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Exploring the probiotic and prebiotic dynamics of cheese: An updated review

Ankur Aggarwal*, Alka Parmar, Sushree Purabi Panigrahi***, Tarun Verma*◆, Priya Dhyani*, Sohan Lal Bajya**** and Manish Kumar Singh*****

*Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005, Uttar Pradesh, India

** Faculty of Dairy Technology, Sher-e-Kashmir, University of Agricultural Science and Technology of Jammu, RS Pura-181102, Jammu, India

*** Department of Extension Education, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005, Uttar Pradesh, India

**** National Dairy Research Institute, Karnal-132001, Haryana, India

***** Department of Food Technology, School of Engineering and Technology, Mizoram University, Aizawl-796004, Mizoram, India

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Abstract

In recent years, the inoculation of different probiotic cultures along with suitable prebiotics into various fermented dairy products has significantly increased in popularity within the food industry. Consumers, who value the distinct tastes and characteristics of regional flavors, have been the driving force behind this trend. The growing interest stems from a shared desire to improve human nutrition, promote better health, and enhance the sensory experience of food products. Probiotic microorganisms present in cheese confer numerous benefits, including protection against harmful gut pathogens, alleviation of specific types of diarrhea, and reduction of high-risk infant discomfort, while prebiotics act as essential nourishment for probiotics, facilitating their growth and activity in the gastrointestinal tract. The synergistic effects of prebiotics and probiotics are pivotal in modulating gut microbiota composition, enhancing immune function, improving nutrient absorption, and mitigating gastrointestinal disorders, underscoring their combined role in promoting gut health and overall well-being. Understanding and harnessing this symbiotic relationship are crucial for developing innovative dairy products that cater to consumer preferences and provide tangible health benefits. This review focuses on the selection, addition, and functionality aspects of various probiotic microorganisms and their suitable prebiotics in cheese, which contribute to creating a wholesome and functional dairy product.

1. Introduction

The Food and Agriculture Organization of the United Nations and the World Health Organization have jointly established the definition of probiotics as live bacteria that, when consumed in sufficient quantities, provide health benefits to the individual (Hill *et al*., 2014). Ganguly *et al.* (2019) specify that for a food product to be labelled as 'probiotic', it must maintain a microbial count at least 6 log colony forming unit (CFU)/gram (g) at the end of its shelf-life, with recent recommendations suggesting a higher concentration of 8 log CFU/g to ensure the provision of health benefits (Ganguly *et al*., 2011). Nobel laureate Elie Metchnikoff significantly contributed to this field by emphasizing the advantageous role of selected bacteria in the gastrointestinal tract, fortifying the natural defence mechanism of the human body (Podolsky, 2012). Probiotic products play a pivotal role in the functional food market, contributing to its global value of USD 68.56 billion in 2022, and are projected to surge in popularity, reaching USD 133.92 billion by 2030 with a compound annual growth rate of 8.7% (Precedence Research, 2022). Dairy-based probiotic foods dominate the worldwide food market, offering live microbial feed supplements with the capacity to positively influence the microbial balance within the host (Fuller, 1989; Bermudez-Brito *et al*., 2012). Recently, cheese has emerged as a preferred carrier for probiotics, playing a pivotal role in many dairy marketing strategies. Its relatively high-fat content provides better protection for probiotic microorganisms in the stomach (Plessas *et al*., 2012; Gomes *et al*., 2017). Diverse strains of probiotic microbes, such as those from the *Bifidobacterium* genus (*e.g*., *B. bifidum, B. longum, B. infantis,* and *B. animalis* ssp. *lactis*) and the *Lactobacillus* genus (*e.g., L. acidophilus, L. casei, L. paracasei, L. rhamnosus,* and *L. plantarum*), have been successfully incorporated into various cheese products. Additionally, lesser-known bacterial strains, such as certain strains of *Propionibacterium*, *Enterococcus, Bacillus*, *etc.*, have also been discussed in this context (Table 2). Despite the increasing interest in probiotic and prebiotic cheese products, there is a lack of comprehensive review articles exploring the various characteristics of these cheeses. Specifically, there is a need for reviews focusing on the types of cheese, both fresh and ripened, as carriers for probiotic and prebiotic elements. This review aims to thoroughly examine and compare the characteristics of fresh and ripened cheese when used as carriers for probiotics and prebiotics. The goal is to shed light on the widespread use of probiotics and prebiotic cheese to deliver these beneficial components to the human gut and discuss the industrial applications associated with this approach.

Corresponding author: Dr. Tarun Verma
Assistant Professor, Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005, Uttar Pradesh, India
E-mail: tarunverma@bhu.ac.in
Tel.: +91-7007314450

2. Cheese as a carrier of probiotics and prebiotics

Several scientific studies have investigated the development of fresh cheeses using probiotic cultures, demonstrating favourable viable counts and positive effects on texture and sensory properties. Sensory properties in ripened cheeses, particularly those with *Bifidobacteria*, are significantly influenced by the production of acetic and lactic acid. While small amounts of acetic acid can enhance aroma, excessive concentrations may lead to undesirable off-flavors. This highlights the importance of assessing the sensory performance of cheeses ripened with probiotics (Grattepanche *et al*., 2008). In a separate study, it was observed that incorporating prebiotic compounds especially inulin did not significantly affect the growth and viability of probiotic strains during the manufacturing process or a subsequent 60-day ripening period. Although, there was an increase in the total free fatty acid content during ripening, prebiotic compounds were found to enhance bacterial lipolytic activity. This study also suggests that integrating prebiotic compounds with probiotic strains in cheese production can improve the inactivation of contaminating microorganisms, boost lipolysis, and result in cheeses with improved functional conjugated linoleic acid compounds (Rodrigues *et al*., 2012).

3. Mechanism of action of probiotics

Probiotics exhibit varying mechanisms of operation across different strains, often involving a combination of activities. The therapeutic effects of probiotics are believed to occur through diverse mechanisms, as illustrated in Figure 1. One potential action involves preventing gastrointestinal infections by impeding the colonization of pathogens in the digestive tract. Probiotics achieve this by competing for nutrients or receptors on the surface of the intestinal epithelium (Monteagudo-Mera *et al*., 2019; Gupta *et al*., 2018).

In addition, probiotics release antimicrobial compounds including organic acids, hydrogen peroxide and bacteriocins, actively combating harmful organisms (Siró, 2011; Harzallah and Belhadj, 2013; Singhal *et al*., 2023). Another mechanism through which probiotics exert their effects is by strengthening the intestinal mucosal barrier. The increased secretion of mucin enhances probiotics adherence to the intestinal mucosa, competitively inhibiting the binding of harmful pathogens to epithelial receptors. This reinforcement of the intestinal barrier restricts pathogen colonization, eliminates invasive foreign antigens, and modulates antigen-specific immune responses (Monteagudo-Mera *et al*., 2019; Gupta *et al*., 2018).

Probiotics also exert influence by modulating the host immune system. Specific strains of lactic acid bacteria (LAB) have the capacity to modify both innate and acquired immune responses. This modulation occurs through the binding of these strains to particular receptors on immune cells and tissues, including the intestinal epithelial tissue. This interaction stimulates the production of diverse immune components including cytokines, T cells, dendritic cells, macrophages, and specific antibodies (Erickson and Hubbard, 2000; Dhyani *et al*., 2023; Verma *et al*., 2023; Meghwal *et al*., 2023).

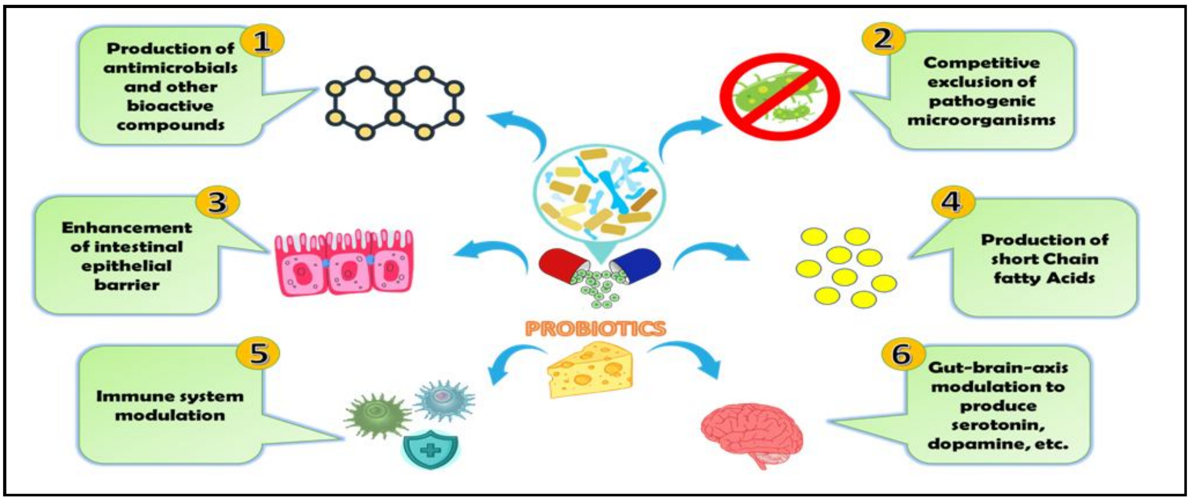

Figure 1: **Mechanism action of probiotic cheese.**

4. Important probiotics associated with cheese

Many strains have been recognized as probiotics with health benefits, and a key criterion is that the strain should naturally inhibit the human gastrointestinal (GI) tract (Abatenh *et al.,* 2018). Additionally, it must withstand challenging gastric conditions, including stomach acid and bile in the small intestine, to exert positive effects. Some of the main strains used in cheese as probiotics are discussed below:

4.1 Lactic acid bacteria

LAB constitute a diverse group of Gram-positive, catalase-negative microorganisms thriving under specific conditions. They are commonly found in the gastrointestinal tracts of both humans and animals, as well as in a variety of fermented foods. Probiotic LAB typically falls within the genera *Lactobacillus*, *Enterococcus*, and *Bifidobacterium* (Fijan, 2014). These bacteria exhibit excellent survival capabilities in the gastrointestinal tract, attributed to their resilience to low pH and bile tolerance (Stasiak-Ró¿añska *et al*., 2021). LAB play a crucial role in inhibiting the growth of harmful bacteria by producing antimicrobial compounds, such as organic acids, hydrogen peroxide, and bacteriocins (Lozo *et al*., 2021). Lactobacilli, renowned for producing bacteriocins like nisin, are utilized as bio-preservatives to counteract food spoilage and enhance the microbiological safety of food. Various bacteriocins have demonstrated effectiveness against harmful microorganisms such as *Pseudomonas*, *Staphylococcus aureus*, and *Listeria monocytogenes* making them subjects of study for potential applications in food preservation (Arokiyamary and Sivakumar, 2011).

Table 1: *Lactobacillus* species used as probiotics

Obligatory homofermentative	Facultative heterofermentative	Obligatory heterofermentative
L. acidophilus	*L. casei*	*L. fermentum*
L. crispatus	*L. paracasei* ssp. *paracasei*	*L. reuteri*
L. amylovarus	*L. paracasei* ssp. *tolerans*	
L. gallinarum	*L. plantarum*	
L. gasseri	*L. rhamnosus*	
L. johnsonii		
L. helveticus		
L. delbrueckii ssp. *bulgaricus*		
L. salivarius ssp. *salivarius*		

4.2 Genus bifidobacterium

Bifidobacterium spp. was first isolated from infant faeces by Tissier in the year 1899. In 1924, there was an initial intention to reclassify *Bifidobacterium* into a distinct genus, but the actual reclassification took place in 1973 (Lee and Sullivan, 2010). These microorganisms are Gram-positive, catalase-negative, obligate anaerobes, non-spore formers, and non-motile. *Bifidobacteria* come in various forms including bifurcated Y-shaped rods, club-shaped rods, and short, curved rods. They thrive best at temperatures between 37-41°C and within a pH range of 6-7. Their growth is completely suppressed below a pH of 4.5 or above a pH of 8.0 (Gomes and Malcata, 1999).

4.3 Genus lactobacillus

The genus *Lactobacillus* is characterized as non-flagellated rods with Gram-positive, catalase-negative, non-sporing, anaerobic, and extensive fermentative properties (Salvetti *et al.,* 2012). As of March 2020, approximately 25 species of *Lactobacillus* have been identified. Reclassification is carried out using a polyphasic approach, considering core genome phylogeny, pairwise average amino acid identity, signature genes, physiological criteria, and ecological factors. Proposed genera like *Holzapfelia*, *Amylolactobacillus*, *Bombilactobacillus* highlight the diverse nature of *Lactobacillus* (Zheng *et al.,* 2020). *Lactobacilli* possess important probiotic features, including the production of digestive enzymes, synthesis of vitamins, breakdown of bile salts, enhancement of immunity, and inhibition of pro-inflammatory mediators (Eslami *et al.,* 2019). Table 1 illustrates common *Lactobacillus* species used as probiotics.

5. Selection criteria for probiotic microorganisms (either bacteria or yeast)

The probiotic organism should have the following desirable properties:

- Tolerance to acid and bile salt: Ensuring survivability of probiotics in the gut (Both *et al*., 2010).
- Attachment to mucosal and epithelial surfaces: Providing health benefits (Monteagudo-Mera *et al*., 2019).
- Antimicrobial activity: Acting against undesirable organisms (Fijan, 2023).
- Cell surface properties: Including features related to probiotic adhesion to host tissue, such as cell surface hydrophobicity, aggregation, *etc*. (Miljkovic *et al*., 2015).

6. Probiotic cheese

6.1 Cheese as a probiotic carrier

LAB strains sourced from traditionally homemade cheeses have undergone genetic and biochemical analysis, revealing their capacity to produce bacteriocins, proteinases, exopolysaccharides, *etc*. These strains are being assessed as potential probiotics for the production of probiotic cheese, with evaluation criteria including survivability in the gastrointestinal tract, adherence to the intestinal mucosa, and potential health benefits associated with their consumption (Topisirovic *et al*., 2006).

The addition of probiotic cultures to cheeses has the potential to enhance both product quality and health status, broadening the range of probiotic products available to consumers (Rizwana *et al*., 2021). However, when utilizing probiotic bacteria in commercial applications, it is essential that they meet specific technological requirements. Additionally, these microorganisms should not adversely affect the product's flavor (Terpou *et al*., 2019).

Cheese emerges as a favorable medium for delivering probiotics compared to other fermented products like yogurt and fermented milk. Notably, cheese often possesses a firmer texture, and increased fat content. These characteristics may be attributed to the potential advantages of incorporating probiotic bacteria within the cheese fat-protein matrix and its inherent buffering capacity, potentially enhancing bacterial survival during gastrointestinal transit (Bergamini *et al*., 2005; Ong *et al*., 2006).

For dairy products containing live bacteria, especially those with probiotics, proper refrigerated storage is imperative. Cold storage plays a crucial role in ensuring the sustained viability of probiotic bacteria at high levels and maintaining the stability of the product. Other factors such as oxygen content, redox potential, and water activity also demand careful consideration, as these elements play a role in facilitating the journey of probiotic bacteria to the intestinal tract (Shah *et al*., 1995).

6.2 Probiotic potential of diverse cheese cultures

Fresh cheeses, such as cream cheese, cottage cheese, quark, fromage frais, and ricotta, can be consumed immediately after production, have a limited shelf-life, and do not require prolonged ripening. This characteristic allows them to maintain probiotic viability during storage, making them a preferred choice in the commercial production of probiotic cheeses (Schulz-Collins and Senge, 2004; Litopoulou-Tzanetaki, 2007). Numerous scientific studies (Table 2) have explored the development of fresh soft cheeses incorporating both established and potential probiotic cultures. These cheeses have demonstrated the ability to maintain viable cell counts and positively impact texture and sensory qualities. Probiotic *Lactobacillus* spp. and *Bifidobacterium* spp. are commonly added to cheese, necessitating modifications in the manufacturing process to ensure their viability (Castro *et al*., 2015).

Sperry *et al*. (2018) reported increased antioxidant and ACE-inhibitory activity in minas frescal cheese with *L. casei* 01, while Kariyawasam *et al*. (2019) observed higher LAB counts, antioxidant activity, and antilisterial effects in cottage cheese with *Lb. rhamnosus* GG or *Weissella cibaria* D30 at 4 ± 1°C. Mushtaq *et al*. (2019) found enhanced antimicrobial activity in probiotic kalari cheese with various probiotic cultures (*Lb. plantarum* NCDC 012, *Lb. casei* NCDC 297 and *Lb. brevis* NCDC 021) highlighting potential health benefits and improved quality.

Low-fat feta cheese with a combination of yogurt and *Bifidobacterium* cultures improved flavor, texture, and maintained probiotics during storage, making it comparable to full-fat feta cheese (Hamdy *et al.,* 2021). Mirkoviæ *et al.* (2021) demonstrated that probiotic strains (*Lactiplantibacillus plantarum* 564 and *Lactiplantibacillus plantarum* 299v), whether free-living or spray-dried, maintained high viability in ultrafiltered (UF) cheese during storage, while sensory evaluation yielded positive results. The addition of *L. rhamnosus*, *L. casei*, and *B. bifidum* to sudanese white soft cheese improved yield and various quality parameters, suggesting their potential as beneficial additives for enhancing cheese quality (Dafalla *et al.,* 2021a). Dafalla *et al.* (2021b) explored the influence of three probiotic bacteria (*L. rhamnosus*, *L. casei, B. bifidum*) on sudanese white soft cheese during a 60-day storage period. Microbiological analysis revealed the highest probiotic count in samples with *L. rhamnosus* (*Lacticasei bacillus rhamnosus)* and the lowest with *B. bifidum (Bifidobacterium bifidum)*, while *L. casei (Lactobacillus casei)* showed an intermediate count. No pathogenic bacteria or yeast and molds were detected. Sensory evaluation favored cheese with *L. rhamnosus*, followed *by L. casei* and *B. bifidum*, compared to controls.

Ngamsomchat *et al.* (2022) selected *Lactobacillus plantarum* (isolate AD73) for probiotic chèvre cheese, extending its shelf life to 8 days with a concentration of 8.6 log CFU/g. Probiotic adjuncts, especially *B. bifidum*, significantly influenced the physicochemical properties and proteolysis of buffalo milk cheddar cheese enhancing the formation of bioactive peptides (Murtaza *et al.,* 2022). Probiotic *B. animalis*, effectively reduced *L. monocytogenes* in soft cheese during ripening, highlighting their potential as natural antimicrobials for food preservation (Ewida *et al.,* 2022). Genome analysis of *Enterococcus durans* LAB18S, isolated from soft cheese, revealed promising probiotic traits including adhesion, acid and bile resistance, antimicrobial activity, prebiotic utilization, and potential selenium metabolism, making it a suitable candidate for probiotic formulations (Comerlato *et al.,* 2022). The incorporation of *Lactobacillus* or *Enterococcus* probiotics into wagashi cheese did not compromise key quality features. In contrast, wagashi cheeses with *Lactiplanti bacillus plantarum (L. plantarum)* and *L. casei* exhibited increased antioxidant activity and maintained probiotic viability throughout production and storage (Anihouvi and Kesenkaº, 2022). Leeuwendaal *et al*. (2022) confirmed *Lacticaseibacillus* strains survival in cheddar cheese during ripening and resistance to simulated gastric digestion. Their addition didn't significantly affect cheese composition or *Lacticaseibacillus* proliferation. The strains maintained viable concentrations (10^7 CFU/g) during ripening and survived simulated digestion (10^6 CFU/g), meeting probiotic product criteria. Abd-Elmonem *et al*. (2022) explored the quality of egyptian hard cheese (Ras type) by introducing selected *Lactobacillus* strains as probiotic adjunct cultures. Over the 90-day ripening period, experimental cheeses displayed decreased pH and moisture content, with significant increases in total nitrogen, fat, fat/dry matter ratio, titratable acidity, and salt content compared to the control. These cheeses exhibited elevated *Lactobacilli* counts, reduced fungal growth, and inhibited coliform bacteria.

Tologana *et al*. (2023) discovered that cream cheese containing *L. plantarum Kita-3* achieved greater sensory preference and improved characteristics compared to mixed cultures, specifically *L. plantarum Dad-13* and *L. plantarum Kita-3*. In another study, Wang *et al*. (2023) effectively employed *Pediococcus acidilactici* AS185 as an adjunct culture in cheddar cheese, leading to enhancements in flavor, taste, and texture while demonstrating resilience through the gastrointestinal system. Microencapsulation improved the survival of *L. plantarum* CCMA 0359 in cream cheese, enhancing protection during digestion and altering acidity without affecting consumer acceptance (de Andrade *et al.,* 2023; Meena *et al*., 2023). Adding *L. rhamnosus* to peruvian fresh cheese before renneting maintained similar physicochemical properties, enhanced probiotic viability, and received the highest sensory preference, making it a suitable matrix for probiotics (Coronado *et al.,* 2023). A study isolated LAB (*Lactiplantibacillus pentosus* L11 and *Lactiplantibacillus plantarum* L33, classified with low to medium proteolytic activity, respectively) from iranian artisanal white cheeses, classified them by proteolytic activity, identified safe and probiotic strains, and found that strains with low to medium proteolytic activity improved the flavor of fermented milk (Zareie *et al.,* 2023). *Lactobacillus helveticus* exhibited the highest ACE-I activity and unique peptides that efficiently interacted with ACE, suggesting its potential for producing bioactive peptides in cheddar cheese (Hao *et al.,* 2023). The probiotic cultures used in different cheeses are summarized in Table 2.

7. Prebiotics used in cheese

In 1995, Glenn gibson and Marcel roberfroid introduced the concept of prebiotics, defining them as non-digestible food components that selectively promote the growth of colon bacteria and enhance host health. In 2008, the International Scientific Association of probiotics and prebiotics expanded this definition and categorized "dietary prebiotics" as selectively fermented ingredients that induce specific changes in the gastrointestinal microbiota for the benefit of the host's health (Gibson *et al*., 2010; Sharma and Sarwat, 2022). To qualify as a prebiotic, a compound must resist stomach acidity, withstand hydrolysis by mammalian enzymes remain unabsorbed in the gastrointestinal tract be fermentable by intestinal microbiota, and selectively stimulate the growth and/or activity of intestinal bacteria to improve host health (Davani-Davari *et al*., 2019).

The primary objective of prebiotics is to promote the development of beneficial bacteria that provide defense against diseases. The fermentation of prebiotics leads to the production of short-chain fatty acids, including acetic acid, butyric acid, and propionic acid.

These compounds provide benefits to the host by serving as a source of energy. Commonly used prebiotics include fructooligosaccharide (FOS), galactooligosaccharide (GOS), and inulin. Synbiotics, a combination of probiotics and prebiotics, offer diverse health benefits, including improved probiotic levels, enhanced liver function, immunomodulation, and reduced infections (Charalampopoulos and Rastall, 2012; Manigandan *et al*., 2012; Pandey *et al*., 2015). Using Jerusalem artichoke-derived inulin in spreadable ricotta cheese effectively preserved probiotic viability, extended shelf-life, and diversified functional dairy product offerings (Rubel *et al.,* 2022). Some of the prebiotic cultures used in different cheeses are summarized in Table 3.

Table 2: Probiotic cultures used in the different cheese

Name of cheese	Probiotic strains	References
Çamur cheese	*Bifidobacterium animalis* ssp. *Lactis*	Çiçek, and Erdoðmuº, 2023
Cream cheese	*Lactiplantibacillus plantarum* CCMA 0359	de Andrade *et al.,* 2023
	Lactobacillus plantarum Dad-13 and *Lactobacillus plantarum Kita-3*	Tologana *et al.,* 2023
Cheese whey	*Lacticaseibacillus paracasei* ItalPN16	Barreto Pinilla *et al.,*2023
Chèvre cheese	*Lactobacillus plantarum* and *L. fermentum*	Ngamsomchat *et al.,*2022
Fresh cheese	*Lactobacillus acidophilus* and *L. rhamnosus*	Coronado *et al.,* 2023
Iranian artisanal white cheese	*Lactiplantibacillus (Lpb.) pentosus L11, Lpb. plantarum*	Zareie *et al.,*2023
Chami (traditional soft cheese)	*Pediococcus pentosaceus*	Mudgil *et al.,*2022
Wagashi cheese	*L. plantarum* and *L. casei* 39	Anihouvi and Kesenkaº, 2022
Ultrafiltered cheese	*Lactiplantibacillus plantarum* 564 and *Lactiplantibacillus plantarum* 299v	Mirkoviæ *et al.,* 2021
Sudanese white soft cheese	*Lacticaseibacillus rhamnosus, Lactobacillus casei,* and *Bifidobacterium bifidum*	Dafalla *et al.,* 2021b
Soft sheep cheese	*B. animalis* subsp. *lactis* BB-12 and *L. acidophilus* LA-5	Cuffia *et al.,* 2018
Akawi cheese	*L. plantarum* KX881772 and KX881779	Al-Dhaheri *et al.,* 2017
Prato cheese	*L. acidophilus 5a and Bifidobacterium BB12*	Chaves and Gigante, 2016
Goat ricotta cheese	*Bifidobacterium animalis* and *Lb. acidophilus*	Meira *et al.,* 2015
Fresh white cheese	*L. lactis* subsp. *lactis, L. lactis* subsp. *cremoris* and *L. acidophilus* 593 N	Yerlikaya and Ozer, 2014
Minas fresh cheese	*L. paracasei* LBC 82*;*	Buriti *et al.,* 2005a
	L. acidophilus La-5*, S. thermophilus;*	De Souza *et al.,* 2008
	B. bifidum BB 12	Fritzen-Freire *et al.,* 2010
Argentinian UF cheese	*L. paracasei* A13, *B. bifidum* A1, *L. acidophilus A3*	Vinderola *et al.,* 2009
Cremoso cheese	*L. casei* I90, *L. plantarum* I91	Milesi *et al.,* 2009
Pikantne cheese	*L. fermentum* ME-3	Songisepp *et al.,* 2004
Gouda cheese	*Bifidobacterium* subsp. *strain Bo,*	
	L. acidophilus strain Ki	Gomes and Malcata, 1999
Edam cheese	*B. bifidum* ATCC 15696	Sabikhi and Mathur, 2001
	L. plantarum TENSIA	Sharafedtinov *et al.,* 2013
Canestrato pugliese hard cheese	*B. bifidum* Bb02, *B. longum* Bb46	Corbo *et al.,* 2001
Cottage cheese	*L. casei* ATCC 373, *Lb. rhamnosus*	Abadia-Garcia *et al.,* 2013
Feta type cheese	*L. casei*	Terpou *et al.,* 2018
Fresh cheese	*L. acidophilus* JCN11047, *L. acidophilus* 1132*T and L. gasseri* JCM11657	Masuda *et al.,* 2009
	B. bifidum A12, L. acidophilus A9, L. paracasei A13	Medici *et al.,* 2004

Soft cheese	*L. plantarum 3037*	Coeuret *et al.*, 2004
	B. animalis	Ewida *et al.*, 2022
	Enterococcus durans LAB18S	Comerlato *et al.*, 2022
Crescenza	*B. bifidum, B. infantis and B. longum*	Gobbetti *et al.*, 1998
Feta cheese	*L. casei ATCC 393*	Kourkoutas *et al.*, 2006
Probiotic goat cheese	*L. delbrueckii* subsp. *lactis*	Fernandez *et al.*, 2005
Cheddar cheese	*E. faecium*	Gardiner *et al.*, 1999
	B. lactis BB-12, *B. longum* BB536	McBrearty *et al.*, 2001
	L. casei ACCC10171 *and L. plantarum* ACCC10639	Chen *et al.*, 2019
	L. casei 334e	Sharp *et al.*, 2008
	Pediococcus acidilactici	Wang *et al.*, 2023
	Lacticaseibacillus rhamnosus DPC7102 and Lacticaseibacillus paracasei DPC7150	Leeuwendaal *et al.*,2022
	Bifidobacterium bifidum	Murtaza *et al.*, 2022
	Lactobacillus helveticus	Hao *et al.*, 2023

Table 3: Prebiotics in different cheeses

Name of cheese	Probiotics	Prebiotics	References
Ricotta cheese	*Lacticaseibacillus paracasei BGP1*	Inulin from Jerusalem artichoke	Rubel *et al.*,2022
Semi-hard cheese	*L. paracasei* INIA P272 or *L. paracasei* INIA P272	Fructo- oligosaccharides (FOS, GOS, Inulin)	Langa *et al.*, 2019
Cream cheese	*L. paracasei* subsp. *paracasei LBC 82*	Inulin	Buriti *et al.*, 2007
	B. animalis subsp. *Lactis* DSM 10140 *L. reuteri*	Inulin, FOS and lactulose	Speranza *et al.*, 2018
Lactobacillus helveticus	Inulin		Krishna *et al.*, 2020
Petit suisse cheese	*L. acidophilus* Lac4 and *B. animalis* subsp. *lactis* BL04	Inulin and/or oligofructose	Cardarelli *et al.*, 2008
	L. acidophilus La-5, *B. lactis*	Inulin, oligofructose, honey	Cardarelli *et al.*, 2007
Fiordilatte cheese	*L. rhamnosus*	FOS	Angiolillo *et al.*, 2014
Cottage cheese	*L. delbrueckii* UFV H2b20	Inulin	Araujo *et al.*, 2010
Fresh cheese	*S. boulardii* (strain CDBB-L-1483 ATCC-MYC-797)	Inulin	Zamora-Vega *et al.*, 2013
White cheese	*L. plantarum* 14	Inulin and maltodextrin	Modzelewska-Kapitu³a *et al.*, 2010
UF- soft cheese	*L. acidophilus* 5, and *S. thermophiles*	Inulin	El-Baz,2013

8. Industrial application aspects of producing probiotic and prebiotic cheese

The global cheese production industry has witnessed significant growth, particularly in the consumption of fresh cheese, leading to a projected global cheese production of 25.2 million metric tons by 2026, *i.e.*, 0.9% increase from the 23.9 million metric tons recorded in 2021. Several European nations, including Germany, France, Italy, and Cyprus, have shown substantial growth in cheese manufacturing (Bhat *et al.*, 2022). The United States has also demonstrated a similar increasing pattern. The popularity of fresh cheese, characterized by its high moisture content, soft flavor, and smooth, flexible texture, has contributed to the surge in cheese consumption over the past decade. The development of probiotic cheese, along with the incorporation of various prebiotics, provides a promising avenue for delivering probiotics to the consumer's gastrointestinal tract. To achieve this, both fresh and ripened cheeses are enriched with probiotic strains, predominantly *Lactobacillus* spp. and *Bifidobacterium* spp., while prebiotics specifically inulin, oligofructose, and maltodextrin, are used to ensure compliance with Generally Recognized as Safe standards and the absence of adverse effects on cheese taste, aroma, texture, and other attributes (da Cruz *et al.*, 2009). Despite these advancements, maintaining probiotic microorganism counts at a standardized level (a minimum of 10^7 CFU g^{-1} probiotic cells) poses a noteworthy challenge. These strains must endure industrial processing conditions and maintain their shelf life. Proper packaging and storage are critical for ensuring the viability of probiotics and the stability of prebiotics in both fresh and ripened cheeses. Packaging materials with low oxygen permeability and vacuum packaging can help preserve probiotic content and enhance organoleptic qualities (Terpou *et al*., 2019; Charalampopoulos and Rastall, 2012). It is crucial to note that unfavourable conditions, such as high temperatures, can harm count in probiotic content, alter organoleptic characteristics, and promote the growth of pathogenic and spoiling microbes. Therefore, maintaining count in probiotic content and preserving the cheese's flavor and freshness during storage is of utmost importance.

9. Conclusion

This review article focuses on live cultivable probiotic microorganisms and their prebiotic ingredients found in cheese, which offer health benefits when consumed in adequate quantities. Commonly used probiotic strains in cheese belong to the *Lactobacillus* and *Bifidobacterium* species due to their safety and positive impact on gut health. Particularly, fresh and soft cheese varieties such as cream cheese and cottage cheese are effective carriers for probiotic cultures. The firm consistency, and relatively higher fat content of these cheeses enhance microbial survival during transit through the gastrointestinal tract. Incorporating probiotic strains into cheese results in minimal alterations in the sensory and physical attributes of the product. Future research directions should explore the effects of new probiotic strains on the physicochemical properties of different cheese types. Additionally, investigating co-culturing these probiotics with various adjunct lactic cultures could prove beneficial for further enhancing the health benefits of probiotic-enriched cheeses.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

References

Abadia-Garcia, L.; Cardador, A.; del Campo, S.T.M.; Arvízu, S.M.; Castaño-Tostado, E., Regalado-González, C. and Amaya-Llano, S.L. (2013). Influence of probiotic strains added to cottage cheese on generation of potentially antioxidant peptides, anti-listerial activity, and survival of probiotic microorganisms in simulated gastrointestinal conditions. Int. Dairy. J., **33**(2):191-197.

Abatenh, E.; Gizaw, B.; Tsegay, Z.; Tefera, G. and Aynalem, E. (2018). Health benefits of probiotics. J. Bacteriol. Infect. Dis., **2**(1):210-217.

Abd-Elmonem, M.A.; Tammam, A.A.; El-Desoki, W. I.; Zohri, A.N.A. and Moneeb, A. H. (2022). Improving the properties of the egyptian hard cheese (ras type) with adding some probiotic Lactobacillus spp. as adjunct cultures. Assiut. J. Agric. Sci., **53**(1):12-30.

Al-Dhaheri, A.S.; Al-Hemeiri, R.; Kizhakkayil, J.; Al-Nabulsi, A.; Abushelaibi, A.; Shah, N. P. and Ayyash, M. (2017). Health-promoting benefits of low-fat akawi cheese made by exopolysaccharide-producing probiotic Lactobacillus plantarum isolated from camel milk. J. Dairy Sci., **100**(10):7771-7779.

Angiolillo, L.; Conte, A.; Faccia, M.; Zambrini, A.V. and Del Nobile, M.A. (2014). A new method to produce symbiotic Fiordilatte cheese. Innov. Food Sci. Emerg. Technol., **22**:180-187.

Anihouvi, E.S. and Kesenkaº, H. (2022). Wagashi cheese: Probiotic bacteria incorporation and significance on microbiological, physicochemical, functional and sensory properties during storage. LWT, **155**:112933.

Araujo, E.A.; de Carvalho, A.F.; Leandro, E.S.; Furtado, M.M. and de Moraes, C.A. (2010). Development of a symbiotic cottage cheese added with *Lactobacillus delbrueckii* UFV H2b20 and inulin. J. Funct. Foods, **2**(1):85-89.

Arokiyamary, A. and Sivakumar, P.K. (2011). Antibacterial activity of bacteriocin-producing Lactobacillus sp., isolated from traditional milk products. Current Botany, **2**(3):05-08.

Barreto Pinilla, C.M.; Brandelli, A.; Galland, F.; Spadoti, L.M. and Torres Silva Alves, A. (2023). Improved functional properties of the potential probiotic *Lacticaseibacillus paracasei* ItalPN16 growing in cheese whey. Lett. Appl. Microbiol., **76**(7):ovad075.

Bergamini, C.V.; Hynes, E.R.; Quiberoni, A.; Suárez, V.B. and Zalazar, C.A. (2005). Probiotic bacteria as adjunct starters: Influence of the addition methodology on their survival in a semi-hard Argentinean cheese. Food Res. Int., **38**(5):597-604.

Bermudez-Brito, M.; Plaza-Díaz, J.; Muñoz-Quezada, S.; Gómez-Llorente, C. and Gil, A. (2012). Probiotic mechanisms of action. Ann. Nutr. Metab., **61**(2):160-174.

Bhat, R.; Di Pasquale, J.; Bánkuti, F.I.; Siqueira, T.T.D.S.; Shine, P. and Murphy, M. D. (2022). Global dairy sector: Trends, prospects, and challenges. Sustainability., **14**(7):4193.

Both, E.; Gyorgy, E.; Kibedi-Szabo, C.Z.; Tamas, E.; Abraham, B.; Miklossy, I. and Lanyi, S. (2010). Acid and bile tolerance, adhesion to epithelial cells of probiotic microorganisms. UPB Bull Sci. Ser. B. Chem. Mater Sci., **72**(2):37-44.

Buriti, F.C.; Cardarelli, H.R.; Filisetti, T.M. and Saad, S.M. (2007). Synbiotic potential of fresh cream cheese supplemented with inulin and *Lactobacillus paracasei* in co-culture with *Streptococcus thermophilus*. Food Chem., **104**(4):1605-1610.

Buriti, F.C.; Da Rocha, J.S. and Saad, S.M. (2005). Incorporation of *Lactobacillus acidophilus* in Minas fresh cheese and its implications for textural and sensorial properties during storage. Int. Dairy J., **15**(12):1279-1288.

Buriti, F.C.; da Rocha, J.S.; Assis, E.G. and Saad, S.M. (2005a). Probiotic potential of Minas fresh cheese prepared with the addition of *Lactobacillus paracasei*. LWT- Food Sci. Technol., **38**(2):173-180.

Cardarelli, H.R.; Buriti, F.C.; Castro, I.A. and Saad, S.M. (2008). Inulin and oligofructose improve sensory quality and increase the probiotic viable count in potentially synbiotic petit-suisse cheese. LWT-Food Technol., **41**(6):1037-1046.

Cardarelli, H.R.; Saad, S.M.; Gibson, G.R. and Vulevic, J. (2007). Functional petit-suisse cheese: Measure of the prebiotic effect. Anaerobe, **13**(5-6):200-207.

Castro, J.M.; Tornadijo, M.E.; Fresno, J.M. and Sandoval, H. (2015). Biocheese: a food probiotic carrier. BioMed Res. Int., pp:1-11.

Charalampopoulos, D. and Rastall, R.A. (2012). Prebiotics in foods. Curr. Opin. Biotechnol., **23**(2):187-191.

Chaves, K.S. and Gigante, M.L. (2016). Prato cheese as a suitable carrier for *Lactobacillus acidophilus* La5 and Bifidobacterium Bb12. Int. Dairy J., **52**:10-18.

Chen, P.; Liu, L.; Zhang, X.; Massounga Bora, A.F.; Li, X., Zhao, M. and Wang, Y. (2019). Antioxidant activity of Cheddar cheese during its ripening time and after simulated gastrointestinal digestion as affected by probiotic bacteria. Int. J. Food Prop., 22(1):218-229.

Çiçek, ª.K. and Erdoðmuþ, S. (2023). Microbiological quality of probiotic-added traditional Çamur cheese. Emir. J. Food Agric., 35(5):452-457.

Coeuret, V.; Gueguen, M. and Vernoux, J.P. (2004). *In vitro* screening of potential probiotic activities of selected lactobacilli isolated from unpasteurized milk products for incorporation into soft cheese. J. Dairy Res., 71(4):451-460.

Comerlato, C.B.; Prichula, J.; Siqueira, F.M.; Ritter, A.C.; Varela, A.P.M.; Mayer, F. Q. and Brandelli, A. (2022). Genomic analysis of *Enterococcus durans* LAB18S, a potential probiotic strain isolated from cheese. Genet. Mol. Biol., 45:e20210201

Corbo, M.R.; Albenzio, M.; De Angelis, M.; Sevi, A. and Gobbetti, M. (2001). Microbiological and biochemical properties of Canestrato Pugliese hard cheese supplemented with Bifidobacteria. J. Dairy Sci., 84(3):551-561.

Gutiérrez Coronado, K.A.; García-Torres, S.M.; Caldas-Cueva, J.P. and Campos-Montiel, R.G. (2023). Physicochemical, Textural, and Sensory Characteristics of Peruvian Fresh Cheese with Added Probiotic Lactic Acid Bacteria. 2023080662. https://doi.org/10.20944/preprints202308.0662.v1

Cuffia, F.; Bergamini, C. and Candioti, M. (2018). Probiotic soft sheep's cheese: evaluation of probiotic survival and its influence on proteolysis and organoleptic characteristics. Int Food Res. J., 25(1):399-407.

da Cruz, A.G.; Buriti, F.C.A.; de Souza, C.H.B.; Faria, J.A.F. and Saad, S.M.I. (2009). Probiotic cheese: Health benefits, technological and stability aspects. Trends Food Sci. Technol., 20(8):344-354.

Dafalla, A.I. and Abdel-Razig, K.A. (2021a). The role of probiotic bacteria on microbiological and acceptability of sudanese white soft cheese. Int. J. Multidiscip. Res. Anal., 4:496-505.

Dafalla, A.; Abdel Razig, K.A. and Elrofaei, N.A. (2021b). Effect of types of probiotic bacteria on physiochemical properties of Sudanese white soft cheese. Am. Sci. Res. J. Eng. Technol. Sci., 78(1):83-97.

Davani-Davari, D.; Negahdaripour, M.; Karimzadeh, I.; Seifan, M.; Mohkam, M.; Masoumi, S.J. and Ghasemi, Y. (2019). Prebiotics: Definition, types, sources, mechanisms, and clinical applications. Foods, 8(3):92.

de Andrade, D.P.; Bastos, S.C.; Ramos, C.L.; Simões, L.A.; Fernandes, N.D.A.T.; Botrel, D.A. and Dias, D.R. (2023). Microencapsulation of presumptive probiotic bacteria *Lactiplantibacillus plantarum* CCMA 0359: Technology and potential application in cream cheese. Int. Dairy J., 143:105669.

De Souza, C.H.; Buriti, F.C.; Behrens, J.H. and Saad, S.M. (2008). Sensory evaluation of probiotic Minas fresh cheese with *Lactobacillus acidophilus* added solely or in co-culture with a thermophilic starter culture. Int. J. Food Sci. Technol., 43(5):871-877.

Dhyani, P.; Goyal, C.; Dhull, S.B.; Chauhan, A.K.; Singh Saharan, B.; Harshita and Goksen, G. (2023). Psychobiotics for mitigation of neuro degenerative diseases: Recent advancements. Mol. Nutr. Food Res., 2300461.

El-Baz, A. (2013). The use of inulin as a dietary fiber in the production of symbiotic soft cheese. Food Dairy Sci., 4(12):663-677.

Erickson, K.L. and Hubbard, N.E. (2000). Probiotic immunomodulation in health and disease. J. Nutr., 130(2):403S-409S.

Eslami, M.; Yousefi, B.; Kokhaei, P.; Hemati, M.; Nejad, Z.R.; Arabkari, V. and Namdar, A. (2019). Importance of probiotics in the prevention and treatment of colorectal cancer. J. Cell Physiol., 234(10):17127-17143.

Ewida, R.M.; Hasan, W.S.; Elfaruk, M.S.; Alayouni, R.R.; Hammam, A.R. and Kamel, D.G. (2022). Occurrence of Listeria spp. in soft cheese and ice cream: effect of probiotic Bifidobacterium spp. on survival of *Listeria monocytogenes* in soft cheese. Foods, 11(21):3443.

Fernandez, M.F.; Delgado, T.; Boris, S.; Rodríguez, A. and Barbés, C. (2005). A washed-curd goat's cheese as a vehicle for delivery of a potential probiotic bacterium: Lactobacillus delbrueckii subsp. lactis UO 004. J. Food Prot., 68(12):2665-2671.

Fijan, S. (2014). Microorganisms with claimed probiotic properties: An overview of recent literature. Int. J. Environ. Res. Public Health., 11(5):4745-4767.

Fijan, S. (2023). Probiotics and their antimicrobial effect. Microorganisms, 11(2):528.

Fritzen-Freire, C.B.; Müller, C.M.O.; Laurindo, J.B. and Prudêncio, E.S. (2010). The influence of Bifidobacterium Bb-12 and lactic acid incorporation on the properties of Minas Frescal cheese. J. Food Eng., 96(4):621-627.

Fuller, R. (1989). Probiotics in man and animals. J. Appl. Bacteriol., 66(5):365-378.

Ganguly, N.K.; Bhattacharya, S.K.; Sesikeran, B.; Nair, G.B.; Ramakrishna, B.S.; Sachdev, H.P.S. and Hemalatha, R. (2011). ICMR-DBT guidelines for evaluation of probiotics in food. Indian J. Med. Res., 134(1):22-25.

Ganguly, S.; Sabikhi, L. and Singh, A.K. (2019). Effect of whey-pearl millet-barley-based probiotic beverage on Shigella-induced pathogenicity in murine model. J. Funct. Foods, 54:498-505.

Gardiner, G.; Stanton, C.; Lynch, P.B.; Collins, J.K.; Fitzgerald, G. and Ross, R.P. (1999). Evaluation of cheddar cheese as a food carrier for delivery of a probiotic strain to the gastrointestinal tract. J. Dairy Sci., 82(7):1379-1387.

Gibson, G.R. and Roberfroid, M.B. (1995). Dietary modulation of the colonic microbiota: Introducing the concept of prebiotics. J. Nutr., 125:1401-1412.

Gibson, G.R.; Scott, K.P.; Rastall, R.A.; Tuohy, K.M.; Hotchkiss, A.; Dubert-Ferrandon, A. and Buddington, R. (2010). Dietary prebiotics: Current status and new definition. Food Sci. Technol. Bull Funct. Foods, 7(1):1-19.

Gobbetti, M.; Corsetti, A.; Smacchi, E.; Zocchetti, A. and De Angelis, M. (1998). Production of Crescenza cheese by incorporation of Bifidobacteria. J. Dairy Sci., 81(1):37-47.

Gomes, A.M. and Malcata, F.X. (1999). Bifidobacterium spp. and *Lactobacillus acidophilus*: biological, biochemical, technological, and therapeutic properties relevant for use as probiotics. Trends Food Sci. Technol., 10 (4-5):139-157.

Gomes, A.M.; Andrade, J.C. and Freitas, A.C. (2017). The use of probiotics in the food industry. Strategies for obtaining healthier foods, 1st edn., Nova Science Publishers Inc, New York, NY, pp:129-182.

Grattepanche, F.; Miescher-Schwenninger, S.; Meile, L. and Lacroix, C. (2008). Recent developments in cheese cultures with protective and probiotic functionalities. Dairy Science and Technology, 88(4-5):421-444.

Gupta, R.; Jeevaratnam, K. and Fatima, A. (2018). 'Lactic acid bacteria: Probiotic characteristic, selection criteria, and its role in human health (A: review)'. Rahul Gupta, Kadirvelu Jeevaratnam, Amrin Fatima. Lactic Acid Bacteria: Probiotic Characteristic, Selection Criteria, and its Role in Human Health (A:review), IJETIR., 5(10):411-424.

Hamdy, A.M.; Ahmed, M.E.; Mehta, D.; Elfaruk, M.S.; Hammam, A.R. and El Derwy, Y.M. (2021). Enhancement of low fat Feta cheese characteristics using probiotic bacteria. Food Sci. Nutr., 9(1):62-70.

Hao, X.; Xia, Y.; Wang, Y.; Zhang, X. and Liu, L. (2023). The addition of probiotic promotes the release of ACE-I peptide of Cheddar cheese: Peptide profile and molecular docking. Int. Dairy J., 137:105507.

Harzallah, D. and Belhadj, H. (2013). Lactic acid bacteria as probiotics: characteristics, selection criteria and role in immunomodulation of human GI muccosal barrier. Lactic Acid Bacteria-R and D for Food, Health and Livestock Purposes; Kongo, M., Ed, 197-216.

Hill, C.; Guarner, F.; Reid, G.; Gibson, G.R.; Merenstein, D.J.; Pot, B. and Sanders, M.E. (2014). Expert consensus document: The International Scientific Association for Probiotics and Prebiotics consensus statement on the scope and appropriate use of the term probiotic. Nat. Rev. Gastroenterol. Hepatol., 11:506-514.

Kariyawasam, K.M.G.M.; Jeewanthi, R.K.C.; Lee, N.K. and Paik, H.D. (2019). Characterization of cottage cheese using *Weissella cibaria* D30: Physicochemical, antioxidant, and antilisterial properties. J. Dairy Sci., 102(5):3887-3893.

Kourkoutas, Y.; Bosnea, L.; Taboukos, S.; Baras, C.; Lambrou, D. and Kanellaki, M. (2006). Probiotic cheese production using *Lactobacillus casei* cells immobilized on fruit pieces. J. Dairy Sci., 89(5):1439-1451.

Krishna, K.N.; Krishna, A. and Ghosh, B.C. (2020). Shelf-life study of developed reduced-fat Synbiotic cream cheese. J. Pharmacogn. Phytochem., 9(4):222-226.

Langa, S.; van den Bulck, E.; Peirotén, A.; Gaya, P.; Schols, H.A. and Arques, J.L. (2019). Application of lactobacilli and prebiotic oligosaccharides for the development of a synbiotic semi-hard cheese. LWT- Food Sci. Technol., 114:108361.

Lee, J.H. and Sullivan, D.J. (2010). Genomic insights into bifidobacteria. Microbiol. Mol. Biol. Rev., 74(3):378-416.

Leeuwendaal, N.K.; Hayes, J.J.; Stanton, C.; O'Toole, P.W. and Beresford, T.P. (2022). Protection of candidate probiotic lactobacilli by Cheddar cheese matrix during simulated gastrointestinal digestion. J. Funct. Foods, 92:105042.

Litopoulou-Tzanetaki, E. (2007). Soft-ripened and fresh cheeses: Feta, Quark, Halloumi and related varieties. Improving the flavour of cheese., pp:474-493.

Lozo, J.; Topisirovic, L. and Kojic, M. (2021). Natural bacterial isolates as an inexhaustible source of new bacteriocins. Appl. Microbiol. Biotechnol., 105:477-492.

Madureira, A.R.; Amorim, M.; Gomes, A.M.; Pintado, M.E. and Malcata, F.X. (2011). Protective effect of whey cheese matrix on probiotic strains exposed to simulated gastrointestinal conditions. Food Res. Int., 44(1):465-470.

Manigandan, T.; Mangaiyarkarasi, S.P.; Hemalatha, R.; Hemalatha, V.T. and Murali, N.P. (2012). Probiotics, prebiotics and synbiotics: A review. Biomed. Pharmacother., 5(2):295.

Masuda, T.; Yamanari, R. and Itoh, T. (2009). The trial for production of fresh cheese incorporated probiotic *Lactobacillus acidophilus* group lactic acid bacteria. Milchwissenschaft, 60(2):167-171.

McBrearty, S.; Ross, R.P.; Fitzgerald, G.F.; Collins, J.K.; Wallace, J.M. and Stanton, C. (2001). Influence of two commercially available bifidobacteria cultures on Cheddar cheese quality. Int. Dairy J., 11(8):599-610.

Medici, M.; Vinderola, C.G. and Perdigón, G. (2004). Gut mucosal immunomodulation by probiotic fresh cheese. Int. Dairy J., 14(7):611-618.

Meena, K.K.; Taneja, N.K.; Ojha, A. and Meena, S. (2023). Application of spray-drying and freeze-drying for microencapsulation of lactic acid bacteria: A review. Ann. Phytomed., 12(1):706-716.

Meghwal, D.; Meena, K.K.; Singhal, R.; Gupta, L. and Panwar, N.L. (2023). Exopolysaccharides producing lactic acid bacteria from goat milk: Probiotic potential, challenges, and opportunities for the food industry. Ann. Phytomed., 12(2):200-207.

Meira, Q.G.S.; Magnani, M.; de Medeiros Júnior, F.C.; do Egito, R.D.C.R.; Madruga, M. S.; Gullón, B. and de Souza, E.L. (2015). Effects of added *Lactobacillus acidophilus* and *Bifidobacterium lactis* probiotics on the quality characteristics of goat ricotta and their survival under simulated gastrointestinal conditions. Food Res. Int., 76:828-838.

Milesi, M.M.; Vinderola, G.; Sabbag, N.; Meinardi, C.A. and Hynes, E. (2009). Influence on cheese proteolysis and sensory characteristics of non-starter *Lactobacilli strains* with probiotic potential. Food Res. Int., 42(8):1186-1196.

Miljkovic, M.; Strahinic, I.; Tolinacki, M.; Zivkovic, M.; Kojic, S.; Golic, N. and Kojic, M. (2015). AggLb is the largest cell-aggregation factor from *Lactobacillus paracasei* subsp. paracasei BGNJ1-64, functions in collagen adhesion, and pathogen exclusion *in vitro*. PLoS One, 10(5):e0126387.

Mirkoviæ, M.; Mirkoviæ, N.; Mioèinoviæ, J.; Raduloviæ, A.; Paunoviæ, D.; Iliæ, M. and Raduloviæ, Z. (2021). Probiotic yogurt and cheese from ultrafiltered milk: Sensory quality and viability of free living and spray dried *Lactiplantibacillus plantarum* 564 and *Lactiplantibacillus plantarum* 299v. J. Food Process Preserv., 45(9):e15713.

Modzelewska-Kapitu³a, M.; K³obukowski, J.; K³êbukowska, L. and Wiœniewska-Pantak, D. (2010). The influence of feeding diets containing white cheese, produced with prebiotics and the potentially probiotic *Lactobacillus plantarum* strain, on the gastrointestinal microflora of rats. Czech J. Food Sci., 28(2):139-145.

Monteagudo-Mera, A.; Rastall, R.A.; Gibson, G.R.; Charalampopoulos, D. and Chatzifragkou, A. (2019). Adhesion mechanisms mediated by probiotics and prebiotics and their potential impact on human health. Appl. Microbiol. Biotechnol., 103:6463-6472.

Mudgil, P.; Aldhaheri, F.; Hamdi, M.; Punia, S. and Maqsood, S. (2022). Fortification of Chami (traditional soft cheese) with probiotic-loaded protein and starch microparticles: Characterization, bioactive properties, and storage stability. LWT, 158:113036.

Murtaza, M.A.; Anees Ur Rehman, M.; Hafiz, I.; Ameer, K. and Celik, O.F. (2022). Effects of probiotic adjuncts on physicochemical properties, organic acids content, and proteolysis in cheese prepared from buffalo milk. J. Food Process Preserv., 46(3):e16385.

Mushtaq, M.; Gani, A. and Masoodi, F.A. (2019). Himalayan cheese (Kalari/Kradi) fermented with different probiotic strains: *In vitro* investigation of nutraceutical properties. LWT- Food Sci. Technol., 104:53-60.

Ngamsomchat, A.; Kaewkod, T.; Konkit, M.; Tragoolpua, Y.; Bovonsombut, S. and Chitov, T. (2022). Characterisation of *Lactobacillus plantarum* of dairy-product origin for probiotic chèvre cheese production. Foods, 11(7):934.

Ong, L.; Henriksson, A. and Shah, N.P. (2006). Development of probiotic Cheddar cheese containing *Lactobacillus acidophilus*, Lb. casei, Lb. paracasei, and Bifidobacterium spp. and the influence of these bacteria on proteolytic patterns and production of organic acid. Int. Dairy J., 16(5):446-456.

Pandey, K.R.; Naik, S.R. and Vakil, B.V. (2015). Probiotics, prebiotics and synbiotics: A review. J. Food Sci. Technol., 52(12):7577-7587.

Plessas, S.; Bosnea, L.; Alexopoulos, A. and Bezirtzoglou, E. (2012). Potential effects of probiotics in cheese and yogurt production: A review. Eng. Life Sci., **12**(4):433-440.

Podolsky, S.H. (2012). Metchnikoff and the microbiome. The Lancet, **380**(9856):1810-1811.

Precedence Research (2022). Food and Beverages, Probiotics Market. https://www.precedenceresearch.com/probiotics-market

Rizwana, E.S.R.; Sondhi, A.; Agarwal, A.; Verma, A.; Kant, K. and Kumar, D. (2021). Consumer's attitude and awareness towards functional foods during COVID-19. Ann Phytomed., **10**(2):56-62.

Rodrigues, D.; Rocha-Santos, T.A.; Gomes, A.M.; Goodfellow, B.J. and Freitas, A.C. (2012). Lipolysis in probiotic and synbiotic cheese: The influence of probiotic bacteria, prebiotic compounds and ripening time on free fatty acid profiles. Food Chem., **131**(4):1414-1421.

Rubel, I.A.; Iraporda, C.; Manrique, G.D. and Genovese, D.B. (2022). Jerusalem Artichoke (*Helianthus tuberosus* L.) inulin as a suitable bioactive ingredient to incorporate into spreadable ricotta cheese for the delivery of probiotic. Bioact. Carbohydr. Dietary Fibre., **28**:100325.

Sabikhi, L. and Mathur, B.N. (2001). Qualitative and quantitative analysis of β-casomorphins in Edam cheese. Milchwissenschaft, **56**(4):198-200.

Salvetti, E.; Torriani, S. and Felis, G.E. (2012). The genus Lactobacillus: A taxonomic update. Probiotics Antimicrob. Proteins, **4**(4):217-226.

Schulz-Collins, D. and Senge, B. (2004). Acid-and acid/rennet-curd cheeses part A: Quark, cream cheese and related varieties. In: Cheese: Chem. Phys. Microbiol., **2**:301-328.

Shah, N.P. (1997). Isolation and enumeration of bifidobacteria in fermented milk products: A review. Milchwissenschaft, **52**:71–76.

Shah, N.P.; Lankaputhra, W.E.; Britz, M.L. and Kyle, W.S. (1995). Survival of *Lactobacillus acidophilus* and *Bifidobacterium bifidum* in commercial yoghurt during refrigerated storage. Int. Dairy J., **5**(5):515-521.

Sharafedtinov, K.K.; Plotnikova, O.A.; Alexeeva, R.I.; Sentsova, T.B.; Songisepp, E.; Stsepetova, J. and Mikelsaar, M. (2013). Hypocaloric diet supplemented with probiotic cheese improves body mass index and blood pressure indices of obese hypertensive patients-a randomized double-blind placebo-controlled pilot study. Nutr. J., **12**:1-11.

Sharma, N. and Sarwat, M. (2022). Functional foods for better health and weight loss. Ann. Phytomed., **11**(2):114-121.

Sharp, M.D.; McMahon, D.J. and Broadbent, J.R. (2008). Comparative evaluation of yogurt and low-fat cheddar cheese as delivery media for probiotic Lactobacillus casei. J. Food Sci., **73**(7):375-377.

Singhal, R.; Meena, K.K.; Meghwal, D.; Gupta, L.; Panwar, N.L. and Meena, S. (2023). Bacteriocin producing lactic acid bacteria from camel milk and its fermented products: A review. Ann. Phytomed., **12**(2):208-215.

Siró, I. (2011). Challenges of Beneficial Health Claims. Probiotics: Biol. Genet. Health Aspects., 243-268.

Songisepp, E.; Kullisaar, T.; Hütt, P.; Elias, P.; Brilene, T.; Zilmer, M. and Mikelsaar, M. (2004). A new probiotic cheese with antioxidative and antimicrobial activity. J. Dairy Sci., **87**(7):2017-2023.

Speranza, B.; Campaniello, D.; Monacis, N.; Bevilacqua, A.; Sinigaglia, M. and Corbo, M.R. (2018). Functional cream cheese supplemented with Bifidobacterium animalis subsp. lactis DSM 10140 and Lactobacillus reuteri DSM 20016 and prebiotics. Food Microbiol., **72**:16-22.

Sperry, M.F.; Silva, H.L.; Balthazar, C.F.; Esmerino, E.A.; Verruck, S.; Prudencio, E.S. and Rocha, R.S. (2018). Probiotic Minas Frescal cheese added with *L. casei* 01: Physicochemical and bioactivity characterization and effects on hematological/biochemical parameters of hypertensive overweighted women: A randomized double-blind pilot trial. J Funct Foods, **45**:435-443.

Stasiak-Ró¿añska, L.; Berthold-Pluta, A.; Pluta, A.S.; Dasiewicz, K. and Garbowska, M. (2021). Effect of simulated gastrointestinal tract conditions on survivability of probiotic bacteria present in commercial preparations. Int. J. Environ. Res. Public Health., **18**(3):1108.

Terpou, A.; Bekatorou, A.; Bosnea, L.; Kanellaki, M.; Ganatsios, V. and Koutinas, A. A. (2018). Wheat bran as prebiotic cell immobilisation carrier for industrial functional Feta-type cheese making: Chemical, microbial, and sensory evaluation. Biocatal. Agric Biotechnol., **13**:75-83.

Terpou, A.; Papadaki, A.; Lappa, I.K.; Kachrimanidou, V.; Bosnea, L.A. and Kopsahelis, N. (2019). Probiotics in food systems: Significance and emerging strategies towards improved viability and delivery of enhanced beneficial value. Nutrients, **11**(7):1591.

Tologana, R.D.; Wikandari, R.; Rahayu, E.S.; Suroto, D.A. and Utami, T. (2023). Correlation between the chemical, microbiological, and sensory characteristics of cream cheese using a mixed and single probiotic culture. J. Food Sci. Technol., **60**(1):181-189.

Topisirovic, L.; Kojic, M.; Fira, D.; Golic, N.; Strahinic, I. and Lozo, J. (2006). Potential of lactic acid bacteria isolated from specific natural niches in food production and preservation. Int. J. Food Microbiol., **112**(3):230-235.

Verma, T.; Dey, P.; Aggarwal, A.; Devpal, R. and Sharma, R. (2023). Optimization and storage study of garlic (*Allium sativum*) incorporated herbal multi-millet sev snack. Food Chem. Adv., **3**:100365.

Vinderola, G.; Prosello, W.; Molinari, F.; Ghiberto, D. and Reinheimer, J. (2009). Growth of *Lactobacillus paracasei* A13 in Argentinian probiotic cheese and its impact on the characteristics of the product. Int. J. Food Microbiol., **135**(2):171-174.

Wang, C.; Gao, L.; Gao, Y.; Yang, G.; Zhao, Z.; Zhao, Y. and Li, S. (2023). Evaluation of *Pediococcus acidilactici* AS185 as an adjunct culture in probiotic cheddar cheese manufacture. Food Sci. Nutr., **11**(3):1572-1583.

Yerlikaya, O. and Ozer, E. (2014). Production of probiotic fresh white cheese using co-culture with *Streptococcus thermophilus*. Food Sci. Technol., **34**(3):471-477.

Zamora-Vega, R.; Montañez-Soto, J.L.; Venegas-González, J.; Bernardino-Nicanor, A.; Cruz, L.G. and Martínez-Flores, H.E. (2013). Development and characterization of a symbiotic cheese added with *Saccharomyces boulardii* and inulin. Afr. J. Microbiol. Res., **7**(23):2828-2834.

Zareie, Z.; Moayedi, A.; Garavand, F.; Tabar-Heydar, K.; Khomeiri, M. and Maghsoudlou, Y. (2023). Probiotic properties, safety assessment, and aroma-generating attributes of some lactic acid cacteria isolated from Iranian traditional cheese. Fermentation, **9**(4):338.

Zheng, J.; Wittouck, S.; Salvetti, E.; Franz, C.M.; Harris, H.M.; Mattarelli, P. and Lebeer, S. (2020). A taxonomic note on the genus Lactobacillus: Description of 23 novel genera, emended description of the genus Lactobacillus Beijerinck 1901, and union of Lactobacillaceae and Leuconostocaceae. Int. J. Syst. Evol. Microbiol., **70**(4):2782-2858.

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