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Influence of probiotics, prebiotics, synbiotics and bioactive phytochemicals on the formulation of functional yogurt

Nurul Farhana Fazilah[a], Arbakariya B. Ariff[a,c], Mohd Ezuan Khayat[b,c], Leonardo Rios-Solis[d], Murni Halim[a,c,*]

[a] Department of Bioprocess Technology, Faculty of Biotechnology and Biomolecular Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[b] Department of Biochemistry, Faculty of Biotechnology and Biomolecular Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[c] Bioprocessing and Biomanufacturing Research Center, Faculty of Biotechnology and Biomolecular Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[d] Institute for Bioengineering, School of Engineering, University of Edinburgh, Edinburgh EH9 3JL, United Kingdom

A R T I C L E I N F O

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A B S T R A C T

The new concept of functional foods has led to the varieties in the production of foods that deliver not only basic nutrition, but can also warrant good health and longevity. Yogurt has become one of the prevalent choices and considered as a healthy food since it provides excellent sources of essential nutrients. As the popularity of yogurt continues to grow, manufacturers and scientists continuously investigate the value adding ingredients such as probiotics, prebiotics and different kinds of plant extracts to produce functional yogurt comprising extra beneficial properties than the conventional yogurt. This review summarises the current knowledge on functional yogurt, applications and roles of probiotic, prebiotic and synbiotic in yogurt as well as the effects of phytochemicals added in innovative yogurt products. Their important properties were focused based on significance influences on quality and sensory attributes of yogurt products and associated health aspects.

1. Introduction

Yogurt or yoghurt is a long time known appreciated dairy food product available in various textures (i.e., liquid, set, smooth), fat contents (luxury, low-fat, virtually fat-free) and flavours (natural, fruit, cereal) (Shah, 2003; McKinley, 2005). It is traditionally made from the spontaneous or induced lactic acid fermentation of milk (Widyastuti, Rohmatussolihat, & Febrisiantosa, 2014). Basically, yogurt can be classified into two groups, which are standard culture yogurt and bio-yogurt or probiotic yogurt (Pandey, Du, Sanromán, Soccol, & Dussap, 2017). Standard yogurt is typically manufactured from the conventional starter culture strains, *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* (Arena et al., 2015). Meanwhile bio-yogurt or probiotic yogurt is supplemented with probiotic strains such as *Bifidobacterium* and *Lactobacillus acidophilus* that are claimed to have numerous health benefits and should remain live at adequate numbers (Lourens-Hattingh & Viljoen, 2001; Weerathilake, Rasika, Ruwanmali & Munasinghe, 2014; Baltova & Dimitrov, 2014; Chen et al., 2017). For instance, the National Yogurt Association (NYA) of the United States specifies that bio-yogurt products must contain 10^8 CFU/g lactic acid bacteria (LAB) at the time of manufacture to using "Live and Active Culture" logo while the Australian Food Standards Code regulations require that the LAB used in yogurt fermentation must be present in a viable form in the final product; nonetheless, the numbers of CFU/g are not specified (Pandey et al., 2017). Yogurt is considered as the most popular vehicle for the delivery of probiotics for the consumers (Lourens-Hattingh & Viljoen, 2001). The most commonly consumed yogurts are the set type yogurt and strains yogurt but nowadays, frozen and drinking yogurts are also part of yogurt's commercial varieties and have become increasingly popular.

Organoleptic, rheological, texture and microstructure properties of yogurt depend on several factors such as fermentation process, type of milk, starter cultures and probiotic strains, packaging and storage conditions. As depicted in Fig. 1, the conventional processing for manufacturing of yogurt involved several steps: initial treatment of milk (an optional step for using a high quality of raw milk (i.e., grade A or grade B milk as defined under the US Pasteurised Milk Ordinance, Food and Drug Administration (FDA) (Murphy, Martin, Barbano, & Wiedmann, 2016) in yogurt production), standardisation of milk, homogenisation, heat treatment, fermentation process, cooling and

* Corresponding author at: Department of Bioprocess Technology, Faculty of Biotechnology and Biomolecular Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
E-mail address: murnihalim@upm.edu.my (M. Halim).

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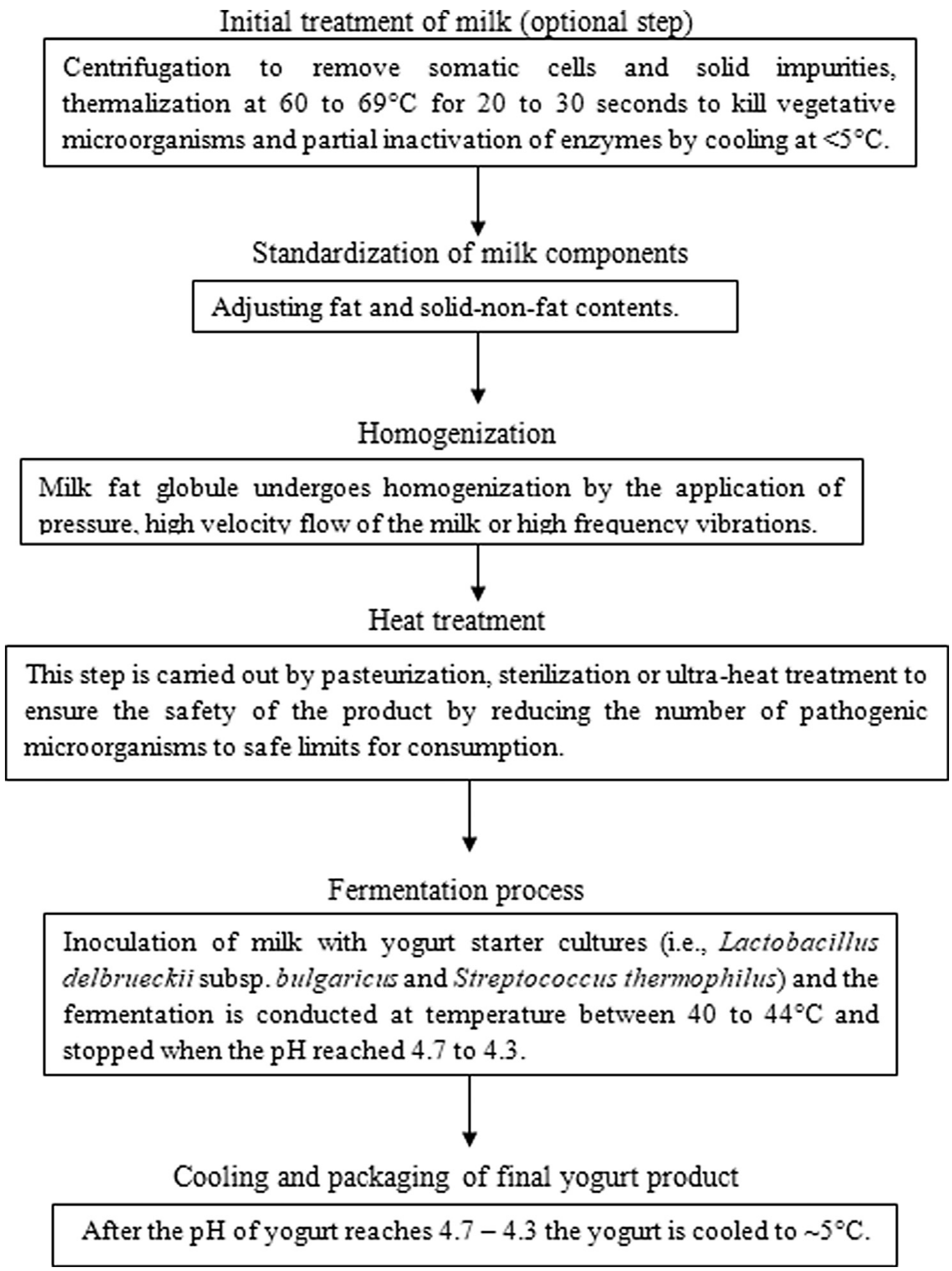

Fig. 1. Standardized yogurt manufacturing process.

ending with the packing of the final yogurt product (Sfakianakis & Tzia, 2014). Yogurt can be manufactured with or without the supplementation of natural derivative of milk (i.e., skim milk powder, caseinates or cream, whey concentrates), the addition of sugars (i.e., sucrose, fructose) and stabilisers (i.e., pectin, starch, gelatine, alginate) and increased solids in milk by adding fat and proteins to alter the texture and flavour (Lee & Lucey, 2010). For instance, protein and fat are commonly added to combat the defects in texture, physical properties and mouthfeel of low fat yogurt (Laiho, Williams, Poelman, Appelqvist, & Logan, 2017). Meanwhile, hydrocolloids stabilisers such as carrageenan, gelatin, xanthan gum and modified starch are often added to milk base to improve the texture, appearance, viscosity, consistency, mouthfeel as well as to prevent whey separation in yogurt (Nguyen, Kravchuk, Bhandari, & Prakash, 2017).

In general, the health benefits of fermented food products can be classified into two groups, which are nutritional function and physiological function (Bell, Ferrao, & Fernandes, 2017). The nutritional effect is related to the food function in supplying sufficient nutrients while physiological function concerns on the prophylactic and therapeutic benefits (Marco et al., 2017) that include the reduction in risk of diabetes (i.e., consumption of fermented kimchi decreases insulin resistance and increases insulin sensitivity (An et al., 2013)) and reduced muscle soreness from the consumption of fermented milk by *Lactobacillus helveticus* (Iwasa et al., 2013). In response to the consumers' awareness of these two imperative benefits, manufacturers are exploiting the demand by producing varieties of fermented food products with additional functional properties (Siro, 2008). Functional foods are currently part of the new market niche and the industry is kept on expanding with natural ingredients as the most influential drivers (Balthazar et al., 2017; da Silva, Barreira, & Oliveira, 2016; Granato, Nunes, & Barba, 2017). In particular, innovative processing of functional yogurt products includes the addition of probiotics, prebiotics or their combination, which is termed as synbiotic and incorporation of various bioactive components from natural sources to improve nutritional values, sensory profile, physiochemical and rheological characteristics as well as to provide therapeutic properties.

2. Varieties and health benefits of yogurt

The microbiology of lactic-producing bacteria and the fermentation biochemistry and technology of yoghurt have been well documented (Apostu & Barzoi, 2002). In general, the nutritional composition of yogurt can be varied depending on several aspects including the strains used as the starter culture, types of milk used (whole, semi or skimmed milk), species of milk obtained (i.e., cow, goat, sheep, buffalo, ewe, camel, yak, non-dairy milk), types of milk solids, solid non-fat, conditions of fermentation process as well as other components added such as sweeteners and flavour (Weerathilake et al., 2014). Yogurt has been considered to have more nutritional benefits than milk as it is nutritionally rich in protein, calcium, riboflavin, vitamin B6 and vitamin B12 (Ashraf & Shah, 2011). Moreover, it can aid the digestion process, boost immunity, ease diarrhoea and protect against cancer (Hassan & Amjad, 2010; Davoodi, Esmaeili, & Mortazavian, 2013; Prasanna, Grandison, & Charalampopoulos, 2014; McFarland, 2015). Yogurt diet is favourable towards weight management. A study revealed that high (at least 7 servings per week) consumption of yogurt is associated with lower incidence of obesity as compared to low (1 to 2 servings per week) consumption (Martinez-Gonzalez et al., 2014). Furthermore, it is associated with the reduction of weight gain when consistently in diet for years (i.e., over a 4-years period of consumption) (Winzenberg, Shaw, Fryer, & Jones, 2007). The high dairy intake from the yogurt products increases the dairy calcium intake on energy balance resulting in lower body weight or body fat mass (Zemel, Shi, Greer, Dirienzo, & Zemel, 2000).

2.1. Types of yogurt

2.1.1. Yogurt from cow milk

Approximately 85% of the world milk production is derived from cattle (FAO, 2015), which is the most common milk used for yogurt production (Ranasinghe & Perera, 2016). Yogurts from cow milk are composed of ca. 80% caseins (αs1-, αs2-caseins, β-casein and k-casein) and ca. 20% whey protein formed by the four major soluble proteins: β-lactoglobulin (β-LG), α-lactalbumin (α-LA), blood serum protein (BSA) and immunoglobulins (Igs) (Jovanovic, Barac, Macej, Vucic, & Lacnjevac, 2007; Ruprichová, Dračková, Borkovcová, & Vorlová, 2012). These proteins represent 50%, 20%, 10% and 10% of the whey proteins fraction, respectively. The whey proteins can bind with many kinds of endogenous and exogenous agents such as dietary polyphenols (Xiao et al., 2011). Whey proteins when exposed to high temperatures (> 65 °C) can irreversibly denature and coagulate, as opposed to caseins, which do not coagulate when subjected to a high heat treatment (Jovanovic et al., 2007). Caseins micelles aggregate through isoelectric precipitation brought about by the action of LAB or organic acids. The casein strands can be broken, decreasing the size of the aggregates. The rearrangement and syneresis of the acid induced casein network in yoghurt occur during storage (Everett & McLeod, 2005).

2.1.2. Yogurt from other animal's milk

Apart from cow's milk, yogurts are also derived from the milk of other animal species. For instance, yogurts derived from goat's, sheep's or buffalo's milk comprising high fat content often resulted in a more creamy texture than those made of milk with lower fat content (Sfakianakis & Tzia, 2014). While goat milk is not very popular in the Western world, it is one of the most widely consumed milk in the rest of the world mainly attributed to its nutrition properties and associated health benefits. In the recent years, the production of goat milk worldwide has increased due to increasing demand for raw goat milk and its value added products including goat milk yogurt (Ribeiro & Ribeiro, 2010). Furthermore, goat milk and its derived products are the good alternatives for people suffering from lactose intolerance as they have better digestibility and lower allergenicity (Yangilar, 2013). Sumarmono, Sulistyowati, and Soenarto (2015) reported that the predominant saturated fatty acids in goat milk yogurt are comparable to the components found in most traditional Greek yogurts, which are myristic acid (C14:0), palmitic acid (C16:0) and stearic acid (C18:0). Yogurt from goat milk has been reported to contain higher CLA (0.47–0.76 g CLA/100 g fat) than that in cow milk (0.24–0.45 gCLA/100 g fat) (Serafeimidou, Zlatanos, Kritikos, & Tourianis, 2013). Free fatty acids were also found to be significantly increased during the goat milk yogurt fermentation process compared to fresh goat milk (Güler, 2007). Frequent consumers' complaints on the rancid, goaty off flavour and odour have been stimulated into the novel formulations of goat milk yogurts supplemented with various fruit juices to add a pleasant taste and aroma. For instance, Damunupola, Weerathilake, and Sumanasekara (2014) evaluated the quality characteristics of goat milk yogurt fortified with beetroot juice. The inclusion of beetroot juice increases the moisture content and lowers the total solid content as observed during 21 days storage. Meanwhile, sensory evaluation revealed that 98% of the panellists preferred the beetroot-goat milk yogurt compared to plain goat milk yogurt. Beetroot juice managed to mask the goaty flavour and goaty odour of the goat milk yogurt thus enhancing the consumers' preference.

Although sheep milk is rarely consumed in nature, the milk is quite common in the yogurt making (Balthazar et al., 2017). Sheep milk yogurt possesses high gel strength with minimum syneresis yogurts and tends to have a slightly grainy body and texture due to higher titratable acidity and calcium content compared to cow and goat milk yogurts (Wendorff, 2005). Oleic acid (C18: 1n9) is the most predominant fatty acids in sheep milk yogurt followed by palmitic acid (C16: 0) and myristic acid (C14: 0) (Balthazar et al., 2016). Hence, the consumption of sheep milk yogurt may be health beneficial as studies showed that diets high in oleic acid could decrease the level of low-density lipoprotein (LDL) cholesterol without affecting the level of high-density lipoprotein (HDL) cholesterol (Molkentin, 2000). Sheep milk Greek yogurt has been also reported to have high content of conjugated linoleic acid (CLA) (between 0.405 and 1.250 g CLA/100 g fat) that may exhibit immunoregulatory effect and activity as anti-obesity, anticarconogenic, antioxidant as well as anti-diabetic (Wang & Lee, 2015; Yuan, Chen, & Li, 2014). Greek sheep milk yogurt is described as a good source of angiotensin-converting enzyme (ACE) inhibitory peptides that benefit those with hypertension and congestive heart failure (Politis & Theodorou, 2016).

Buffalo milk has higher concentration of protein, fat, calcium, phosphorus and total solid that other animal's milks (Nguyen, Ong, Lefèvre, Kentish, & Gras, 2013; Bilgin & Kaptan, 2016). Consequently, buffalo milk yogurt tends to contain higher fat and non-fat dry matters that provide unique texture and sensorial properties. In addition, the high total solid content and high viscosity of buffalo milk lead to an increase in gel firmness and decrease in whey production. From the textural and sensory property perspectives, yogurts made from buffalo milk alone present distinct characteristics and higher values than mixed milks of cow and ewe yogurts (Yilmaz-Erzan, Ozcan, Akpinar-Bayizit, & Delikanli-Kiyak, 2017).

2.1.3. Non-dairy probiotic products

Nowadays, the production of yogurt from non-animal based milk such as soy milk, coconut milk, rice milk, sunflower silk milk and cashew milk is also increasing, which is influenced by several factors especially health awareness and change in consumer demand (Masamba & Ali, 2013). For instance, soy yogurt is becoming popular due to its beneficial advantages in terms of nutrition and health as the product contains high protein and absence of cholesterol or lactose and only a small amount of saturated fatty acids (Kolapo & Olubamiwa, 2012). Furthermore, soy milk yogurt is considerably cheap as the soy raw material can be obtained at a much cheaper price than the cow milk. Makanjuola, (2012) previously reported the formulation of soy-corn yoghurt as a substitute for milk based yogurt with high content in protein and well balanced amino acid composition. Soy milk used for yogurt preparation has low acidification rate and slow growth of probiotic bacteria as well as prolonged fermentation time due to the low concentration of soluble carbohydrates in soy milk (Donkor, Henriksson, Vasiljevic, & Shah, 2007). Bioyogurt formulated with mixtures of 25% of soy milk and 75% of cow or buffalo milk received high scores for sensory evaluation and the optimum combination of milks helped to enhance the viable cells of probiotic bacteria (Ghoneem, Ismail, El-Boraey, Tabekha, & Elashrey, 2017). Bernat, Chafera, Chiralt, and Gonzalez-Martinez (2015) formulated a non-dairy yogurt-like product from the fermentation of almond milk by combining probiotic strains, *Lactabacillus reuteri* and *S. thermophilus*. The viability of both probiotic strains in almond milk yogurt was found to be decreasing throughout 28 days of cold storage. Nevertheless, the cell count of probiotic *L. reuteri* was above the minimum level recommended for probiotic products, which was retained at $\sim 10^7$ CFU/mL. Meanwhile, corn milk is another alternative for vegetable based yogurt products bearing balance nutritional content with sweet taste and nice aroma (Yasni & Maulidya, 2014). Sensory analysis showed that the yogurt formulated with corn extract from corn kernels mixed with 5% full cream milk powder and 10% sugar obtained the highest score. During 4 weeks of cold storage, the cell count of probiotics (*L. delbruekii*, *Streptococcus salivarius* and *Lactobacillus casei*) in the yogurt sample was retained at 1.5×10^9 CFU/mL, which was above the number for probiotics critical threshold.

2.1.4. Fruit yogurt

Besides potential health benefits, consumers tend to choose flavour as the key factor in food criteria for acceptance; thus, the addition of different fruits in yogurt to improve its flavour has been attempted progressively (Ndabikunze et al., 2017). Various studies demonstrated that adding some materials particularly fruits can increase the appealing taste of yogurt and improve the quality of yogurt particularly its nutritional properties (Hossain, Fakruddin, & Islam, 2012; Çakmakçı, Çetin, Turgut, Gürses, & Erdoğan, 2012). Organoleptic evaluation has shown a marked preference for fruity yogurt as it has more taste and pleasing flavour. In the meantime, the utilisztion of persimmon marmalade in yogurt production has improved the taste, odour, appearance, perceived sweetness and fruits taste, acidic taste, structure and overall acceptability scores (Arshlan & Bayrakci, 2016). Common fruits frequently used in formulating a functional yogurt production are peaches, orange, strawberry, pineapple, cherries, apricots and blueberries (Arslan & Özel, 2012). In general, fruits may be added to yoghurt formulae as single or blends in the form of refrigerated, frozen, canned fruit, juice or syrup (Cinbas & Yazici, 2008).

3. Roles of probiotic organisms in yogurt

3.1. Probiotic

Probiotic can be defined as a live microbial food supplement that gives health benefit through its effects in the intestinal tract (Aurelia et al., 2011; FAO/WHO, 2002). Most probiotics fall into the group of organisms' known as lactic acid-producing bacteria and are normally consumed in the form of yogurt, fermented milks or other fermented foods (Handa & Sharma, 2016). Various species of *Lactobacilli* and *Bifidobacteria* are formulated in more than 90% of probiotic products and popular among health conscious consumers (Shah, 2000; Ranadheera, Evans, Adams, & Baines, 2014). These bacteria are also considered as the Generally Recognized as Safe (GRAS) (Oakey, Harty, & Knox, 1995). Table 1 shows the genera of bacteria commonly used as a probiotics in fermented dairy product.

Table 1
Genera of bacteria that are commonly used as a probiotics in fermented dairy product (Granato, Branco, Cruz, Faria, & Shah, 2010).

Lactobacillus ssp.	*L. bulgaricus, L. cellebiosus, L. delbrueckii, L. acidopillus, L. reutri, L. brevis, L. casei, L. gasseri, L. salivarius, L. helveticus, L. rhamnosus, L. fermentum, L. plantarum, L. johnsonii*
Bifidobacterium ssp.	*B. lactis, B. thermophilum, B. longum, B. breve, B. infantis, B. bifidium, B. adalescentis, B. bifidium*
Streptococcus/ Lactococcus ssp.	*L. cremoris, L. diacetilactis, S. thermophillus, S. intermedius, S. lactis*
Bacillus ssp.	*B. subtilis, B. pumilus, B. lentus, B. licheniformis, B. coagulans*
Leuconostoc ssp.	*Leu Mesenteroides*
Propionibacterium ssp.	*Propionibacterium freudereichii* sssp. *shermanii*
Bacteriodes ssp.	*B. capillus, B. suis, B. amylophilus, B. ruminicola*
Yeast	*S. cerevisae, C. torulopis*
Fungus	*A. niger, A. oryzae*

In dairy fermentation, probiotic plays a role in assisting the preservation of milk by generating lactic acid (Ming, Halim, Rahim, Wan, & Ariff, 2016; Othman et al., 2017a; Othman et al., 2017b) and possibly antimicrobial compounds (Goudarzi, Kermanshahi, Moosavi-Nejad, & Dalla, 2017; Halder, Mandal, Chatterjee, Pal, & Mandal, 2017), production of desirable flavour compounds (i.e., acetaldehyde, diacetyl in yogurt) (Ott, Hugi, Baumgartner, & Chaintreau, 2000; Pinto, Clemente, & De Abreu, 2009) and other metabolites. These properties provide a product with organoleptic properties desired by the costumers, improve the nutritional value of food and provision of special therapeutic or prophylactic properties as cancer (Davoodi et al., 2013) and control the serum cholesterol level (Ngongang et al., 2016). For example, *Lactobacillus* isolated from a fermented vegetable called Makdoos has been demonstrated to be able to inhibit the growth of several pathogens and highly effective against *Bacillus cereus*, *Salmonella typhimurium* and methicillin-resistant *Staphylococcus aureus* (MRSA) isolate (Mahasneh & Mahasneh, 2017). Moreover, the strains comprised antibiotic resistance that was pronounced against tetracycline, streptomycin kanamycin and trimethoprim. In the meantime, *Lactobacillus animalis* LMEM6, *Lactobacillus plantarum* LMEM7, *L. acidophilus* LMEM8 and *Lactobacillus rhamnosus* LMEM9 isolated from curd showed antibiotic like activity against bacterial infection to humans (Halder et al., 2017). The potential benefits may result from the growth and action of the bacteria during the manufacturing of cultured foods (Chen et al., 2017).

Additionally, foods that contain viable probiotic microorganisms showed several health benefits such as reduction and prevention of diarrhoea, improved intestinal microbiota balance through antimicrobial effects, decreased lactose intolerance symptoms and food allergy, improved immune potency, anti-tumorigenic activities and reduced risk of colon cancers (McFarland, 2006; Vasudha & Mishra, 2013; Prasanna et al., 2014; Granato, Nazzaro et al., 2018). Probiotics also play roles as immune modulators, anti-hypertensive agents, hypocholesterolemics and perimenopausal treatments (Liong, 2007). The mechanisms by which probiotics exert their effects are largely unknown, but may involve modifying gut pH, antagonising pathogens through production of antimicrobial compounds, competing for pathogen binding and receptor sites as well as for available nutrients and growth factors, stimulating immunomodulatory cells and producing lactase (Bengmark, 2000; Benchimol & Mack, 2004). As depicted in Fig. 2, there may be four different mechanisms in which probiotic may defend against pathogens (Bermudez-Brito, Plaza-Díaz, Muñoz-Quezada, Gómez-Llorente, & Gil, 2012).

3.2. Probiotic yogurt

Probiotic products must contain an adequate numbers of viable cells from at least 10^6 to 10^7 CFU/mL at the time of consumption to certify their beneficial effects (Sohail, Turner, Coombes, & Bhandari, 2013). Conventional yogurt starter culture strains, *L. delbrueckii* subsp. *bulgaricus* and *S. thermophilus* are lack in the ability to survive passage through the intestinal tract (Mater et al., 2005). These starter culture strains may not play a significant role as probiotics in the human gut

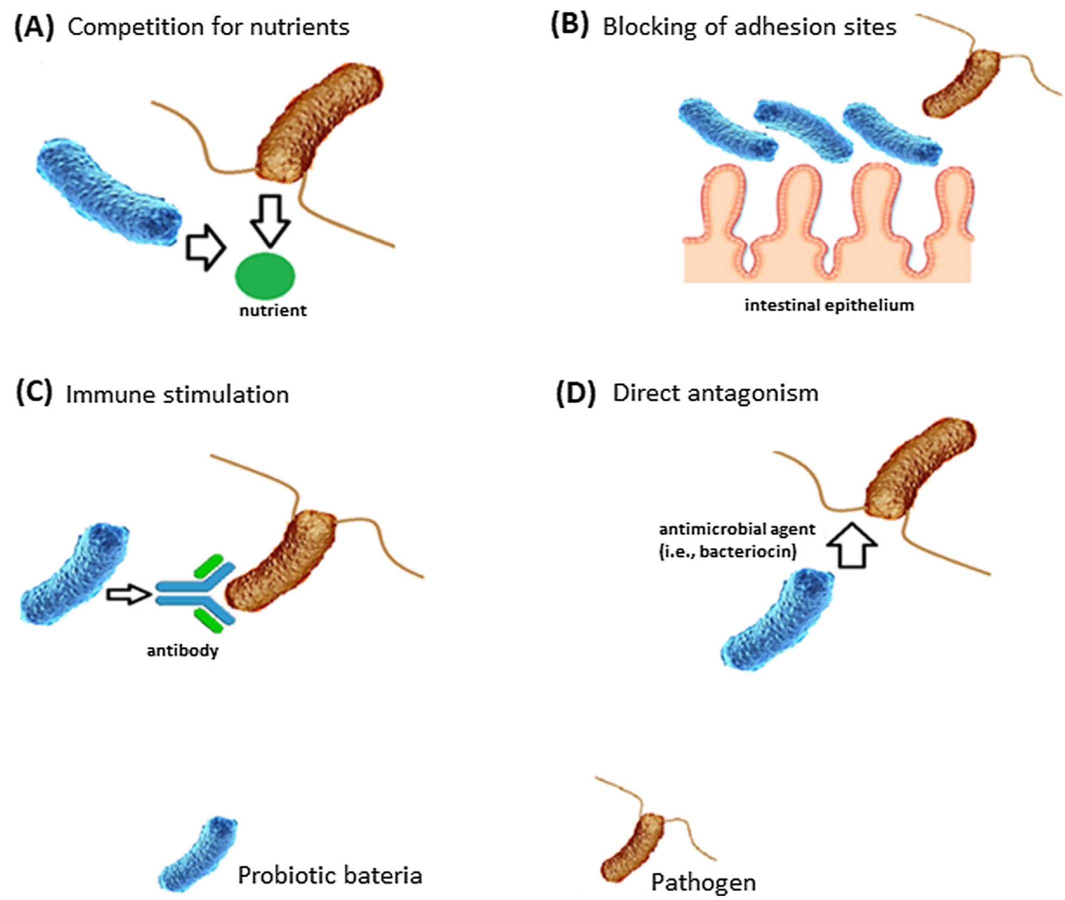

Fig. 2. Probiotics may defend against pathogen in the intestine by (A) competing against pathogens for the same essential nutrients thus leaving less available for the pathogen to utilize; (B) binding to adhesion sites and therefore preventing pathogen attachment by reducing surface area that available for pathogen colonization; (C) sending signal to immune cells which result in the secretion of cytokines, that target pathogen for destruction; (D) attacking the pathogenic organisms by releasing antimicrobial agent such as bacteriocins that kill them directly.

due to their incapability of colonizing the human intestine (McFarland, 2015). Therefore, the current trend is to add other probiotic strains during yogurt fermentation along with the starter culture bacteria to induce the probiotic effect. Basically, the manufacture of probiotic yogurt involves several steps starting from milk supplementation with dairy ingredients to increase protein concentration, homogenisation of the fortified milk, heating at 90 °C for 10 min, cooling down to 42 °C prior to inoculation with yogurt starter culture and selected probiotic bacteria (Marafon, Sumi, Alcantara, Tamime, & de Oliveira, 2010). In general, probiotic strains are selected on the basis of their safety, nutritive value and health promoting properties besides other valuable properties that may influence the shelf life, texture and appearance of the probiotic yogurt. Furthermore, selection criteria of probiotic strains must also considered the possible interactions among strains and dairy products as well as starter culture bacteria to optimise their performance and survival during storage (Casarotti, Monteiro, Moretti, & Penna, 2014). It is a common practice to combine these probiotic strains with the yogurt starter culture bacteria to reduce fermentation time (Damin, Minowa, Alcantara, & Oliveira, 2008). Nevertheless, some probiotic bacteria grow slowly in milk due to lack of essential proteolytic activity and their acidifying characteristic may affect the product texture (Lucas, Sodini, Monnet, Jolivet, & Corrieu, 2004). In comparison to yogurt starter culture, probiotic bacteria are often having a poor acidification performance in milk (Almeida, Tamime, & Oliveira, 2008). The addition of probiotic culture can reduce the acid accumulation during storage period (Kailasapathy, 2006). Furthermore, post exopolysaccharides have been observed in yogurts supplemented with probiotic cultures compared to yogurt without probiotics. High exopolysaccharides may provide a better texture for yogurt (Han et al., 2016). It is known that microbial exopolysaccharides may improve body and texture of fermented products as they serve as emulsifying or gelling agents, thickening and stabilising agents. Among various LAB, *Bifidobacterium* and *Lactobacillus* are the commonly selected genera added in the probiotic yogurt products (Chen et al., 2017). Generally, the efficiency of added probiotic bacteria in yogurt depends on dose level and their viability must be maintained throughout storage and survive the gut environment (Aryana, Plauche, Rao, McGrew, & Shah, 2007). The combination of probiotic bacterium *Bifidobacterium animalis* spp. *lactis* BL 04 with *S. thermophilus* produces rheological characteristics similar to yogurt and hence suitable to be used in the production of probiotic fermented milk (Damin et al., 2008). *Lactobacillus gasseri* 4/13 was successfully applied as an adjunct culture to yogurt starters (*L. delbrueckii* subsp. *bulgaricus* and *S. thermophilus* in combination with a commercial Direct Vat Set (DVS) yogurt starter cultures (LBB 41-8 or LBB 5-54V or LBB 435)) producing yogurt with well-accepted taste and concentration of viable *L. gasseri* 4/13 that remained above the critical threshold of 10^6 CFU/mL during 21 days storage period (Baltova & Dimitrov, 2014). Human origin probiotic strain, *L. gasseri* 4/13, is an attractive adjunct monoculture in the production of functional foods as the strain was demonstrated to have a high rate of adhesion to Caco-2 human epithelial cells, good ability in reducing cholesterol and capable of inducing the production of interferon gamma. *L. rhamnosus* GR-1 and RC-14 are other probiotic strains with the ability to be delivered in a yogurt form with good survival rate, resulting in palatable taste and texture (Hekmat & Reid, 2006). A study on the effects of short term (1 month) consumption of yogurt supplemented with probiotic strains, *L.*

rhamnosus GR-1 and RC-14, demonstrated the promotion of a desirable anti-inflammatory environment formation in the peripheral blood of inflammatory bowel disease patients without any harmful side effects (Baroja, Kirjavainen, Hekmat, & Reid, 2009).

3.3. Applications of encapsulated probiotic bacteria in yogurt

Despite the benefits offered by the incorporation of probiotic bacteria in dairy products especially yogurt, the main challenge is to maintain the viability rate of the bacteria above the critical threshold of 10^6 CFU/mL throughout the product shelf life (Lourens-Hattingh & Viljoen, 2001; Shah, 2000). Furthermore, upon consumption, the probiotic bacteria must be resistance to low pH, bile acids and digestive enzymes to remain viable during their passage through the gastrointestinal tract (Halim et al., 2017). Several brands of probiotic yogurt available in the market has been analysed to have inadequate presence of viable cells of probiotic strains such as *L. acidophilus* and *Bificobacteria* (Shah, 2000; Iwana, Masuda, Fujisawa, & Mitsuoka, 1993). This inspection has led to a new trend of application of encapsulated bacterial cells in functional food products such as yogurt aiming at increasing the viability of probiotic bacteria during shelf life. Several commonly used methods for encapsulation of probiotic strains include extrusion (Halim et al., 2017), emulsion (Kumar & Kumar, 2016), spray drying (Hernandez-Carranza, Lopez-Malo, & Jimenez-Munguia, 2014) and phase separation (Borza et al., 2010). Meanwhile, alginate (Kumar and Kumar, 2016), gelatine (Mathews, 2017), gellan gum (Totosaus, Ariza-Ortega, & Perez-Chabela, 2013), carrageenan (Cheow & Hadinoto, 2013) and starch (Donthidi, Tester, & Aidoo, 2010) are among the widely used materials for coating probiotic cells in the encapsulation process. Coating materials must be selected based on their attributes in preventing cell release and increasing the mechanical and chemical stability of the bead produced. Microencapsulated probiotic strains may be added either before or after yogurt fermentation (Krasaekoopt, Bhandari, & Deeth, 2004). It has been reported that the addition of spray dried-microencapsulated *Bifidobacterium breve* R070 and *Bifidobacterium longum* R023 in whey protein polymers have increased the survival and viability of the probiotic strains in yogurt during 28 days storage at 4 °C (Picot and Lacroix, 2004). The advantage of supplementation of encapsulated probiotic cells in yogurt has been also presented by Iyer & Kailasapathy (2005). In the study, probiotic strains *L. acidophilus* CSCC 2400 and *L. acidophilus* CSCC 2409 were coated with different coating polymers (alginate, chitosan and poly-L-lysine) by immersion technique. During a 6 weeks storage period, it was observed that the viable cell count of yogurts in the presence of encapsulated and co-encapsulated (chitosan coated) of probiotic beads was decreased only by 2-log and 1-log cycle, respectively, compared to yogurt with non-coated probiotic cells that recorded a 4-log drop in cell numbers. Meanwhile, yogurt supplemented with alginate micoencapsulated *L. rhamnosus* was more stable in terms of viability in comparison to carrageenan microencapsulated and free culture probiotic yogurts (Kumar & Kumar, 2016). In a food product application, besides the number of probiotic viable cells that mostly influenced by the encapsulation method and coating materials, the size of probiotic bead produced must also be considered. The presence of microencapsulated probiotics should not affect the sensory attributes of the products. An assessment study conducted by Krasaekoopt & Tandhandskul (2008) found that the consumer acceptances for plain and fruit yogurt containing probiotic beads were as high as 82.3% and 94.9%, respectively. Probiotic cells can also be incorporated in yogurt via immobilisation in natural supports including fruits and grains. For instance, yogurt supplemented with immobilised *L. casei* on fresh apple pieces, wheat grains or dried raisins showed improved cells viability (7 log CFU/g) after 60 days of storage at 4 °C than that obtained in yogurt with free probiotic cells (Bosnea, Kopsahelis, Kokkali, Terpo, & Kanellaki, 2017). In particular, raisins and wheat grains were the most promising supports for *L. casei* as their matrix seemed to protect the cells from acidic environment and presented less syneresis (appearance of liquid on the milk gel surfaces and gel shrinkage) due to their water holding capacity.

4. Roles of prebiotics in yogurt

Prebiotics fall into a category of functional food and can be defined as the non-digestible food ingredients that beneficially affect their host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon, thus improving host's health (Csutak, 2010). The most prevalent forms of prebiotics are classified as soluble fiber and traditional dietary sources of prebiotics including soybeans, inulin sources (such as Jerusalem artichoke, jicama, and chicory root), raw oats, unripe wheat, unripe barley, onion, banana, asparagus and yacon (Ozcan & Kurtuldu, 2014; Manning & Gibson, 2004; Oliveira et al., 2009). Nevertheless, the level of prebiotics in these food sources is generally too low to exhibit any significant effect on the composition of intestinal microflora. Thus, prebiotics are commercially extracted and concentrated from fruits and vegetables through the hydrolysis of polysaccharides from dietary fibers or starch, or through enzymatic generation. Prebiotics are the mixtures of indigestible oligosaccharides except for inulin, which is a mixture of fructooligo- and polysaccharides (Manning & Gibson, 2004; Gibson, Berry, & Rastall, 2000). Nowadays, prebiotic oligosaccharides are increasingly added to foods due to their health benefits. Some oligosaccharides used in this manner are fructooligosaccharides (FOS), xylooligosaccharides (XOS), polydextrose and galactooligosaccharides (GOS) (Csutak, 2010). Table 2 shows several studies conducted to explore the prebiotic potential of foods and their influences on LAB.

In yogurt, prebiotic acts as a substrate for the growth of probiotic

Table 2
Examples of prebiotic compounds and their influences on lactic acid bacteria (LAB).

Prebiotic	The main findings	References
Raw and roasted almonds (*Prunus amygdalus*)	Both almonds promoted the growth of *Lactobacillus acidophilus* (La-14) and *Bifidobacterium breve* (JCM 1192) and no significant differences were found between these two nuts	Liu, Wang, Huang, Zhang, and Ni (2016)
Oligosaccharides from honey	Increase growth and populations of bifidobacteria and lactobacilli	Sanz et al. (2005)
Pomegranate peel (*Punica granatum*)	Fermentation of pomegranate peel flour by colonic bacteria generated propionic, acetic and butyric acids	Gullon, Pintado, Fernández-López, Pérez-Álvarez, & Viuda-Martos (2015)
Japanese bunching onion (JBOVS)	Ingestion of JBOVS, contributed to lactate and acetate production by intestinal microbiota. Increase populations of *Lactobacillus murinus* and *Bacteroidetes* sp. in intestine	Yasuhiro et al. (2014)
Oligosaccharides from Pitaya (*Hylocereus undatus* (Haw.))	Increase resistance to gastric acidity and growth of *Lactobacillus* and *Bifidobacterium*	Wichienchot, Jatupornpipat , & Rastall (2010)
Goji berries and honey	The fortification of honey in yogurt affected the entire yoghurt microflora including LAB, manifesting bactericidal effect. The addition of goji berries in yogurt maintained the viability of LAB at probiotic levels (10^6–10^7log CFU/ml) during 21 days of storage	Rotar et al. (2015)

bacteria and consequently enhance the gastrointestinal functions and immune system. Prebiotics can also increase the absorption of calcium and magnesium, influence blood glucose levels and improve plasma lipids (Csutak, 2010). Prebiotics may also provide a positive influence on probiotic bacteria multiplication. Kumari, Ranadheera, Prasanna, Senevirathne , and Vidanarachchi (2015) observed the increase in cell count of *Bifidobacterium* in yogurt incorporated with rice compared to the plain yogurt due to the prebiotic effect. Likewise, Amarakoon et al. (2013) demonstrated that cooked rice can facilitate the growth and survival of probiotic bacteria including *Bifidobacteria*. A natural polymer, guar gum obtained from the seeds of *Cyamopsis tetragonolobus*, is another prebiotic compound that may help to stimulate the growth of probiotic bacteria or native gut microflora (Mudgil, Barak, Patel, & Shah, 2018). Previously, Mudgil, Barak, and Khatkar (2016) studied the supplementation of partially hydrolysed guar gum to act as soluble fiber enrichment while formulating a functional yogurt. In their study, guar gum was first subjected to enzymatic hydrolysis by cellulase from *Aspergilus niger* and freeze dried to powder form prior to application in yogurt. Guar gum was observed to have prominent effects on several characteristics of yogurt. In comparison to control yogurt, guar gum fortified yogurt showed an increase in pH, viscosity, water holding capacity but lower titratable acidity and was generally well accepted in terms of functional and sensory quality. In contrast, Hassan, Haggag, Elkalyoubi, Abd AL-Aziz, El-Sayed, and Sayed (2015) reported that the addition of 2.5% guar gum or 0.5% cress seed mucilage did not affect the pH, fermentation time and proteolysis extent of set-yogurt throughout the 15 days storage period at 5 ± 2 °C. Nevertheless, the presence of these potential prebiotic compounds improved the quality of set-yogurt compared to the polysaccharide free yogurt. Yogurts with good organoleptic (in terms of flavour, appearance, body and texture) acceptance were previously formulated with several polysaccharides extracted from taro corm *(Arum colocasia*), mature okra fruit (*Hibiscus esculents*) and whole plant Jew's-mallow (*Corchorus olitorius*) (Hussein et al., 2011). Further study on the effects of these plant polysaccharides on the growth of probiotic bacteria in yogurt determined their potential as prebiotic compounds.

5. The importance of synbiotic concept in yogurt

Synbiotic is a combination of probiotic and prebiotics that affects the host beneficially by improving the survival and implantation of selected live microbial strains in gastrointestinal tract (Khurana & Kanawjia, 2007). Synbiotics have great benefits to health such as antimicrobial, anticancer, anti-allergic and immune-stimulating properties (Buterikis et al., 2008). The combination of probiotic bacteria with prebiotic compound can cause the release of antibacterial substances such as bacteriocin, which can retard the growth of pathogenic bacteria. A study by Kleniewska, Hoffmann, Pniewska, and Pawliczak (2016) proven that the administration of synbiotics containing 4×10^8 CFU/mL *L. casei* and 400 mg of inulin can give positive influences on the human plasma antioxidant capacity and antioxidant enzymes activities. In addition, synbiotics can improve the absorption of minerals, prevent diarrhoea and optimise the assimilation of nutrients (Buterikis et al., 2008).

Among the commonly used probiotic strains for synbiotic product formulations are *Lactobacilli*, *Bifidobacteria* spp, *Saccharomyces boulardii* and *Bacillus coagulans*, whereas the major prebiotics used include oligosaccharides such as fructooligosaccharide (FOS), galactooligosaccharides (GOS), xyloseoligosaccharides (XOS), inulin and prebiotic from natural sources like yacon roots and chicory (Pandey, Naik, & Vakil, 2015). The formulation of synbiotic soy yogurt using probiotic strains of *L. acidophilus* NCDC11, *S. salivarius* subsp. *thermophilus* NCDC118 as well as fructooligosaccharide as prebiotic has been previously optimized using response surface methodology (RSM) (Pandey & Mishra, 2015). The mathematical modelling and optimization tools were employed to evaluate several parameters (combined effects of FOS, fermentation temperature and time, inoculum level of probiotic strain, whey separation, yogurt texture and sensory attributes) aiming to improve product characteristics and consumer acceptability. In particular, the synbiotic soy yogurt produced was satisfactory in terms of textual and sensory characteristics with good nutritional properties. Mishra & Mishra (2013) also carried out an attempt to reduce the aftertaste of soymilk yogurt and improve acidification rates and growth of probiotics by adding the FOS. The presence of 2% (w/v) FOS as recommended in dairy products provides sweetness that improves the sensory profile of soy yogurt. In the meantime, the supplementation of total dietary fibers from apple and banana in probiotic yogurt also increased the shelf life of probiotic strains, *L. acidophilus* and *B. animalis* subsp. *lactis* (do Espírito Santo et al., 2012). The effects can be associated with the high content of pectin and fructooligosaccharides in both fruits (Emaga, Robert, Ronkart, Wathelet, & Paquot, 2008). The addition of passion fruit rinds that are rich in pectin in yogurt containing similar probiotic strains (*L. acidophilus* and *B. animalis* subsp. *lactis*) exhibited a higher viscosity than the control yogurt (Espirito-Santo et al., 2013). In terms of sensory analysis, the probiotic yogurt enriched with passion fruit fiber received a good score for appearance, colour and odour, but the intensity of the flavour was considered weak. A few other studies on synbiotic yogurts and their important findings are summarised in Table 3.

6. Role of phytochemicals in yogurt

6.1. Bioactive phytochemicals

Phytochemical comes from Greek word phyto, which means plant. It is biologically active, naturally occurring chemical compounds found in plants that impart health benefits for humans beyond their use as macronutrients and micronutrients (Bloch, 2003). Generally, it is the plant chemicals that help to protect plant cells from environmental hazards or threats such as drought, UV exposure, pollution, stress and pathogenic attack (Gibson, Wardel , & Watts, 1998; Mathai, 2000). Phytochemicals recognized for their health potentials include phenolic compounds (i.e., flavonoids, phenolic, phytoestrogens), carotenoids, phytosterols and phytostanols, organosulfur and nondigestable carbohydrate compounds (Rodriguez, Flavier, Rodriguez-Amaya, & Amaya-Farfán, 2006; Saxena, Saxena, Nema, Singh, & Gupta, 2013). The health related properties of bioactive phytochemicals such as carotenoids and phenolic are believed to be due to their antioxidant activity (Prior & Cao, 2000). Antioxidant activity inhibits the oxidation of molecules caused by free radicals and is hence important for dairy food for the shelf life of the product and to provide protection for the human body against oxidative damage upon consumption (Alenisan, Alqattan, Tolbah, & Shori, 2017). Phytochemicals can be isolated and characterized from fruits, vegetables, grains, legumes, spices, beverages such as green tea and red wine as well as numerous other sources (Doughari & Obidah, 2008; Doughari, Human, Bennade, & Ndakidemi, 2009).

6.2. Applications of bioactive phytochemicals in yogurt

Owing to consumers' preferences and demands for functional foods, bioactive phytochemicals from various sources are progressively being applied as the ingredients to improve quality traits, nutritional and therapeutic properties (He et al., 2015; Alenisan et al., 2017; Granato, Santos et al., 2018). Phytochemicals can be introduced in yogurt in the form of essential oil or plant extract. The present findings by Azizkhani and Tooryan (2016) suggested that adding zataria, basil, or peppermint essential oil into probiotic yogurt formulation can improve the potential functionality of the product and provide an inhibitory effect against *Listeria monocytogenes* and *Escherichia coli.* Moreover, the addition of lemongrass leaves and stem into yogurt have been seen to improve the physicochemical properties as well as sensory characteristics of yogurt

Table 3
Examples of synbiotic yogurts.

Probiotic	Prebiotic	The main findings	Reference
Lactobacillus rhamnosus, Lactobacillus reutri	Inulin, lactulose, oligofructose	High quality of synbiotic yogurt was produced. Inulin shows more pronounced positive effect on probiotic survival as well as quality of yogurt	Shaghaghi, Pourahmad, and Mahdavi Adeli (2013)
Lactobacillus bulgaricus, Sreptococcus thermophilus	Fructo oligosaccharides (FOS)	Addition of FOS shows there is good water holding capacity and in sensory analysis, FOS incorporated product has good taste and smooth mouth feel. Natural probiotics incorporation develops good components mainly lactate, aroma compounds and exopolysacharides	Shireesha, Penchala Raju, Shobha, and Kuna (2014)
Lactobacillus casei	Fresh and freeze dried apple pieces, dried resins and wheat grains	The fruits and grains tested showed excellent prebiotic character by significantly increased the viability of probiotic strain during storage	Bosnea et al. (2017)
Lactobacillus acidophilus, Bifidobacterium animalis	Okara flour, inulin, pasteurized and frozen mango pulp, pasteurized and frozen guava pulp	The formulation of synbiotic soy yogurts showed probiotic viabilities ranging from 8 to 9 log CFU/g. The presence of mango pulp and guava pulp did not affect the viability of probiotics during storage but decreased the survival of probiotics to simulated gastrointestinal stress	Bedani, Vieira, and Rossi (2014)
Lactobacillus acidophilus, Lactobacillus plantarum, Lactobacillus rhamnosus, Streptococcus salivarius subsp. *thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*	Fructo oligosaccharides	Improved soy yoghurt characteristics with shorter fermentation time and high viable counts (9 log CFU/mL) of probiotics after 28 days of storage at 4 °C	Mishra and Mishra (2013)
Streptococcus thermophilus, Lactobacillus delbrueckii subsp. *bulgaricus, Bifidobacterium lactis*	Vegetal oil emulsion (Fabulles™), passion fruit (*Passiflora*) peel powder	The addition of vegetal oil emulsion and passion fruit peel powder did not influence the yogurt fermentation time but affected its instrumental firmness	Perina et al. (2015)

(Shaaban, Abo, Hassan, Bayoum, & Eissa, 2010). Apart from that, they also play a role in the decontamination from mycotoxigenic fungi and mycotoxins formation in yogurt. Some *in vitro* studies showed that phytochemicals in spices have significantly enhanced the growth of probiotics while inhibiting pathogens in yogurt (Be, Gamlath, & Smith, 2009; Sutherland et al., 2009). Guava (*Psidium guajava*) leaf extract was supplemented in functional yogurt made from a skimmed buffalo's milk as a source of phenolic compounds and natural antioxidant (Ziena and Abd Elhamid, 2009). The water extract of guava leaf showed changes in titratable acidity and pH during 5 days of cold storage but did not influence any deterioration effect in the organoleptic properties and the storage ability. Sun-Waterhouse, Zhou, and Wadhwa (2013) developed a drinking yogurt with supplementation of blackcurrant berry as a source of polyphenols (i.e., flavonols, flavanols, anthocyanins, proanthocyanidins, hydroxybenzoic acids and hudroxycinnamic acids). Polyphenols hold the potential heath promoting properties such as antioxidant, reduce muscle fatigue and increase peripheral blood flow. Blackcurrant berry can be incorporated into drinking yogurt to add flavour and provide antioxidant properties in the form of juice or an extract (higher polyphenol content) during pre- or post-fermentation. Blackcurrant polyphenols added during pre-fermentation of yogurt resulted in polyphenolic metabolism to small phenolic molecules and 3.5–9.5 times the total extractable polyphenol content value of drinking yogurt was obtained when blackcurrant polyphenols was added during post-fermentation. Additionally, the presence of polyphenols also influenced the appearance, growth and survival rate of *Streptococcus* and *Lactobacillus* yogurt starter cultures. Meanwhile, yogurt fortified with *Azadirachta indica* (neem) showed higher antioxidant effect with higher total titratable acid and lower pH than that observed for the plain yogurt during 28 days of cold storage period (Shori & Baba, 2013). *A. indica* yogurt showed considerably high inhibition for α-amylase, α-glucosidase and angiotensin-1 converting enzyme with a great potential to be further developed as a functional yogurt targeted to consumers with diabetes and hypertension. Table 4 summarises several other plants applied in the formulation of functional yogurt rich with various phytochemical components.

6.3. Bioactive phytochemical form fruit waste and its application in yogurt

Formulation of functional foods is directed towards the use of fruit processing wastes as they are rich in bioactive compounds and dietary fibers besides serving as practical and economic sources of antioxidant (Reddy, Gupta, Jacob, Khan, & Ferreira, 2007). High antioxidant activity in yogurt may be favourable in terms of reducing lipid oxidation process that might be responsible for unwanted chemical compounds and the formation of undesired flavour (Berset, Brand-Williams, & Cuvelier, 1994). Pomegranate peel extracts was used in the formulation of functional stirred yogurt owing to its therapeutic properties for treating various illnesses such as fever, diarrhoea, malaria, bronchitis, urinary tract infection and vaginitis (El-Said, Haggag, El-Din, & Gad, 2014). The addition of pomegranate peel extract in the yogurt prior to inoculation with yogurt starter cultures resulted in higher antioxidant activity than that measured in yogurt added with pomegranate peel extracts after the inoculation step of starter cultures. Pomegranate peel extracts had no significant effects on the flavour, appearance, body and texture, but decreased the viscosity of yogurt when added at concentrations above 25%. Recently, pineapple waste has been formulated into a functional yogurt aimed at establishing prebiotic potential, antioxidant as well as antimutagenic properties (Sah, Vasilijevic, McKenie, & Donkor, 2016). The inclusion of oven and freeze dried peel and pomace of pineapple powder increased the cell count of three probiotic strains (*L. acidophilus*, *L. casei* and *Lactobacillus* spp. *paracasei*) by 0.3–1.4 log cycle. The soluble peptide extracts of yogurt samples showed high antioxidant activity via *in-vitro* assays and exhibited antimutagenic activity when tested against mutagenicity effect of sodium azide on *S. typhimurium*. Meanwhile, Marchiani et al. (2016) utilized grape skin flour from grape pomace as a source of polyphenolic compounds in yogurt prepared by UHT whole milk and YO-MIX 401 starter culture (a mixture of *S. thermophiles* and *L. delbruckii* subsp. *bulgaricus*). Yogurt fortified with grape skin contained higher phenolic content (+55%), antioxidant activity (+80%) and acidity (+25%), but lower pH, syneresis (−10%) and fat (−20%) than those obtained in the control yogurt. Sensory analysis revealed that the yogurt fortified with grape skin showed a loss of textural quality.

Table 4
Examples of plant fortified yogurts with enriched of bioactive phytochemical components.

Plant sources	Target bioactive phytochemicals	Type of milk yogurt/starter cultures	Physiochemical/microbiological/sensory properties	References
Olive fruit	Polyphenol	Commerial Greek yogurt with 2% fat form fresh semi-skimmed cow's milk, commercial starter culture of *Lactobacillus bulgaricus* and *Streptococcus thermophiles*	Olive fruit encapsulated in maltodextrin improved polyphenol solubility, prevents decolorization of yogurt, facilitated homogenization and gradual release into yogurt matrix. Olive polyphenols influenced yogurt acidity. Populations of *Streptococcus thermophiles* and *Lactobacillus bulgaricus* were higher by 04–1.3 log CFU/g and 0.2–1.2 log CFU/g, respectively in the presence of olive polyphenols as compared to control yogurt	Georgakouli et al. (2016)
Carrot	Caratenoid, phenolic compounds	Fresh whole cow's milk, freeze-dried yogurt starter culture YC-X11 CHR HANSEN	Carrot juice increased pH and synersis of yogurt but decreased titratable acidity, and total viable counts. Higher total carotenoid content but insignificant total phenolic contents and antioxidant ferric reducing power were determined in carrot juice-yogurt as compared to control	Kiros, Seifu, Bultosa, and Solomon (2016)
Strawberry	Anthocyanins, Phenolic compounds, catechin, epicatechin, kaempferol and quercetin- 3-rutinoside	Commercial low fat white yoghurt	Strawberry decreased total antioxidant activity (−23%) and total phenolic content (−14%) in yogurt. Catechin , epicatechin, kaempferol and quercetin- 3-rutinoside were decreased after 24 h in strawberry yogurt but increased by 47%, 6%, 4% and 18%, respectively during storage	Oliveira et al. (2015)
Green, white and black tea	Phenolic compounds	Pasteurized whole milk, commercial starter culture (Chris-Hansen) containing a mixture of *Lactobacillus acidophilus* LA-5, *Bifidobacterium animalis* subsp. *lactis* Bb-12, *Lactobacillus casei* LC-01, *S. thermophiles* Th-4 and *Lactobacillus delbrueckii* spp. *bulgaricus* (ratio 4:4:1:1:1).	Green tea yogurt showed the highest phenolic content followed by white and black tea yogurts. All yogurts showed higher ferric reducing antioxidant power and ferrous ion chelating values than control yogurt during 21 days storage. Their antioxidant activities remained constant throughout the storage period	Muniandy, Shori, & Baba (2016)
Oyster mushroom (*Pleurotus ostreatus*)	Polyphenols, Phenolic compounds	Skimmed milk powder, commercial starter culture (BV-Bela Vista, YOG-03) consisting of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*.	Oyster mushroom aqueous extract increased the CFU counts of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* in yogurt. Oyster mushroom yogurt exhibited lower syneresis and firmness, but more springiness, cohesiveness and adhesiveness with darker colour and higher polyphenols and antioxidant activity than control yogurt	Vital et al. (2015)
Curcuma longa, *Tetracapidium conophorum*, *Chrysophyllum albidum* and *Piper guineese*	Alkaloids, glycosides, peptides, flavonoids, steroids, saponins	Powder whole milk (peak milk), skimmed milk, yoghurtmet culture (a mixture of *Streptococcus thermophiles* and *Lactobacillus bulgaricus*)	Yogurt fortified with *Curcuma longa* and *Chrysophyllum albidum* extracts showed the presence of flavonoids, saponins, sugars and peptides with alkaloids exhibited anti-fermentation effects. *Curcuma longa* fortified yogurt was the most preferred yogurt than the other three	Daramola, Oje, and Ouola (2013)
Açai pulp	Fatty acid, α-linolenic and conjugated linoleic acids	Skim milk, *Lactobacillus acidophilus L*10, *Bifidobacterium animalis* ssp. *lactis* Bl04 and *Bifidobacterium longum* Bl05	The addition of açai pulp in yogurt increased the monosaturate and polysaturated fatty acid, enhanced the productions of α-linolenic and conjugated linoleic acids, and increased the cell counts of probiotic strains during 4 weeks cold storage	do Espírito Santo (2010)
Pomegranate	Phenols, flavonoids, tannis, alkaloids, saponins, glycosides, triterpenoids and steroids, vitamin C	Fresh skim milk, commercial starter cultures containing a mixture of *Streptococcus thermophilus*, *Lactobacillus delbruckii* subsp. *bulgaricus* and *Bifidobacterium lactis* (Danisco France SAS CO)	Addition of crude pomegranate juice in yogurt increased the contents of ash, fat, protein and total carbohydrate, but viscosity, pH and bacteria cell counts were decreased	Ali (2016)

7. Conclusions and future aspects

Yogurt has always been one of the vital players in the spectrum of fermented food products that transform science and technology into health and wellness through diet. The science to develop functional yogurt with specific quality and potential benefits must recognize the complex biology underlying four main features, which are milk, bacteria, functional components and consumers. As probiotics and prebiotic industries are flourishing, consumers are more likely to invest on products with the highest quality and benefits. The growing interest and undeniable roles played by both probiotic and prebiotic in improving functionality of the products, enhancing sensory characteristics and extending the shelf life by inhibiting pathogens have nourished their combination as synbiotic yogurts. Moreover, the relationship of food and well-being is further enhanced with the incorporation of bioactive phytochemicals in yogurt varieties to act as functional components for health maintenance. Considering the fast evolution of functional yogurts either at research stage or marketplace, further development should demand an accurate measure of quality, safety and efficacy to meet consumers' expectations on quality and claimable health benefits. The confirmation of health promoting properties and efficacy would involve a broader range of study from *in vitro* experiments to *in vivo* and clinical studies.

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Conflict of interest

The authors have declared no conflict of interest.

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