Potentiality of probiotic yoghurt as a functional food – a review

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Abstract

Purpose – Yoghurt is most popular and more acceptable throughout the world because of its general positive image among consumers because of its diverse nutritional and therapeutic properties and can be the most suitable probiotic carrier. Key factors for consumer’s inclination towards functional foods are increased awareness for healthy foods because of health deterioration resulting from busy lifestyles, growing healthcare cost and the aspiration for an improved quality life in later years. Yoghurt is still not consumed in certain parts of the world because of a lack of a cultural tradition of consuming yogurt and further people are not aware of the health benefits associated with yogurt consumption. In this study an attempt has been to project probiotic yoghurt as a functional food in the current era of self-care and complementary medicine.

Design/methodology/approach – Attempt has been made to review the literature on the biochemical activities of yoghurt cultures and their behavior in association with diverse probiotic cultures. Both review and research papers related to biochemical activities and functional properties of yoghurt cultures in association with probiotics and their health benefits published in diverse journals under Pub Med and Science Direct have been considered. Keywords used for data search included functional foods, yoghurt, probiotic, health benefits, etc.

Findings – Functional properties of yoghurt can be further enhanced with fortification of minerals and vitamins or inclusion of probiotic cultures. Diversity in biochemical behavior yoghurt cultures in association with different probiotic cultures has been reported. Conjugated application of probiotics with yoghurt cultures would result in a product with enhanced functional properties to extend health benefits.

Originality/value – Inclusion of probiotic cultures in yoghurt is suggested to extend the functional properties of normal yoghurt, thus providing necessary nutrients, improving health and preventing or reducing nutrition-related diseases. Regular intake of probiotic yoghurt is suggested for healthy lifestyles, as it will help in retaining their health and reduce the potentially long-term risk of disease. Food industries can have profit-driven business by projecting the probiotic yoghurt as a functional food.

Keywords Probiotic, Functional, Food, Yogurt

Paper type Literature review

Introduction

According to Functional Food Center, functional food may be defined as natural or processed foods that contains known or unknown biologically active compounds; the foods, in defined, effective and non-toxic amounts, provide a clinically proven and documented health benefit for the prevention, management or treatment of chronic disease (Martirosyan and Singh, 2015). Global demand for functional foods is expanding dramatically because of technological innovations, development of new products (Granato et al., 2010a) coupled with increasing consumer’s consciousness about health (Szkaly et al., 2012) and demand for healthy foods (Bigliardi and Galati, 2013). Functional food products resemble conventional food in terms of appearance but are composed of bioactive compounds that may offer physiological health benefits beyond nutritive functions (Arora et al., 2013).

During food processing and product development, microbial food cultures perform two major roles:
Among diverse fermented milk products, yoghurt is most popular and more acceptable throughout the world (Kumar et al., 2015) because of its general positive image among consumers (Rad et al., 2016), as it contains health-promoting ingredients (Allgeyer et al., 2010) and is considered as a nutrient-dense probiotic food, with unique properties that enhance the bioavailability of some of these nutrients and potentiality for enhancing health (El-Abbadi et al., 2014). Yoghurt possesses high nutritional value because of abundance of calcium, zinc and vitamin B (El-Abbadi et al., 2014) and exerts positive bioactive effects. Animal feeding trial revealed significantly higher apparent absorption of calcium in groups fed with traditional yoghurt with respect to the control but had no effect on absorption of magnesium and iron (Ghanem et al., 2004). Nutritional value of yoghurt can be further enhanced with mineral or vitamin fortification or introduction of probiotics. No improvement in iron status indicators but a significant improvement in hemoglobin levels and in height gain among the children ingesting yoghurt fortified with iron, zinc, vitamin A and iodine were recorded (Sazawal et al., 2013). A significant increase in plasma calcium was found in groups consuming probiotic yoghurt containing Lactobacillus casei, Lactobacillus reuteri and Lactobacillus gasseri with respect to rats receiving plain yoghurt (Ghanem et al., 2004). Rats fed with probiotic yoghurt containing Bifidobacterium lactis Bb-12 or Bifidobacterium longum Bb-46 showed an increment of apparent absorption of calcium, phosphorus and zinc by 24.7-26.6, 24-38 and 51-70 per cent, respectively, as compared with control (Abd El-Gawad et al., 2014). Nutritional composition of different varieties of yoghurt is depicted in Table I.

Recent awareness of consumers towards innovative fermented milk products containing probiotic organisms and much healthier foods (Sarkar, 2010) coupled with documented health benefits of probiotics have led to a rapid growing interest in probiotics as functional foods in the current era of self-care and complementary medicine (Sarkar, 2013a). Diverse

<table>
<thead>
<tr>
<th>Component</th>
<th>Whole milk yoghurt</th>
<th>Low fat yoghurt</th>
<th>Non-fat yoghurt</th>
<th>Greek-style yoghurt</th>
<th>Drinking yoghurt</th>
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<tbody>
<tr>
<td>Energy (kcal)</td>
<td>79</td>
<td>56</td>
<td>54</td>
<td>133</td>
<td>62</td>
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<tr>
<td>Protein (g)</td>
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<td>5.4</td>
<td>5.7</td>
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<td>Carbohydrate (g)</td>
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<td>7.4</td>
<td>8.2</td>
<td>4.8</td>
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<tr>
<td>Fat (g)</td>
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<td>0.2</td>
<td>10.2</td>
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<tr>
<td>Thiamin (mg)</td>
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<td>0.12</td>
<td>0.04</td>
<td>0.12</td>
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<tr>
<td>Riboflavin (mg)</td>
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<td>0.29</td>
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<td>Niacin (mg)</td>
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<td>0.1</td>
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<td>Vitamin B6 (mg)</td>
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<td>0.01</td>
<td>0.07</td>
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<tr>
<td>Vitamin B12 (mg)</td>
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<tr>
<td>Folate (μg)</td>
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<td>8</td>
<td>6</td>
<td>12</td>
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<tr>
<td>Carotene (μg)</td>
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<td>Trace</td>
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<tr>
<td>Vitamin D</td>
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<td>Trace</td>
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<tr>
<td>Potassium (mg)</td>
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<td>Phosphorus (mg)</td>
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<td>143</td>
<td>151</td>
<td>138</td>
<td>81</td>
</tr>
</tbody>
</table>

Source: Dairy Council (2013)
health benefits such as normalization of intestinal flora, anticarcinogenesis, hypcholesterolemic effect, alleviation of lactose malabsorption and allergy extended by probiotics led to their application as functional foods (Sarkar, 2013a). Further, reviewed literature indicated that functional properties of traditional yoghurt could be enhanced with the introduction of probiotic cultures and the resultant product may be recommended for consumption as a dietary adjunct (Sarkar, 2008).

With the increasing popularity of yoghurt, manufacturers are continuously investigating value-added ingredients to entice health-conscious consumers (Allgeyer et al., 2010) and designing of functional foods is a key research priority and a challenge for both the industry and science sectors (Granato et al., 2010b). During developing of functional probiotic foods, selection of a suitable food system to deliver probiotics is a vital factor (Ranadheera et al., 2010) and retention of viability and sensory characteristics are the major criteria for the success of these products in the market (Rouhi et al., 2013). Different probiotic strains may exhibit diverse biotechnological behavior in association with yoghurt cultures; therefore, interactive behavior among probiotic and yoghurt cultures must be evaluated before their commercial application. In this article, an attempt has been made to highlight the functional properties of yoghurt and probiotics and to evaluate their suitability for conjugated application for producing probiotic yoghurt with augmented dietetic value than traditional yoghurt.

Factors affecting consumer’s interest in functional food

According to Academy of Nutrition and Dietetics, functional foods is defined as “whole foods along with fortified, enriched, or enhanced foods that have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis at effective levels based on significant standards of evidence” (Crowe and Francis, 2013). Recent societal interest in healthy foods has led to the development of functional dairy products that basically provide health benefits in addition to their fundamental nutrients (Shiby and Mishra, 2013). Research indicated existence of a significant relationship between lifestyle and health behavior towards consumer’s preference for functional food products (Szakaly et al., 2012). Reviewed literature also indicated that generalized predictions regarding consumer choices regarding different functional foods could not be made, as it is differs considerably with gender, age, level of education, personal health status and consumer understanding of the health claims of functional foods (Ozen et al., 2012). Worldwide demand for functional food is steadily increasing, but few factors such as demographic and socio-economic characteristics (Carrillo et al., 2013), awareness and perception related to functional foods (Anunziata and Vecchio, 2013) have been identified as possible constraints for the consumer’s acceptance and subsequently development of the functional food market. Diverse factors affecting consumer’s interest in functional food are depicted below:

- rising health care costs resulting in growing trend to self-medicate to keep costs lower (Schieber, 2012);
- increasing age of the population, the obesity epidemic and the high levels of lifestyle diseases (Thompson and Moughan, 2008); and
- scientific evidence ensuring that diet can reduce diseases risk (Saini, 2017).

Plenty of functional food products are available in the market, but the consumers are either unfamiliar with the term (Christidis et al., 2011) or failed to categorize these products correctly, resulting in a significant decline in the interest towards functional foods.
Functional foods available in market can be categorized as following general groups (Crowe and Francis, 2013):

- conventional foods containing natural bioactive food compounds that provide benefits beyond basic nutrition;
- modified foods containing bioactive food compounds through enrichment or fortification; and
- food ingredients that are synthesized

Health benefits of functional foods
Marco et al. (2017) reported that enhanced nutritional and functional properties of fermented foods may be because of transformation of substrates and formation of bioactive or bioavailable end-products. Sarkar et al. (2016) declared the most promising targets of functional foods as:

- intestinal function including those control transit time, bowel habits, mucosal motility and modulate epithelial cell proliferation;
- gastrointestinal (GI) function that are associated with a balanced colonic microflora, control of nutrient bioavailability, modify GI immune activity or that are mediated by the endocrine activity of the GI system; and
- systemic function such as lipid homeostasis that are indirectly influenced by nutrient dosage or fermentation.

Further, Sarkar et al. (2016) also highlighted extension of following health benefits to human beings due to consumption of functional foods:

- reduced risk of cardiovascular disease;
- reduced risk of cancer;
- improved health in general;
- improved memory;
- improved weight loss/management;
- reduced risk of other diseases;
- reduced osteoporosis;
- improved mental health;
- quicker reaction time; and
- improved fetal health.

Functional properties of yoghurt
Functional properties of microorganisms in fermented foods include probiotics properties (Hill et al., 2014), antimicrobial properties (Meira et al., 2012), antioxidant (Perna et al., 2013), peptide production (De Mejia and Dia, 2010), fibrinolytic activity (Koth, 2012), poly-glutamic acid (Chettri and Tamang, 2014) and degradation of anti-nutritive compounds (Babalola, 2014). During food fermentation, bioactive peptides are formed by proteolytic microorganisms (De Mejia and Dia, 2010), which exhibits certain functional properties such as immunomodulatory (Qian et al., 2011), antithrombic (Singh et al., 2014) and antihypertensive properties (Phelan and Kerins, 2011).
Yogurt is an excellent dietary source of minerals and its bioavailability from yogurt is essentially equal to that from milk (Chandan and O’Rell, 2013). Yogurt consumers in comparison to non-consumers had higher potassium intakes, lower levels of circulating triglycerides, glucose and lower systolic blood pressure and insulin resistance and adequate intakes of vitamins B2 and B12, calcium, magnesium and zinc, indicating better diet quality of yogurt (Wang et al., 2013).

To compensate with the mineral and vitamin deficiency, attempts has also been made to obtain fortified yoghurt. Bonjour et al. (2015) encountered a greater prevention of secondary hyperparathyroidism and accelerated bone resorption in women consuming vitamin D (10 μg/day) and calcium (800 mg/day) fortified yogurts as compared to non-fortified control yogurts (280 mg/day). El-Kholy et al. (2011) reported no effect on the total lactic acid bacteria in iron fortified (20 mg/Kg) yoghurt even during storage. No difference in microbial growth in calcium citrate fortified (500 and 600 ppm) yoghurt; however, a decline in viable population was noted in calcium phosphate fortified yoghurt than in control yoghurt (Kaushik and Arora, 2017).

Metabolic syndrome (MetS) comprises a cluster of risk factors, including abnormal obesity, dyslipidemia, increased blood pressure and high fasting plasma glucose, which markedly increase the risk of diabetes (Type 2) and cardiovascular disease (CVD). With the exception of high blood pressure, participants consuming whole-fat yoghurt had a significantly lower risk of developing each of the MetS components than them cherishing low-fat yoghurt (Babio et al., 2015). Systematic review and meta-analysis concluded that daily intake of ≥200 g yoghurt was significantly associated with a lower risk of CVD (Wu and Sun, 2017). However, a contrary report indicated no significant alteration in blood pressure, heart rate or serum lipid concentrations compared to control milk in overweight men and women (Ivey et al., 2015).

Imbalances in GI microbiota have been referred as dysbiosis, which has been linked to several health problems such as allergies, obesity and diabetes (Biedermann and Rogler, 2015). Diabetes (Type 2) has been recognized as a serious metabolic disorder characterized by chronic hyperglycaemia as a result of insulin resistance. Several cohort studies reported strong inverse associations between yogurt consumption and the risk of Type 2 Diabetes (Chen et al., 2014a, 2014b). Recently, Salas-Salvado et al. (2017) noted a 14 per cent lower risk of Type 2 diabetes in healthy and older adults at high cardiovascular risk because of consumption (80-125 g/day) of yoghurt in comparison to subjects consuming no yoghurt. Further children with obesity and Type 2 diabetes are greater risk to hypertension, dyslipidemia, chronic inflammation, hyper-insulinemia and CVD. Higher consumption of yogurt and yogurt-based beverages may be associated with lower body fat, lower risk for CVD and higher cardio-respiratory fitness (Moreno et al., 2015).

Yogurt possesses some unique properties that may enhance its possible role in weight maintenance, but results are contradictory or non-conclusive (Jacques and Wang, 2014), inconsistent or not always statistically significant (Sayon-Orea et al., 2017). No significant difference in loss of weight, total fat, waist circumference, sagittal diameter and trunk fat could be noted in overweight women consuming yoghurt (Thomas et al., 2011). Review literature of two randomized controlled trials on human revealed greater weight losses with yogurt interventions, but the difference between the yogurt intervention and the control diet was only significant in one of these trials (Jacques and Wang, 2014). However, Chen et al. (2012) reported that ingestion of yogurt induced a 33 per cent greater reduction in body weight, a 60 per cent greater loss of body fat and a 31 per cent reduction in the loss of lean body mass in comparison to the control diet. Epidemiological studies indicated association of yoghurt consumption with lower body mass index, lower body weight/weight gain,
smaller waist circumference and lower body fat (Eales et al., 2016). Potential mechanisms of action of yogurt might be because of an increase in body fat loss, decrease in food intake and increase in satiety, decrease in glycemic and insulin response, altered gut hormone response, replacement of less healthy foods and altered gut microbiota (Panahi and Tremblay, 2016). Eales et al. (2016) suggested carefully designed Randomized Control Trials and large community-based studies for concluding impact of yoghurt on body weight or composition.

Certain people report intestinal discomfort with the consumption of lactose because of passage of undigested colonic fermented lactose through the small intestine. *L. delbrueckii subsp. bulgaricus* and *S. thermophilus* used during yogurt production contain substantial quantities of ß-D-galactosidase (Shah et al., 2013) and auto-digestion of lactose by yogurt bacteria improves its absorption, compared with other dairy products in lactase-deficient people as the bacterial lactase from yoghurt cultures can withstand the acidic conditions of the stomach, because of buffering capacity of yogurt (Savaiano, 2014).

Inactivation of potential pathogens like *Salmonella enteritidis* (Szczechowski et al., 2014) and *Listeria monocytogenes* (Szczechowski et al., 2016) in commercially produced yoghurt has been observed. Al-Nabulsi et al. (2016) recorded diversity in behavior of *Listeria monocytogenes* and *Escherichia coli* O157:H7 during manufacture and storage of camel yogurt. During fermentation, an increment in the numbers of *L. monocytogens* (0.3 log cfu/ml) and *E. coli* O157:H7 (1.6 log cfu/ml) but a declining trend (1.2 to 1.7 log cfu/ml reduction) for the former pathogen during 14 days and non-detectable level (6.3 log cfu/ml reduction) for the latter pathogen after seven days of storage at 4 or 10°C were noted.

**Functional properties of probiotic**

Reviewed literature indicated that probiotics are linked with diverse health benefits (Iannitti and Palmieri, 2010; Sarkar, 2013a; Kechagia et al., 2013; Shi et al., 2016) and beneficial microbes colonizing in the gut are able to ameliorate the overall health of humans by restructuring the gut microbial balance (Nueno-Palop and Narbad, 2010). It has been established that dietary alterations plays an important role in shaping the intestinal microflora and can induce large, temporary microbial shifts within 24 h, thereby modulating risk of several chronic diseases such as inflammatory bowel disease, obesity, Type 2 diabetes, CVD and cancer (Singh et al., 2017).

Probiotics contribute to the health of gut microbiota and can affect the composition and their metabolic functions through gastrointestinal pathways or modulation of the gut bacterial community (Kobyliak et al., 2016). Gut colonization, safety concerns (Sarkar, 2013b), documented health benefits (Sarkar, 2013a) and functional properties of probiotics and their clinical significance in preterm infants (Sarkar, 2016) and human (Begum et al., 2017) have been reviewed. Avadhani (2013) classified available evidence for health benefits conferred by probiotics into three groups:

1. **Level A recommendation** is based on strong, positive, well-conducted controlled studies in the primary literature, which are not in abstract form.

2. **Level B recommendation** is based on positive controlled studies, but in the presence of some negative studies.

3. **Level C recommendation** is based on some positive studies, but clearly an inadequate amount of data to establish the certainty of Levels A or B recommendation.

Rijkers et al. (2010) categorized the diverse health benefits extended by probiotics into three groups:
Probiotic microorganisms act directly within the GI tract through direct interaction with the intestinal microbiota or by enzymatic activities.

Probiotic microorganisms interact directly with the intestinal mucus layer and epithelium, thereby influencing the intestinal barrier function and the mucosal immune system.

Probiotic microorganisms can have effects outside the GI tract such as on the systemic immune system and other organs.

Health benefits extended by probiotic include preventing allergies (Singh et al., 2013), relieving constipation (Agrawal et al., 2009), reducing drug-associated diarrhea (de Vrese et al., 2011), reducing the duration of acute respiratory infections (King et al., 2014), reducing anxiety (Messaoudi et al., 2011), improving immune parameters in HIV patients (Hemsworth et al., 2012), prevention and control of cancer, reduction of cholesterol, regulation of blood fat, facilitation, enhancement of mineral absorption and body immune (Mishra and Mishra, 2012), management of gastric ulcers (Khoder et al., 2016), reducing skin and urogenital diseases (Iannitti and Palmieri, 2010) and extend antimutagenic, anticarcinogenic, anti-osteoporosis and immunomodulatory effects on the host (Chiang and Pan, 2012).

Some lactic acid bacteria such as Lactobacillus casei 2 W, Lactobacillus rhamnosus 27 (Chen et al., 2014a), Lactobacillus plantarum, Lactobacillus fermentum and Lactobacillus casei (Panwar et al., 2014) have been reported to possess α-glucosidase inhibitory activity and might serve to alleviate the effects of diabetes (Chen et al., 2014b; Panwar et al., 2014). Diverse health benefits extended by probiotics have been confirmed by clinical feeding trials on animals and human subjects. Lactobacillus acidophilus CCFM6 and Lactobacillus plantarum CCFM47 were able to inhibit rat intestinal α-glucosidase and can be used as probiotics with antihyperglycaemic potential in the formulation of yoghurt (Muganga et al., 2015). Among various hypoglycaemic agents, Dipeptidyl peptidase IV (DPP-IV) inhibitors from natural sources, such as dairy proteins, might be more desirable as novel anti-diabetes drugs (Lacroix and Li-Chan, 2013). L. plantarum strains ZF06-1, ZF06-3 and IF2-14 and L. brevis strain IF2-17 were found able to inhibit DPP-IV and porcine intestinal α-glucosidase and may serve as potential candidates for the management of Type 2 diabetes (Zeng et al., 2016; Angelakis et al., 2012).

Composition of gut microbiota is strongly connected with the weight of human (Dror et al., 2017) and can contribute to obesity (Angelakis et al., 2012). Obesity, in contrast to normal weight, is associated with a disease-specific dysbiotic shift in the faecal microbiota and also a lower bacterial richness (Chatelier et al., 2013). Turnbaugh et al. (2006) reported that the altered microbiota in the gut of subjects with obesity were more efficient in harvesting energy from the diet and contributed to further weight gain. Oral administration of viable strains of probiotics has been proposed for the manipulation of gut ecosystem for weight reduction or decrease weight gain (Sanders, 2016). Research-based evidence has confirmed that mechanisms of probiotic activity are diverse and are strain-specific rather than conserved within a species or genus. Some species were linked to weight gain, whereas others species were associated with weight loss. Meta-analysis revealed that Lactobacillus acidophilus, Lactobacillus fermentum and Lactobacillus ingluviei administration resulted in significant weight gain, whereas Lactobacillus plantarum and Lactobacillus gasseri are associated with weight loss (Million et al., 2012). Another report stated Bifidobacterium animalis to be associated with normal weight, whereas Lactobacillus reuteri induced obesity (Million et al., 2012). Further, an animal interventional study failed to prove any anti-obesity potential of Lactobacillus acidophilus NCDC 13 (Arora et al., 2012). Data on the effects of probiotics on body weight (BW) and body-mass index (BMI) are limited and inconsistent.
Significant reduction (Kadooka et al., 2013) or no benefits (Kadooka et al., 2010) in BMI were recorded because of intake of probiotics. Clinical trials reported that probiotic microorganisms such as Lactobacillus gasseri SBT 2055, Lactobacillus rhamnosus ATCC 53103 and the combination of L. rhamnosus ATCC 53102 and Bifidobacterium lactis Bb12 may reduce adiposity, body weight and weight gain (Mekkes et al., 2014). Functional properties of probiotic suggest their inclusion during the production of probiotic yoghurt with augmented functionality, but activities of diverse probiotic cultures must be evaluated in yoghurt matrix.

**Probiotic viability in yoghurt matrix**

Both Streptococcus thermophilus and Lactobacillus bulgaricus are capable to grow individually in milk and can have a symbiotic interaction in mixed cultures (Smid and Lacroix, 2013). Normally, yoghurt is obtained by co-fermentation employing S. thermophilus and L. bulgaricus (Sieuwerts et al., 2010) and proto-cooperation between these two species induces a more rapid growth, acidification, higher production of aroma compounds and exopolysaccharides and more pronounced proteolysis (Corrieu and Beal, 2016). Greater extent of acidification because of co-fermentation than pure culture in fresh milk (101° D ± 3.2, 62° D ± 2.7, 30° D ± 2.2) as well as in the reconstituted milk (63° D ± 1.2, 32° D ± 2.1, 20° D ± 0.6) confirmed synergistic effect or proto-cooperation between yoghurt cultures (Mchiouer et al., 2017). During yoghurt fermentation, S. thermophilus starts growing initially and utilizes the nitrogen compounds but being very sensitive to lactic its growth ceases earlier and then growth of L. delbrueckii subsp. bulgaricus begins and prolonged even at low pH, because of the better resistance to acidity. Growth of S. thermophilus is promoted by free amino acids and small peptides that arise from milk proteins by the action of the cell wall protease PrtB of L. delbrueckii subsp. bulgaricus. On the other hand, growth of L. delbrueckii subsp. bulgaricus is stimulated by formic acid, folic acid and CO₂ synthesized by S. thermophilus in milk (Corrieu and Beal, 2016). Sumarmono et al. (2015) declared that despite the synergism between S. thermophilus and L. bulgaricus, during yoghurt fermentation, higher microbial population of S. thermophilus was noted both at initial (8.20-8.70 log cfu/ml) and final stage (7.98-8.34 log cfu/ml) in comparison to those observed for L. bulgaricus (7.34-4.58 log cfu/ml). This behavior is associated with the characteristics of commercial co-cultures and may lead to a lower sensory impact resulting because of lower production of acetic acid by L. bulgaricus (do Espirito Santo et al., 2012). Settachaimongkon et al. (2014) further demonstrated that only non-proteolytic S. thermophilus strain exhibited proto-cooperation with L. delbrueckii.

Yoghurt matrix may not be suitable for every probiotic strain. Diversity in associated growth of yoghurt cultures with different probiotic organisms was noted. During yogurt fermentation, viable population of yoghurt cultures increased by an average of 1.7 log10 cycles; however, lower corresponding values of 0.88 log10 cycles and 0.61 log10 cycles, respectively, were reported when applied in conjugation with of B. breve and B. longum (Rosburg et al., 2010). An increase in the growth of L. delbrueckii ssp. bulgaricus (Log cfu/g) with the inclusion of probiotics such as B. pseudocatenulatum G4 (8.17 ± 0.03) or B. longum BB 536 (8.17 ± 0.01) in yoghurt (8.11 ± 0.03) were noted; however, probiotic supplementation induced a decline the growth of S. thermophilus (8.46 ± 0.03 to 8.47 ± 0.03 vs. 9.10 ± 0.04) with regard to control yoghurt (Al-Shereji et al., 2012a). Sarkar (2008) has reviewed the effect of probiotics on biotechnological characteristics in yoghurt matrix and suggested combined introduction of probiotic cultures such as Bifidobacterium bifidum, Bifidobacterium infantis and Lactobacillus acidophilus to augment the functional properties of traditional yoghurt.
Bandiera et al. (2013) reported that step of administration of probiotic microorganism (1h before the addition of the starter culture, together with the starter culture, after the fermentation of milk by starter culture attaining pH 4.8) during yoghurt processing did not affect the viability of probiotics and the populations of *L. casei* in yoghurt remained above 8 log cfu/g during 21 days of storage at 4°C. Tripathi and Giri (2014) announced food ingredients and additives, temperature, pH, water activity, oxygen contents and redox potentials, packaging aspects and competing bacteria to be the most critical factors affecting the viability of probiotic cells during storage. Viable population of *Lactobacillus delbrueckii* ssp. *bulgaricus* remained at levels required to confer a probiotic effect (≥6 log cfu/g) only up to ten days but *Lactobacillus casei* ATCC 393 retained its viability (≥6 log cfu/g) after 30 days but could not be detected after prolonged storage for 67 days at 4°C of storage at 4°C could in yoghurt matrix (Sidira et al., 2013). During storage of probiotic yogurts, a decline in viable population of both *S. thermophilus* (7 to 33 per cent after 21 days) and *L. delbrueckii* ssp. *bulgaricus* (50 per cent after five days) were recorded. Probiotic bacteria also lost viability but a viable population of ≥10^7 cfu/ml was retained up to 35 days for *L. acidophilus*, up to seven days for *L. casei* and up to 14 days for *L. reuteri* (Mani-Lopez et al., 2014). Remarkable loss of probiotic viability at room temperature compared to refrigerated storage (Ferdousia et al., 2013) and an increase in loss of viability with the increasing storage time, temperature and relative humidity (Min et al., 2017) were recorded.

**Selection criteria for probiotics**

Selection of suitable probiotic cultures is of utmost importance for their successful application in functional foods. Giraffa (2012) has alienated selection criteria for probiotics to be used in the food industry into four categories as safety aspects, functional aspects, technological aspects and stress response. Selection of probiotics must be based on the following important criterion which includes origin, safety, functional and pro-technological characteristics (Chassard et al., 2011):

- human or animal origin;
- resistance to bacteriocins and acids produced by the endogenic intestinal microbiota;
- competitiveness with microbiota of the intestinal ecosystem;
- high storage survival rate in finished products;
- resistance to bacteriophages (EFSA, 2005);
- validated and documented health effects;
- good sensory properties;
- large-scale production (Vasiljevic and Shah, 2008);
- survive low gastric pH;
- survive industrial manufacturing and storage conditions (Iannitti and Palmieri, 2010);
- survive low pH and proteolytic enzymes (Adams, 2010);
- acid and bile tolerant;
- adhesion to mucosal surfaces;
- antimicrobial activity against pathogenic bacteria;
- bile salt hydrolase activity (Kechagia et al., 2013);
• proliferation and colonization of the digestive tract (Saad et al., 2013);
• viability into food;
• functionality into food;
• impact on food quality;
• presence of defense mechanisms to enhance survival;
• must be suitable for commercialization (Giraffa, 2012);
• phenotype and genotype stability including plasmid stability;
• carbohydrate and protein utilization patterns;
• antibiotic resistance patterns (Wedajo, 2015);
• capability for exopolysaccharide producing (Han et al., 2016); and
• adhesion to epithelial cells (Abdelazez et al., 2017).

Potentiality of probiotic yoghurt

Functional properties probiotic yoghurt
Yoghurt is also abundant in probiotics (El-Abbadi et al., 2014) and extends diverse health benefits (El-Abbadi et al., 2014). After yogurt consumption, Lactobacillus delbrueckii ssp. bulgaricus could be detected in 73 per cent of fecal samples from yoghurt consumers, whereas only 28 per cent of samples from non-yoghurt consumers (Wang et al., 2013). Yoghurt may be further supplemented with additional probiotics with positive health outcomes (El-Abbadi et al., 2014). Significant elevation in the fecal Bifidobacterium animalis subsp. lactis BB-12 and Lactobacillus acidophilus LA-5 accompanied by significant lowering of fecal enterococci following ingestion of probiotic yoghurt by healthy adults indicated that probiotic cultures remained viable during gut transit and are associated with an increase in beneficial bacteria and a reduction in potentially pathogenic bacteria (Savard et al., 2011). A Phase I, double-blinded, randomized controlled study reported that healthy adults concurrently taking antibiotics consuming yoghurt containing Bifidobacterium animalis subsp lactis BB-12 had modestly higher fecal B. lactis and was safe and well-tolerated (Merenstein et al., 2015). Mice fed with yoghurt containing cell-free extract from Lactobacillus acidophilus La5 for four days, when subjected to a single dose of E. coli 0157:H7 (10^7 cfu per mouse) showed significantly less severe clinical manifestations of the infection (Zeinhom et al., 2012), indicating antivirulent effect.

Non-alcoholic fatty liver disease (NAFLD) is the most common form of chronic liver disease and includes simple steatosis, non-alcoholic steatohepatitis and fibrosis, which can ultimately develop into cirrhosis and even hepatocellular carcinoma (Lomonaco et al., 2013). Consumption of probiotic yogurt containing Lactobacillus acidophilus La5 and Bifidobacterium lactis Bb12 by NAFLD patients resulted in reductions of 4.67, 5.42, 4.10 and 6.92 per cent in serum levels of alanine aminotransferase, aspartate aminotransferase, total cholesterol and low-density lipoprotein cholesterol, respectively, in contrast to control group (Nabavi et al., 2014).

Gastrointestinal infections and the leakage of microbial products from the gut have a profound impact on the deterioration of the immune system among people living with human immunodeficiency virus (HIV). An improvement in productivity, nutritional intake, tolerance to antiretroviral treatment (Irvine et al., 2010) and immune function (CD4 count) in HIV-infected persons (an additional increase of 0.28 cells/mL/day versus 0.13 cells/mL/day) because of consumption of probiotic yogurt supplemented with Lactobacillus rhamnosus GR-1 (Irvine et al., 2010) have been reported. In another
study, Hummelen et al. (2011a, 2011b) observed a decline in the progression of HIV but no effect on the intestinal barrier or the intestinal microbiota with micronutrient supplementation of probiotic yogurt containing *L. rhamnosus* GR-1. However, greater decrement in CD4 count was observed in the micronutrient, probiotic group in comparison to micronutrient control group (−70 cells/μL vs −63 cells/μL).

Abnormal pattern of colonization in pre-term infants may contribute to the pathogenesis of neonatal Necrotizing Enterocolitis (NEC), an acquired GI disease associated with significant morbidity and mortality. Probiotic supplementation induced colonization of intestinal flora with *Bifidobacterium lactis* Bb12 in preterm infants and resulted in beneficial effects on survival, infection rate and incidence of NEC (Thomas and Greer, 2010) and a recent double-blind, randomized, controlled clinical trial concluded that oral probiotic supplementation with *B. breve* and *L. casei* reduced the occurrence of NEC (Braga et al., 2011). It has been established that administration probiotic such as *B. infantis, S. thermophilus* and *B. lactis* (Jacobs et al., 2013) or *Lactobacillus reuteri* (Shadkam et al., 2015) may be safe and is diminishing the incidence of NEC in very low birth weight premature infants. Reviewed literature on clinical studies indicated that probiotics may not be equally effective for all disease or disorder, all patient groups especially those born prematurely or with immune deficiency and is influenced by specific strains used, dosage and duration of administration of probiotics (Sarkar et al., 2017).

Ingestion of yoghurt supplemented with *Bifidobacterium lactis* Bb12 by women induced an increase in secretory IgA output in faeces, suggesting the ability of probiotics to prevent gastrointestinal and lower respiratory tract infections (Kabeerdoss et al., 2011). Pu et al. (2017) reported that oral administration (300 mL/day) of yoghurt supplemented with *Lactobacillus paracasei* N1115 (3.6 × 10^7 cfu/ml) for 12 weeks reduced the risk of acute upper tract infections in elderly people. Salarkia et al. (2013) noted a reduction in the number of episodes of respiratory infections and duration of some symptoms such as dyspnea and ear pain in young adult female endurance swimmers following intake of probiotic yoghurt containing *Lactobacillus acidophilus* SPP and *Bifidobacterium bifidum*.

Higher level of total cholesterol or low-density lipoproteins in human plasma is associated with higher risk of coronary heart disease. Rats fed with cholesterol-enriched diet supplemented with yoghurt containing *Bifidobacterium pseudocatenulatum* G4 or *Bifidobacterium longum* induced significant lowering of plasma total cholesterol, low-density lipoprotein cholesterol, very-low-density lipoprotein cholesterol and malondialdehyde as well as marked increase faecal excretion of bile acids (Al-Sheraji et al., 2012b). A randomized double blind controlled trial revealed that ingestion of probiotic yoghurt supplemented with *L. acidophilus* La5 and *Bifidobacterium lactis* Bb12 by subjects with Type 2 diabetes and low-density lipoprotein cholesterol was found to improve total cholesterol and low-density lipoprotein cholesterol (Ejtahed et al., 2011).

Tyramine is formed by decarboxylation of tyrosine which has a role in the central nervous system but the threshold toxic level of tyramine is 600 mg/Kg (Benkerroum, 2016) as higher exogenous tyramine causes adverse effects on human health such as migraine and hypertensive crisis (EFSA, 2011). *L. delbrueckii* subsp. *bulgaricus* DSM 20081 did not produce tyramine; however, it exhibited synergistic interactions with *S. thermophilus* RSKK 04082 (20.46 ± 2.62 mg/Kg) and *S. thermophilus* RSKK 04082+*L. plantarum* RSKK 02030 (29.23 ± 2.19 mg/kg) in terms of tyramine production (Yilmaz and Gokmen, 2017).

Recent studies suggested that manipulation of the composition of the gut microbiota might be a novel approach in the treatment of obesity. It was reported that lean and obese individuals have different ratios of Bacteroidetes and Firmicutes in contrast to normal human subjects and dietary intervention through probiotic supplementation can decrease...

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the blood glucose through improved inflammation and prevented β-cell destruction. A meta-analysis suggested that probiotic supplementation might improve metabolic control in subjects with Type 2 diabetes (Kasinska and Drzewoski, 2015) and a significant glucose-lowering effect because of intake of probiotic yoghurt containing Bifidobacterium lactis Bb12 and L. acidophilus La5 by human subjects have been noted (Ejtahed et al., 2012). Another Meta-analysis suggested that ingestion of probiotic yoghurt containing probiotics may improve glucose metabolism, higher being noted with a longer duration of intervention is ≥8 weeks or multiple species of probiotics (Zhang et al., 2015).

Peptides identified from yoghurt were reported to possess Angiotensin converting enzyme inhibition, antioxidant, antimicrobial and immunomodulatory activities (Jin et al., 2016). Yogurt supplemented with Lactobacillus casei PRA205 had higher amounts of antihypertensive and antioxidant peptides than yoghurt containing Lactobacillus rhamnosus PRA331 and could be used as adjunct culture for producing bi-functional yogurt enriched in bioactive peptides (Rutella et al., 2016).

Conclusion
Probiotic yoghurt may be a potential alternative to cater the expanding market of functional foods. Yoghurt is popular for its healthy image and can be suitably utilized as a probiotic carrier. Functional properties of normal yoghurt can be enhanced with the inclusion of probiotics, but yoghurt environment may not be favorable for all probiotic culture; therefore, bioactivity of probiotic cultures in yoghurt matrix must be evaluated before its commercial application. Inclusion of probiotic cultures in yoghurt is suggested to extend the functional properties of normal yoghurt and may emerge as most common healthful food for healthy lifestyle.

References


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