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Review Article

Potentiality of Probiotic Fruit Yoghurt as a Functional Food - A Review

S. Sarkar*

Department of Quality Assurance, Metro Dairy Limited, West Bengal, India

Abstract

Purpose: Health consciousness coupled with enhanced health care cost has led consumer's inclination towards functional foods. Amongst diverse fermented milk products, yoghurt is mostly employed for development of functional foods due to its health image. Yoghurt can be a most suitable probiotic carrier and yoghurt containing probiotic are available in the world market. Fruits being a potential source of phenolic compounds, vitamins, bioactive compounds and minerals may also be a suitable vehicle for probiotics and recently fruit-based foods have created great interest for the development of functional foods. Fruits may not be an ideal medium, therefore bioactivities of yoghurt cultures and probiotic strains in fruit as well as milk-fruit matrix must be evaluated prior to formulation of functional foods.

Design/Methodology/Approach: Both review and research papers related to bioactivities of yoghurt cultures and probiotic cultures in fruit and milk-fruit matrices have been considered. Keywords used for data search included fruit yoghurt, fruit *dahi*, probiotic fruit yoghurt etc.

Findings: *Streptococcus thermophilus* and *Lactobacillus bulgaricus* exhibited diversity in growth behavior in plain and fruit yoghurt and were dependent on the type and concentration of fruits as well as duration of storage. Enhanced probiotic viability was noted in fruit supplemented yoghurt than plain yoghurt due to rapid utilization of phenolic compounds and organic acids such as citric acid by probiotic cultures. Inclusion of probiotic cultures and fruits in yoghurt is recommended for enhancing functional properties of traditional yoghurt.

Originality/value: Probiotic fruit yoghurt formulated with the conjugate application of probiotic cultures and fruits in yoghurt will be a most innovative functional food.

Keywords: Fruit; Functional food; Health benefits; Probiotic; Yoghurt

***Corresponding author:** S. Sarkar, Department of Quality Assurance, Metro Dairy Limited, Barrackpore-Barasat Link Road, Subashnagar, P.O. Neelgunj Bazar, District 24 Parganas (North), West Bengal, India, Pin - 700121, E-mail: drsurajitsarkar@yahoo.co.in

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Introduction

A worldwide inclination of consumers towards healthful foods has resulted in coining the term "functional foods". Health benefits of fermented food products can be classified into two groups such as nutritional function and physiological function [1]. The nutritional effect is related to the food function in supplying sufficient nutrients while physiological function concerns on the prophylactic and therapeutic benefits [2] that include prevention of diseases. Amongst diverse fermented milk products, yoghurt is well known for its healthy image and can be suitably utilized as a probiotic carrier [3,4] as milk proteins in yoghurt provide important protection to the probiotic bacteria during passage through the stomach [5]. Probiotic administration is generally recognized as safe [6] and reviewed literature on functional properties of yoghurt and probiotics suggested inclusion of probiotics in yoghurt for augmenting the functionality of plain yoghurt [7].

Fruit juices may be a better carrier than milk for probiotic due to the favorable acidic pH (2.5 to 3.7) of fruit juices [8] and good sources of saccharides, which promote probiotic growth [9], whereas the pH values (4.0 to 5.0) in milk results in loss of viability of probiotics during storage [10]. Fermented milks incorporated with fruits may be an alternative dairy product to deliver probiotic bacteria [11] and recently fruit-based foods have created great interest for the development of functional foods and nutraceuticals [12]. A significant inclination towards consumption of yoghurt with the introduction of fruits and vegetable flavoured yoghurt has been reported [13].

Use of fruits like peaches, cherries, apricots, papaya, cactus pear and blueberries during yoghurt production [14] resulted in an improvement in its nutritional and sensory properties [15]. Attempts have also been made to augment the functional properties of yoghurt with the inclusion of passion fruit peel powder [16] and pineapple waste powder [17]. Recently, it has been noted that conjugate intake of yoghurt and fruit could provide probiotics, prebiotics, high-quality protein, important fatty acids and a mixture of vitamins and minerals that have the potential to exert synergistic health effects [18]. In this article an endeavour has been made to review literature pertaining to the functionality of probiotics in yoghurt matrix with incorporated fruit pulps/juices fruits for their application during the production of yoghurt with augmented functional properties.

Viability of Yoghurt Cultures in Fruit Matrix

The initial and final counts (log cfu/ml) of *S. thermophilus* was found to be higher (8.20-8.70 and 7.98-8.34, respectively vs. 7.34-4.58) than those obtained for *L. bulgaricus* [19]. An increase in counts (log cfu/g) of *S. thermophilus* (9.02±0.06 to 9.34±0.44), but a decline in viability of *L. delbrueckii* subsp. *bulgaricus* (7.35±0.40 to7.23±0.11) during 7 days of storage of plain yoghurt was noted [20]. Total viable count (log cfu/ml) of 2-5.60 for plain yoghurt during 9 days of storage was reported [21].

It has been demonstrated that the survival of probiotic cultures in milk products can be increased with the inclusion of phenolic rich compounds [22]. Recent studies showed that olive polyphenols may stimulate the growth of several lactic acid bacteria in vitro [23] and also accelerate the drop of pH during yoghurt fermentation [24]. In presence of olive polyphenols, *S. thermophilus* had higher population (0.4-1.3 log cfu/g) during fermentation but no growth of after 7th day of storage in comparison to normal yoghurt. On the other hand *L. bulgaricus* achieved a significantly higher growth or survival (0.2-1.2 log cfu/g) in the polyphenol-enriched yoghurt not only during fermentation but also throughout the storage period [25].

It has been declared that homogenate of pineapple and kiwi to be greater inhibitory than papaya or kaki for both *S. thermophilus* and *L. bulgaricus*, latter being more sensitive due to the high osmotic pressure resulting from addition of sugar and/or fruit homogenates [26]. Diversity in growth behavior of *S. thermophilus* and *L. bulgaricus* in plain and fruit yoghurt was influenced by the type and concentration of fruits as well as duration of storage [27]. Initial viable counts (log cfu/ml) of *S. thermophilus* and *L. bulgaricus* in red berry yoghurts containing a mixture of red berry pulps of strawberry, raspberry and "pitanga" were 9.21±0.25 and 7.68±0.63, respectively which attained a value of 9.22±0.09 and 7.49±1.10, respectively after 21 days of storage at 4ºC [28]. However, no significant variation in total viable population (cfu/g) in yoghurt with the incorporation of water melon ($3.4\pm0.17x10^5$ vs. $3.3\pm0.10x10^5$) could be recorded [29]. A decline in total bacterial count (cfu/ml) of yoghurt ($6.18x10^6$) with the inclusion of papaya (7.21×10^5) or cactus pear (3.43×10^6) were reported, highest fall being noted at higher concentrations of fruits but viable counts enhanced gradually during storage in all varieties [30]. Plain yoghurt containing no fruit juice had highest (7.22 log cfu/ml) lactic acid bacteria (LAB) count, which declined (7.03 log cfu/ml) with the increasing concentration (10-25%) of fruit juice (mango and papaya) in fruit flavoured yoghurt [31]. In contrast to plain yoghurt, the total viable counts (log cfu/ml) remained lower (1.60-5.34) in yoghurt fortified with 5-15% strawberry, however highest increment was noted with the inclusion of 10% orange (2.10-5.76) and 10% grape (2.20-6.55) during 9 days of storage [21]. Addition of some types of fruit juices at concentrations higher than 15% (v/v) inhibited bacterial growth in yoghurt and this effect was more pronounced on the starter *L. bulgaricus* than on *S. thermophilus* [32]. Adding of persimmon marmalade- and (10 and 12%) induced an increase in counts of *S. thermophilus* (9.60±0.00 and 9.70±0.14, respectively) after 1 day of storage, but a declining trend was noted for *L. delbrueckii* subsp. *bulgaricus* (6.93±0.04 and 6.94±0.02). Extended storage resulted in further decline in viability of both yoghurt cultures, higher being noted at elevated concentration [20]. Result indicated better stability of *S. thermophilus* than *L. bulgaricus* in fruit matrix and is concentration dependent.

Viability of Probiotic in Fruit Matrices

Fruit may be considered ideal substrates for probiotic as they contain nutrients such as vitamins, minerals, carbohydrates, fibers and antioxidant compounds [33-35], however diversity in probiotic viability in fruit juices were reported (Table 1).

Fruits/Juices	Effect on probiotics viability	References
Grape fruit juice	Growth inhibition of *L. delbrueckii* NRRL B5448 and *L. casei* NRRL B1922 but stimulatory effect on *L. acidophilus* NRRL B4495	[36]
Lemon juice	Growth inhibition of *L. delbrueckii* NRRL B5448 and *L. casei* NRRL B1922 but stimulatory effect on *L. acidophilus* NRRL B4495	[36]
Sweet lemon juice	Retention of viability of *L. plantarum* LS5 (7.14±0.21 log cfu/ml) after after 28 days of storage at 4ºC	[37]
Orange juices	Viability of *L. reuteri* DSM 20016 decrease only by 1 log cfu/ml after 52.52 days of storage at 4ºC	[38]
Pineapple pieces	Retained viability of *L. plantarum* (7.3 log cfu/g) and *L. fermentum* (6.3 log cfu/g) after 8 days of storage at 5ºC	[35]
Pineapple juice	Viability of *L. reuteri* DSM 20016 decrease only by 1 log cfu/ml after 45.52 days of storage at 4ºC	[38]
Pomegranate juice	Growth stimulatory effect on *L. plantarum* and *L. delbrueckii* in after 14 days of storage at 4 °C	[39]
	Greater viability loss of *Lactobacillus plantarum*	[40]
	No survival of *L. paracasei* and *L. acidophilus* but short time (2 weeks) survival of *L. plantarum* and *L. delbrueckii*	[39]
Litchi juice	Viability of *L. casei* remained stable (48.0 log cfu/ml) after 4 weeks of storage at 4°C	[41]
Black currant juice	Strong viability loss of *Lactobacillus plantarum*	[40]
Aronia juice	After 24 h of incubation at 37ºC viability of *L. acidophilus*, *L. casei*, *L. rhamnosus* and *L. lactis* increased from 10.60±0.07 to 10.64±0.05-0.82±0.10 with increasing concentration of juice from 1-3%	[42]
Fig juice	Higher retention of viability of *L. delbrueckii* (6 log cfu/ml) and *L. plantarum* (5 log cfu/ml) after 4 weeks of cold storage at 4 °C, whereas *L. casei* (3 log cfu/ml) survived until 2nd week of cold storage time	[43]
Jackfruit juice	Total viabile count of yoghurt cultures (2.52×107 cfu/ml) reduced (1.52×107 to 1.85×107) with increasing concentration of juice from 5-15%	[44]
Mango juice	Retention of viability of *L. acidophilus* (1.5±1.0×107), *L. plantarum* (1.4±0.4×107), *L. casei* (1.0±0.3×106) and *L. delbrueckii* (1.6±0.4×106) after 4 weeks of storage at 4ºC	[45]
Apple juice	Retention of viability of *L. paracasei* ssp. paracasei (< log 6 cfu/ml) after 28 days of storage at 4ºC	[46]
	Retention of viability of *L. plantarum* (107 cfu/g) after 6 days of storage at 4ºC	[47]
Peach	No effect on probiotics	[48]
Red fruit juice	Viability of *L. reuteri* DSM 20016 decrease by 1 log cfu/ml after only 0.47 days of storage at 4ºC	[38]

Table 1: Probiotic viability in fruit juices.

Inclusion of probiotic cultures in juices of orange [49], acerola [50], tangerine [51], strawberry [52], cornelian cherry [53] and beet [54] has been investigated.

Grapefruit juice and lemon juice inhibited the growth of *L. delbrueckii* NRRL B5448 and *L. casei* NRRL B1922 but found stimulatory for *L. acidophilus* NRRL B4495, however grapefruit peel and lemon peel stimulated growth of all probiotic cultures [36]. Juice of pineapple [8], cashew apple [55] and melon [56] were efficient in retaining the viability of probiotics (> 8.00 log cfu/ml) even after 6 weeks of storage [55], however citric orange juice exhibited inhibitory effect [57]. White grape juice was found as a suitable medium for incorporation of *Lactobacillus paracasei*, which retained its viability ($>10^9$/200 ml) during 21 days of storage, but in simulated gastrointestinal conditions, the functional properties could be guaranteed during the 28 days of refrigerated storage [58].

Earlier vivo studies have been shown an increase in the number of Lactobacillus and Bifidobacterium with the inclusion of fruit extracts [59-62]. Fermentation of pomegranate juice by *Lactobacillus plantarum*, *Lactobacillus delbrueckii*, *Lactobacillus paracasei* and *Lactobacillus acidophilus* revealed that only *L. plantarum* and *L. delbrueckii* were capable to survive well during the first two weeks of storage [39]. Both *L. casei* and *L. plantarum* fermented sterilized papaya juice, however latter organism was more active as revealed by a more rapid drop in pH [63]. Fermentation of sweet lemon juice employing *L. plantarum* induced a significant reduction in citric acid, total phenolic compounds and sugar contents, indicating their metabolism by probiotics. After 36 h of fermentation viable population of *L. plantarum* was 8.52 log ± 0.34 log cfu/ml, which retained at a level of 7.14 log ± 0.21 log cfu/ml even after 28 d of storage at 4°C and could be used as a non-dairy functional food product [37]. Viability of probiotics noted in the *L. plantarum* fermented sweet lemon juice [37] was within the range of minimum therapeutic dosage (10^7 cfu/ml) for conferring health benefits [64,65] suggesting fruit juices as media for cultivating probiotic bacteria [66]. High nutritional value in carbohydrates, salts, minerals, dietary fiber, vitamins, fatty acids, amino acids and protein induced an increase in the viability of *B. bifidum* (7.10 log cfu/g) in supplemented yoghurt enriched with 2% of date syrup compared to plain yoghurt (6.81 log cfu/g) during 10 days of storage [67]. Amongst different fruit homogenates such as papaya, kiwi, pineapple and kaki, papaya and pineapple fruits have been selected as best flavour enhancer fruits for stirred yoghurts compared to kiwi and kaki fruits [26].

Reasons attributable for enhanced probiotic viability in presence of fruits are rapid utilization of phenolic compounds and organic acids such as citric acid by probiotic cultures [39,40,59,61]. It has been declared that fruits like apple, guava, banana and melon are potential probiotic carriers due to strong adherence of probiotics on fruit tissue [68]. Additionally, typical processing steps of fruits such as peeling and cutting can promote microbial adhesion to the fruits tissue, increasing the surface contact and the release of cellular content rich in nutrients which are ideal substrates for probiotic culture growth [35,69]. Factors affecting probiotic viability in fruit juice are strain, method of culture preparation, state of the inoculated cells, storage temperature and contents of oxygen and fibres [70,71].

Probiotic Viability in Milk-Fruit Matrices

Organic acids and phenolic components contained in fruits are used as an energy source by the probiotic bacteria whereas the water-soluble dietary fibers obtained from plant tissues exhibit a prebiotic effect [34,60,68]. Higher total antioxidant capacity (217.42 µmol Trolox/100 mL) in probiotic fermented milk beverages with cornelian cherry samples due to the high levels of ascorbic acid (7.79 mg/100 mL) and total phenolic compounds (72.32mg GAE/100 g dry weight) were reported [11].

Lowest milk coagulation time for yoghurt supplemented with aronia juice (2 h 23 min) in comparison to those supplemented with blueberry juice (2 h 40 min) or natural yoghurt (2 h 55 min) is due to greater enhancement in counts of both yoghurt cultures in yoghurt with aronia juice containing biologically active substances [72]. Diversity in viability of *Streptococcus thermophilus*, *Lactobacillus delbrueckii* subsp. *bulgaricus*, *Lactobacillus acidophilus* and *Bifidobacterium lactis* was noted in probiotic fermented milk beverages containing black mulberry, red grape and cornelian cherry, however viability of all cultures remained within the recommended biotherapeutic levels of >10^6 log cfu/mL [11]. Poor survival rate of *L. acidophilus* La-5 (32.8±3.5 vs 35.3±5.8) in mango pulp containing soy yoghurt in contrast to those containing guava pulp but no difference in extent of survival of *B. animalis* Bb-12 (83.0±1.5 vs. 83.0±1.9) in either of the fruit pulps containing soy yoghurt after 28 days under simulated gastrointestinal conditions were observed [73]. Highest total viable counts were encountered in yoghurt obtained employing *Lactobacillus rhamnosus* using blueberries (8.93log 10 cfu/g) than apple juice (8.71log 10 cfu/g) after 28 days of storage at 4±1°C [74]. However, lower total viable counts were encountered in yoghurt obtained employing *Lactobacillus acidophilus* using blueberries (7.60log 10 cfu/g) or apple juice (8.48log 10 cfu/g).

Amongst diverse probiotics, *B. animalis* subsp. *lactis* is the most promising strain in the red-fruit juice, while *L. plantarum* c19 in apple juice [75]. Probiotic custard apple *dahi* obtained by fermenting milk containing 2% custard apple powder employing *L. acidophilus* had greater Lactobacilli count (26.25x10^6 cfu/gm vs. 25.0x10^6 cfu/gm) in comparison to control *dahi* [76]. Highest viable counts (log10 cfu/g x 10^7) of *L. plantarum* (0.470±0.05) than *L. acidophilus* (0.439±0.04) or *L. casei* (0.385±0.05) in probiotic *dahi* obtained by culturing milk containing pasteurized pomegranate pulp were encountered [77]. Highest viability (1.47x10^8 cfu/g) of probiotic bacteria (*Lactobacillus acidophilus* and *Bifidobacterium aninals*) were noted in fruit yoghurt obtained employing papaya in contrast to pineapple or mango due to greater retention and survival of probiotics as papaya have more porous structure [78]. Apple fruit matrix was found most suitable as probiotic carrier due to its high porosity and better incorporation of probiotics [60] coupled with minimal viability losses (1 log cfu/g) during harsh treatment like hot air-drying [79] or passage through the gastro-intestinal tract [47].

A recent study revealed that flavour can alter the genes expressed by probiotic yoghurt organisms [80] and a product with a different flavour may have altered probiotic effects [81]. Several studies reported that addition of fruit juices or pulps in dairy beverages might also be deleterious to the viability of some species and strains of probiotics due to acidity and the presence of antimicrobial compounds such as benzoic acid and flavor compounds [82-85]. Loss of viability of *L. acidophilus* LA-5 below10^6 cfu/g were noted in yoghurts made employing *Lactobacillus acidophilus* LA-5, *Bifidobacterium animalis* subsp. *lactis* BB-12 and *Propionibacterium jensenii* 702, however the addition of fruit juice resulted in significantly increased the viability of lactobacilli, which remained higher than in plain yoghurt throughout the shelf life [86]. Results indicated that viability of probiotic cultures in milk-fruit matrix is dependent upon the type of probiotics and fruits employed.

Factors Influencing Viability of Probiotics in Fruit Matrices

- Several factors such as storage temperature, oxygen levels, pH and the presence of competitor microorganisms govern the viability of probiotic microorganisms in food matrices and therefore probiotics must be carefully evaluated prior to their inclusion to foods [87]. Further, beneficial effect of probiotics is strain-specific, therefore following minimum criteria must be considered during their administration in food products [88].
- The need to identify a probiotics at genus, species, and strain levels, using the high resolution techniques
- The viability and the presence of a sufficient amount of the probiotic in product at the end of shelf-life

- the proof of functional characteristics inherent to probiotic strains, in the controlled experiments.

Fruit juices may be a suitable vehicle for probiotics as it contains high levels of phenolic compounds [89], vitamins, bioactive compounds and minerals [90,91]. Fermentation by probiotic microorganisms enhance shelf-life as well as the nutritional and sensory properties [92] but the activity and viability of probiotics in fruit matrix is unknown [68]. Various factors effecting probiotic viability in juices can be grouped as food parameters, processing parameters and microbiological parameters [93]. Diversity in probiotic viability in fruit matrix may be attributed to the following factors:

- Different physical and chemical characteristics of the fruits
- Porosity of the fruit tissue [94]
- Concentration of phenolic compounds [52]
- Strains of probiotic cultures, inoculation state, incubation and storage temperature, content of oxygen and carbohydrates/sweeteners [74,95].
- pH of product matrix [53]
- Concentration of citric acid, protein and dietary fiber content of fruit [52]
- Storage temperature of inoculated juice [96,97].
- Concentration of acetic acid of the final product [98,99].
- All fruit juices are not equally suitable media for all probiotics [60].
- Diverse criteria for selection of probiotics in fruit matrix are depicted below.
- Must be tolerant to acidic environments of fruit juices.
- Do not lead to undesirable aromas and flavors [100]
- Must be tolerant to antimicrobial environment [92]

Probiotic Fruit Yoghurt

Yoghurt is not a major source of phenolic compounds [101] but fruits, being the major dietary source of phenolic compounds [102] can be utilized in the form of fruit juices, powders and extracts in yoghurt to enhance its phenolic content [101]. Beneficial synergistic relation between fruit and probiotic bacteria led to their incorporation in dairy products resulting in new era in functional food innovations [103,104]. A significant increase in the functionality of probiotic fermented goat milk involving *L. rhamnosus* HN001 were noted with the use of grape juice because of positive effect on the modulation of gut microbiota due to greater protective effect of grape pomace extract on the viability and antioxidant properties of grape polyphenols [105].

In Europe, strawberry is the leading fruit used for flavouring yoghurt [106] and fruit flavoured yoghurts containing sour cherries, apricots, strawberries and wild berries are commercially available in Romanian diary market [107]. Most common fruits used in yoghurt formulae are cherries, apricots, blueberries [14], papaya, cactus pear [30] and apple [108]. List of diverse fruits used for yoghurt production are depicted in Table 2.

Fruits	Scientific Name	References
Apple	*Malus pumila*	[108, 109]
Papaya	*Carica papyya L.*	[110 , 111]
Banana	*Musa sapientum*	[110, 111]
Strawberries	*Fragaria alpina*	[112, 113]
Pineapple	*Ananas comosus*	[109, 114]
Jackfruit	*Artocarpus heterophyllus*	[44, 115]
Mango	*Mangifera indica Linn*	[78, 116]
Grapes	*Vitis vinifera*	[110, 113]
Orange	*Citrus sinensis*	[21, 117]
Passion fruits	*Passiflora edulis*	[86, 118]
Water Melon	*Citrallus lanatus*	[29, 111]
Guava	*Psidium guajava*	[73]
Persimmon	*Diospyros kaki*	[20]
Sweet Lemon	*Citrus limetta*	[109]
Gac fruits	*Momordica cochinchinensis*	[118]
Isabel grapes	*Vitis labrusca L.*	[19]
Aronia	*Aronia melanocarpa L.*	[72]
Palmyrah	*Borrasus flabellifer*	[119]
Dragon	*Hylocereus undatus L.*	[120]
Fig	*Ficus carica*	[121]
Pepper	*Dennettia tripetala*	[114]
Pomegranate	*Punica granatum L*	[113]
Sapota	*Manilkara zapota*	[122, 110]
Apricot	*Prunus armeniaca*	[123]
Raspberries	*Rubus ellipticus*	[123]
Jamun	*Syzygium cumini*	[123]
Dates	*Phoenix dactylifera*	[67]
Jucara	*Euterpe edulis M.*	[124]
Gac fruit	*Momordica cochinchinensis*	[125]
Black currant	*Ribes nigrum*	[116]
Peach	*Prunus persica*	[126]

Table 2: Fruits used in yoghurt

Nutritional Benefits of Probiotic Fruit Yoghurt

Diversity in nutritional composition of plain as well as fruit yoghurt is noted (Table 3).

Inclusion of papaya induced greater carbohydrate content (8.52 vs. 7.10 g), whereas use of banana resulted in higher calcium (145 vs. 116.19 mg) and vitamin C (1.54 vs. 1.47 mg) during yoghurt manufacture [110]. An increment in contents of total solids (25.70 to 26.57%) and carbohydrate (16.84 18.56%) but a decline in ash (0.73 to 0.71%), protein (3.52 to 2.94%) and fat (4.61 to 4.06 %) in fruit yoghurt with the inclusion of 5% pineapple juice were reported [109]. However, a declining trend in all chemical parameters such as total solids (25.13, 25.40%), ash (0.68, 0.70%), protein (3.45, 3.01%) and fat (4.36, 4.02 %) were noted with the addition of 5% apple juice or 5% sweet lemon juice. Nuts constitute a good source of bioactive compounds, vegetable protein, fiber, minerals, tocopherols, phytosterols and phenolic compounds [128] and are also a good source of prebiotics with non-digestible carbohydrates [17].

Significantly higher antioxidant activity in strawberry yoghurt supplemented with bifidobacteria than plain yoghurt could be attributed to both the strawberries and probiotics [129]. Antioxidant rich fruit yoghurt developed utilizing seabuckthorn (*Hippophae rhamnoides*), fruit syrup had higher content of fat, protein, carbohydrate and antioxidants (vitamin C, vitamin E, carotenoids, phenols, anthocyanins) when compared to a commercial yoghurt [130]. Supplementation of yoghurt with natural antioxidant-rich extracts such as apple polyphenols [104], grape and grape callus extracts [131] have also been reported.

Nutrients	Whole milk Plain Yoghurt	Whole milk Fruit Yoghurt	Low-fat Plain Yoghurt	Low-fat Fruit Yoghurt	Virtually fat free fruit Yoghurt	Greek style Plain-Yoghurt
Protein (g)	8.6	6.0	7.2	6.3	7.2	8.6
Folate (µg)	27	15	27	24	12	9
Niacin (mg)	2.3	1.3	1.7	1.7	1.7	2.5
Riboflavin (mg)	0.40	0.24	0.33	0.32	0.44	0.20
Thiamin (mg)	0.09	0.18	0.18	0.18	0.06	0.18
Vitamin B12 (µg)	0.3	0.5	0.5	0.5	0.3	0.3
Calcium (mg)	300	183	243	210	195	189
Magnesium (mg)	29	20	24	23	20	20
Phosphorus (mg)	255	144	215	180	165	207
Zinc (mg)	1.1	0.6	0.9	0.8	0.6	0.8

Table 3: Nutritional composition (150 g/serving) of common varieties of yoghurt [127].

Total phenolic content of fruit flavoured yoghurts varied between 362.3 and 926.7 µg gallic acid equivalents/mL whereas the antioxidant activity ranged between 197.1- 653.8 µM Trolox [107]. In a randomized double-blind, crossover design ingestion of 400 g of olive fruit polyphenol-enriched yoghurt with 50 mg of encapsulated olive polyphenols for two weeks induced a significant decrement in levels of low density lipoprotein (LDL) cholesterol and thiobarbituric acid reactive substances [25]. Higher antioxidant potential of probiotic yoghurts than conventional yoghurt may be attributed to proteolytic activity of probiotics releasing antioxidant peptides [132].

Therapeutic Benefits of Probiotic Fruit Yoghurt

Recent interest in the development of fruit pulp based yoghurt with probiotics has been noted due to the appealing taste profiles, healthy and refreshing food [122] and an important source of active compounds providing specific health benefits including antioxidant, anti-inflammatory and antimicrobial activities [133,134]. Intake of fruits has been reported to induce significantly lowering of the risk of distal colon cancer [135] and lower odds of depression [136]. In a controlled, randomized, double-blind study ingestion of probiotic fruit yoghurt containing *Lactobacillus acidophilus* LA-5 and *Bifidobacterium lactis* BB-12 by *Helicobacter pylori*-infected subjects induced shortening of the duration of antibiotics-associated diarrhoea and improve gastrointestinal complaints [137]. Health benefits may be attributed not only to probiotic bacteria but also to the components of acidified milk such as lactic acid [137].

Incorporating citrus fruits and berries that contain phyto-chemicals may improve good health and reduce the risk of diseases [138,139], thereby improving their longitivity. Olive polyphenols induced significant decrease in LDL cholesterol after two-week consumption of polyphenol-enriched yoghurt which is attributed to the olive fruit polyphenol [25].

Dairy products including yoghurt do not contain fiber. Benefits associated with an adequate intake of dietary fiber include regulation of intestinal transit and prevention or treatment of diabetes, cardiovascular disease, colon cancer [140,141], hyperlipidaemia, hypercholesterolaemia and hyperglycaemia [141]. Fruit fibers can improve the fatty acid profile of probiotic yoghurts and utilization of by-products containing fibers from fruit processing may result in development of new high value-added fermented dairy products [85]. Addition acai pulp enhanced monounsaturated and polyunsaturated fatty acid contents in probiotic yoghurt and elevated the production of linolenic and conjugated linoleic acids during fermentation of skim milk cultured with *B. animalis ssp. lactis* B104 and B94 strains [142]. Fibers from apple, banana and passion fruit enhanced the contents of short chain and polyunsaturated fatty acid in yoghurt and a synergistic effect between banana fiber and the probiotic strain on the conjugated linoleic acid content was observed resulting in elevated amount of α-linolenic acid [85]. Dietary fiber from pineapple [17] has been reported to significantly change the population of lactic acid bacteria compared with control yoghurt [143] as dietary fiber provide additional source of carbohydrate for lactic acid bacteria. Fibers are reported to be composed of oligosaccharides, which resist digestion in the small intestine and are transported to the colon where they provide energy for gut bacteria [144].

Production of extracellular folate (22.3-135 µg/L) by isolated strains of *L. bulgaricus* and *S. thermophilus* from artisanal Argentinean yoghurts were reported [145]. Yoghurt containing walnut and almond had higher concentrations of folic acid than those fortified with pistachio and hazelnut [146]. Folic acid, selenium and tocopherol have been shown to reduce the risk of cancer and cardiovascular disorders [147]. Similar concentrations of selenium was found in yoghurt incorporated with almond or hazelnut whereas those containing pistachio (2.65–2.78 µg/100g) and almond (1.26–1.30 µg/100 g) had the highest and lowest concentration, respectively [146]. Ingestion of yoghurt containing apple revealed greater impact on reduction of dental plaque pH (4.0 vs. 5.6) in contrast to plain yoghurt, which may be attributed to added fermentable carbohydrates from fruit [108]. Highest average viable population of lactobacilli were encountered in apple juice (8.7-10.3 log cfu/ml) than in grape juice (8.0-9.8 log cfu /ml) or orange juice (7.9-8.4 log cfu /ml) after 48 of fermentation of fermentation [148]. Lower viable population (cfu/g) in banana- probiotic yoghurt ($42x10^{12}$) and sapota probiotic yoghurt ($34x10^{12}$) in comparison to normal probiotic yoghurt ($57x10^{12}$) but retention of higher viability in fruit containing probiotic yoghurt ($15\text{-}21x10^{8}$) than normal probiotic yoghurt ($9x10^{8}$) after 14 days of storage at 4±1°C were observed [148].

Conclusion

Functional properties of traditional yoghurt can be enhanced with the conjugate application of probiotic cultures and fruits. Yoghurt may not be an equally suitable media for all probiotic cultures or fruits. Bioactivities of yoghurt cultures and probiotic strains in fruit as well as milk-fruit matrix must be evaluated prior to formulation of functional foods. Probiotic fruit yoghurt is more functional than traditional yoghurt and is recommended for consumption as a dietary adjunct.

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