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Review

Probiotic cheese as a functional food

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Abstract: Nutrition style and preference is one of the priority issues on which health-protective and disease-preventive measures are taken for a healthy life. For this purpose, functional foods that show beneficial effects on health as well as the nutrional value have become increasingly important. Among functional foods, probiotic foods which are produced by using probiotic microorganisms constitute the most important and interesting group. In order for a probiotic food to show its beneficial effect on health, it must contain minumum 10^6-10^7 cfu of microorganisms in grams or mililitres during its shelf life. Milk and dairy products are the foods in which probiotics are commonly used. However, the development of probiotic dairy products seems to focus on fermented milk (e.g., kefir) and yoghurt. Cheese has more advantages over fermented milk or yoghurts as a carrier food to intestinal environment due to the fact that it has a low oxygen content, high pH, high fat content and a firmer texture. In this review, the general characteristics of functional foods and probiotics are explained and evaluations are made using the potential of cheese as a probiotic carrier product. This study can shed light on new studies on the use of cheese as a functional probiotic food.

Keywords: probiotic; probiotic cheese; functional food

1. Introduction

The awareness of healthy and quality living has increased due to not only social, scientific, and technological advancements but also the outbreak of epidemic diseases like the Covid-19 pandemic in recent times. It is crucial to take measures to protect health and prevent diseases in order to lead a healthy life. Diet and dietary prefences for a healthy life are one of the priorities where health-protective and disease preventing measures are taken. In this respect, functional foods, which are defined as foods that have a beneficial effect on consumer health in addition to their special nutritional value, stand out (Murtaza *et al*., 2022; Nagpal *et al*., 2007; Uymaz, 2010).

Functional foods are offered to consumers in a wide range of products (for instance dairy products, confectionary, beverages, cakes, baby foods) in today's product profile. Among functional foods, probiotic foods (for instance fermented dairy products) produced with the addition of microorganisms with probiotic potential or proven to be probiotic, constitute the most important and interesting group (Ahmed *et al*., 2016; Cuffia *et al*., 2017; Heperkan, 2021; Uymaz, 2010). Probiotics are live organisms that produce beneficial effects on health when consumed in sufficient proportions (Demers-Mathieu *et al*., 2016). In recent years, studies aiming at improving functional properties of probiotics, which have beneficial effects on individual health and that support immune system by adding them to the foods, have been a subject of interest of researchers (Amiri *et al*., 2022; Mantzourani *et al*., 2018; Sarı and Çalışkan, 2021).

Lactic acid bacteria (LAB) are generally used as probiotics in foods and pharmaceutical products (Mantzourani *et al*., 2018). These commonly used LABs are species in the genera *Lactobacillus*, *Streptococcus*, *Enterococcus*, *Leuconostoc* and *Pediococcus* (Abd-Elmonem *et al*., 2022; Kabir *et al*., 2016; Yangılar, 2010; Yörük and Güner, 2011). *Bifidobacterium* spp. is a widely used genus of probiotic microorganisms (Hossain *et al*., 2018). Species in the genera *Lactobacillus* spp. and *Bifidobacterium* spp. are more commonly used as probiotics due to their presence in the intestinal microflora (Demers-Mathieu *et al*., 2016; Hossain *et al*., 2018; Kabir *et al*., 2016). This widespread use is due to their tolerance to salt, oxygen, temperature, acidity, gastro-biliary enzymes and good adhesion to intestinal epithelium (Oliveira *et al*., 2014; Tripathi and Giri, 2014). In addition *Aspergillus*, *Baccillus* and *Saccharomycess* microorganisms are also used as probiotics (Yangılar, 2010; Yörük and Güner, 2011).

Today probiotics can be found in fermented milk, yoghurt, cheese, buttermilk, milk powder, butter, baby foods, icecream, and fruit juices, besides food, they can also be found in the market in the form of powder in pharmaceutical capsules and cachets (Ceyhan and Alıç, 2012; Mukhtar *et al*., 2020; Özden, 2013; Rehman *et al*., 2021). Probiotic milk and dairy products are among the most important group of probiotic foods. Among probiotic dairy products, studies aimed at probiotic carrier foods focus widely on fermented milk (Burns *et al*., 2008; Murtaza *et al*., 2022). However, the short shelf life, low pH, low amount of dry substance content and soft matrix of these products, as well as the damage of probiotic bacteria by digestive enzymes, gastric pH and bile salts along the gastrointestinal tract pose a disdvantage for these products (Nagpal *et al*., 2007). Cheese constitues a very valuable alternative to fermented milk and yogurt as a probiotic carrier food to the gastrointestinal tract due to its particular potential advantages (Cruz *et al*., 2009; Murtaza *et al*., 2022; Verruck *et al*., 2015).

Cheese is considered to have a more appropriate food profile among dairy products in terms of having more solid matrix, high pH, and fat content, low oxygen levels, ripening conditions and shelf life in order to sustain the survival and development of probiotic cultures. Moreover, cheese has the capacity to tampon gastric acidity (Cuffia *et al*., 2017; Cruz *et al*., 2009; Sabikhi *et al*., 2014; Stanton *et al*., 2001). These properties of cheese provide the preservation of probiotic bacteria during the storage period of probiotic food and throughout the passage of gastrointestinal area. Cheese is a more suitable product that enables carrying higher amounts of probiotic bacteria to intestinal environment than other fermented products (Cruz *et al*., 2009; Ranadheera *et al*., 2010; Verruck *et al*., 2015).

In order for cheese produced using probiotic cultures to be defined as a functional food, the probiotic must maintain its viability (10^6-10^7 cfu/g or ml) during the storage of the product and must not have a negative effect on the composition, structure and sensory properties of the cheese (Murtaza *et al*., 2022; Schoina *et al*., 2018; Stanton *et al*., 2001). With the production of probiotic cheese, a functional product variety that carries probiotics to the gastrointestinal tract can be introduced to the dairy industry as an alternative to fermented milk and yogurt. In this review, the general characteristics of functional foods and probiotics are explained and evaluations are made using the potential of cheese as a probiotic carrier product.

2. Functional foods

The demand for functional foods, which were first defined and produced in Japan in 1980s, began to increase in European countries in the 1990s and production became widespread worldwide. Functional foods is defined as "food that, in addition to its nutritional properties, can be clearly demonstrated to have beneficial effects by making the individuals body healthier and better and/or reducing the risk of disease" by European International Life Sciences (Erbaş, 2006; Nagpal *et al*., 2007; Siro *et al*., 2008).

As a general acknowledgement, the properties that functional foods should have are stated as follows (Colmenero *et al*., 2001; Cuffia *et al*., 2017; Hasler, 2002; Sarker *et al*., 2017; Siro *et al*., 2008).

i. They should be foods that can be consumed as part of the daily diet every day and have a traditional character.
ii. In addition to being a nutritious food it should be able to demonstrate beneficial health functions.
iii. In addition to beneficial effects on an individual's health, it should be able to demonstrate its protective effects from physiological and psychological diseases.
iv. The functional qualities of functional food must be scientifically demonstated, its consumption should be risk-free and approved.

v. A food that has been given functional qualities by different technological processes should not lose its known traditional nutritional properties.
vi. Functional food should be of a type that can be used frequently in the daily diet and appropriate daily intake amounts should be determined.
vii. A functional food should not be in drug or capsule format.

In Turkey the term functional food was introduced legally with the amendment made in 2004 to the Law No. 5179 on “Production, consumption and supervision of foods”. According to this law, functional foods are defined as “Foods that, in addition to their nutritional effects, have health-protective, health-correcting or disease risk- reducing effects depending on one or more effective components, and these effects have been scientifically and clinically proven (Food Law No:5179, 2004).

Functional foods are also referred to as “terapetics”, “supplementary foods”, “medicinal foods”, “enriched foods”, “dietary product” (Suna, 2020). Functional food groups avaibale on the market are shown in Table 1. A food product may have naturally occuring compounds with functional properties (e.g, probiotics and prebiotics, phenolic phytochenmicals, terpenes, bioactive peptides, unsaturated fatty acids) or it may gain functional properties by various methods (e.g, modification, enhancement) (Siro *et al*., 2008; Suna, 2020).

Consumption of functional foods may have beneficial effects on the prevention and treatment of major chronic diseases of our age (e.g., cardiovascular disease, diabetes, cancer) (Alaşalvar and Pelvan, 2009; Mantzourani *et al*., 2018). Functional food products are generally offered to consumers with many types such as dairy products, confectionary, beverages, cakes and baby foods in the world. Probiotic foods (especially probiotic dairy products) produced with the addition of probiotics are the most focused groups of functional foods (Cuffia *et al*., 2017; Heperkan, 2021; Uymaz, 2010).

Table 1. Functional food groups.

Functional food types	Definition/Method	Sample (s)	Resources
Natural functional foods (plant and animal origin)	A natural food that contains compounds beneficial for health	Tomatoes with high levels of lycopene, dairy products rich in calcium and probiotic bacteria	Colmenero *et al.* (2001); Sevilmiş, (2013)
Fortified foods or specially formulated foods	i) Foods prepared with the addition of nutrients (e.g, vitamin, mineral) or a new food ingredient	i) Fruit juice with added Vitamin C, dairy products prepared with the addition of probiotics and prebiotics	Kotilainen *et al.* (2006); Siro *et al.* (2008)
	ii) Foods produced by developing/growing under special conditions	ii) Eggs produced by adding omega -3 to chicken feeds	
Foods produced by altering their structure	Foods obtained by removing any substance from the structure of the food	Lactose-free dairy products	

3. Probiotics

Probiotics are defined as “live microorganisms which have beneficial effects on host health when consumed in sufficient amounts as a component of foods” by the Food and Agriculture Organization (FAO)/World Health Organization (WHO) (Hill *et al*., 2014; Murtaza *et al*., 2022).

Probiotics are non-pathogenic microorganisms (e.g., *Lactobacillus* spp., *Bifidobacterium* spp.) that are the natural members of host gastrointestinal (GI) tract microflora (Ferdous *et al*., 2020; Gibson, 2002; Hossain *et al*., 2018). Although the GI environment of a newborn baby is sterile, contamination with microorganisms occur in a period of 3-10 hours. The GI microflora of an adult contains more than 500 bacteria types. Species in the genera *Lactobacillus* spp., *Bifidobacterium* spp., *Bacteroides* spp., *Peptostreptococcus* spp. and *Fusobacterium* spp. are predominant in GI microflora (Yeşilova *et al*., 2010). Stress, disease, antibiotics, old age and changes in the diet can affect GI nicroflora. Probiotics contribute to the formation of microbial balance by improving intestinal microflora as well as they can suppress patogens by binding to intestinal receptors through competition (Amiri *et al*., 2022; Yavuzdurmaz, 2007). In order to maintain the balance of intestinal microflora, probiotics must be intaken through various carriers (e.g., probiotic food or a tablet /capsule containing probiotics) (Mukhtar *et al*., 2020; Yavuzdurmaz, 2007).

Probiotics are added to a wide range of foods (e.g., fermented milk, yogurt, cheese, buttermilk, milkpowder, butter, baby foods or fruiit juice) and introduced to the market as probiotic foods. They are also marketed as pharmaceutical preparations (e.g., tablets, capsules) health supplements (Özden, 2013; Rehman *et al*., 2021). Probiotic dairy products are among the most important probiotic foods. In this group the most well-known products are fermented milk and yoghurt (Burns *et al*., 2008; Murtaza *et al*., 2022). Some commercial products which are developed by adding various probiotic cultures to fermented milk and yoghurt in the world are shown in Table 2 (Analie and Viljoen, 2001; Ceyhan and Alıç, 2012; Çelikel *et al*., 2018).

Table 2. Some dairy product that contain probiotics.

Commercial name	Food product	Country	Culture used*
Yakult	Fermented milk	Japan	*L. casei* Shirota
Diphilus milk	Fermented milk	France	A+B cultures
Acidophilus bifidus yoghurt	Yoghurt	Germany	A+B+Yoghurt culture
Acidophilus milk	Fermented milk	ABD, Japan	A culture
Bifidus milk	Fermented milk	Many Countries	*B. bifidum* or *B. longum*
Vitagen	Fermented milk beverage	Malasia, Singapore	A culture
Bio Jogurt (mild)	Yoghurt	Germany	A+B cultures
Mil-Mil	Fermented milk	Japan	A+B+ *B. breve*
Arla Cultura	Yoghurt, Fermented milk	Denmark-Sweden	A+B cultures
BA live	Yoghurt	The UK	A+B+Yoghurt culture
Kyr	Yoghurt	Italy	A+B+Yoghurt culture
BIO	Yoghurt	France	A+B+Yoghurt culture
Bio ABC Joghurt	Yoghurt	Germany	A+B+*L. casei*
Emmi Aktifit	Yoghurt	Switzerland	A+B+*L. casei* GG
Zabady	Yoghurt	Egypt	*B. bifidum*+Yoghurt culture
Activia	Yoghurt	Turkey	ActiRegularis+Yoghurt culture
Yovita	Yoghurt	Turkey	A+B+Yoghurt culture
Kefirix	Fermented milk	Turkey	A+B+Kefir culture

*A: *Lactobacillus acidophilus*, B: *Bifidobacterium bifidum*, Yoghurt culture: *S. Thermophilus* and *L. bulgaricus.*

For the production of a probiotic food with functional qualities, various properties that a probiotic microorganism to be added to the product should have are listed below (Guarner *et al*., 2005; Mukhtar *et al*., 2020; Shah, 2001; Tripathi and Giri, 2014).

i. With some molecular techniques (e.g., DNA-DNA hybridization method, 16 s rRNA sequence analysis), strains must be precisely defined, harmless and reliable.
ii. In order to maintain its viability in the gastrointestinal tract, pancreatic enzymes must tolerate acid and bile secretions.
iii. Must be able to attach to the epithelial wall of the intestinal system and adapt to the natural microflora by colonizing there.
iv. It should have antioxidant effect and stimulate enzymatic activity (e.g. lactase, maltase, feruloyl esterase) in the intestinal epithelium.
v. It should have antagonistic action against carcinogenic compounds and pathogens by producing antimicrobial agents (e.g. bacteriocin, hydrogen peroxide).
vi. It should be able to resist technological processes in food production and must remain active and alive during storage process.
vii. It must have no pathogenic features (e.g., toxin production).
viii. Have metabolical effects (e.g., cholesterol assimilation, vitamin production).
ix. Contribute to the immune system by stimulating the immune system.

Table 3. Microorganisms that can be used as probiotics in foods.

Microorganism species	Microorganism types
Lactobacillus spp.	*L. acidophilus, L. bulgaricus, L. plantarum, L. paracasei, L. lactis, L. rhamnosus, L. gasseri, L. cellebiosus, L. salivarius, L. delbrueckii, L. fermentum, L. reuteri, L. curvatus, L. johnsonii, L. helveticus, L. casei*
Bifidobacterium spp.	*B. bifidum, B. longum, B. adolescentis, B. infantis, B. thermophilum, B. breve*
Lactoccocus spp.	*L. lactis subsp. lactis, L. lactis subsp. cremoris*
Bacillus spp.	*B. subtilis, B. licheniformis, B. pumilus, B. lentus, B. coagulans*
Streptococcus spp.	*S. thermophilus, S. intermedius, S. diacetilactis*
Pediococcus spp.	*P. acidilactici, P. cerevisiae, P. pentosaceus*
Enterococcus spp.	*E. faecalis, E. faecium*
Bacteriodes spp.	*B. ruminicola, B. capillus, B. suis, B. amylophilus*
Mold	*A. niger, A. oryzae*
Yeast	*S. cerevisiae, C. torulopsis*

Many microorganism species can be used as probiotics in foods but mostly lactic acid bacteria, which constitute the normal microflora of the GI tract or closely related strains of lactic acid bacteria (e.g., *Bifidobacterium* spp.) are used (Mantzourani *et al*., 2018). The bacteria mostly used as probiotics in food and food supplements are *Lactobacillus* spp. and *Bifidobacterium* spp. (Tripathi and Giri, 2014). Probiotic microorganisms that are used in food and food supplements are classified in Table 3 (Ceyhan and Alıç, 2012; Guarner *et al*., 2005; Özden, 2013; Shah, 2001; Uymaz, 2010; Yeşilova *et al*., 2010).

3.1. Mechanisms of action and health protective effects of probiotics

A large proportion of pathogenic microorganisms that have harmful effects on human health are setteled in GI tract. The intestinal microflora acts as an organ, generating the necessary stimuli to promote the development of immune system cells and the activation of immune system (Sarı and Çalışkan, 2021; Sommer and Backhed, 2013). Microorganisms in the intestinal microflora produce antimicrobial substances (e.g., bacteriocins) that compete with pathogens for food and adhesion to receptors at adhesion sites, as well as inhibit the attachment and growth of pathogens in the intestinal tract. In addition, the microbiota of the intestinal tract ensures the production and absorption of vitamins B_1, B_2, B_3, B_5, B_6, K and H (biotin) through the intestinal wall (Mukhtar *et al*., 2020; Tripathi and Giri, 2014).

It is stated that in some human diseases (e.g., allergies, hypertension, diabetes, obesity, autoimmune diseases, Parkinson's, anxiety, depression, Alzheimer's, cancer, autism), the balance in the GI microflora (dysbiosis) has been distrupted (Kankaya *et al*., 2021; Sarı and Çalışkan, 2021).

Since the beneficial effects of probiotic microorganisms are specific to the strain, it is not possible to see all the beneficial properties in one strain or different strains of the same species at the same time (Vasiljevic and Shah, 2008). The main mechanisms of action of probiotics and their beneficial effects on health are given in Table 4 (Guandalini, 2011; Hossain *et al*., 2017; Mukhtar *et al*., 2020; Shah, 2007; Sheu *et al*., 2002; Tripathi and Giri, 2014; Watson and Preedy, 2016).

Table 4. The main mechanisms of action of probiotics and their beneficial effects on health.

Mechanisms of action	Beneficial effects on health
• Attachment to the surface (caco-2 cells) by competing with pathogenic microorganisms) • Increase IL-10 release and Ig A production. • Balancing the intestinal microflora and regulating permeability. • Inhibiting the conversion of dietary procarcinogens (e.g., nitrosamines) to carcinogens. • Antimicrobial substances e.g., H_2O_2, organic acid, bacteriocin) production. • Reducing the release of urease • Deconjugation of bile salts • Antioxidative effect. • Lowering plasma triglycerides, lipoprotein levels. • Improving the epithelial surface and reducing inflammation. • β-D-galactosidase enyme production.	• The use of antibiotis and the prevention of symptoms of diarrhea caused by certain viruses (e.g., rotavirus) • Strengthening the inmmune system. • Reducing the risks posed by mutagens and carcinogens. • Prevention of allergies (e.g., atopic eczema, food allergies). • The inhibition of some intestinal pathogens especially *Helicobacter pylori* • Lowering cholesterol levels and preventing obesity. • The prevention of Inflammatory Bowel syndrome (IBS) (Ulcerative colitis, Crohn's disease) • Reduction of lactose intolerance effects. • Prevention of neurodegenerative disorders.

3.2. Critical points in probiotic food production

In general, in the addition of probiotics to foods; the probiotic culture and food type/ matrix should be appropriate, the activation of the culture and the inoculation rate should be well adjusted, food production/ ripening conditions should be created to support the viability of probiotics and the probiotic shouldn't have a negative effect on the quality of the product (Beykaya, 2018; Boylston *et al*., 2004; Murtaza *et al*., 2022).

The structure of the the food to be added to the probiotic culture and and the GI tract may have conditions that will prevent the development of the probiotic microorganism. Probiotic microorganisms can develop poorly under the influence of conditions (e.g., pH, temperature, oxygen content) that occur during the ripening process of food. Furthermore, the development of probiotics, especially in fermented dairy products can be affected negatively due to the presence of microorganisms that may be present in the structure of the food or microorganisms that are added as additional cultures during the production phase. This condition may be due to the competition of the probiotics and other microorganisms for the same nutrient or due to the antimicrobial substances that they produce (e.g., lactic acid, bakteriocin, hydrogen peroxide) (Boylston *et al*., 2004; Mukhtar *et al*., 2020; Tripathi and Giri, 2014). In addition to the conditions in the production of food and storage process, in vivo GI conditions (e.g., pH, bile salts, hyrolytic enzymes) along with the consumption of food can also significantly affect the viability and the development of probiotics (Tamime, 2005).

3.3. The level of consumption of probiotic food for the probiotic effect

In order for a food to be referred as a "probiotic food", it must contain 10^6-10^7 cfu of live probiotic microorganisms in grams or mililitres during its shelf life. It is stated that the number of probiotic bacteria that should be added to the food in order to obtain probiotic food may be similar in number (10^6-10^7 cfu/g or ml) or slightly higher (10^7-10^8 cfu/g or ml) depending on the characteristics of the food. It has been reported that in order for probiotics to show beneficial effects on health, probiotic food should be taken at the daily consumption level (100 g or over ml daily). Thus, it is also repoted that the number of 10^8-10^9 bacteria/day required for the probiotic microorganisms to have a functional effect in the intestine can be reached (Abd- Elmonem *et al*., 2022; Cruz *et al*., 2009; Heperkan, 2021; Murtaza *et al*., 2022).

The minimum number of bacteria that should be present in g or ml of probiotic food during its shelf life may vary between countries. This number is regulated as 10^6 cfu/g or ml in Turkey, Argentina, Paraguay, Brazil and Uruguay and 10^7 cfu/g or ml probiotic bacteria in Japan (Turkish Food Codex, 2006; Yangılar, 2010).

4. Cheese

Milk creates a suitable environment for the growth of microorganisms due to its high nutrient content. In order to prevent the deterioration of milk, and to obtain new products in terms of taste, aroma and texture, a significant part of the milk is processed into dairy products with a longer shelf life. Among these products, cheese, one of the oldest fermented foods produced by mankind, has an important place (Fox *et al*., 2017).

Cheese is defined in the Turkish food codex communication on cheese (Turkish Food Codex, 2015) as "Cheese obtained by cagulation of milk using a suitable coagulant an separation of whey from the clot or by coagulation after the separation of the milk permeate, of different hardness and fat content, with or without salting with brine or dry salting, a dairy product that is produced with or without the use of starter culture, with or without boiled curd, with or without seasoning, produced in accordance with the technique, consumed before or after ripening, and showing the characteristic features specific to its variety."

Cheese is a type of food which is rich in terms of nutrients and valuable for consumer health. Cheese is a food of high nutritional value as it contains high quality protein, highly digestable fat, minerals (especially calcium and phosphorus) and vitamins (especially vitamins A, B_2 and B_{12}) (Feeney *et al*., 2021). In addition to macro- and micronutrients, ripened cheeses contain bioactive compounds (e.g., bioactive peptides) with beneficial health effects. The beneficial bacteria that can be found in cheese structure is another feature that increases the importance of cheese in terms of health (Santiago-Lopez *et al*., 2018; Waltner *et al*., 2008). The fact that it contains low amounts of lactose higlights cheese as a suitable food for patients with beta galactosidase deficiency (lactose intolerance) and diabetes mellitus (Monti *et al*., 2017).

Table 5. Basic cheese types and their classfication.

Structure factor	Moisture %	Ripening microorganisms	Basic cheese types	Cheese flavour	Country of origin
Extra hard cheeses	25–35	Bacteria	Parmesan	Fruit flavour and salt	Italy
			Romano	Strong aroma	
Hard cheeses	35–45	Bacteria	Emmanuel	Fruity aroma and flavour stimulation	Switzerland
			Gruyere	Aromatic, rich and smooth scent	
			Cheddar	Walnut flavour	The UK
Semi-hard cheeses	45-50	Bacteria	Gouda	Caramel ve creamy sugar	The Netherlands
			Edam	Sweet ve walnut	
Semi-soft cheeses	42-55	Bacteria	Brick	Spicy	Germany
			Limburg	Spicy	
		Mold	Roquefort	Strong salt aroma	France, Denmark
			Blue	Strong spice	
			Camembert	Soft mild aroma	France
Soft cheeses	55-80	Unripened	Cottage	Soft mild aroma	The USA
			Cream	Slightly sour	

Although there are more than 2000 cheese types in the world, it is reported that there are actually 12 main cheese types. Differences in cheese types are mostly due to the cheese production technology and the composition of raw material milk (Aydemir Atasever *et al*., 2019; Zheng *et al*., 2021). The classification of cheese types produced in the word according to the moisture content is given in Table 5 (Zheng *et al*., 2021).

4.1. Probiotic cheese production studies

As an alternative to yoghurt and fermented milks produced by adding probiotic cultures, cheese is a very valuable alternative in the development of probiotic dairy products and offers important advantages as a probiotic carrier food (Cruz *et al*., 2009; Murtaza *et al*., 2022; Verruck *et al*., 2015). Cheese is considered to have a more appropriate food profile among dairy products in terms of having more solid matrix, high pH, and fat content, low oxygen levels, ripening conditions and shelf life in order to sustain the survival and development of probiotic cultures. Moreover, cheese has the capacity to tampon gastric acidity (Cuffia *et al*., 2017; Sabikhi *et al*., 2014; Stanton *et al*., 2001).

The starting point of scientific studies on the production of probiotic cheese is the study of hard and semi-hard cheeses (especially cheddar and gouda), which are usually produced by single or combined additions of probiotics (Borrás-Enríquez *et al*., 2018; Elwahsh and El-Deeb, 2020; Murtaza *et al*., 2022; Mc Brearty *et al*., 2001; Ong *et al*., 2006). When historical process of probiotic cheese production is examined, it is determined that probiotic cheese production studies (Table 6.) were carried out in many different cheese types (e.g., coalho, edam, minas, cheddar cheese, tulum cheese). In these studies, probotic cultures have generally been reported to improve cheese quality and functional properties (e.g., probiotic count above the effect level).

In studies on probiotic cheese production, it is generally reported that the addition of probiotics doesn't have a negative effect on physical, chemical and microbiological quality of the cheese and increases the quality (e.g., sensory properties) and functional properties (e.g., probiotic effect) of the cheese due to biochemical events in the ripening process (e.g., by increasing glycolysis, proteolysis and lipolysis).

Table 6. Probiotic cheese production studies.

Cheese type	Probiotic culture used	Storage time (days)	Probiotic count (cfu/g)**	Resources
Cheddar cheese	*B. lactis* BB-12 *B. longum* BB536	180	$\geq 10^8$ 10^5	Mc Brearty *et al*. (2001)
White cheese	*B. bifidum* BB-02 *L. acidophilus* LA-5	90	4×10^6, 1.1×10^6 2×10^6, 9×10^6	Yılmaztekin *et al*. (2004)
Pategras Argentino	*L. acidophilus* *L. paracasei*	60	10^8 10^8	Bergamini *et al*. (2005)
Minas	*L. acidophilus*	21	6.66 log 6.10 log	Buriti *et al*. (2005)
Cheddar Cheese	*L. acidophilus* 4962 *L. casei* 279 *B. longum* 1941 *L. acidophilus* LAFTI L10 *L. paracasei* LAFTI L26 *B. lactis* LAFTI B94	180	≥7.5 log	Ong *et al*. (2006)
Kashar cheese	*L. acidophilus* LA-5 *B. bifidum* BB-12	90	10^6	Uzun (2006)
Crescenza cheese	*L. acidophilus* H5 *L. paracasei* A13	12	7 log 8 log	Burns *et al*. (2008)
Cheddar cheese	*L. casei* ATTC 334	90	10^7	Sharp *et al*. (2008)
White cheese	*E. faecium* *L. paracasei* subsp. *paracasei* *B. bifidum*	90	6.74×10^7 1.11×10^8 8.1×10^7	Gursoy and Kinik (2010)
Iranian white cheese	*L. acidophilus*	60	7.10-8.21 log	Sabbagh *et al*. (2010)
Iranian white cheese	*L. casei* ATCC 39392 *L. plantarum* ATCC 8014 *B. bifidum* ATCC 29521	60	10^6-10^7	Zomorodi *et al*. (2011)
White cheese	*B. bifidum* *B. longum* *L. acidophilus* LA-5	60	≥ 6 log 5.20 log 5.13 log	Yangılar and Özdemir (2013)
Feta cheese	*L. casei* ATCC 393	70	≥ 6 log	Dimitrellou *et al*. (2014)
White cheese	*B. longum*	90	1.0×10^7	Gursoy *et al*. (2014)
Coalho cheese	*L. acidophilus* LA-5 *L. casei* 01 *B. lactis* BB-12	1	7-8 log	Oliveira *et al*. (2014)
White cheese	*L. acidophilus* DSMZ 20079 *B. bifidum* DSMZ 20456	120	$>10^6$	Erkaya and Şengul (2015)
Edam cheese	*B. bifidum* ATCC 15696	90	10^7	Sabikhi *et al*. (2015)
Minas Frescal cheese	*B. animalis* ssp. *lactis* BB-12	30	8.36 log	Verruck *et al*. (2015)
Minas Frescal cheese	*L. casei* Zhang	21	8.28-9.02 log	Dantas *et al*. (2016)
Cheddar cheese	*B. animalis* subsp. *lactis* *L. rhamnosus* *L. paracasei/casei* *L. plantarum*	120	<6 log ≥8 log ≥8 log ≥8 log	Demers-Mathieu *et al*. (2016)
Pasta filata type cheese	*L. rhamnosus* GG	15	$3\text{x}10^7$	Cuffia *et al*. (2017)
Tulum cheese	*B. animalis* ssp. *lactis* *L. acidophilus*	90	4.99-5.94 log 4.94-5.03 log*	Beykaya (2018)
Gouda cheese	*B. lactis*	40	$\geq 10^8$	Borras-Enriques *et al*. (2018)

Table 6. Contd.

Cheese type	Probiotic culture used	Storage time (days)	Probiotic count (cfu/g)**	Resources
Domiati cheese	*B. bifidum* *B. infantis*	90	6.96-6.81 log 6.95-6.65 log	Kamaly *et al*. (2018)
White cheese	*L. acidophilus* *B. bifidum*	90	$\geq 10^8$	Karahançer (2018)
Feta cheese	*L. paracasei* SP3	70	8.18 log*	Mantzourani *et al*. (2018)
Myzithra cheese	*L. casei* ATCC 393	30	≥ 9 log	Schoina *et al*. (2018)
Feta cheese	*L. casei* ATCC 393	120	~8 log	Terpou *et al*. (2018a)
White brine cheese	*L. paracasei* K5	70	7-8 log	Terpou *et al*. (2018b)
Tulum cheese	*L. acidophilus* LA-5 *L. paracasei* (*casei* 431) *L. rhamnosus*	180	5.21 log* 7.32 log* 7.01 log*	Kalender (2020)
Mozzarella cheese	*L. acidophilus*	15	3.21×10^7- 2.54×10^8	Mukhtar *et al*. (2020)
Ras cheese	*L. acidophilus*, *L. helveticus* *L. casei*	90	8.75 log* 8.96 log* 8.71 log*	Abd-Elmonem *et al*. (2022)
Edam cheese	*L. casei* LAFTI-L26	61	≥ 9 log	Amiri *et al*. (2022)
Cheddar cheese	*L. acidophilus* *B. bifidum*	120	Unspecified	Murtaza *et al*. (2022)

*Expressed as the number of *Lactobacillus* spp. growing on MRS agar **The number of probiotics at the end of storage period is indicated.

5. Conclusions

When probiotic cheese production studies are evaluated, it is revealed that probiotic cultures which are frequently used in yoghurt and fermented milk production can be safely used in cheese production. Considering the physical, chemical and microbiological properties of cheese, it can be concluded that cheese is an effective and suitable food product for the transportation of probiotics to the intestinal environment at the probiotic effect level. It may be appropriate to improve the functionality of cheeses produced in Turkey with the addition of probiotics and to conduct studies to increase the probiotic food properties. By increasing the commercial production of probiotic cheeses as well as the experimental production of probiotic cheese production, the dairy industry can gain a functional food variety with probiotic properties that contribute to consumer health.

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Data availability

Not applicable.

Conflict of interest

None to declare.

Authors' contribution

Halit MAZLUM and Mustafa ATASEVER wrote the manuscript. All authors have read and approved the final manuscript.

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