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Article *in* Journal of Food Science and Technology -Mysore- · October 2020

DOI: 10.1007/s13197-020-04857-w

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J Food Sci Technol
https://doi.org/10.1007/s13197-020-04857-w

REVIEW ARTICLE

Fermented dairy products as delivery vehicles of novel probiotic strains isolated from traditional fermented Asian foods

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Revised: 8 October 2020 / Accepted: 14 October 2020

Abstract The screening of novel probiotic strains from various food sources including fruits, vegetables, herbs, and traditional fermented foods, have been of growing concern recently. Most of these potential probiotic lactic acid bacteria isolates were distinguished from the commercial probiotics based on multiple therapeutic effects and functionalities. Recent in vitro and in vivo investigates have also verified the usage of probiotics to lower the risk of diseases. Application of these novel strains in fermented dairy products is also an emerging trend to improve the physical and quality characteristics, functional properties, and safety of dairy products. Moreover, since dairy products are one of the highest consumed products in the globe, the dispatch channels for fermented dairy products are already established. Therefore, incorporating novel probiotic strains into fermented dairy products might be the most feasible approach for their delivery. In this context, our aim is to discuss the feasibility of dairy products as delivery vehicles for novel probiotic strains. Thus, we summarize the scientific evidence that points to a dynamic future for the production of fermented dairy-based probiotics.

Keywords Probiotics · Traditional fermented food · Probiotic carrier · Fermented dairy product · Functional effect

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Introduction

The paradigm of food consumption behavior has drastically changed, and consumers tend to purchase foods that promote health and lower the risk of diseases. This has inevitably led to an increase in functional food development (Turkmen et al. 2019). Functional foods are described as foods that are able to modulate targeted body functions through enhancing some physiological responses, reducing the risk of disease or both, that extend beyond nutritional and energy supply (ILSI 2006). Furthermore, functional foods can be classified as fresh, fortified, and enriched foods, encompassing a very broad range of products including probiotics, prebiotics, and synbiotic (Turkmen et al. 2019). Probiotics have a wide range of possible health benefits, which has led to an upsurge of probiotic consumption globally (Champagne et al. 2018). The probiotic industry is expected to raise $57.4 billion by 2022 while sustaining a compound annual growth rate (CAGR) of 7.7% during the 2016–2022 projection period (Allied Market Research 2019). Probiotics are live microorganisms that provide human health benefits when given in sufficient quantities (FAO/WHO 2006). Many probiotics belong to the lactic acid bacteria (LAB) genera of *Lactobacillus*. Other probiotic genera include *Leuconostoc*, *Lactococcus*, *Pediococcus*, *Enterococcus*, and *Streptococcus* (Le and Yang 2018).

Traditionally, fermented dairy products have commonly been used as a primary tool for supplying probiotics to consumers all over the globe. Moreover, numerous probiotic strains have been isolated from fermented milk (James and Wang 2019). Recently, consumers have become more conscious of health and nutrition, and consequently, different strains with various therapeutic properties are constantly being identified from traditional fermented foods

Published online: 23 October 2020

from many countries. These traditional fermented foods are produced from a range of raw materials, including fish, beef, pork, seafood, soybeans, fruits, and vegetables. Korean kimchi, the Chinese *serofluid* dish, *boza* (a Turkish fermented cereal-based beverage), and *hantak* (Indian fermented fish) are some of the traditional fermented foods evaluated for their probiotic activities (Sornplang and Piyadeatsoontorn 2016). Based on in vivo studies, LAB isolated from fermented foods are involved in the modulation of obesity and type 2 diabetes (Lee et al. 2018), hypocholesterolemic activity by lowering plasma cholesterol (Jo et al. 2015) and immunomodulation (Lee et al. 2014a). Some LAB contain beneficial compounds and are associated with antioxidant activity, antimicrobial activity, angiotensin-converting enzyme (ACE) inhibitory activity, exopolysaccharide (EPS)-producing activity, bacteriocin production, and anti-inflammatory activity (James and Wang 2019). Therefore, incorporation of these LAB in fermented dairy products might deliver benefits to the consumer. In this regard, we discuss the feasibility of using LAB from ethnic food sources in dairy products.

Lactic acid bacteria in traditional fermented Asian foods

The LAB in Asian traditional fermented foods include *Lactobacillus casei, Lb. plantarum*, *Lb. brevis*, *Lb. paracasei*, *Leuconostoc mesenteroides*, *Leu. kimchi*, *Weissella koreenis*, *W. confusa*, *W. cibaria*, and *Pediococcus pentosaceus* many of which are considered to be potential probiotics (Nuraida 2015; Kim et al. 2020; Kwun et al. 2020). Table 1 shows the lactic acid bacteria isolated from various fermented foods and their functional activities. These isolated LAB, having beneficial effects, can be adopted in commercial food manufacture and industrial applications. In particular, several probiotics have been identified as possible sources of enzymes such as alkaline protease, esterase, and amylase (Zhao et al. 2019). Some studies have proposed that probiotics to be used as feed additives to boost livestock health, such as swine, cattle, and poultry. Additionally, certain probiotics are applied to various types of functional foods and introduced as probiotic carrier foods that enable consumers to ingest significant quantities of probiotic bacteria for therapeutic benefits. In this context, fermented dairy products are considered the key vehicle for probiotics in different region of the world.

Trends and probiotic cultures in the current dairy market

Milk is a rich source of macro-and micronutrients, and thus provides the nutrients and energy needed for growth. Milk products play a major role in regulating public health and are the main component of the food pyramid. In South Asia, India is the main supplier of raw milk required for dairy products, with a record production of $26.9 billion in 2014 (Nozaki 2017). Milk products are the major contributors to the functional food market (60%) in Europe, with yoghurt accounting for the largest segment of the probiotic market (Vella et al. 2013). In fact, yoghurt has been widely recognized for its nutritional properties and health benefits and has been consumed for thousand years (Min et al. 2019). *Lb. delbrueckii* subsp. *bulgaricus* and *S. thermophilus* are used as starter cultures in conventional yoghurt productions. Nevertheless, these bacteria are not acid and bile salt tolerance and do not withstand the passage across the gastrointestinal tract (GIT). However, in response to the increasing consumer interest in health, the food industry has developed fermented dairy probiotic products supplemented with probiotics. Figure 1 indicates the health benefits associated with probiotic dairy products. As a result of these benefits, milk consumption has also increased in countries in East Asia, where milk consumption was lower in the period from 1981 to 2000 (FAO 2009). In the global dairy market, China is becoming more competitive and the entire industry has gradually shifted from scale-up development to efficiency upgrading. In China, gross dairy sector revenue was 359.04 billion yuan (0.53 billion USD) in 2017, with an increase of 7.85% (Daxue Consulting 2020). Table 2 shows the dairy-based probiotics currently available in the global market and the constituent probiotic species.

Application of novel probiotic strains in fermented dairy products

As consumers are aware of the health-promoting effect of the diet, the food industry is trying to develop or modify dairy foods to give the consumer maximum health benefits while preserving the product's traditional mouth feeling. In this scenario, milk companies may find multiple opportunities for the use of novel probiotics. Table 3 shows the application of novel probiotics in fermented dairy products. In latter discussed the various application of novel probiotics for the preparation of fermented dairy products.

Bio-preservative and antagonistic properties

In dairy fermentation, lactic acid production by probiotic bacteria plays a crucial role in the preservation of the food, preventing food spoilage and the proliferation of pathogens (Othman et al. 2017). Probiotic isolates have shown antagonistic activity towards food-borne pathogens and organisms that cause food spoilage. LAB produces a broad spectrum of antimicrobial metabolites, including primary

Table 1 The functional properties of lactic acid bacteria isolated from different fermented foods

Microorganism	Origin	Functional property	Country	Reference
Lb. plantarum KLAB21	Kimchi	Anti-mutagenic activity	Korea	Park and Rhee (2001)
Lb. plantarum SY11 and *Lb. plantarum* SY12	Kimchi	Anti-allergic activity	Korea	Lee et al. (2014b)
Lb. plantarum sp.	Kimchi	Atopic dermatitis inhibition activity	Korea	Won et al. (2011)
Lb. plantarum 200661	Kimchi	Anticavity activity	Korea	Lim et al. (2020)
Leu. kimchii GJ2	Kimchi	Cholesterol lowering activity	Korea	Jo et al. (2015)
Lc. lactis NK34	Kimchi	Antioxidant and β-galactosidase activity	Korea	Son et al. (2017)
Lb. paraplantarum SC61	Jangajii (fermented vegetable)	Antioxidant and immunostimulatory activity	Korea	Son et al. (2018)
Lb. buchneri KU200793	Kimchi	Neuroprotective activity	Korea	Cheon et al. (2020)
Lb. plantarum Ln4	Kimchi	Modulate obesity and type 2 diabetes	Korea	Lee et al. (2018)
Leu. citreum EFEL2061	Kimchi	Immunomodulatory activity	Korea	Kang et al. (2016)
Lb. plantarum AAS3	Hentak (fermented fish)	Hemolytic, DNase, and gelatinase activities	India	Aarti and Khusro (2019)
Lb. brevis LAP2	Hentak (fermented fish)	Proteolytic activity and antioxidant activity	India	Aarti et al. (2017)
Lb. paraplantarum MTCC 9483	Gundruck (fermented leafy green vegetable)	Anti-inflammatory activity	Nepal	Devi et al. (2018)
Lb. plantarum JLK0142	Fermented tofu (fermented soy milk)	Immunomodulatory activity	China	Wang et al. (2018)
Lb. s193 and s292	Funazushi (fermented soybean)	Anti-inflammatory activity	Japan	Okada et al. (2018)
Lb. plantarum S-SU5 and *P. pentosaceus* S-SU6	Fermented fish	Antioxidant activity and anti-inflammatory activity	Japan	Kuda et al. (2014)
Lb. plantarum (B0040, B0110) and *W. cibaria* (B0145)	Fermented mustard	Immunopotentiating activity and anti-mutagenic activity	Taiwan	Chang et al. (2015)
Lb. plantarum K68	Fu-tsai (fermented mustard)	Anti-inflammatory and immunomodulatory activity	Taiwan	Liu et al. (2011)
Lb. plantarum MB 427				
Lactobacillus sp.	Mandai	Shortened duration of diarrhea and induced secretion of IgA and IgG	Indonesia	Nuraida (2015)
Lb. plantarum sa28k, *Lb. acidophilus* FNCC116, and *Lb. casei* FNCC262	Sauerkraut	Assimilating cholesterol and lowering serum cholesterol	Indonesia	Nuraida (2015)
W. hellenica BCC 7293	Nham (fermented pork sausage)	Bacteriocin production	Thailand	Woraprayote et al. (2015)

Names of genera are abbreviated as *Lb.*, *Lactobacillus*; *Lc.*, *Lactococcus*; *Leu., Leuconostoc; W., Weissella; P., Pediococcus*

and secondary metabolites (Choi et al. 2018). The important metabolites produced are ethanol, hydrogen peroxide, free fatty acids, bacteriocins, and antifungal compounds, all of which may play an antagonistic role against bacteria, viruses, and fungi (Shokryazdan et al. 2017). Recently, there is a global trend of increasing resistance to use of chemical preservatives, while natural compounds are gaining popularity. The antimicrobial compounds produced by LAB are appealing in this context as they can promote food bio-preservation, while eliminating some of the side effects of the chemical preservatives. In certain dairy products *Lc. lactis* strains with antimicrobial properties

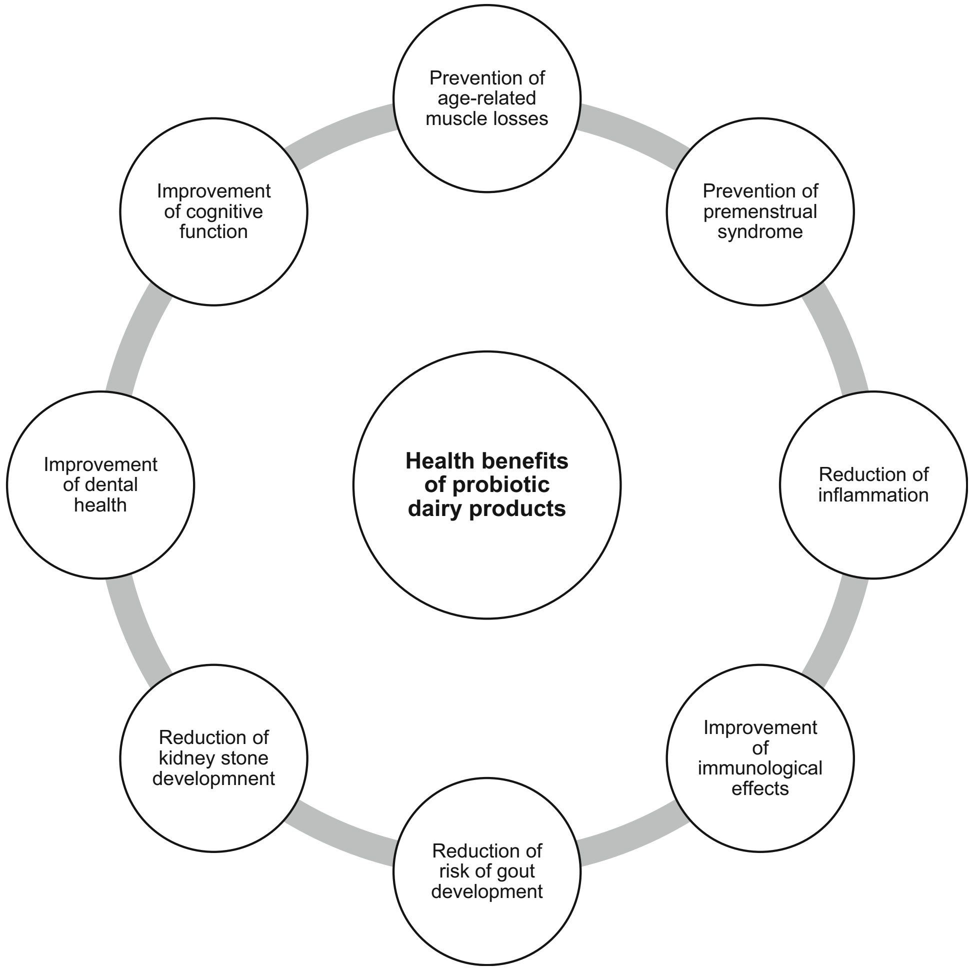

Fig. 1 Health benefits of probiotic dairy products

have appeared as promising bio-preservatives particularly for the prevention of listeriosis which is a serious infection caused by *Listeria monocytogenes. L. monocytogenes* is a post-processing contaminant in refrigerated ready-to-eat foods like soft cheeses as it can grow at low temperatures and is highly acid and salt tolerant (Ho et al. 2018). However, many scientific investigations confirmed the feasibility of enhancing the safety of dairy probiotic foods through the incorporation of novel probiotic strains derived from traditional fermented foods. For example, Ho et al. (2018) isolated *Lc. lactis* strains from herbs, fruits, and vegetables and successfully incorporated the bacterium in cheese to inhibit the proliferation of well-known foodborne pathogen *L. monocytogenes*. Similarly, *W. cibaria* D30, derived from Korean kimchi, was effectively used as a bio-preservative in ready-to-eat cottage cheese (Kariyawasam et al. 2019).

In addition, despite the use of yeast and molds in the processing of many fermented food products, including dairy products, they are a major cause of spoilage for many processed dairy foods. Ryu et al. (2014) was reported the antifungal activity of *Lb. plantarum* HD1 isolated from Korean kimchi and potential use as a powerful bio-preservative system which is capable of preventing fungal spoilage and mycotoxin formation in the food. Furthermore, Cheong et al. (2014) have reported the antifungal activity of LAB isolated from various herbs, fruits, and vegetables and potential for use as bio-preservatives in cheese.

Therapeutic properties

Typically, milk products fermented with *Lb. delbrueckii* subsp. *bulgaricus* and *S. thermophilus* starter strains may not play a vital role in the human GIT as they are unable to colonize in a human epithelial cell layer (Mcfarland 2015). Nonetheless, probiotics have been documented for restoring GIT microbiota and offering numerous health benefits (James and Wang 2019).

The role of probiotics in mitigating and reducing the duration of diarrhea, particularly antibiotic associated diarrhea is well documented. Another, indication is the administration of *Lactobacillus reuteri* DSM 17938, which decreases the duration of diarrhea and improves the chance

Table 2 Dairy probiotic products available in the global market (adapted from Granato et al. 2010; Mishra et al. 2018)

Product category	Brand name	Manufacturer	Probiotic strains
Fermented milk	Yakult	Yakult Honsha	*Lb. casei* Shirota
	Yakult	Korea Yakult Co., Ltd	*Lb. paracasei*
	Rela	Ingman foods Oy	*Lb. reuteri*
	Chamyto	Nestle Co., Ltd	*Lb. johnsonii* and *Lb. helveticus*
	Activia	Danone Co., Ltd	*B. animalis* DN173010
	Vigor-Club	Vigor Co	*Lb. acidophilus* and *Lb. casei*
	Batavito	Batavo	*Lb. casei*
	Bob Sponja	Batavo	*Lb. casei*
Yoghurt (set type, stirred, and drinking)	Activia (stirred, drinkable)	Danone Co., Ltd	*B. animalis* DN173010
	Actimel (drinkable)	Danone Co., Ltd	*Lb. casei* Immunitas
	Activia (creamy yoghurt)	Danone Co., Ltd	*B. lactis*
	Hellus	Tallinna Piimatööstuse AS	*Lb. fermentum* ME-3
	Jovita Probiotisch	H&J Bruggen	*Lactobacillus* strain
	ProViva	Skanemejerier	*Lb. plantarum*
	Rela	Ingman Foods	*Lb. reuteri*
	Revital	Olma	*Lb. reuteri*
	Active		
		Olma	*Lb. reuteri*
	Vifit	Campina	*Lactobacillus* strain
	Vitamel	Campina	*Lb. casei,*
	Doctors choice	Bio foods Ltd	*B. bifidum,*
			Lb. acidophilus
			Lb. acidophilus, and S. thermophilus
Cheese	Kraft	Kraft Heinz Co	*B. lactis* and *Lb. rhamnosus*
	Saputo	Saputo Inc	
	Miyoko's	Nestle Co. Ltd	

Names of genera are abbreviated as *Lb.*, *Lactobacillus*; *Lc.*, *Lactococcus*; *W.*, *Weissella; B.*, *Bifidobacterium*

of recovery in healthy children (Urbanska and Szajewska 2014). In addition, the consumption of yoghurt comprising the probiotic *Lb. rhamnosus* GR-1 and *Lb. reuteri* RC-14 address mild diarrhea in HIV/AIDS patients (Anukam et al. 2008). Furthermore, fermented milk can minimize the risk of common cold as well as its duration (Makino et al. 2010). One research reported that children consuming *Lb. rahmnosus* GG (LGG) supplemented milk had less days of respiratory issues than the participants in the control group (Kumpu et al. 2013).

In addition to primary health benefits, probiotics have also shown several health benefits, including improved immunomodulatory activity, anti-proliferative activity against tumor cells, reduced risk of colon cancers, and antigenotoxicity, anti-mutagenicity, and hypocholesterolemic effects (Vasiljevic et al. 2008; Jang et al. 2019). As various probiotics isolated from traditional fermented foods with various therapeutic effects current trend is to incorporate these probiotic bacteria along with starter culture during fermentation to accentuate the therapeutic properties.

Lee et al. (2014b) and Song et al. (2016) reported the utilization of *Lb. plantarum* species isolated from Korean kimchi as yoghurt starters that could help in the prevention of Th2-related immune disorders. Moreover, some authors suggested the use of *Lb. plantarum*, *Lb. brevis*, and *W. cibaria* as adjunct cultures in fermented dairy products to enhance the therapeutic properties including immunomodulatory activity, antitumor activity, antioxidant activity, and anti-inflammatory activity (Table 3). Cai et al. (2019) demonstrated the antidiabetic scores of probiotics isolated from pickles, *P. acidilactici* 004 and *Lb. plantarum* 152 were higher than those of the LGG, which suggested that these two strains are promising probiotics

Table 3 Dairy fermented products incorporated with potential probiotics isolated from traditional fermented Asian foods

Microorganism	Origin	Functional property	Dairy product	Reference	Concentration and shelf life of the product
Lb. plantarum DKL119	Korean kimchi	Cold-shock induced cryotolerance, and β-galactosidase and proteolytic activity	Yoghurt	Cho et al. (2013)	15 d, 1.0 × 10^9 cfu/mL
Lc. lactis strains	Herbs, fruits, and vegetables	Antilisterial activity, adjunct cultures in cheese to enhance the flavor	Cheese	Ho et al. (2018)	10^8–10^9 cfu/mL, no shelf life study
Lb. plantarum strains	Herbs, fruits, and vegetables	Antifungal activity	Cottage cheese	Cheong et al. (2014)	10^8–10^9 cfu/mL, 29 days
Lb. plantarum SY11 and *L. plantarum* SY12	Kimchi	Anti-allergic effects	Yoghurt	Lee et al. (2014a, b)	No shelf-life study
Lb. plantarum Lb41	Kimchi	Anti-inflammatory activity and anticancer activity	Cottage cheese	Jeon et al. (2016)	10^9 cfu/mL, 28 days
Lb. plantarum RS20D	Pao cai (Chinese homemade fermented vegetable)	Immunoregulatory activity and exopolysaccharide producing activity	Yoghurt	Zhu et al. (2019)	No shelf life study
Lc. lactis SL6	Kimchi	Antioxidant activity	Fermented skim milk	Kim et al. (2017)	No shelf life study
Lb. plantarum JLK0142	Tofu	Antioxidant, ACE inhibition, α-amylase and β-glucosidase inhibitory activity, and antitumor activity	Cheddar cheese	Wang et al. (2019)	No shelf life study
Lb. plantarum L67	Kimchi	Anti-allergic activity	Yoghurt	Song et al. (2016)	No shelf life study
Gluconobacter oxydans and *Dekkera anomala*	Kombucha	Antihypertensive activity	Fermented milk	Elkhtab et al. (2017)	No shelf life study
W. cibaria D30	Kimchi	Antioxidant and antilisterial activity	Cottage cheese	Kariyawasam et al. (2019)	10^6 cfu/g, 28 days
Lb. brevis KU200019	Jeotgal	Antioxidant activity	Fermented milk	Kariyawasam et al. (2020)	10^8 cfu/mL, 28 days

Names of genera are abbreviated as *Lb.*, *Lactobacillus*; *Lc.*, *Lactococcus*; *W.*, *Weissella*

with antidiabetic properties. Moreover, in vitro and in vivo studies of Lee et al. (2018) suggested that *Lb. plantarum* Ln4 isolated from kimchi has attenuates diet-induced obesity and insulin resistance, highlighting the potential of Ln4 as a therapeutic probiotic agent for metabolic disorders.

Moreover, Lim et al. (2020) demonstrated the anti-cavity activity of *Lb. plantarum* 200661 derived from Korean Kimchi. Furthermore, author has suggested the use of this novel strain as adjunct in cheese-like products to mediate the dental health issues among young children. Lee et al. (2019) was reported the prevention of oxidative damage of DNA by probiotic *S. cerevisiae* strains; KU200270, KU200280, and KU200284 isolated from cucumber jangajji. Furthermore, *S. cerevisiae* KU200284 was demonstrated for potential use in starter culture for kefir milk production (Hong et al. 2019). Thus, these novel strains can be incorporated into fermented dairy products along with starter cultures in order to obtain various health benefits.

Physical properties

Textural properties of fermented dairy products are important attributes in determining consumer acceptance. Attributes such as viscosity, springiness, smoothness, thickness, and structural resistance are considered important. Therefore, many methods have been used in the cheese and yoghurt manufacturing industries, including increasing the total solid content by adding fat, sugars, or proteins, and addition of stabilizers such as starch, pectin, and gelatin. However, consumers are reluctant to accept these methods due to side effects associated with them. Moreover, in some countries the amount of stabilizer used is strictly regulated for yogurt manufacture (Zhu et al. 2019). Consequently, the use of EPS-producing probiotic bacteria to enhance the textural properties of food has become a popular approach as it is possible to combine textural improvement with certain health benefits. Some investigators have reported probiotics with a high EPS-production ability and capability of improving the texture of yoghurt (Han et al. 2016). Zhu et al. (2019) stated that the EPS-producing *Lb. plantarum* derived from conventional fermented vegetable products is capable of optimizing the texture of yoghurt and is associated with elevated immunomodulatory activity. Chen et al. (2019) was also reported the textural improving and immunoregulatory activity of EPS producing probiotics isolated from fermented vegetables in Taiwan. Therefore, these studies confirmed the feasibility of incorporating probiotics isolated from traditional fermented products into fermented milk products to improve the textural properties of these products.

Detoxification properties

Food security has become a major public health concern. Contaminated food intake is considered to be the primary route of human exposure to harmful compounds. Milk and milk derivatives have been reported as a significant source of aflatoxin M1 (AFM1) to humans. AFM1 is a known potent carcinogenic substance that regularly poses a public health concern (Panwar et al. 2018). However, there is no effective method available to mitigate the problem of AFM1 from milk and milk products. Panwar et al. (2018) described the feasibility of probiotic lactobacilli mitigating the toxic effects of AFM1. The propensity for detoxification of milk products may be attributed to the LAB possessing affinity to certain heavy metals and organic contaminants (Reid 2015). Furthermore, Monachese et al. (2012) showed the ability of probiotic yoghurt to sequester toxic heavy metals. This is a new application of dairy products. Studies conducted by Zhang et al. (2014) confirmed the potential of fermented skimmed milk to accelerate the degradation of the organophosphate pesticides malathion, diazinon, fenitrothion, and chlorpyrifos. Thus, dairy-based probiotics have the potential to detoxify some carcinogenic compounds and can be used to enrich food products.

Merits of probiotic dairy foods as probiotic carriers and recent advancement of probiotic dairy foods

Dairy products are by far the most probiotic food category available on the market. The success relates to the multiple benefits of dairy products as probiotic carriers and their technological advancements. These benefits and recent advances are discussed in the following sections.

High viability of probiotics

The most important criteria for using any probiotic food is that the viability and activity of the probiotics is maintained until the end of the shelf-life of the product since an adequate number of viable cells needs to be administered and survive in the gut long enough to colonize the gut properly and deliver the putative health benefits associated with probiotics (Mcfarland 2015). Effective promotion of probiotic products often demands the guarantee that there will be a sufficient amount of viable probiotic cells during the shelf life of the product. The major crucial key factors affecting probiotic viability are probiotic strain, processing temperatures, processing procedures, and storage conditions (Fig. 2). Therefore, selection of a suitable food carrier can ensure the maximum viability of probiotics throughout storage, which is essential to deliver the optimal therapeutic benefits to the consumer.

Dairy fermented foods have been reported to be suitable for probiotics addition, as the fermentative process facilitates optimization of microbial viability; and consumers are familiar with the fact that these products contain living microorganisms. The refrigerated storage also helps to stabilize the probiotic cultures throughout the storage period. In addition, extensive changes in technology or manufacturing process do not require to include the probiotic cultures in the dairy food matrix, as the matrix has the ability to protect probiotics through the gastrointestinal tract (Granato et al. 2019). In particular, cheese has beneficial characteristics, such as high fat, water activity, and pH, which can ensure the maximum viability of probiotic strains during shelf-life and even through the gastric transit

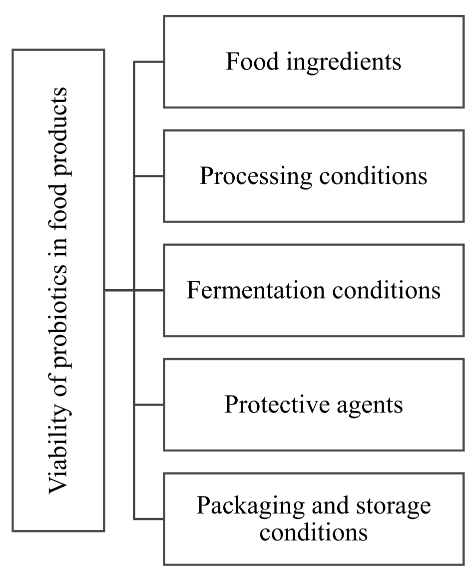

Fig. 2 Factors affecting viability of probiotics in foods (Adapted from Tripathi and Giri 2014)

(Kariyawasam et al. 2019; Makelainen et al. 2009). Previous authors have reported the successful incorporation of various probiotic cultures isolated from traditional fermented foods as adjuncts in fermented milk products to enhance the therapeutic value, while maintaining the live probiotic count during storage (Ho et al. 2018; Jeon et al. 2016). Jeon et al. (2016) reported cottage cheese containing *Lb. plantarum* Lb4, isolated from Korean kimchi with 9 log cfu/mL survival rate at the 28 days of the refrigerated storage. Papadopoulou and Chorianopoulo (2016) reported the fresh cheese added with the probiotic strain *Lb. plantarum* T57, isolated from traditional Greek products. The probiotic viability was 7.5 log cfu/g at the end of the shelf-life. Ice cream also has good potential for use as a probiotic carrier because of its neutral pH and high total solid level providing protection for probiotic cells (Ergin et al. 2016). However, the different technical steps taken during the production of ice cream could have a negative impact on probiotic viability. Extra attention should therefore be paid to technical steps, such as overrun where air is incorporated, storage at freezing temperatures, and how the bacterial inoculum is added to the product. Several strategies, including strain selection, prebiotic incorporation, microencapsulation, the addition of the probiotic at an optimum inoculation level, pH adjustment, adjustment of the level of cream fermentation, and freezing control, have been proposed to improve the survival of the probiotics in ice cream (Granato et al. 2019).

The major limitation of yogurts and fermented milk in probiotic viability is the low pH because most of the probiotic cultures have an optimal growth pH between 5 and 9. Therefore, it is advised to select probiotic strains that are more resistant to the acidity of the medium (Granato et al. 2019). Probiotic cultures isolated from traditional fermented foods generally have high resistance to acidic environments. Kariyawsam et al. (2020) reported fermented milk incorporated with *Lb. brevis* KU200019 (Korean *jeotgal* isolate) and observed a high survival rate of over 8 log cfu/mL and high antioxidant activity. Another approach is the use of whey protein concentrates (WPC), probiotic whey beverages presented a significant contribution to the survival of the probiotic cultures. The main reasons are the buffering capacity of the WPC, delaying the post acidification of the products; and the sulfur amino acid release during the heat treatment, lowering the redox potential of the media (Shori 2016). Even a significant increase in probiotic whey beverages is due to the health effects of the whey proteins. Rosa et al. (2020) reported antiproliferative and apoptotic effects of probiotic whey dairy beverages in human prostate cell lines.

In addition, the microencapsulation of probiotic culture appears to offer a good technological alternative for use in the dairy sector and to enhance probiotic viability. The most foodstuff containing microencapsulated probiotics are milk based foods and account for 49%. The common techniques used for probiotic microencapsulation are freeze drying, spray drying, emulsion, and extrusion (Iravani et al. 2015). Different types of cheeses were recently evaluated as a carrier of probiotic cultures, including cheddar, pecorino, fresh cream, pasta filata, soft cheese, coalho, minas frescal, and prato (Granato et al. 2013).

High sensory quality

Sensory quality is one of the most important element that determines the marketability of the food product. Dairy products are consumed by all age groups, and their nutritional and sensory properties mainly influence this consumption. The market for dairy desserts has increased in recent years and a wide range of ready to eat dairy desserts have been introduced the probiotic market (Buriti et al. 2016).

In addition, there are many studies discussing the organoleptic properties of probiotic foods, all of which indicate improvement in acceptability following the introduction of probiotics to milk products (Granato et al. 2010). Yerlikaya and Ozer (2014) reported probiotic fresh white cheese using co-culture with *S. thermophiles* and was observed incorporation of co-culture did not have any negative impact on the sensory properties including cheese components. Moreover, Lee et al (2014b) reported potential use of *Lb. plantarum* SY11 and *Lb. plantarum* SY12 as yoghurt starters with no defects in sensory properties.

The dairy industry has also taken the lead by producing hybrid dairy products that combine dairy and fruit to offer healthier and more appealing products to the consumer. Various authors reported that fortification of plain yoghurt with fruit pieces and pulp, including that of carrot, strawberry, acai, and pomegranate, enhanced the microbiological, sensory, and physicochemical properties of the yoghurt (Kiros et al. 2016). Ranadheera et al. (2012) reported fruit based material could lead to enhance the sugar content and consequently, contribute for appealing aroma and flavor. Besides the addition of fruit pulps, some other authors reported addition of plant extracts such as *Inula britannica* to cheddar cheese to enhance the functional properties and red ginseng extract to milk to enhance the antioxidant activity of milk and observed enhanced flavor and aroma in those products (Jung et al. 2015; Lee et al. 2016). Jang et al (2018) reported quality improvement of probiotic yoghurt using *Lb. plantarum* NK181 (Korean jeotgal isolate) and ginseng extract powder. Thus, dairy products can be modified to enhance the functional properties while maintaining the palatable sensorial properties.

Low cost of production

The development of novel non-dairy probiotic products has its own unique challenges. Essentially, many factors should be strictly regulated in order to maintain a viable dose of microorganisms capable of providing health benefits. The factors to be taken into account are the appropriate selection of cultures and their concentrations, adequate processing step at which inoculums are applied, regulation of processing methods, transport and storage temperatures. In addition, food producers need to optimize the specific formulas for each product, taking in to consideration the required sensory, physical and chemical properties, prolonged shelf-life, and chemical consistency, as each food matrix is distinctive (Dey 2018). Moreover, qualitative and quantitative investigations of both the product and the customers are needed before launching these products into the market (Jousse 2008), industrializing novel non-dairy fermented products is a time-consuming and expensive process.

Synbiotic application

Synbiotic foods are foods that contain both probiotics and prebiotics and improve host health by enhancing the viability and implantation of beneficial bacterial microflora in the GIT (Mohanty et al. 2018). The global demand for synbiotic food has grown tremendously, and consequently, the addition of prebiotics including oligosaccharides, inulin, and pyrodextrins to various food sources has also increased. Moreover, some authors reported that the regular consumption of synbiotic yoghurt (which is enriched with bifidobacteria and *Lb. rhamnosus* GG) boosted the gut health of healthy adults and aging population suffering from constipation (Granata et al. 2013). In addition, Kulka et al. (2015) reported that synbiotic yoghurt containing the probiotic bacteria *S. thermophilus*, *Lb. delbrueckii* subsp. *bulgaricus*, and *B. animalis* subsp. *lactis* BB-12 and inulin greatly decreased the duration of fever and increased children's physical and mental activity.

New formulation of milk-based dairy desserts has made using the inulin due to various health and technological properties. In particular, inulin has incorporated into dairy desserts as a fat replacer and subsequently, to reduce the calorific value of the products. The success in the market implies the maintenance of the mouthfeel and texture of traditional full-fat dairy products (Buriti et al. 2016). Balthazar et al. (2017) reported the prebiotics to replace milk fat and developed a sheep milk-based ice cream with improved nutritional and physiological values. Kariyawasam et al. (2020) reported the utilization of prebiotics to enhance anti-adhesion of pathogenic organism to HT-29 cell line in vitro and improved *Lb. brevis* KU200019 viability in fermented skim milk.

In addition, academia and industry attention is focused to feasibility use of various starches along with dairy based desserts to enhance the nutritional quality. Parussolo et al. (2017) evaluated feasibility use of yacon flour as a prebiotic ingredient. The addition of yacon enhanced the probiotic viability (above 10^7 cfu/g) and high sensory scores, demonstrating that this ingredient has potential for use as a prebiotic in the dairy food matrix.

Perspectives and conclusion

Dairy probiotic products have been widely explored by industry and scientific researchers due to their health appeal and the continuous increase in consumer demand. This success is due primarily to the well-known dairy product history as being healthy products and well-established market channels around the world. However, in order to keep a high demand in the functional food market, there must be consistent, convincing, and truthful health claims with appropriate sensory and nutritional appeal and beneficial properties when consumed on a regular basis. In this context, therapeutic effects, textural qualities, sensory properties, and other technological advances of probiotic dairy products can be enhanced by applying beneficial probiotics isolated from traditional fermented foods, as discussed in this review. Although the scientific community has continuously studied the beneficial effects of probiotic microorganisms isolated from various traditional fermented foods and even the possible use of these organisms in dairy probiotic products, these studies are limited to laboratory level. Food companies must therefore use this approach at industrial level to re-engineer products and processes in order to ensure the quality, safety and therapeutic advancement of highly consumed dairy foods.

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