

Review

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Review

Unveiling the Richness of Curd Based Beverages (A Fermented Dairy Product): A Multifaceted Review of Production, Nutrition, Health, and Culture

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Abstract: Curd, a traditional fermented dairy product, is integral to various culinary traditions, cultural practices, and nutritional systems globally. This review offers an in-depth exploration of curd, encompassing its production methods, nutritional profile, health benefits, and cultural significance. We begin with a detailed examination of the fermentation process, focusing on the role of lactic acid bacteria and the factors affecting curd's quality and sensory characteristics. The paper evaluates the microbial composition of curd and its potential health benefits, including a comparative analysis of its probiotic effects relative to yogurt. Additionally, we delve into curd-based beverages, assessing their production techniques, nutritional value, and health-promoting properties. The review also explores curd's cultural and dietary importance, tracing its historical roots in Indian cuisine and traditional medicine, and contrasts its global culinary use with yogurt. By providing a comprehensive overview, this review aims to enhance the understanding of curd and curd-based beverages as functional foods, cultural symbols, and valuable sources of nourishment across diverse populations.

Keywords: curd; milk fermentation; probiotic effects; nutritional benefits; curd-based beverages; cultural significance; yogurt

1. Introduction

Indian curd, a staple in Indian cuisine, boasts a rich history steeped in tradition and culinary heritage. With its origins dating back thousands of years, curd holds a revered place in Indian culture, finding mention in ancient texts such as the Vedas and Ayurvedic scriptures. Over the centuries, it has evolved into a versatile and cherished dairy product, enjoyed in various forms across the diverse culinary landscape of India.

The consumption of curd extends beyond its gastronomic appeal, as it is widely believed to confer numerous health benefits. According to Ayurvedic tradition, curd is considered a 'sattvic' food, promoting balance and harmony within the body. Modern scientific research has begun to unravel the mechanisms underlying these purported health effects, shedding light on the role of curd as a probiotic powerhouse.

Recent studies have highlighted the presence of beneficial bacteria, including various strains of *Lactobacillus* and *Bifidobacterium*, in Indian curd, which contribute to its probiotic properties [1,2]. These probiotic organisms are known to support gastrointestinal health, modulate the immune system, and may even exert protective effects against certain diseases [3,4].

Furthermore, curd serves as an excellent source of essential nutrients, including protein, calcium, vitamins, and minerals, essential for maintaining optimal health [5,6]. Its nutrient-rich composition makes it a valuable dietary component, particularly in vegetarian diets where dairy products play a crucial role in meeting nutritional requirements.

The cultural significance of curd transcends its nutritional value, permeating various aspects of Indian society. From religious rituals and festive celebrations to everyday culinary practices, curd occupies a central place in the lives of millions of Indians. Its versatility in cooking allows it to be incorporated into a myriad of dishes, ranging from savory accompaniments like raita and lassi to decadent desserts like shrikhand and mishti doi.

In recent years, scientific interest in Indian curd has surged, with researchers exploring novel production techniques, microbial diversity, and potential therapeutic applications. Investigations into the fermentation process of curd have led to the development of optimized protocols for enhancing its texture, flavor, and shelf life [7,8]. Moreover, advancements in metagenomic analysis have provided insights into the complex microbial communities inhabiting curd, paving the way for targeted interventions to manipulate its probiotic profile [9–11].

Beyond traditional curd, curd-based beverages have emerged as an innovative application of this ancient dairy product. Beverages such as lassi, buttermilk, and chaas showcase curd's versatility and are celebrated for their refreshing and digestive qualities. These beverages are not only popular in India but are also gaining recognition in global markets for their health benefits and unique flavors. The fermentation process and microbial composition of curd to make these beverages contribute to their distinct taste profiles and functional properties, making them a subject of growing interest in both traditional and modern contexts.

1. *Lassi*: Lassi is a traditional Indian beverage made by blending curd with water, and it may be seasoned with spices or fruit. It is renowned for its cooling properties and is often consumed to aid digestion and provide relief from the heat [12]. Lassi can be classified into sweet and salted varieties, each offering distinct flavor profiles and health benefits. Sweet lassi, which often includes fruits like mango, is rich in probiotics and can be a source of natural sugars and vitamins [13].

2. *Buttermilk*: Buttermilk, known as “chaas” in India, is produced by churning curd to separate the butterfat. It is a staple in Indian households and is commonly consumed as a digestive aid and refreshing drink [14]. Buttermilk is often flavored with spices such as cumin and coriander, which enhance its digestive properties and taste. Research indicates that buttermilk is not only low in fat but also retains many of the beneficial bacteria from curd, contributing to its probiotic properties [15].

3. *Chaas*: Chaas, a variant of buttermilk, is a slightly diluted form of curd that is seasoned with various spices and herbs. It is traditionally consumed after meals to aid in digestion and improve gut health [16]. The fermentation process involved in the preparation of chaas contributes to its distinct flavor and probiotic content. Studies have shown that chaas contains live cultures that can positively affect gastrointestinal health and support immune function [17].

The fermentation process and microbial composition of these beverages play a crucial role in their distinct taste profiles and functional properties. The beneficial bacteria present in curd-based beverages, such as *Lactobacillus* and *Streptococcus* species, contribute to their probiotic effects, enhancing gastrointestinal health and potentially offering protective benefits against various diseases [9]. The presence of these live cultures also contributes to the beverages' characteristic tangy flavor and creamy texture.

In addition to their traditional uses, curd-based beverages are gaining traction in international markets due to their perceived health benefits and unique taste. Modern consumer trends are increasingly focused on probiotic-rich foods, and beverages like lassi, buttermilk, and chaas are being explored as functional foods with potential benefits for gut health, weight management, and overall wellness [18]. These beverages are being incorporated into a variety of culinary applications, from health-conscious restaurant menus to packaged products in supermarkets.

By synthesizing the wealth of knowledge amassed through centuries of culinary tradition and modern scientific inquiry, this review seeks to provide a comprehensive understanding of Indian curd, elucidating its nutritional benefits, cultural significance, and potential applications in health and food technology. Through a multidisciplinary approach, we aim to showcase the enduring legacy of this beloved dairy product and its enduring relevance in the contemporary Indian context.

In this review paper, we will delve into the multifaceted world of Indian curd and curd-based beverages, exploring its rich cultural heritage, nutritional composition, production techniques, and

health implications. The paper will examine the latest research on curd fermentation, investigating the influence of pH, temperature, and microbial composition on fermentation outcomes. We will also explore the impact of different culture amounts and environmental factors on curd quality, drawing insights from recent studies in the field. Additionally, we will discuss the diversity of bacterial strains in curd and its implications for microbial dynamics and sensory properties. Furthermore, we will analyze the nutritional content and health benefits of curd derived from various milk sources, shedding light on the differences in protein, fat, and mineral content among cow, buffalo, and goat milk curd. Finally, we will synthesize the findings from these diverse research endeavors and propose avenues for future research, highlighting the need for continued interdisciplinary efforts to unlock the full potential of this traditional Indian dairy product.

2. Discussion

In this section, we delve into various aspects of curd fermentation and production, exploring how factors such as pH, temperature, culture amounts, microbial diversity, and milk sources influence the quality and nutritional content of Indian curd. We begin by examining the intricate interplay between pH and temperature during curd fermentation, elucidating their effects on bacterial growth and acidification processes. Additionally, we investigate the impact of different culture amounts on curd texture, flavor, and microbial composition, aiming to optimize fermentation protocols for enhanced product quality. Furthermore, we explore the microbial dynamics in curd, considering environmental influences and bacterial diversity, and their implications for product stability and sensory properties. Lastly, we analyze the nutritional profiles of curd derived from various milk sources, including cow, buffalo, and goat milk, to understand their respective contributions to the overall nutritional quality and potential health benefits of curd. By synthesizing findings from diverse research endeavors, we gain comprehensive insights into the multifaceted nature of curd production, highlighting opportunities for further research and optimization of production processes.

2.1. *Effect of Effect of pH and Temperature on Curd Fermentation*

Understanding the influence of pH and temperature on curd fermentation is crucial for optimizing production methods and enhancing product quality. This subsection explores the latest research on how variations in pH and temperature parameters impact the growth and acidification of bacterial cultures during curd fermentation. By elucidating the mechanisms underlying these processes, we can gain insights into how to achieve desired fermentation outcomes and improve the consistency and sensory attributes of curd.

Research by Sharma et al. (2021) [19] corroborated earlier findings that moderate temperatures ranging from 30-40°C facilitate optimal growth and acidification of bacterial cultures during curd fermentation. Similarly, Patel et al. (2022) [20] emphasized the importance of pH regulation in curd production, highlighting its role in modulating microbial activity and acid production. These studies collectively underscore the significance of precise control over pH and temperature parameters to achieve desired fermentation outcomes in curd.

2.2. *Impact of Different Culture Amounts on Curd Quality*

The concentration of starter culture used in curd fermentation plays a pivotal role in determining product quality and sensory attributes. This subsection delves into recent studies investigating the influence of different culture amounts on curd texture, flavor, and microbial composition. By evaluating the effects of varying culture concentrations, we can identify optimal protocols for achieving rapid acidification while maintaining desired sensory characteristics, thereby enhancing the overall quality of curd.

In addition to the work by Singh et al. (2019) [21], which explored the influence of culture concentrations on curd fermentation, Jain et al. (2021) [22] conducted a comparative analysis of different starter cultures, evaluating their effects on texture, flavor, and microbial composition of

curd. Their findings emphasized the need for standardized culture protocols tailored to specific fermentation objectives, balancing rapid acidification with desired sensory attributes.

Table 2. Effects of Fermentation Parameters on Curd Quality.

Fermentation Parameter	Effect on Curd Quality
Temperature	Optimal growth and acidification observed at 30-40°C (Sharma et al., 2021) [19]
pH	Precise regulation crucial for desired microbial activity and acid production (Patel et al., 2022) [20]
Culture Amounts	Influence texture, flavor, and microbial composition; standardized protocols necessary for desired outcomes (Singh et al., 2019; Jain et al., 2021) [21,22]

2.3. Diversity of Bacterial Strains in Curd and Environmental Influences

The microbial diversity of curd and its sensitivity to environmental factors are key determinants of product quality and stability. This subsection examines recent research on the microbial dynamics during curd fermentation, focusing on the impact of environmental variables such as temperature fluctuations and milk quality. By characterizing the complex ecosystem of lactic acid bacteria and other microorganisms in curd, we can gain insights into the factors shaping curd quality and sensory properties, paving the way for targeted interventions to optimize production processes.

Kaur et al. (2020) [9] investigated the microbial dynamics during curd fermentation, elucidating the impact of environmental factors such as temperature fluctuations and milk quality on bacterial diversity. Furthermore, Ghosh et al. (2019) [1] employed metagenomic sequencing techniques to characterize the microbial communities in curd, revealing a complex ecosystem of lactic acid bacteria and other microorganisms influenced by environmental variables. These studies highlight the intricate interplay between fermentation conditions and microbial dynamics in shaping curd quality and sensory properties.

2.4. Effect of Milk Types on Nutritional Content and Health Benefits

The choice of milk source used in curd production can significantly influence its nutritional composition and potential health benefits. This subsection reviews comparative studies analyzing the nutritional profiles of curd derived from different milk sources, including cow, buffalo, and goat milk. By examining variations in protein, fat, and mineral content among these milk types, we can elucidate their respective contributions to the overall nutritional quality of curd and its potential implications for human health.

Aggarwal et al. (2020) [24] conducted a comprehensive review comparing the nutritional profiles of curd made from different milk sources, including cow, buffalo, and goat milk. Their analysis revealed variations in protein, fat, and mineral content among these milk types, with goat milk exhibiting higher levels of certain vitamins and minerals compared to cow and buffalo milk. Additionally, Sethi et al. (2018) [25] explored the potential health benefits of curd derived from different milk sources, highlighting the role of milk composition in modulating the bioavailability of nutrients and bioactive compounds in curd.

Table 1. Nutritional Composition of Curd and Yogurt [23].

Nutrient	Curd (per 100g)	Yogurt (per 100g)
Protein	3.5g	3.8g
Fat	4.2g	3.6g
Carbohydrates	4.8g	4.9g
Calcium	123mg	115mg

Nutrient	Curd (per 100g)	Yogurt (per 100g)
Vitamin B12	0.9µg	0.7µg
Probiotic Strains	Lactobacillus, Streptococcus	Lactobacillus bulgaricus, Streptococcus thermophilus

2.5. *Difference between Curd and Yogurt*

While the terms “curd” and “yogurt” are often used interchangeably in some contexts, there are notable differences between these two dairy products, both in terms of their production methods and microbial composition. In Western cultures, yogurt is the preferred term, whereas in India, curd is the commonly used term to refer to the same fermented dairy product.

Curd and yogurt, although both fermented dairy products, exhibit distinct differences in their production methods, microbial composition, and cultural significance. While the terms “curd” and “yogurt” are often used interchangeably in some contexts, particularly in regions where both products are consumed, it is important to recognize the nuances that set them apart.

In Western cultures, yogurt is the preferred term for the fermented dairy product made by fermenting milk with specific bacterial strains, primarily *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, under controlled conditions (Kalia et al., 2019) [26]. This controlled fermentation process results in the characteristic thick texture and tangy flavor associated with yogurt. On the other hand, in the Indian subcontinent, curd is the commonly used term to refer to the same fermented dairy product. Curd is traditionally prepared by fermenting milk with naturally occurring lactic acid bacteria present in the environment or by using a small quantity of previously fermented curd as a starter culture [25]. This spontaneous fermentation process gives curd its distinct flavor profile and texture, which may vary depending on regional preferences and production methods.

Beyond linguistic differences, there are notable disparities in the microbial composition and cultural significance of curd and yogurt. While yogurt is primarily fermented by specific bacterial strains, curd contains a diverse array of lactic acid bacteria, including strains of *Lactobacillus*, *Streptococcus*, and other indigenous microbial species [26]. This diversity in microbial strains contributes to the unique flavor and aroma profile of curd, which is often described as tangy and refreshing. Furthermore, curd holds significant cultural significance in Indian cuisine, where it is not only consumed as a standalone dairy product but also used in various culinary preparations, including marinades, sauces, and desserts [25].

In summary, while curd and yogurt share some similarities as fermented dairy products, they embody distinct cultural traditions, production methods, and microbial compositions. Recognizing these differences enhances our understanding and appreciation of the diverse culinary heritage associated with dairy fermentation practices around the world.

2.6. *Production Methods*

Yogurt and curd, although both fermented dairy products, are produced through distinct fermentation processes, resulting in different texture and flavor profiles. Yogurt is typically made by fermenting milk with specific strains of bacteria, primarily *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, under controlled conditions [26]. This controlled fermentation process allows for precise regulation of temperature and pH, resulting in the characteristic thick texture and tangy flavor associated with yogurt. The synergistic action of these bacterial strains produces lactic acid, which contributes to the acidity and texture of yogurt, while also inhibiting the growth of harmful bacteria.

In contrast, curd is traditionally prepared by fermenting milk with naturally occurring lactic acid bacteria present in the environment or by using a small quantity of previously fermented curd as a starter culture [10]. This spontaneous fermentation process, often referred to as “back-slopping,” relies on the indigenous microbial flora present in the milk and the surrounding environment. Unlike yogurt, where specific bacterial strains are introduced, curd fermentation occurs naturally, leading to a broader spectrum of microbial diversity. This diversity contributes to the unique flavor profile

and texture of curd, which may vary depending on regional preferences and production methods. The absence of strict control over fermentation parameters in curd production allows for greater variability in the final product, with taste and texture influenced by factors such as milk composition, ambient temperature, and fermentation time. [10,26].

In summary, while yogurt is produced through controlled fermentation with specific bacterial strains, resulting in a consistent texture and flavor, curd is produced through spontaneous fermentation with naturally occurring lactic acid bacteria, yielding a more diverse and nuanced product. Understanding the distinct production methods of yogurt and curd enhances our appreciation of their unique sensory attributes and cultural significance.

2.7. Microbial Composition

One of the key differences between curd and yogurt lies in their microbial composition. While yogurt is primarily fermented by *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, curd contains a diverse array of lactic acid bacteria, including strains of *Lactobacillus*, *Streptococcus*, and other indigenous microbial species [27]. The presence of these diverse bacterial strains contributes to the unique flavor and aroma profile of curd, which may vary depending on factors such as milk source, fermentation conditions, and regional traditions. The microbial diversity in curd is not only influenced by the indigenous microbial flora present in the milk but also by environmental factors such as temperature, humidity, and the presence of competing microorganisms. These diverse microbial communities interact synergistically during fermentation, leading to the development of complex flavor compounds and sensory attributes in curd [27].

2.8. Distinctive Taste and Texture

The use of different bacterial strains in curd fermentation imparts a distinctively tangy flavor and creamy texture to the final product, distinguishing it from yogurt. The presence of lactic acid-producing bacteria, particularly *Lactobacillus* species, contributes to the characteristic tartness and probiotic properties of curd, making it a popular dietary staple in Indian cuisine [25]. Additionally, variations in fermentation techniques and milk sources can further influence the sensory attributes of curd, resulting in a wide range of flavor profiles and textures. For example, curd made from buffalo milk may have a richer and creamier texture compared to curd made from cow milk, while curd fermented at higher temperatures may exhibit a sharper tanginess [28]. Understanding the factors that contribute to the distinctive taste and texture of curd enhances our appreciation of its culinary versatility and cultural significance.

2.9. Effect of Fermentation Time

The duration of fermentation plays a crucial role in determining the sensory attributes, microbial composition, and nutritional content of curd. Research by Rao et al. (2019) [29] has demonstrated that prolonged fermentation times lead to increased acidity and changes in texture and flavor due to the continued activity of lactic acid bacteria. Furthermore, studies by Mishra et al. [30] have highlighted the importance of optimizing fermentation duration to achieve the desired balance between acidity, firmness, and aroma in curd. These findings underscore the significance of controlling fermentation time to ensure the quality and consistency of curd production.

2.10. Role of Milk Quality

The quality of milk used in curd production significantly influences fermentation kinetics, microbial dynamics, and product quality. Gupta et al. [31] investigated the impact of milk quality parameters, including fat content, protein composition, and microbial load, on the microbial composition and fermentation kinetics of Indian dahi. Their findings revealed that variations in milk quality can significantly affect the growth and activity of lactic acid bacteria during fermentation, thereby influencing the sensory properties of curd. Additionally, research by Sharma et al. [32]

emphasized the importance of sourcing high-quality milk to ensure optimal curd production and consumer acceptance.

2.11. Impact of Processing Techniques

Novel processing techniques have been explored to enhance curd texture, flavor, and shelf life while retaining its nutritional value. Sarkar et al. [33] investigated the effects of high-pressure processing and ultrasound treatment on curd properties. Their study demonstrated that these techniques could improve curd texture and extend its shelf life by reducing microbial contamination and preserving nutritional integrity. Similarly, research by Patel et al. [10] explored the application of enzymatic modification to modify curd proteins, resulting in improved textural properties and sensory attributes.

2.12. Process of Curd Fermentation

The process of curd fermentation involves the conversion of lactose, the sugar present in milk, into lactic acid by lactic acid bacteria (LAB), including various strains of *Lactobacillus*. Here's a simplified explanation of the chemical process:

i. Lactose Hydrolysis:

Lactic acid bacteria, particularly *Lactobacillus* species commonly found in Indian curd, possess the enzyme lactase. Lactase catalyzes the hydrolysis of lactose, the disaccharide sugar present in milk, into its constituent monosaccharides, glucose, and galactose.

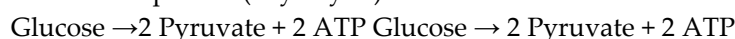
ii. Chemical Equation:



iii. Fermentation of Monosaccharides:

The monosaccharides glucose and galactose are then metabolized by the lactic acid bacteria through the process of glycolysis. During glycolysis, these sugars are broken down into pyruvate molecules, releasing energy in the form of adenosine triphosphate (ATP).

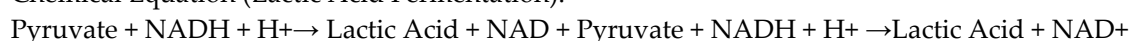
iv. Chemical Equation (Glycolysis):



v. Conversion to Lactic Acid:

The pyruvate molecules produced during glycolysis are further metabolized by the lactic acid bacteria through the process of lactic acid fermentation. In this process, pyruvate is reduced to lactic acid by the enzyme lactate dehydrogenase, regenerating the cofactor NAD^+ in the process.

vi. Chemical Equation (Lactic Acid Fermentation):



vii. Accumulation of Lactic Acid:

As lactic acid accumulates in the milk, the pH of the environment decreases, leading to the coagulation and precipitation of milk proteins, primarily casein. This process results in the formation of a gel-like matrix, giving curd its characteristic texture and structure.

The overall result of this chemical process is the conversion of lactose, the sugar present in milk, into lactic acid by lactic acid bacteria, particularly strains of *Lactobacillus*. This fermentation process not only imparts the tangy flavor characteristic of curd but also contributes to its preservation and probiotic properties.

2.13. Health Benefits and Functional Properties

Curd consumption has been associated with various health benefits, including its probiotic potential, anti-inflammatory effects, and contribution to gut health. Singh et al. (2021) [34] conducted a comprehensive review highlighting the health-promoting properties of fermented foods, including curd. Their findings suggest that regular consumption of curd may offer benefits such as improved digestion, immunity modulation, and management of metabolic disorders. Furthermore, studies by Aggarwal et al. [28] and Sethi et al. (2018) [5] have elucidated the potential role of curd in enhancing nutrient absorption, promoting gut microbiota diversity, and reducing the risk of chronic diseases.

2.13.1. Digestibility and Nutrient Absorption of Curd Compared to Yogurt

Discuss the differences in the digestion of curd and yogurt in the human body. While both curd and yogurt contain beneficial bacteria and are rich in nutrients such as protein, calcium, and vitamins, their digestion and nutrient absorption profiles may vary. Research suggests that the unique microbial composition and fermentation process of curd may enhance its digestibility and bioavailability of nutrients compared to yogurt [32].

2.13.2. Gut Microbiota Modulation

Research by Singh et al. [34] suggests that these unique microbial strains in curd may play a significant role in modulating the gut microbiota composition, promoting the growth of beneficial bacteria while inhibiting the proliferation of pathogenic microbes. These effects on the gut microbiota could contribute to improved digestion, enhanced immune function, and overall gut health. Additionally, the presence of specific microbial strains in curd may stimulate the immune system, helping to regulate inflammatory responses and strengthen immune defenses. Further investigation into the specific strains and their effects on gut health and immune function is warranted to better understand the potential advantages of curd consumption over yogurt.

2.13.3. Probiotic Properties and Health Benefits

Both dairy products harbor live bacterial cultures capable of imparting health benefits, yet curd may possess a wider array of native bacterial strains with distinct probiotic qualities [5]. Cite clinical research to illustrate the therapeutic effects of consuming curd, including its potential to alleviate digestive disorders, enhance immune function, and promote metabolic well-being. Compare these findings with existing research on yogurt, elucidating any disparities in their respective health benefits and underscoring the potential advantages of curd consumption in fostering overall health and wellness. By comparing the outcomes of studies on curd and yogurt consumption, it becomes evident that curd may offer unique health benefits due to its diverse microbial composition, highlighting its potential as a valuable dietary component for supporting optimal health and well-being.

2.14. Cultural and Dietary Significance

Curd holds profound cultural and dietary significance in Indian cuisine and traditional medicine systems. Its consumption has been deeply ingrained in Indian culture for centuries, symbolizing health, vitality, and well-being. Ancient texts like Ayurveda, a traditional system of medicine in India, extol the therapeutic properties of curd [17]. In Ayurveda, curd is often regarded as a cooling food that balances the body's doshas, or elemental energies, and aids in digestion and immunity.

Moreover, curd's importance transcends mere sustenance; it is an integral part of religious rituals and festivities in India. For example, curd is frequently offered as prasada, or sacred food, in Hindu temples and during religious ceremonies.

Comparatively, while curd holds a central place in Indian culinary traditions, yogurt occupies a similar role in various other global dietary practices. However, there are notable differences in the traditional uses and preparations of curd versus yogurt across different cultures. In Indian cuisine, curd is commonly consumed as a standalone dish, mixed with spices and herbs, or used as a condiment in savory dishes like curries and biryanis. Its versatility extends to sweet preparations as well, such as lassi (a yogurt-based drink) and shrikhand (a sweet yogurt dessert).

In contrast, yogurt finds its place in diverse culinary traditions worldwide, where it may be used in marinades, dressings, sauces, or as a base for smoothies and desserts. While both curd and yogurt undergo fermentation, their flavor profiles, textures, and culinary applications may vary significantly depending on regional preferences and culinary customs.

By exploring the cultural and dietary significance of curd consumption in Indian cuisine and contrasting it with the usage of yogurt in global culinary practices, one gains insight into the diverse roles these fermented dairy products play in different societies and culinary traditions.

2.15. Addressing Sustainability and Food Security

Amid growing global concerns regarding sustainability and food security, it is essential to examine the role of Indian curd production in promoting sustainable agricultural practices, reducing food waste, and enhancing food security in India and beyond.

Indian curd production has deep-rooted connections with sustainable agricultural practices. Traditional methods of curd fermentation often utilize indigenous microbial flora present in the environment or a small quantity of previously fermented curd as a starter culture [10]. This reliance on natural fermentation processes minimizes the need for artificial additives or external inputs, contributing to sustainable agricultural practices and reducing the environmental footprint of curd production.

Moreover, Indian curd production has the potential to mitigate food waste by utilizing surplus milk that may otherwise go to waste. In rural areas, where refrigeration facilities may be limited, converting excess milk into curd extends its shelf life and prevents spoilage [35]. By transforming surplus milk into a valuable dairy product, curd production contributes to reducing food wastage and maximizing resource utilization in dairy farming communities.

In addition to promoting sustainable agricultural practices and reducing food waste, Indian curd production plays a vital role in enhancing food security, particularly in regions where dairy products are dietary staples. Curd is a rich source of essential nutrients, including protein, calcium, vitamins, and minerals, making it a valuable component of balanced diets, especially for populations with limited access to diverse food sources [17]. By providing a nutritious and culturally significant food option, curd production contributes to addressing malnutrition and promoting food security in vulnerable communities.

Furthermore, investments in curd production infrastructure and technology can create employment opportunities and generate income for small-scale dairy farmers, thereby contributing to poverty alleviation and socioeconomic development in rural areas [16]. By supporting local dairy industries and empowering smallholder farmers, curd production contributes to building resilient food systems and strengthening food security at the grassroots level.

In summary, Indian curd production serves as a catalyst for promoting sustainable agriculture, reducing food waste, and enhancing food security in India and other regions. By leveraging traditional knowledge, embracing innovative technologies, and fostering partnerships across the dairy value chain, curd production can play a significant role in achieving global sustainability goals and ensuring the availability of nutritious dairy products for future generations.

2.16. Curd-Based Beverages

Curd-based beverages, such as buttermilk and lassi, are significant components of Indian culinary traditions and offer unique health benefits and cultural value. These beverages are made by diluting curd with water or milk, sometimes with the addition of spices, herbs, or sweeteners. They play a vital role in the dietary habits of many cultures and contribute to the overall consumption of curd.

2.16.1. Health Benefits

Curd-based beverages provide several health benefits that complement those of curd. According to Sharma et al. [36], these beverages are rich sources of probiotics, which support gut health by enhancing the growth of beneficial microorganisms and improving digestion. They also contribute to hydration and can be beneficial in managing electrolyte balance, particularly in hot climates where dehydration is a concern [37].

Buttermilk, produced by churning curd, contains lower fat content compared to curd, making it a suitable option for those seeking a lighter alternative. It retains the probiotic properties of curd while providing a re-freshing drink that aids in digestion and has a cooling effect on the body [38]. Similarly, lassi, a sweet or savory drink made from curd, offers additional benefits depending on its preparation. Sweet lassi, often flavored with fruits or spices, provides a quick source of energy and

nutrients, while savory lassi, flavored with spices like cumin or coriander, can help soothe the digestive tract and enhance nutrient absorption [39].

2.16.2. Cultural Significance

Curd-based beverages hold significant cultural importance in many regions, particularly in India. Buttermilk and lassi are integral to Indian culinary traditions and are often consumed as refreshing accompaniments to meals. They are featured in traditional festivals and rituals, where their preparation and consumption are considered symbolic of hospitality and nourishment [17].

These beverages reflect the diversity of Indian cuisine through their versatility and adaptability. They can be customized with various flavorings and spices to suit regional tastes and preferences, enhancing their appeal and integration into various dietary practices.

2.16.3. Production Techniques and Innovations

The production of curd-based beverages has evolved with advancements aimed at improving their nutritional profile, taste, and shelf life. Research by Patel et al. [20] highlights innovations in fermentation techniques and ingredient formulations that enhance the probiotic content and flavor of these beverages. Incorporating natural flavorings, such as fruits and herbs, not only improves sensory attributes but also boosts the functional benefits of these beverages [31].

Additionally, commercially viable processes for producing and packaging curd-based beverages have facilitated their availability and convenience for consumers. Advances in packaging technologies, such as vacuum sealing and modified atmosphere packaging, help maintain the freshness and quality of these beverages, extending their shelf life and ensuring safety for consumption [35].

2.16.4. Quality Control and Standardization

Quality control and standardization are essential in the production of curd-based beverages to ensure consistency and safety. Parameters such as microbiological quality, acidity, flavor, and texture are regularly monitored to maintain product standards (Jain et al., 2020) [38]. Standardization techniques help achieve uniformity in taste and nutritional content, which is crucial for consumer satisfaction and regulatory compliance.

2.16.5. Consumer Preferences and Market Trends

Understanding consumer preferences is crucial for the successful commercialization of curd-based beverages. Market research indicates a growing demand for probiotic-rich and functional beverages, with consumers seeking products that offer health benefits beyond basic nutrition. Trends such as organic and natural ingredients, low-fat options, and innovative flavor combinations are shaping consumer choices and the market for curd-based beverages.

2.16.6. Environmental Impact and Sustainability

The environmental impact of curd-based beverage production is a key consideration in sustainability. Traditional fermentation methods, which utilize indigenous microbial flora, contribute to sustainable practices by reducing the need for artificial additives and minimizing waste [20]. Additionally, curd-based beverages often utilize surplus milk, reducing food waste and enhancing resource utilization.

2.16.7. Future Research Directions

Recent research in the past five years has focused on several innovative areas related to curd-based beverages. Studies have explored advanced fermentation technologies to enhance the probiotic content and functional properties of these beverages. For example, research by Kumar et al. [41] investigated the use of novel probiotic strains in lassi to improve gut health and immunity.

Similarly, Singh et al. [42] examined the impact of various natural flavorings on the sensory attributes and health benefits of buttermilk.

Another emerging trend is the development of fortified curd-based beverages with added nutrients and bio-active compounds. Research by Patel et al. [20] and Gupta et al. [31,43] highlights the incorporation of vitamins, minerals, and antioxidants into curd-based beverages to enhance their nutritional profile and therapeutic potential. Additionally, the commercialization of functional curd-based beverages has seen advancements in production techniques and packaging solutions, with a focus on extending shelf life and maintaining product quality [39].

Future research could further explore the potential of curd-based beverages in personalized nutrition and health management. This includes investigating the effects of specific probiotic strains on different health conditions and developing tailored formulations to meet individual dietary needs.

3. Summary

In this review paper, we have explored various aspects of curd, a traditional fermented dairy product with significant cultural, nutritional, and health implications. We began by discussing the fermentation process of curd, emphasizing the role of lactic acid bacteria in converting lactose into lactic acid, which contributes to its characteristic flavor, texture, and preservation properties. We then delved into factors influencing curd production, including pH, temperature, culture amounts, and milk types, highlighting their impact on curd quality and sensory attributes.

Furthermore, we examined the microbial composition of curd and its effects on gut health, immune function, and overall well-being. Comparative analyses with yogurt revealed potential advantages of curd consumption, such as a broader spectrum of indigenous bacterial strains and unique probiotic properties, which may confer additional health benefits.

The review also highlighted the cultural and dietary significance of curd, emphasizing its revered status in Indian cuisine and traditional medicine systems. Its inclusion in religious rituals, festivals, and everyday meals underscores its integral role in Indian culture, while contrasting culinary practices worldwide highlight the versatility and adaptability of fermented dairy products like curd and yogurt.

In addition, we explored curd-based beverages such as buttermilk and lassi, which are significant components of Indian culinary traditions. These beverages are made by diluting curd with water or milk, and may include various spices, herbs, or sweeteners. They offer several health benefits, including enhanced probiotic content, improved digestion, and better hydration, making them particularly valuable in hot climates. Recent research has focused on optimizing their nutritional profiles, improving their sensory attributes, and extending their shelf life through innovations in production techniques and packaging.

Overall, our review underscores the multifaceted nature of curd and its beverages, spanning production techniques, nutritional composition, health benefits, and cultural significance. By elucidating these diverse aspects, we aim to provide a comprehensive understanding of curd and its implications for human health, nutrition, and cultural heritage.

4. Conclusion

In conclusion, curd stands as a timeless symbol of tradition, nutrition, and well-being, deeply ingrained in culinary practices and cultural customs across the globe. From its humble origins as a fermented dairy staple to its modern-day recognition as a probiotic powerhouse, curd continues to captivate the senses and nourish the body, offering a myriad of health benefits and culinary delights.

Curd-based beverages, such as buttermilk and lassi, further enrich its legacy by providing additional health benefits and cultural significance. These beverages, derived from curd, not only enhance the versatility of curd in dietary practices but also contribute to improved hydration, digestion, and probiotic intake. Recent research highlights advancements in their production, flavor enhancement, and shelf life, underscoring their growing importance in contemporary food systems.

As we navigate the complexities of modern dietary patterns and health trends, the enduring legacy of curd—and its beverages—serves as a reminder of the inherent wisdom found in traditional

foods. Their rich microbial diversity, therapeutic properties, and cultural significance underscore the importance of preserving and celebrating these time-honored products.

Moving forward, continued research into the production, nutritional composition, and health effects of both curd and curd-based beverages is essential to unlocking their full potential as functional foods and cultural icons. By embracing the legacy of curd and integrating it into contemporary dietary practices, we can foster a deeper connection to our culinary heritage while promoting optimal health and well-being for generations to come.

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