (Patel and Upadhyay, 2015).

8. Nutraceutical and Functional Food Applications

The growing market for functional foods provides new opportunities for valorization of ghee residue. Owing to its richness in proteins, phospholipids, minerals, and bioactive compounds, ghee residue may serve as a valuable ingredient in nutraceutical products (Yadav et al., 2011).

The potential applications include Protein-enriched snacks, Nutritional bars, Functional bakery products, Dairy-based nutritional supplements, Sports nutrition products and Elderly nutrition formulations. Recent trends toward sustainable nutrition and clean-label foods further enhance the attractiveness of ghee residue as a natural functional ingredient (Sarkar, 2015).

9. Sustainability and Circular Bioeconomy

The concept of circular bioeconomy emphasizes efficient utilization of food-processing by-products to minimize waste and maximize resource recovery. Utilization of ghee residue aligns strongly with these principles (Patel and Upadhyay, 2015). Conversion of ghee residue into value-added food ingredients can Reduce processing losses, Improve dairy industry profitability, Minimize environmental burden, Support sustainable food production, Enhance resource-use efficiency. Such approaches are increasingly important in modern dairy processing systems where sustainability has become a key performance indicator (Yadav et al., 2011).

10. Future Research Opportunities

Despite considerable potential, scientific information regarding ghee residue remains limited. Future research should focus on following areas:

- Comprehensive compositional characterization.
- Identification of bioactive compounds.
- Antioxidant and nutraceutical properties.
- Product development and optimization.
- Shelf-life enhancement strategies.
- Encapsulation technologies.
- Consumer acceptance studies.
- Commercial-scale processing technologies.

Advanced analytical techniques such as proteomics, lipidomics, metabolomics, and flavor chemistry

may further improve understanding of the functional properties of ghee residue and facilitate development of novel food products.

11. Conclusion

Ghee residue is a nutritionally valuable and functionally versatile dairy by-product possessing substantial potential for value addition. Rich in proteins, milk fat, phospholipids, minerals, and flavor compounds, it can be effectively utilized in confectionery, bakery, snack foods, and functional food formulations. Scientific exploitation of ghee residue can contribute significantly to sustainable dairy processing, circular bioeconomy, and development of innovative value-added food products. Future research directed toward functional characterization, process optimization, and commercialization will facilitate wider utilization of this underexploited dairy resource.

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