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RESEARCH ARTICLE

# Ghee's Multifaceted Benefits for Daily Nutrition and Health

**Sadhna Semwal[1]*, Rahul Kumar[1], Prof. Rajkumar D R [2], Pooja Jha[3], Surbhi[4], Suman[5], Dr. N. Murugalatha[6], Prof. Barkha Khurana[7], Kunal Bijalwan[8], Chhavi Singh9, Dipika Rawat[10]**

[1]Assistant Professor, DIT, University College of Healthcare Professions.
[1]Assistant Professor, Quantum University, Paramedical Sciences,
[2]Principal, Shri Guru Ram Rai College of Nursing, Kotdwar.
[3]Assistant Professor, Vivekanand Institute of Paramedical Sciences.
[4]Assistant Professor, Shri Dev Suman Subharti Medical College.
[5]Tutor, Department of Anatomy, Adesh Medical College & Hospital.
[6]Professor and Head of Department, Quantum University
[7]Principal, DIT University, College of Healthcare Professions.
[8]Assistant Professor, DIT University, College of Healthcare Professions.
[9]Assistant Professor, Quantum University, Paramedicalsciences.
[10]Assistant Professor, Uttaranchal College of Health Sciences, Uttaranchal University.

*Corresponding Author
Sadhna Semwal

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**Abstract:** Ghee, a traditional form of clarified butter produced by heating and separating milk fat, has been an integral component of Indian dietary and medicinal practices for centuries. Its unique nutritional profile comprises a rich blend of bioactive lipids, including butyric acid, conjugated linoleic acid (CLA), medium-chain triglycerides (MCTs), phospholipids, and essential fat-soluble vitamins such as A, D, E, and K. These constituents collectively position ghee as a functional dietary fat with a wide range of physiological benefits beyond basic nutrition. Recent biochemical and nutritional research has highlighted the therapeutic potential of ghee in promoting gastrointestinal health, metabolic regulation, immune modulation, and cellular protection.
Mechanistic insights reveal that butyric acid, a short-chain fatty acid abundant in ghee, plays a critical role in maintaining gut homeostasis. It acts as a primary energy source for colonocytes, enhances epithelial barrier integrity, and exhibits potent anti-inflammatory activity via histone deacetylase (HDAC) inhibition, which contributes to epigenetic regulation and suppression of pro-inflammatory pathways. Similarly, conjugated linoleic acid (CLA), another important component, has been associated with multiple health-promoting actions, including reduction of oxidative stress, improvement in lipid metabolism, attenuation of atherosclerotic processes, and potential anticancer effects observed in preclinical and clinical studies. In addition to its therapeutic properties, ghee provides medium-chain triglycerides that are rapidly metabolized, supporting energy balance and potentially improving insulin sensitivity. Its antioxidant constituents, including vitamin E and various phospholipids, may further protect cells from oxidative damage and support immune function. Despite these benefits, the high content of saturated fatty acids (SFAs) in ghee raises concerns, particularly for individuals with dyslipidemia, cardiovascular risks, or metabolic syndrome. Current evidence on the relationship between ghee consumption and lipid profiles remains mixed, indicating the need for individualized dietary recommendations and consideration of portion sizes, lifestyle patterns, and overall dietary composition. This review consolidates existing biochemical, preclinical, clinical, and epidemiological findings to provide a comprehensive understanding of the health impacts of ghee consumption. It critically evaluates the dual nature of ghee as both a nutrient-dense functional fat and a potential source of dietary saturated fats. By examining its mechanisms of action, population-based effects, and cultural and culinary relevance, the review emphasizes a balanced, evidence-informed perspective on incorporating ghee into modern diets. Future research should prioritize controlled human trials, dose–response assessments, and long-term metabolic studies to better define ghee's risk–benefit profile and therapeutic potential across diverse populations.

**Keywords**: butyric acid, conjugated linoleic acid (CLA), rapidly metabolized.

## INTRODUCTION

Ghee, or clarified butter, has been a dietary mainstay in South Asia for centuries. Derived from the slow heating of butter or cream to separate water and milk solids, ghee retains nearly pure milk fat. Traditional culinary usage has long appreciated its flavor, stability, and high smoke point. However, in recent decades, modern nutritional science has begun to uncover ghee's complex lipid profile, which includes not only saturated fatty acids, but also bioactive lipids such as short-chain fatty acids, CLA isomers, phospholipids, and vitamins (A, D, E, K).

Unlike many industrial fats, ghee carries physiologically relevant concentrations of butyrate (a short-chain fatty acid), CLA, and other minor lipids that influence metabolic pathways, gut-immune signaling, and epigenetic regulation [1]. These molecules have been the focus of molecular, animal, and epidemiological studies, thus motivating a re-evaluation of ghee's role in modern nutrition.

This review provides a detailed analysis of the biochemical composition of ghee, its mechanistic actions in the body, health-promoting effects, and potential risks, using evidence drawn from peer-reviewed literature.

## BIOCHEMICAL COMPOSITION OF GHEE

### Short-Chain Fatty Acids: Butyrate

One of the most biologically significant components of milk fat is butyric acid (butyrate), a 4-carbon short-chain fatty acid. Butyrate acts as a potent histone deacetylase (HDAC) inhibitor, regulating gene expression epigenetically (e.g., increasing expression of anti-inflammatory genes) [27, 4]. Butyrate also activates free fatty acid receptors (GPR41/GPR43), influencing energy homeostasis, appetite, and immune responses [12, 26, 47]. Furthermore, it enhances epithelial barrier functions in the gut, partly through upregulation of Milk Fat Globule-EGF Factor 8 (MFG-E8), a factor involved in epithelial restitution and immune tolerance [4].

### Medium-Chain Triglycerides (MCTs)

Ghee contains a non-negligible fraction of medium-chain triglycerides, which are absorbed rapidly, bypass the lymphatic system, and are oxidized preferentially in mitochondria, supporting metabolic flexibility and rapid energy production [11, 33].

### Conjugated Linoleic Acid (CLA)

CLA is a group of linoleic acid isomers, most notably the c9,t11 and t10,c12 forms. CLA is known for anti-inflammatory, anti-atherogenic, and anti-proliferative effects. It modulates peroxisome proliferator–activated receptor gamma (PPAR-γ), influences lipid metabolism, and upregulates antioxidant defenses [6, 9, 13, 17]. Mechanistic studies have demonstrated that CLA can suppress cyclooxygenase-2 (COX-2) expression, induce apoptosis in cancer cells, and enhance antioxidant enzyme activity (catalase, superoxide dismutase, glutathione S-transferase) [21, 4].

### Phospholipids and Sphingolipids

Ghee also contains phospholipids and sphingomyelin, which contribute to membrane integrity and are implicated in neural and immune signaling pathways [43]. These lipids may support cognitive functions and cell signaling.

### Fat-Soluble Vitamins

Milk fat in ghee also carries fat-soluble vitamins A, D, E, and K. These vitamins are essential for antioxidant defenses (vitamin E), bone and calcium homeostasis (vitamin D), immune regulation (vitamin A), and coagulation or vascular health (vitamin K). While specific quantification in ghee varies, their presence contributes to its functional nutritional profile.

## PHYSIOLOGICAL EFFECTS AND HEALTH BENEFITS

### 1. Gastrointestinal Health and Immunomodulation

Butyrate's role in maintaining gut epithelial integrity is well documented. It promotes tight junction protein expression, reduces epithelial apoptosis, and enhances mucosal healing in models of intestinal injury [4, 28]. By inhibiting HDACs, butyrate also regulates cytokine production, reducing pro-inflammatory mediators (e.g., TNF-α, IL-6) and promoting anti-inflammatory responses [27]. Additionally, butyrate-mediated activation of GPR43 has been linked to regulatory T cell (Treg) expansion, contributing to immunological tolerance in the gut [12].

Moreover, butyrate and other short-chain fatty acids influence gut hormone secretion (such as peptide YY and GLP-1), which can modulate satiety and glycemic responses [44, 26].

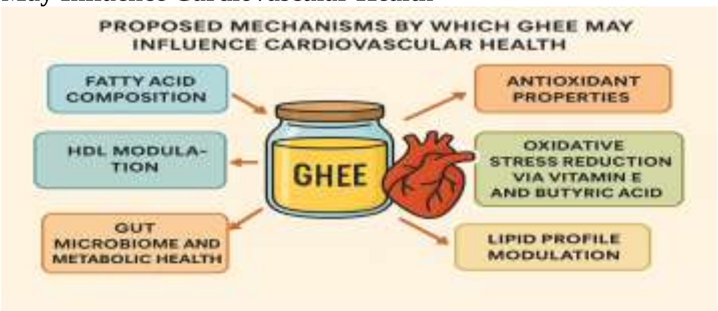
### 2. Metabolic Regulation and Energy Homeostasis

Due to its MCT content, ghee provides fatty acids that are metabolized more quickly than long-chain triglycerides, supporting rapid energy utilization and possibly reducing adiposity when consumed in moderation [11, 35]. Butyrate also contributes to improved metabolic flexibility by enhancing mitochondrial biogenesis in skeletal muscle and modulating gene expression associated with energy metabolism [35]. Activation of GPR41/43 by butyrate influences systemic energy homeostasis, affecting both insulin sensitivity and fat oxidation [12].

### 3. Cardiovascular Health

CLA is particularly significant in cardiovascular health. Animal studies (e.g., in rats) show that CLA-enriched diets raise antioxidant enzyme activity and reduce oxidative stress, thereby lowering lipid peroxidation and atherogenic risk [4]. Epidemiological evidence supports these findings: higher adipose CLA content has been correlated with reduced incidence of myocardial infarction in humans [5]. Moreover, CLA's anti-inflammatory actions, including suppression of COX-2 and modulation of PPAR-γ, contribute to vascular protection fig 1, [17, 21].

**Figure 1. Proposed Mechanisms by Which Ghee May Influence Cardiovascular Health**




### 4. Anticancer Potential

Preclinical models provide strong evidence that dietary CLA inhibits tumor formation. For instance, rodent studies show significantly lower rates of mammary and colon tumor formation when CLA is included in the diet [6, 14]. The mechanisms include induction of apoptosis (through caspase activation), suppression of COX-2, and reduction of proliferation markers (e.g., Ki-67) [9, 21]. Human observational studies, such as those in colorectal cancer cohorts, have observed inverse associations between CLA intake and cancer risk [7]. However, results are not entirely consistent — some prospective studies indicate neutral or even weak positive associations with breast cancer risk [8].

**5. Antioxidant and Anti-Inflammatory Effects**

Beyond its anticancer activity, CLA enhances endogenous antioxidant defenses. Studies in both animals and humans have demonstrated increases in catalase, superoxide dismutase (SOD), and glutathione S-transferase activity following CLA supplementation [4, 39]. CLA's suppression of pro-inflammatory mediators and activation of PPAR-γ also reduce systemic inflammation [17].

**6. Insulin Sensitivity and Type 2 Diabetes**

Emerging data suggest butyrate may improve insulin sensitivity. In clinical or preclinical settings, butyrate stimulates GLP-1 and other incretins, enhances β-cell function, and improves peripheral glucose uptake [26, 48]. CLA might also modulate glucose metabolism by influencing adipose tissue lipid metabolism, though dose- and isomer-specific effects remain under study [20].

## SAFETY, RISKS, AND LIMITATIONS

**Saturated Fat Content**

A major concern with ghee is its high saturated fat content, which may raise LDL-cholesterol levels in susceptible individuals. While its bioactive lipids confer benefits, excessive consumption may negate these advantages, especially in populations with dyslipidemia or cardiovascular risk. Long-term human intervention studies specifically comparing ghee to other fats are limited, creating uncertainty about safe daily intake thresholds.

**Variability in Composition**

The content of butyrate, CLA, and other bioactives in ghee depends strongly on the diet of the dairy animal (e.g., grass-fed vs grain-fed), as well as the method of ghee production (temperature, duration). As such, not all ghee products are alike, and inconsistent composition may influence efficacy and safety [43].

**Dose-Dependence and Isomer Specificity**

The health effects of CLA in particular are highly dose-dependent and isomer-specific. For example, the c9,t11 isomer is generally more benign, while t10,c12 may have mixed metabolic effects. Outcomes from animal models do not always translate to humans, and high-dose CLA supplementation has in some contexts resulted in insulin resistance or fatty liver, highlighting the need for careful dose optimization [9, 10, 22].

**Long-term Clinical Evidence**

While preclinical and epidemiological studies are promising, randomized controlled trials (RCTs) specifically using ghee in human populations remain scarce. Most clinical trials on CLA use purified CLA or supplement, not ghee itself. There is a need for rigorously designed RCTs to discern the net benefits and risks of ghee intake in different populations (healthy, metabolic

## Conclusion

Ghee represents a unique milk-fat matrix with more than just caloric value; it contains a diverse profile of bioactive lipids that exert measurable physiological effects. Beyond its role as a concentrated energy source, ghee is enriched with butyrate, conjugated linoleic acid (CLA), medium-chain triglycerides, fat-soluble vitamins (A, D, E, and K), and various phospholipids, all of which contribute to its functional properties. These components have attracted scientific interest as emerging evidence highlights their roles in gut health, metabolic regulation, antioxidant defense, cardiovascular protection, and cancer prevention. Unlike many other dietary fats, ghee undergoes a thermal clarification process that removes milk solids and moisture, which not only enhances its shelf stability but also influences the concentration of specific beneficial compounds.

Growing experimental research demonstrates that butyrate, a short-chain fatty acid abundant in ghee, supports intestinal homeostasis by acting as the primary metabolic fuel for colonocytes. It enhances mucosal barrier integrity, reduces intestinal permeability, and modulates immune responses within the gut. Butyrate also plays a significant role in epigenetic regulation through its ability to inhibit histone deacetylase (HDAC), thereby suppressing pro-inflammatory gene expression and promoting cellular repair pathways. These mechanisms collectively suggest a protective effect of ghee on gastrointestinal function, particularly in conditions characterized by inflammation or barrier dysfunction.

Similarly, CLA present in ghee has been widely studied for its potential health benefits. Experimental models and human studies indicate that CLA may reduce adiposity, improve lipid metabolism, and exert anti-atherogenic effects. It also demonstrates antioxidant and anticancer properties through mechanisms such as free radical scavenging, induction of apoptosis in malignant cells, and modulation of carcinogenic pathways. Fat-soluble vitamins, especially vitamin E and vitamin A, contribute additional antioxidant and immunoregulatory effects, protecting cellular membranes from oxidative stress and supporting vision, bone health, and immune modulation.

Despite these advantages, ghee's high proportion of saturated fatty acids raises understandable concerns, especially for individuals with hyperlipidemia or cardiovascular risk factors. However, the relationship between ghee intake and cardiovascular disease remains complex. Some studies from rural Indian populations suggest that modest ghee consumption may be neutral or even beneficial for cardiovascular biomarkers, particularly when consumed as part of a traditional diet rich in whole foods. Variations in animal diet, method of ghee preparation, and serving size significantly influence its final composition, making standardized evaluation challenging.

Epidemiological data on ghee's metabolic effects are promising but limited, underscoring the need for robust, controlled human clinical trials. Critical knowledge gaps remain regarding optimal intake levels, long-term safety, and interactions with dietary patterns and genetic factors. Addressing these gaps will be essential for evidence-based dietary recommendations.

With strategic and targeted research, ghee holds strong potential to be repositioned as a functional dietary fat rather than merely a traditional culinary ingredient. A deeper understanding of its bioactive components, mechanisms of action, and population-specific effects may open pathways for its incorporation into therapeutic nutritional protocols. As scientific interest continues to grow, ghee may emerge as a valuable component of modern dietetics, bridging traditional knowledge with contemporary health science.

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