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Probiotic Bacteria and its Applications in the Cheese: A Review

Heba G. M. Rezk[1*] and Muhammad Ashmawi[2]

[1]Faculty of pharmacy, Ain Shams University 11566
[2] Faculty of Medicine, Benha University 13511, Egypt

*Corresponding author

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ABSTRACT

This investigation aims to explain the efficacy of cheese as a vehicular medium for the administration of probiotics into the human gastrointestinal environment, emphasizing its capacity to augment the survival rates of these advantageous microorganisms. Probiotics, acknowledged for their contributory effects on health when administered in appropriate quantities, have been progressively integrated into a diverse array of dairy products, such as fermented beverages, yogurt, and, notably, cheese. The objective of this paper is multifaceted: initially, it seeks to rationalize and elucidate the potential advantages of employing cheese as a conduit for probiotics, spotlighting its proficiency in sustaining the viability of these organisms. Subsequently, the research examines the physicochemical and organoleptic properties of cheese infused with probiotics in comparison to conventional cheese variants devoid of probiotics. Finally, the study provides a comprehensive overview of the health benefits derived from the incorporation of probiotics into cheese, underlining the significant role these fortified dairy products play in the augmentation of dietary health through the facilitation of beneficial microbial activity within the gastrointestinal tract.

Introduction

Probiotics are live microorganisms that, when consumed in sufficient quantities, can offer health advantages to the host (Ahmed *et al.,* 2021). These benefits include protection against various pathogens, boosting the immune system, aiding in lactose digestion, and reducing cholesterol levels. There is a growing interest in research on enriching various dairy products with probiotics to enhance their nutritional benefits (Ramirez-Parada *et al.,* 2023). Commonly, strains of bifidobacteria and lactobacilli are used in the production of these probiotic-enriched foods (Alsaleem *et al.,* 2023). Dairy items like yogurt, cheese, and fermented milk are among the products frequently fortified with probiotics to improve their health-promoting properties (Alsaleem and Hamouda, 2024). For probiotic benefits to be realized by humans or hosts, the viable count of probiotics in different products at the point of consumption should be between 5.0 and 7.0 log cfu/g (Vinderola *et al.,* 2000). Cheese serves as an excellent vehicle for delivering probiotic bacteria, backs to its ability to buffer against the acidic environment of the gastrointestinal tract during digestion and to offer protection in the stomach (Mirzaei *et al.,* 2012). A variety of cheeses have been produced incorporating probiotic bacteria, including Karish, Cheddar, Gouda, Ras, Cottage, and various white or fresh cheeses (Hamouda, 2015). The choice of probiotic strains is tailored to the specific type of cheese and its manufacturing process. Notably, fresh cheese or cheese at the initial stages of ripening shows a higher total count of lactic acid bacteria. In contrast, the population of non-lactic acid bacteria tends to increase as the cheese matures (Gomes de Oliveira *et al.,* 2014).

This study focuses on examining the integration of probiotics into cheese, specifically targeting the viability of various strains of bifidobacteria and lactobacilli, and their impact on cheese quality and sensory attributes throughout the maturation process. While some research indicates that the incorporation of probiotics does not compromise the sensory properties of cheese, other studies suggest a potential alteration in these properties. The objective is to ensure that the introduction of probiotics not only confers health benefits but also does not negatively influence the flavor profiles of the product, essential for its successful market acceptance. Additionally, this review will delve into the health advantages offered by probiotics, underscoring their significance in cheese production.

Probiotics

The importance of beneficial bacteria on human health was first hypothesized by the Russian bacteriologist and Nobel Prize laureate Elie Metchnikoff at the beginning of the 20th century. He concluded after studying the good health of Bulgarian farmers, who basically feed on dais, that the presence of lactic acid bacteria (LAB) in yogurt may prevent harmful influences of pathogens in the Gastrointestinal Tract. This is considered the basic step for the beginning of the modern dairy industry (Jawad, 2016).

Definition

The term "Probiotics" originates from the Greek word meaning "for life" and was first introduced by Werner Kollath in 1953 (Hamilton-Miller, 2003). In 1965, Lilly and Stillwell defined probiotics as "a substance secreted by one microorganism that stimulates another microorganism" (Ahmed *et al.,* 2021). (Parker, 1974) expanded this definition to include "organisms and substances that contribute to intestinal microbial balance." Over time, various researchers have proposed numerous definitions of probiotics. The World Health Organization has provided a comprehensive definition, stating that probiotics are "live microorganisms which, when administered in adequate amounts, confer a health benefit on the host". The majority of probiotic products available today contain one or more bacterial strains, although certain products like kefir also contain yeasts (Ross *et al.,* 2003). The bacterial genera most commonly associated with probiotics are Lactobacillus and Bifidobacterium (Khalifa, 2005). These genera are preferred due to their well-documented beneficial effects on human health and their generally recognized safety profile (Khalifa, 2005; Rizkalla, Mark, 2024; Rizkalla, Mark, *et al*., 2024)

Bifidobacteria

Bifidobacteria, an essential group of probiotic bacteria, were first isolated and characterized by Henry Tissier at the Pasteur Laboratory. He named the type species *Bacillus bifidus*, noting their prevalence in infants' stools (Kurmann and Rasic, 1991). Over time, the nomenclature for these bacteria has varied, often incorporating variations of "bifid" in their species names like bifidus, bifidum, bifida, and parabifidus. The term "bifidus" originates from Latin, meaning "spilled or divided," highlighting the characteristic split ends of these bacteria's cells when subjected to restricted nutrition conditions (Naidu *et al.,* 1999). The genus Bifidobacterium can be described phenotypically and morphologically as Pleomorphic bacilli, with regular, short, thin cells forming slightly bifurcated club-shaped elements arranged in star-like aggregates or "Y" or "Palisade" arrangements. The appearance of these rods can vary considerably and may be influenced by the composition of the growth medium. They are non-motile, Gram-positive, non-spore-forming, and typically test negative in the catalase test. On agar, their colonies are convex with entire edges, appearing smooth, and ranging in color from white to cream with a glistening texture (Boylston *et al.,* 2004). While generally anaerobic, some species within the Bifidobacterium genus exhibit aerotolerance. Certain strains, such as *B. longum, B. breve,* and *B. infantis*, have mechanisms to mitigate oxygen toxicity, demonstrated by their limited metabolic activity and ability to produce acid even under aerobic conditions (Shimamura *et al.,* 1992). The optimal growth temperature range for many human strains of Bifidobacteria is between 36-38°C, while animal-derived strains thrive at higher temperatures, typically between 41 to 43°C. Preincubation at 37°C for 18 hours has been shown to enhance survival during subsequent refrigerated storage (Ellenton, 1999). These bacteria exhibit optimal growth in a pH range of 6.5 – 7, with no growth observed under sharp acidification conditions (pH 4.0) or alkaline conditions (pH 8.0 – 8.5). The pH preferences are species and strain-specific (Lourens-Hattingh and Viljoen, 2001). Many species of Bifidobacteria possess the ability to ferment various carbohydrates. Glucose fermentation via the fructose-6-phosphate shunt pathway leads to lactic acid production. Unlike some other bacteria, Bifidobacteria do not produce carbon dioxide (CO2) during fermentation; instead, they utilize ammonia (NH3) as a nitrogen source. The acids produced during fermentation contribute to Bifidobacteria's defense against pathogens by exerting a toxic effect on microorganisms and stimulating intestinal peristalsis (Tamime, 2002).

The growth of Bifidobacteria can be inhibited by lactic acid and other metabolic byproducts generated by lactic acid bacteria during the processing and storage of cultured dairy products (Blanchette *et al.,* 1996). Recent studies have identified thirty species of Bifidobacteria isolated from diverse sources such as animals, insects, humans, soil flora, and dairy products. Among these, six human-origin species Bifidobacterium bifidum, B. lactis, B. *adolescentis, B. breve, B. infantis, and B. longum* have been utilized in dairy product formulations. Bifidobacteria are characterized as gram-positive, non-motile, and non-spore-forming bacteria (Tamime, 2002).

Lactobacillus delbrueckii ssp. bulgaricus

Lactobacilli are commonly found in various sources rich in carbohydrates, leading to diverse habitats such as mucosal membranes in humans and animals, particularly in the oral cavity, intestines, or on plant material and fermenting foods.

They are strictly fermentative, showing aerotolerance to anaerobic conditions, and are acidophilic or aciduric, with complex nutritional requirements. Lactobacilli do not synthesize porphyrins, hence lacking heme-dependent activities. However, certain strains can utilize environmental porphyrins and exhibit catalase activities, nitrate reduction, or even possess cytochromes. *Lactobacillus delbrueckii* ssp. bulgaricus can be described phenotypically and morphologically as rod-shaped with rounded ends, occurring singly or in short chains of 3-4 cells. Long chains may form during the late stationary phase, often arranged in palisades. They are Gram-positive, non-motile rods, and non-spore-forming, containing metachromatic granules that can be observed through Gram or methyl blue staining, particularly in older cells. These bacteria are homofermentative, producing D (-) lactic acid as the major end product, fermenting glucose, fructose, and lactose while not utilizing arginine. They are catalase-negative, facultative anaerobes, and highly sensitive to oxygen exposure. The optimum growth temperature for *Lactobacillus delbrueckii* ssp. bulgaricus is 45°C, with a maximum growth temperature range of 50-55°C. In broth culture, the pH typically reaches 4-4.5 by the end of the incubation period.

Streptococcus thermophilus

The Streptococcus strain produces formic acid, which promotes the growth of Lactobacillus. In turn, Lactobacillus contributes flavor compounds such as acetaldehyde and proteolytic activity, aiding in the sustained growth of the Streptococcus strain in milk. The Streptococcus genus comprises Gram-positive bacteria with similar metabolic properties but inhabits different niches and exhibits numerous physiological differences. Over the past two decades, several significant Streptococcus species have been reclassified into newly named genera like Enterococcus and Lactococcus. The only remaining dairy-associated streptococcus is S. thermophilus. Streptococci are categorized into "oral," "pyogenic," and "other streptococci" groups. The "oral" Streptococci are further divided into four groups: *S. mutans, S. mitis, S. anginosus*, and *S. thermophilus* groups. Although *S. thermophilus* is phylogenetically classified within the "S. thermophilus group," it stands alone as the sole bacterium within Streptococci with a dairy origin. Other Gram-positive cocci genera sharing the same habitat as S. thermophilus include Enterococci, Lactococci, Pediococci, and Leuconostocs. Phenotypically and morphologically, Streptococcus thermophilus is described as having spherical/ovoid cells measuring 0.7-0.9µm in diameter, occurring in pairs or long chains of 10-20 cells.

It is Gram-positive, non-motile, non-spore-forming, catalase-negative, lacks cytochromes, and is homofermentative, producing L(+) lactic acid as the major end product. It is a facultative anaerobe that does not utilize arginine. The optimum growth temperature ranges between 40-45°C, and it is thermotolerant, surviving at 60°C for 30 minutes. In broth culture, the final pH typically ranges from 4-4.5.

Probiotic cultures in cheese

The FAO/WHO has recognized probiotics as living microorganisms that confer health benefits when consumed in sufficient quantities. There is substantial evidence supporting the positive effects of probiotics in treating conditions such as lactose intolerance. Various probiotic microorganisms, including enterococci, lactobacilli, and propionibacteria, are well-suited for use in cheese manufacturing. Additionally, probiotic strains like bifidobacteria and lactobacilli are commonly incorporated into the production of milk, yogurt, ice cream, and desserts to create probiotic dairy products. However, it's important to note that the environments in probiotic dairy products differ from those in the human gut/intestine, which can have detrimental effects on the viability of probiotic microorganisms. Probiotics thrive in conditions characterized by low temperatures, low acidity, low oxygen levels, and high-fat content. Consequently, cheese serves as a suitable carrier for probiotic microorganisms (Boylston *et al.,* 2004).

Cheese as a probiotic food delivery

Probiotic foods are intended to convey their benefits to consumers by ensuring that the probiotic bacteria they contain survive the journey through the digestive system, including the harsh conditions of hydrochloric acid and bile salts in the stomach and small intestine, respectively. Cheese stands out as an effective carrier of probiotic microorganisms compared to fermented milk and yogurts. It offers several advantages, such as acting as a buffer against stomach acid, increasing pH levels, and creating a favorable environment for probiotic bacteria. Moreover, the thickness and high fat content of cheese can protect probiotic microorganisms during consumption and digestion. Studies have examined the viability of probiotic strains like *Lactobacillus casei* 334e in yogurt and reduced-fat Cheddar cheese under refrigeration and gastric conditions at pH 2. These studies revealed that the viability of these bacteria remained high (7.0 log cfu/g) in both products. However, under acidic conditions, the viable cell count decreased to 4.0 log cfu/g after 120 minutes in low-fat Cheddar cheese, while it decreased to 1.0 log cfu/g in yogurt. Research on requeijão cheese, similar to gastrointestinal conditions, indicated a reduction in the viability of probiotics like *Bifidobacterium animalis, Lactobacillus acidophilus, Lactobacillus paracasei*, and *Lactobacillus brevis* when exposed to acidic hydrochloric solution (pH 2.5–3.0), pepsin concentration (1000 units per mL) at 37 °C, and bile salts solution (0.3 gm per 100 mL). Similarly, Fresco cheese from Argentina was studied with different probiotic cultures of *L. acidophilus, Bifidobacterium* spp., and *L. casei.* These cultures exhibited viability even after 3 hours under acidic conditions (pH = 2 and pH = 3), with *L. casei* Cl showing higher resistance compared to other cultures at pH = 3 and pH = 2 (Vinderola *et al.,* 2000).

Cheese as probiotic food matrix

Cheese is regarded as an effective vehicle for delivering probiotics to the human intestine compared to fermented milks due to its chemical composition and physical properties, including high pH, low acidity, high fat content, strong buffering capacity, low oxygen levels, and dense texture, all of which contribute to increased probiotic viability. Probiotic bacteria have been integrated into the production of various cheese varieties worldwide. These include Ras or Roumy cheese, Mascarpone cheese, Minas fresh cheese, soft cheese, fresh cream cheese supplemented with inulin, Festivo cheese, Crescenza cheese, Fresco cheese, cottage cheese, Petit-Suisse cheese, Pategrás cheese, Tallaga cheese (El-Zayat and Osman, 2001), Iranian-type white cheese (Mirzaei *et al.,* 2012), Karish cheese, Cremoso cheese, Gouda cheese, probiotic goat's cheese, Canestrato Pugliese hard cheese, Turkish white cheese, Cheddar cheese, Turkish-type Beyaz cheese, white brined cheese, and cheese dips. Numerous probiotic strains such as *B. animalis* ssp. lactis, *Bifidobacterium longum*, *B. bifidum*, *B. infantis, L. acidophilus, L. casei, L. paracasei, Lactobacillus plantarum, Lactobacillus rhamnosus, Lactobacillus gasseri,* and *Propionibacterium freudenreichii* ssp. Shermanii have been successfully incorporated into various cheese types. The minimum viable count of probiotics should be equal to or greater than 10^6 colony-forming units per gram (cfu/g) at the time of consumption to ensure their health benefits. When incorporating probiotics into cheese production, it's crucial for these strains to survive the manufacturing process and maintain viability until the cheese is consumed. Therefore, the selection of probiotic strains should consider the specific cheese type and manufacturing conditions. After probiotic cheese production, a high count of starter lactic acid bacteria is typically observed immediately (e.g., in fresh cheese), while non-starter lactic acid bacteria increase during storage. This dynamic can complicate maintaining viable probiotics in aged cheeses. However, studies have shown that viable probiotic bacteria can still be present in various cheese types at the end of storage, with only a slight reduction in viability over time. In several studies, the viable probiotic counts were found to be greater than 10^6 cfu/g at the end of the aging or maturation period for different cheeses, affirming cheese as an excellent carrier of probiotics until consumption. While it's crucial for probiotics to remain alive in products until consumption, their viability in the gastrointestinal tract environment after ingestion is also essential. Food matrices like cheese have a higher potential to deliver probiotics into the intestine compared to liquid carriers. In vitro experiments simulating the gastrointestinal environment have been conducted to assess probiotic viability, but few studies have specifically examined probiotic survival in cheeses under gastrointestinal conditions. Some studies have evaluated simulated gastrointestinal conditions using B. bifidum and L. casei in various cheeses such as Fresco cheese, Cheddar cheese, and Minas cheese, demonstrating good support from the cheese matrix with a loss of 2–3 log cycles in viability (Vinderola *et al.,* 2000). Besides maintaining viable bacteria throughout processing and consumption in the gastrointestinal tract, other aspects of probiotic cheese, including sensory characteristics, chemical stability, and microbiological properties during cheese ripening, are also important considerations.

The viability of some probiotics in cheese

The minimum viable count of probiotics in cheese at the marketing or consumption stage is typically considered to be 6.0 log cfu/g to ensure their health benefits. Based on this criterion, various types of cheese appear to be suitable carriers for delivering probiotics while maintaining stable viable counts during the ripening or storage period (see Table 1). Bifidobacteria and lactobacilli, originating from the gut, are known as anaerobic bacteria. However, their resistance to oxygen can vary among different strains and species. Both types of bacteria exhibit low resistance under prolonged acidic conditions, although bifidobacteria tend to be more affected by these conditions compared to lactobacilli. For instance, yogurt produced using *Lactobacillus delbrueckii* subsp. bulgaricus typically has an initial pH of 4.1–4.4, which decreases to 3.8–4.2 during storage. In contrast, soft curd cheeses like Camembert cheese have a pH below 5.0 after manufacturing, but this pH quickly rises to 6.8 in the cheese core and 7.5 on the cheese rind over a 35-day ripening period. The pH of semi-hard and hard cheeses is initially above 5.0 after manufacturing and remains stable during the ripening process. Additionally, factors such as temperature, duration of ripening, presence of nonstarter lactic acid bacteria with antagonistic activities, milk heat treatment, and added salts can all impact the viability of probiotics in cheese (Yilmaztekin *et al.,* 2004). Various Bifidobacterium strains are effectively utilized in cheese production without altering the traditional manufacturing process. In contrast, yogurt production typically relies on *B. animalis* due to its ability to withstand high acidity and oxygen levels, which differs from human gut bifidobacteria. Cheese, on the other hand, serves as an excellent medium for incorporating a wider range of Bifidobacterium strains into functional foods. Additionally, cheese provides enhanced protection against the harsh conditions of the stomach. Studies have shown that probiotic strains like *B. bifidum, L. acidophilus*, and *L. casei* used in Fresco cheese production remained viable for up to 3 hours at a pH of 3.0 and 37°C (Vinderola *et al.,* 2000). In vitro testing with Cheddar cheese containing Enterococcus faecium demonstrated greater protection for the strain compared to yogurt. Moreover, *P. freudenreichii* used in Swiss-type cheese production exhibited increased resistance to acidic conditions. Although cheese serves as an effective carrier for probiotics, increasing viable cell counts could potentially impact the organoleptic properties and overall quality of the cheese.

The effects of bifidobacteria and lactobacilli on the quality of cheese

The addition of probiotic bacteria to cheeses has generally not been found to significantly alter their chemical composition. However, when Bifidobacterium lactis strain Bb-12 was used in Cheddar cheese production, there was an increase in moisture content from 38% (in control) to 40%. This increase was attributed to the rapid acidification caused by Bifidobacterium lactis Bb-12 in Cheddar cheese (Mc Brearty *et al.,* 2001). The higher moisture content led to a decrease in body and texture scores during sensory evaluations (Mc Brearty *et al.,* 2001). The incorporation of probiotics into cheese production does not significantly impact proteolysis, which is primarily influenced by coagulant agents and to a limited extent by plasmin. However, studies have reported increased proteolysis and higher levels of amino acids when probiotics are added during cheese production (Mc Brearty *et al.,* 2001). This increased proteolysis can contribute to cheese flavor attributes such as acidity, sweetness, bitterness, and maltiness due to the production of small peptides and amino acids, which may also lead to the synthesis of other flavors, including off-flavors. Lipolysis also plays a crucial role in developing cheese characteristics during ripening. However, the high lipolysis activity of starter cultures and some non-starter lactic acid bacteria means that probiotic microorganisms typically do not significantly affect the free fatty acids content in cheese throughout the aging period.

Due to heterofermentation in lactobacilli and bifidobacteria, several types of cheese made with these species exhibit high acetic acid content (Mc Brearty *et al.,* 2001). Bifidobacteria produce acetic and lactic acid in a 2:3 ratio through the fructose 6-phosphate shunt pathway during lactose fermentation. In contrast, some lactobacilli produce limited amounts of acetic acid compared to bifidobacteria. The presence of acetic acid contributes to the distinctive flavor of various cheeses, but excessive amounts can result in off-flavors. The β-galactosidase activity of bifidobacteria may increase lactose maldigestion.

In cheeses like Crescenza, Canestrato Pugliese, and Cheddar-like cheeses made with bifidobacteria, lactose is completely hydrolyzed, leading to the accumulation of small galactose molecules. Numerous studies have confirmed that cheese provides a suitable environment for probiotic bacteria (Boylston *et al.,* 2004). However, compared to yogurts or fermented milk, fewer probiotic strains have been developed for cheese. It's crucial to carefully select probiotic strains to ensure their viability during cheese production and ripening while minimizing changes in organoleptic characteristics. Propionibacteria, recently recognized as probiotic bacteria, could be further explored for use in probiotic cheeses, particularly Swiss-type cheeses.

The sensory characteristics of Probiotic and nonprobiotic cheese

The addition of probiotic bacteria to cheese should not significantly alter its flavor compared to non-probiotic cheese. The impact on flavor and odor is primarily influenced by the added species and strains, as well as their metabolic activity during manufacturing and ripening. Numerous studies have demonstrated that incorporating probiotics into cheese manufacturing does not markedly affect the sensory properties of the final product compared to controls. For example, using bifidobacteria in Cheddar cheese did not lead to increased metabolic activity or affect cheese quality (flavor, texture, appearance) during a 24-week ripening period. While the incorporation of bifidobacteria in cheeses resulted in higher acetic and lactic acid contents, no differences in sensory properties were observed (Ong *et al.,* 2007). Similarly, adding a mixture of *L. paracasei* and *Lactobacillus salivarius* did not adversely affect organoleptic characteristics or chemical composition compared to control cheeses. Some researchers have found that probiotic bacteria have no significant effects on the texture and flavor of cheese. Studies have also shown that *L. acidophilus* La-5 had no discernible impact on Minas fresh cheese during storage at 5°C for 7 days. These types of cheese are acidified either directly with lactic acid or by adding a mixture of *Lactococcus lactis* ssp. lactis and *L. lactis* ssp. cremoris (mesophilic lactic culture). Adding Lactobacillus paracasei as a coculture with Lactobacillus salivarius during Cheddar cheese production did not alter organoleptic properties compared to control cheeses. Similar results were observed with the incorporation of *L. paracasei* in Cheddar cheese, and adding *L. acidophilus* La-5 to Minas fresh cheese maintained sensory characteristics for up to 14 days, with increased stability when added as a coculture with Streptococcus thermophilus.

However, adding probiotic bacteria to cheeses has been reported to decrease their flavor acceptability compared to control cheeses. The proteolytic enzymes produced by lactic acid bacteria break down milk proteins to produce small peptides and amino acids, affecting the flavor profile. Incorporating different strains of probiotics into Cheddar and Ras cheeses resulted in decreased flavor compared to control cheeses (Ong, 2007).

Bitterness, sourness, and vinegary tastes were more pronounced in cheeses with probiotic bacteria. The bitterness score was notably elevated in cheeses made with specific strains of lactobacilli (Ong, 2007). The complex peptidase system of lactobacilli contributed to the bitterness in Cheddar cheese, particularly during the first 6 months of ripening.

Managing bitterness and acidity is crucial to producing high-quality probiotic cheeses. Incorporating *L. paracasei* ssp. paracasei strain CHCC 2115 resulted in milder characteristics in cheese. However, some bifidobacteria strains contributed to off-flavors with a strong acetic or vinegary taste (Mc Brearty *et al.,* 2001).

Beneficial and potential effects of probiotic foods

There is a growing agreement on the useful effects of Bifidobacterium strains in human health. It is clear that Bifidobacterium that exists in the intestine is useful for protection of human health. A number of health benefits for consuming dairy products containing probiotic bacteria have been debated as follows:-

Production of antimicrobial substances

noted that certain strains of Bifidobacteria can inhibit various pathogenic bacteria through mechanisms unrelated to acidity. Specifically, Bifidobacterium bifidum is capable of producing a bacteriocin that acts antagonistically against strong pathogenic intestinal bacteria and food spoilage bacteria, including Bacillus, Listeria, Lactobacillus, Leuconstoc, Enterococcus, and Pediococcus species. Additionally, Lactobacilli and Lactococci are known to produce bacteriocins as well.

Lactobacilli and bifidobacteria can produce varying amounts of short-chain fatty acids as metabolic end products, which may exert an antagonistic effect against certain microorganisms. These end metabolites can aggregate, leading to a decrease in pH in their environment, thereby creating unfavorable conditions that may reduce or inhibit the growth of harmful and pathogenic organisms. reported that probiotic bacteria can halt the production of Shiga toxin type 2 from enterohemorrhagic (EHEC) E. coli O157: H7, depending on their ability to produce organic acids.

Certain probiotic bacteria are known for their ability to inhibit the growth of mycotoxigenic molds. This includes species such as Leuconostoc, Lactococcus, Pediococcus, and Lactobacillus.

Improving immunity system

There is evidence suggesting that probiotic bacteria have the ability to modulate the immune system by enhancing the host's endogenous defense mechanisms. Several studies have demonstrated that probiotic bacteria can modify various immune parameters, including cellular, humoral, and non-specific immunity. The immunomodulatory effects observed may be influenced by factors such as the dosage of probiotics consumed, the immune status of the host, and potential variations between specific strains.

Prevention and treatment of gastroenteritis

The probiotics have been extensively studied and shown to potentially treat various forms of gastroenteritis. They can reduce the duration of symptoms and the recurrence of diarrhea. The mechanisms proposed for this protective effect include enhancing the host immune system, competitively blocking receptor sites (leading to inhibition of virus attachment and invasion), and producing substances that can inactivate virus particles. Numerous investigations have validated the efficacy of probiotics in the prevention and treatment of other common gastrointestinal disorders, such as Helicobacter pylori infection and inflammatory bowel diseases like irritable bowel syndrome and Crohn's disease (Hamilton-Miller *et al.,* 2003). The probiotic bacteria play a crucial role in preventing the pathogenesis of inflammatory bowel diseases and that using a combination of probiotic strains may be more effective in alleviating the symptoms than using a single strain.

Reduction of serum cholesterol

Several hypotheses suggest that lactobacilli and bifidobacteria can significantly reduce total cholesterol levels when consumed. This reduction may occur because cholesterol synthesis begins in the intestines, where intestinal microorganisms influence lipid metabolism. Numerous studies have reported that probiotic bacteria can lower serum cholesterol levels and enhance the resistance of low-density lipoproteins to oxidation, leading to decreased blood pressure conducted in vitro experiments demonstrating that Lactobacillus acidophilus can remove cholesterol from a medium through assimilation during growth and binding to the cellular surface. This mechanism was observed even with non-growing and dead cells, indicating the efficacy of cholesterol removal. Other hypocholesterolemic effects include enzymatic hydrolysis by intestinal microorganisms like Lactobacillus and Bifidobacterium species. Utilizing cholesterol for synthesizing new bile acids can also lead to reduced cholesterol concentration in the blood demonstrated the cholesterol-lowering effect of Lactobacillus plantarum in vivo. Similar results were observed, who found that *Lactobacillus plantarum* reduced serum cholesterol levels.

Bifidobacterium longum has been shown to significantly decrease total cholesterol and low-density lipoprotein levels while increasing high-density lipoprotein levels reported that Enterococcus faecium, along with a combination of simvastatin and isoflavones, had beneficial effects on lipid levels and atherosclerosis development in rabbits with induced hypercholesterolemia.

Using *E. faecium* strains could potentially complement or serve as an alternative to drug therapy for hypercholesterolemia assessed the effects of probiotic strains on cholesterol metabolism in hypercholesterolemia-induced rats and mice. They found that supplementing the diet with probiotics led to reduced serum cholesterol levels in these animals.

Effect of probiotics Anti-carcinogenic

Probiotics have shown anti-cancer effects in both animal and human studies, as well as in vitro investigations using carcinoma cell lines and antimutagenicity assays. These effects are believed to result from a combination of mechanisms, including the induction of anti-inflammatory, pro-inflammatory, or secretory responses that can inhibit carcinogenesis. However, understanding the role of immunity in probiotic-mediated anti-carcinogenesis is complicated by strain-dependent variability, particularly in terms of immune modulation effects. Further research is necessary to evaluate the long-term impact of probiotics on host immunity concerning anti-carcinogenesis. It's worth noting that immune-based anticancer therapies have not yet demonstrated their efficacy due to limited clinical trials being conducted.

Other beneficial effects for probiotics

Regular intake of probiotic foods offers a multitude of health benefits, including modifying the intestinal flora in leukemia patients, enhancing intestinal motility, inhibiting the absorption of ammonia and amines through the intestinal walls in both animals and humans, improving lactose digestion to alleviate symptoms of lactose intolerance, aiding in the treatment of food allergies, synthesizing vitamins in foods (especially the B complex), increasing calcium bioavailability, and predigesting proteins to improve the nutritional value of foods.

Additionally, probiotics are utilized for limiting infections and controlling urinary tract issues, as noted. These diverse benefits underscore the importance of incorporating probiotic-rich foods into a balanced diet for overall health and well-being.

Side effects and safety of Probiotic

Probiotics, especially those containing Bifidobacteria and Lactobacilli, have a well-established safety record, although the experience with other microorganisms used as probiotics is more limited. While it's important to note that there are no completely risk-free interventions, particularly given varying levels of host sensitivity, probiotics are generally regarded as safe (GRAS) with minimal reported side effects in ambulatory care settings.

Their use during pregnancy and early infancy is also considered safe. However, caution should be exercised as probiotics may contain hidden food allergens and may not be safe for individuals allergic to hen’s eggs or cow’s milk. Instances of reported infections related to probiotic use have mainly been observed in immunocompromised adults, with invasive infections being extremely rare in infants and children.

The health benefits of probiotic cheese

Probiotics have demonstrated potential health benefits, as indicated. Numerous studies have outlined these benefits, including their positive effects on gastrointestinal infections, antimicrobial activity, lactose metabolism improvement, serum cholesterol reduction, immune system stimulation, anti-mutagenic and anti-carcinogenic properties, anti-diarrheal effects, alleviation of inflammatory bowel disease, and suppression of Helicobacter pylori infection through the addition of selected strains to food products (Boylston *et al.,* 2004). It is crucial for probiotic dairy foods to maintain their health benefits while ensuring that food processing does not alter their characteristics, as emphasized. Therefore, it is imperative to conduct in vivo examinations to determine the viability of probiotic bacteria in cheese during processing and up until consumption. Additionally, the antagonistic and symbiotic effects of mixed probiotic strains should be evaluated in products containing multiple strains (Ross *et al.,* 2003). Consumption of probiotic cheeses has been shown to offer health benefits to both humans and animals, with Cheddar cheese exhibiting high viability and delivery of *E. faecium* Fargo 688 throughout the storage period compared to yogurt.

Fresh Argentinean cheese containing the A9 strain of *L. acidophilus*, A12 strain of B. bifidum, and A13 strain of *L. paracasei* demonstrated immune system improvement in mice after 2, 5, and 7 days of consumption, along with increased phagocytic action in peritoneal macrophages in the small intestine. Notably, IgA+ levels also rose in the large intestine after 5 days of ingestion, indicating the probiotic bacteria's antigen interaction in both intestines. Phagocytic cells play a crucial role in combating infectious bacteria, while IgA antibodies, responsible for humoral immunity, dominate mucosal surfaces and protect the gut mucosa from pathogens. In another study, the efficacy of Edam cheese enriched with L. rhamnosus LC705 and L. rhamnosus GG ATCC53103 (LGG) was evaluated for its impact on dental caries. Although no significant differences were observed in Streptococcus mutans counts between the control and probiotic Edam cheese groups, the latter showed a trend towards reducing high *Streptococcus mutans* counts. After 3 weeks, Streptococcus mutans decreased by 21% in the probiotic group compared to only 8% in the control group. Additionally, the probiotic increased salivary lactobacilli counts during cheese production. Although no significant effects were found in salivary microbial counts, the incorporation of probiotics in cheese was reported to potentially decrease dental caries. conducted a study to investigate the benefits of probiotic consumption on candidosis in elderly individuals. Ninety-two participants consumed cheese containing a combination of L. rhamnosus GG, L. rhamnosus LC705, *Propionibacterium freudenreichii* spp., and Shermani JS, and their oral yeast levels were analyzed four times using saliva samples. The microbial group's counts (> 104 cfu/g) decreased by 25.0% and 20.7% after 8 and 16 weeks, respectively, in the probiotic group, compared to a 34.0% increase in the nonprobiotic/control group. Additionally, the yeast population decreased by 75.0% in the probiotic group. The study also noted a positive trend in unstimulated saliva flow. The authors suggested that probiotics can influence saliva composition, mucin concentration, and salivary immunoglobulins, leading to a decrease in hyposalivation and dry mouth sensation. They concluded that probiotic cheese could serve as a prophylactic food to promote oral health.

Application of probiotic bacteria in Dairy products

Increasing public knowledge of diet-related health matters has confirmed the request for probiotic food. Many numbers of dairy products including cheeses, yogurt, spray dried milk powder, ice cream, frozen fermented dairy desserts, and freeze dried yogurt have been utilized as transmission vehicles for probiotics to consumers (Ong, 2007).

From all dairy products, cheeses have the highest consumption rate worldwide because of its versatility. Fresh cheeses are generally minimally aged, have high moisture content, got a very mild flavor and a soft texture and not have a rind. In this class, milk coagulation is due to acid and/or rennet produced from a bacterial culture or other sources such as organic acid. When bacteria are involved in their manufacture, they also share in developing exemplary flavors, to improve quality, and/or to promote health benefits if they display probiotic properties (Cárdenas *et al.,* 2014).

Probiotics are usually used in dairy products. As well as cheese is a good vehicle for these microorganisms. Besides the viability of probiotics in cheese, it is important that incorporation of probiotic bacteria should not affect the expected sensory characteristics (flavor, appearance, and texture) of conventional (non-probiotic) cheeses. Although several studies have shown probiotic starter didn't considerably affect the sensory quality of cheese, it is thought that their addition might contribute to different flavor and texture characteristic (Karimi *et al.,* 2012a; b).

Cheeses have many advantages over other fermented products such as yogurt as a delivery system for applicable probiotic to gastrointestinal tract in that cheeses tend to have a high acidity and more solid consistency where the matrix of the cheese and its relatively high-fat content may offer protection to probiotic bacteria during passage through the gastrointestinal tract. Cheeses also have high buffering capacity than yogurt (Ong, 2007).

Generally, the results gained for a blend of bifidobacteria in cheese are hopeful; the success of addition of probiotic bacteria depends upon bacteria species used as well as interactions with lactic starters, the acidity of the product conditions of fermentation, and the presence of oxygen and storage temperature. Several factors which can influence the capacity of probiotics to survive in cheese and to remain active must be considered (Ward and Roy, 2005).

Traditionally, starters are not used in the manufacture of Egyptian cheeses. Several attempts have been made to isolate salt-tolerant organisms from ripened Domiati cheese for use as starters. These include *Enterococcus faecalis, Pedicoccus spp., Lb. mesenteroides* and *Lb. casei*. They are considered to be suitable starters for Domiati cheese made from pasteurized milk (Al Esawy, 2017). Certain starters have been estimated for the industry of White brined cheeses and it has been suggested that *Lactobacillus delbrueckii* subsp. *bulgaricus* and *lactococci*, or even a yogurt starter can give favorable results with respect to acidification of the milk (Bintsis and Papademas, 2002).

Osman (2000) manufactured fresh skimmed milk cheese (Karish) using *Lactococcus lactis spp. lactis, Lb. acidophilus* Lb-5 and *Bif. lactis* Bb-12 with or without salt and storage at 3 ˚C for 28 days. It was found that a slight decrease in acidity and increase of SN/TN% were observed. The number of *Lb. acidophilus* Lb-5 and *Bif. lactis* Bb-1 in probiotic skimmed milk cheese was more than 6 log cfu/g until the end of storage period. Control cheese had the highest scores for organoleptic properties when fresh or during the storage period.

Mc Brearty *et al.,* (2001) manufactured Cheddar cheese, with a different strain of commercial probiotic bifidobacteria in an effort to develop probiotic Cheddar manufacture. The starter contained *Bif. lactis and Bif. longum*. *Bif. lactis* survived at high numbers, where numbers of *Bif. longum* were reduced, following six months of ripening. The addition of *Bif. longum* did not adversely affect cheese composition, while the addition of *Bif. lactis* had a partial negative effect. During the early ripening, more extensive proteolysis and improved flavor were indicated in the *Bif. lactis* cheese compared with the control cheese.

El-Zayat and Osman (2001)**,** used the *Lb. acidophilus* La-5 and *Bif. lactis* Bb-12 in the manufacture of Tallage cheese. The resultant cheese was analyzed at intervals at storage at 3˚C for 28 days. Moisture and total nitrogen contents decreased while acidity%, SN and fat contents increased during storage. The count of *Lb. acidophilus* La-5 and *Bif. Lactis* Bb-12 were more than 106cfu/g during the storage period. Control, *Lb. acidophilus* La-5 and *Bif. lactis* Bb-12 treated cheese had the highest scores for organoleptic properties.

Mehanna *et al.,* (2002)**,** used different types of probiotic starter cultures (*Lb. acidophilus, Lb. reuteri, Lb. rhamnosus,* and *Bif. bifidum*) in the manufacture of soft cheese. The cheeses were stored in the refrigerator (5-7˚C) for 4 months. Results indicated that the pH values and moisture content of control and all treatments cheeses decreased at the end of the storage period. Salt, water SN and fat contents of different treatments Increased directly proportional with storage. Lactic acid bacterial counts in all treatment slightly increased to the maximum after two months and decreased along the storage period, reaching a minimum at the end of the storage period.

Yilmaztekin *et al.,* (2004)**,** studied the viability of probiotic cultures used as a starter in white brined cheese including *Bif. bifidum* BB-02 and *Lb. acidophilus* LA-5. The microbiological and biochemical properties of cheese were studied throughout 90 days of storage. Two inoculum rates for probiotic starters were compared with the control cheese. The obtained results showed that a higher inoculums rate resulted in faster proteolysis. The cheese inoculated with 5% probiotic strains had higher water-soluble nitrogen, non-protein nitrogen, than the other experimental cheese at the end of storage. It was also found that the colony counts of both probiotic microorganisms declined during storage. After 90 days of storage, the number of probiotic colonies was still around the threshold for a minimum probiotic effect (10^6cfu/g).

El-Fak *et al.,*(2005)**,** studied the effect of two probiotic starter cultures, (*Bif. bifidum* and *Bif. breve*) as well as yogurt culture containing *S. salivarius subsp. thermophilus* and *Lb. delbrueckii subsp. bulgaricus* on compositional properties and ripening of white soft cheese. The obtained results indicated that there were no differences between soft cheese containing probiotic cultures and the chemical composition when fresh and during ripening except the acidity of the cheese which was relatively higher in the probiotic cheese than the control. With ranged to the NPN, SN, and TVFA, it was noticed that their values were relatively higher in cheese made with probiotic bacteria compared with the control cheese. On the other hand, sensory evaluation of cheese showed no considerable difference in the scores gained for all cheese.

Effat *et al.,* (2012)**,** used *Streptococcus thermophilus* as a main strain mixed (1:1) mixed with one of the selected *Lactobacilli* starter (*Lactobacillus delbrueckii ssp. bulgaricus, Lactobacillus hilgardii, Lactobacillus johnsonii* and *Lactobacillus curvatus*) with adding 3% of one of the selected prebiotics (litesse and dextrin) in the manufacture of soft cheese. The chemical compositions, microbiological and sensory evolution properties during storage at refrigerator condition for 30 days of resultants cheeses were estimated. The results showed that there were significant differences in all studied properties of white soft cheese. They recommended that combination among litesse and dextrin as prebiotics with *Lactobacilli* starter (*Lactobacillus hilgardii*, *Lactobacillus johnsonii* and *Lactobacillus curvatus*) as probiotics for manufacturing symbiotic white soft cheeses with healthy characteristic and high quality.

Yerlikaya and Ozer (2014)**,** used the probiotic *Streptococcus thermophilus* as co culture to produce probiotic white soft cheese. The results showed that the use of *Streptococcus thermophilus* as co culture in probiotic cheese production did not affect negatively the cheese components. Organoleptic properties revealed that the highest total points were recorded in cheeses produced with *Str. thermophilus* + *L. casei,* while other probiotic bacteria combinations had been affected less in regard to taste or appearance.

Cárdenas *et al.,* (2014) found that the addition of the *L. salivarius* strains did not change the chemical composition of the cheese nor the texture parameters after the storage period (4°C, 28days), although cheeses manufactured with *L. Salivarius* CECT5713 presented significantly higher values of hardness. A total of 59 volatile compounds were identified in the experimental cheeses, and some *L. salivarius* associated differences could be identified. All cheeses presented good results of acceptance after the sensory evaluation. Consequently, the results indicated that fresh cheese can be a good vehicle for the *L. salivarius* strains analyzed in this study.

Haddad *et al.,* (2015) produced Probiotic soft white cheese from cow's milk using *Lactobacillus acidophilus*, *Bifidobacterium lactis* and a combination of the two. The probiotic bacteria were either added to the cow's milk used in the production before renneting or to the curd before pressing. They concluded that it is better to add probiotic bacteria to the milk than to the curd. Most cheese treatments had probiotic counts >106 CFU g-1 after one week. All soft white cheeses produced in this study were rated acceptable by a sensory panel at the end of the study.

Author Contributions

Heba G. M. Rezk: Investigation, formal analysis, writing—original draft. Muhammad Ashmawi: Validation, methodology, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

References

Ahmed, M.E., K. Rathnakumar, N. Awasti, M.S. Elfaruk, and A. R. A. Hammam. 2021. Influence of probiotic adjunct cultures on the characteristics of low-fat Feta cheese. Food Sci. Nutr. 9:1512–1520. https://doi.org/10.1002/fsn3.2121.

Al Esawy, S.A.E.I. 2017. Studies on Probiotic bacteria.

Alsaleem, K.A., and M.E.A. Hamouda. 2024. Optimizing Probiotic Low-Fat Yogurt: The Benefits of Incorporating Defatted Rice Bran for Enhanced Quality and Functionality. Food Sci. Nutr. 1–13. https://doi.org/10.1002/fsn3.4558.

Alsaleem, K.A., M.E.A. Hamouda, R.R. Alayouni, M.S. Elfaruk, and A.R.A. Hammam. 2023. Effect of Skim Milk Powder and Whey Protein Concentrate Addition on the Manufacture of Probiotic Mozzarella Cheese. 9(11), 948; https://doi.org/10.3390/fermentation9110948

Bintsis, T., and P. Papademas. 2002. Microbiological quality of white-brined cheeses: a review. Int. J. Dairy Technol. 55:113–120. http://dx.doi.org/10.1046/j.1471-0307.2002.00054.x

Blanchette, L., D. Roy, G. Belanger, and S.F. Gauthier. 1996. Production of cottage cheese using dressing fermented by bifidobaceria. J. Dairy Sci. 79:8–15. https://doi.org/10.3168/jds.S0022-0302(96)76327-0

Boylston, T.D., C.G. Vinderola, H.B. Ghoddusi, and J.A. Reinheimer. 2004. Incorporation of bifidobacteria into cheeses: challenges and rewards. Int. Dairy J. 14:375–387. https://doi.org/10.1016/j.idairyj.2003.08.008.

Cárdenas, N., J. Calzada, Á. Peirotén, E. Jiménez, R. Escudero, J.M. Rodríguez, M. Medina, and L. Fernández. 2014. Development of a potential probiotic fresh cheese using two Lactobacillus salivarius strains isolated from human milk. Biomed Res. Int. 2014.

https://doi.org/10.1155/2014/801918
Effat, B.A.M., A.M.M. Mabrouk, Z.I. Sadek, G.A.M. Hussein, and M.N.I. Magdoub. 2012. Production of novel functional white soft cheese. J. Microbiol. Biotechnol. Food Sci. 1:1259.
El-Fak, A.M., A.M. Rabie, M.M. El-Abbassy, and M.A. El-Sayed. 2005. Compositional properties and ripening of White soft cheese made with probiotic cultures. Zagazig J. Agric. Res 32:577–588.
Ellenton, J.C. 1999. Cellular Morphology of Bifidobacteria and Their Survival When Encapsulated in Calcium Alginate Beads.
El-Zayat, A.I., and M.M. Osman. 2001. The use of probiotics in Tallaga cheese. Egypt. J. Dairy Sci. 29:99–106.
Gomes de Oliveira, M.E., E. Fernandes Garcia, C.E. Vasconcelos de Oliveira, A.M. Pereira Gomes, M.M. Esteves Pintado, A.R.M. Ferreira Madureira, M.L. da Conceição, R. de C. Ramos do EgyptoQueiroga, and E.L. de Souza. 2014. Addition of probiotic bacteria in a semi-hard goat cheese (coalho): Survival to simulated gastrointestinal conditions and inhibitory effect against pathogenic bacteria. Food Res. Int. 64:241–247. https://doi.org/10.1016/j.foodres.2014.06.032.
Haddad, M.A., M.I. Yamani, and K. Abu-Alruz. 2015. Development of a Probiotic Soft White Jordanian Cheese. Am. J. Agric. Environ. Sci. 15:1382–1391. https://doi.org/10.5829/idosi.aejaes.2015.15.7.12635.
Hamilton-Miller, J.M.T. 2003. The role of probiotics in the treatment and prevention of Helicobacter pylori infection. Int. J. Antimicrob. Agents 22:360–366. https://doi.org/10.1016/s0924-8579(03)00153-5
Hamouda, M.E.A. 2015. Manufacturing of Probiotic Low Fat White Soft Cheese. https://doi.org/10.13140/RG.2.2.10558.92484.
Jawad, E. 2016. Technological benefits and potential of incorporation of probiotic bacteria and inulin in soft cheese.
Karimi, R., A.M. Mortazavian, and M. Karami. 2012a. Incorporation of Lactobacillus casei in Iranian ultrafiltered Feta cheese made by partial replacement of NaCl with KCl. J. Dairy Sci. 95:4209–4222. https://doi.org/10.3168/jds.2011-4872
Karimi, R., S. Sohrabvandi, and A.M. Mortazavian. 2012b. Sensory characteristics of probiotic cheese. Compr. Rev. Food Sci. Food Saf. 11:437–452. https://doi.org/10.1111/j.1541-4337.2012.00194.x
Khalifa, S.A.A. 2005. Technological Studies on Cheese.
Kurmann, J.A., and J.L. Rasic. 1991. The Health Potential of Products Containing Bifidobacteria. Therapeutic Properties of Fermented Milks. Applied Food Sci.
Lourens-Hattingh, A., and B.C. Viljoen. 2001. Yogurt as probiotic carrier food. Int. dairy J. 11:1–17. https://doi.org/10.1016/S0958-6946(01)00036-X
Mc Brearty, S., R.P. Ross, G.F. Fitzgerald, J.K. Collins, J.M. Wallace, and C. Stanton. 2001. Influence of two commercially available bifidobacteria cultures on Cheddar cheese quality. Int. Dairy J. 11:599–610. https://doi.org/10.1016/S0958-6946(01)00089-9.
Mehanna, N.S., B.A. Effat, N.M.A. Dabiza, N.F. Tawfik, and O.M. Sharaf. 2002. Incorporation and viability of some probiotic bacteria in functional dairy foods. Minufiya J. Agric. Res 27:225–241.
Mirzaei, H., H. Pourjafar, and A. Homayouni. 2012. Effect of calcium alginate and resistant starch microencapsulation on the survival rate of Lactobacillus acidophilus La5 and sensory properties in Iranian white brined cheese. Food Chem. 132:1966–1970. https://doi.org/10.1016/j.foodchem.2011.12.033.
Naidu, A.S., W.R. Bidlack, and R.A. Clemens. 1999. Probiotic spectra of lactic acid bacteria (LAB). Crit. Rev. Food Sci. Nutr. 39:13–126. https://doi.org/10.1080/10408699991279187
Ong, L. 2007. Influence of probiotic organisms on proteolytic pattern, release of bioactive compounds and sensory attributes of cheddar cheese.
Osman, M.M. 2000. Probiotic fresh skimmed milk (Karish) cheese. Ann. Agric. Sci. Moshtohor 38:995–1006.
Parker, R.B. 1974. Probiotics, the other half of the antibiotic story. Anim Nutr Heal. 29:4–8.
Ramirez-Parada, K., A. Gonzalez-Santos, L. Riady-Aleuy, M.P. Pinto, C. Ibañez, T. Merino, F. Acevedo, B. Walbaum, R. Fernández-Verdejo, and C. Sanchez. 2023. Upper-Limb Disability and the Severity of Lymphedema Reduce the Quality of Life of Patients with Breast Cancer-Related Lymphedema. Curr. Oncol. 30:8068–8077. https://doi.org/10.3390/curroncol30090585
Ross, R.P., G. Fitzgerald, J.K. Collins, M. Coakley, C.

Desmond, and C. Stanton. 2003. Challenges facing development of probiotic-containing functional foods. E.R. Farnworth, ed. CRC press. http://dx.doi.org/10.1201/9780203009727.ch2

Rizkalla, Mark. 2024. Feasibility Study of Managing Peak Cooling Loads to Achieve Energy Cost Reduction in a Northern Climate Campus. Master of Science Thesis, South Dakota State University. https://openprairie.sdstate.edu/etd2/983/

Rizkalla, Mark, David Rezkallah, and Mahmoud Hamouda. 2024. Engineering Evaluation of Methods for Measuring Total Solids in Food Products. 13 (12): 31–34. https://doi.org/10.20546/ijcmas.2024.1312.004.

Shimamura, S., F. Abe, N. Ishibashi, H. Miyakawa, T. Yaeshima, T. Araya, and M. Tomita. 1992. Relationship between oxygen sensitivity and oxygen metabolism of Bifidobacterium species. J. Dairy Sci. 75:3296–3306. https://doi.org/10.3168/jds.s0022-0302(92)78105-3

Tamime, A.Y. 2002. Microbiology of starter cultures. Dairy Microbiol. Handbook. Microbiol. milk Prod. 261–366.

Vinderola, C.G., W. Prosello, D. Ghiberto, and J.A. Reinheimer. 2000. Viability of probiotic (Bifidobacterium, *Lactobacillus acidophilus* and *Lactobacillus casei*) and nonprobiotic microflora in Argentinian Fresco cheese. J. Dairy Sci. 83:1905–1911. https://doi.org/10.3168/jds.S0022-0302(00)75065-X.

Ward, P., and D. Roy. 2005. Review of molecular methods for identification, characterization and detection of bifidobacteria. Lait 85:23–32. https://doi.org/10.1051/lait:2004024.

Yerlikaya, O., and E. Ozer. 2014. Production of probiotic fresh white cheese using co-culture with Streptococcus thermophilus. Food Sci. Technol. 34:471–477. https://doi.org/10.1590/1678-457x.6365

Yilmaztekin, M., B.H. Özer, and F. Atasoy. 2004. Survival of Lactobacillus acidophilus LA-5 and Bifidobacterium bifidum BB-02 in white-brined cheese. Int. J. Food Sci. Nutr. 55:53–60. https://doi.org/10.1080/09637480310001642484.

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