Trends in Milk and Milk Products Fortification with Dietary Fibers

Simran Kaur Arora¹, AA Patel¹, and OP Chauhan²*

Received 4 November 2014; Published online 31 January 2015

© The author(s) 2015. Published with open access at www.uscip.us

Abstract

Dietary fiber (DF) is the indigestible portion of food which helps in fighting against several diseases mainly associated with the modern life-style. However, milk is a concentrated source of life-sustaining nutrients with high digestibility and is purely devoid of DF. DF is added to milk and milk products globally either for health or for technological benefits or for sensory reasons. In the current article, those innovated dairy products are reviewed which have been developed with the incorporation of pure DF or DF rich natural sources.

Keywords: Dietary fibers; Dairy; Fortification; Health benefits

1. Introduction

Milk is nearly a balanced food as it supplies various nutrients to meet the recommended daily allowances for the body to support its growth and development. A large part of its total solids content is constituted by fat, protein and lactose. The remaining portion is water which makes almost 63-87.6% of the milk of various mammals (Belitz et al., 2009). However, fruits, and vegetables have moisture content in the range of 80-90% (Belitz et al., 2009) though among some vegetables it may vary from 72.1% in peas to as high as 96.3% in cucumbers (Table 1). It is interesting to note that though milk at similar moisture range as that of fruits and vegetable is liquid in state whereas fruits and vegetables are solids. This may be accredited to the presence of dietary fiber (DF) in fruits and vegetables which provides them rigidity and structure forming a matrix and holding water in it unlike milk, which is devoid of it. It has been established that DF helps to fight against several diseases mainly associated with the modern life-style and changed eating habits of the people, particularly those living in urban areas (Hauner et al., 2012; Anderson et al., 2009; Spiller, 2001; DeVries, 1999; Aldorí et al., 1994; Normand et al., 1987; Cummings, 1986; Anderson, 1981; Burkitt et al., 1974). Therefore, DF nowadays is widely recognized for its health
promoting roles. Dhingra et al. (2012) reviewed latest developments with regards to the extraction, applications and DF in different food products. Another interesting fact about DF is its indigestible nature. It is a well-known fact that the DF represents that portion of food which cannot be broken down by human digestive enzymes. Milk, on the other hand, is highly digestible with high protein digestibility of 95 (Malet, Blais and Tome, 2011). This may be explained by understanding the reason of production of milk by nature. The nature has provided milk to fulfill the growth demands of the newborns, which have essentially no requirement of DF due to their underdeveloped digestive system, small stomach size and need of concentrated source of nutrients to survive and grow. Overall nutritional quality of foods can be improved by consuming dairy foods (Miller et al., 2000) and is rich source of calcium (Miller et al., 2001). Over the years, there has been recorded an improvement in the availability and consumption level of milk and milk products in the World e.g. in industrialized countries the per capita availability of milk was 581.3gm/day in 1997-1999 and is expected to increase to 605.5gm/day in 2030 while that in the developing countries it was 122.2gm/day and is expected to increase to 180.3gm/day, respectively (WHO, 2003) there is a trend of fall in the per capita consumption of DF than the recommended level in the developed countries like US and in the urban areas of the developing countries. Recently King et al. (2012) published an article mentioning mean daily dietary fiber intake in US was 15.6 g/day in 1999-2000, 16.1g/day in 2001-2002, 15.5 g/day in 2003-2004, 15.8 g/day in 2005-2006, and 15.9 g/day in 2007-2008, and, these levels are much below the recommended level by WHO, i.e. 27-40g/day of total DF (Cho et al., 1999). In general, one can have DF from a variety of food sources, but certain foods are particularly valuable in this regard, as indicated in the Table 1. Keeping in view the established positive roles of milk and DF in improving the health status of individuals along with the opposite change in the intake pattern of milk and fiber, there seems a need to emphasize the higher and regular intake of both by the people across globe along with a reduced consumption of fat and active lifestyle to remain healthy. To achieve this, there seems the possibility of developing new product range with superior quality and high sensory acceptability with the fortification of dietary fibres from fruit and vegetable sources and suitable combinations of milk and milk products with DF in order to satisfy the growing needs for healthful, nutritive and balanced diet for people of all ages across globe enabling the reduction in the burden of metabolic diseases and disorders, for example, constipation, diverticulosis, diabetes, hypercholesterolemia, cancer, osteoporosis and obesity. The burden of these chronic diseases is rapidly increasing throughout world. According to a study in 2001, chronic diseases were found to cause approximately 60% of the 56.5 million total reported deaths in the world contributing approximately 46% of the global burden of disease (WHO, 2002). Therefore, in this article the recently innovated dairy products that are developed using varied sources of DF have been reviewed.

2. Dietary Fibers in Dairy Foods

Dairy products are valued for their sensory qualities as well as nutritional superiority over most foods. Because of the many virtues of milk, human being had traditionally continued to produce milk on large scale and manufacture a variety of milk products. The growing health concerns and low intake of DF had put a demand in market for dairy products fortified with DF so as to increase the consumption of DF by all the populations. Such fiber-fortified dairy products constitute a healthful food with high commercial applications too. The fortification of milk and milk products with DF has resulted from mainly under the below discussed reasons.
Enhancement of fiber content of the product

DF can be incorporated into milk and milk products as purified fiber or as fiber-rich source (Patel and Arora, 2005a). For example, bran obtained from wheat, oat, rice or other cereals have been used to fortify milk and milk products. In one research work, Sekhon et al., (1997) studied the effect of incorporation of rice bran at 5-15% level to the semolina on the extrusion behavior and the use of the extruded rice bran-added-semolina to develop kheer, a milk-based porridge. Extrusion-cooked wheat bran could also be added to yoghurt for enhancing their fiber content (John et al., 1990). Aportela-Palacios et al. (2005) studied the effect of natural and toasted wheat bran with two different flavours on yogurt quality. The pH increased while syneresis decreased with increase in fiber content (1.5, 3.0 and 4.5%). Natural bran showed greater effect on consistency than the toasted bran. Effect of fortification with date fiber, a by-product of date syrup production, on fresh yogurt has also been studied (Hashim et al. 2009). They drew a comparison between yogurt fortified with 1.5, 3.0 and 4.5% date fiber and a yoghurt with 1.5% wheat bran with ‘yogurt without fiber’. Yogurt fortified with date fiber at 3% level was found similar in sensory acceptability as the yogurt without any fiber. Ares et al. (2009) studied the incorporation of high amylose maize starch (a source of RS) into milk pudding and reported the maximum acceptable level to be 1.4% while the higher levels resulted in unacceptable changes in terms of sensory properties. Garcia et al., (1998) developed yoghurt with the use of oat fiber @1.32% while Nawar et al. (2010) reported fortification of yoghurt with microcrystalline cellulose (MCC) and found 0.1% level of incorporation of MCC to be the best in terms of organoleptic acceptability. Sendra et al. (2008) studied the effect of addition of orange fiber or lemon fiber @ 1% to the fermented milk on the probiotic bacteria and reported an increase in rheological parameters with the increase in orange fiber dose for the pasteurized fiber yoghurt (Sendra et al. 2010). Polydextrose, maltodextrin and pea fibers were reported to improve the texture and viscosity at 1.5 per cent in yoghurt (Barrantes et al., 1994; Tamime et al., 1996) without altering the activity of the starter culture. The yoghurt with polydextrose received higher sensory scores for the flavour and aroma attributes as compared to pea fiber, but the yoghurt with P-fiber 150C showed the least whey syneresis. Staffolo et al. (2004) reported that various sensory and rheological properties of yoghurt added with commercial fibers from apple, wheat, bamboo as well as inulin were acceptable at 1.3 % of addition. An innovative way of using the blends of soluble and insoluble fibers had been developed by Arora (2006) for the DF fortification of sweetened milk, yoghurt and reduced-fat rice-based milk pudding (kheer) resulting into high levels of DF in the dairy products. Fiber fortification of some other dairy products like table spread and paneer (Indian cottage cheese) have also been achieved (NDRI, 2006). Inherently milk and milk products are milky white or slightly creamish, if cooked by intense heating. Sometimes the incorporation of DF into milk products imparts some colour which may be undesirable. Garcia-Perez et al. (2005) reported that yogurt containing 0.6%, 0.8% and 1% orange fiber had more red and yellow colour than the control while Sanz et al. (2008) found that the incorporation of fiber obtained from asparagus shoots imparted a yellowish-greenish colour to the yoghurt. Because orange colour generally goes well with orange flavor therefore the yoghurt with orange fiber can be possibly flavoured with the orange flavor with the limitation of use of other flavours, for example strawberry, which is normally associated with pink colour. Also, use of orange flavor will not be ok for the yoghurt with DF from asparagus shoots and the limitations of colour will force the manufacturer to try using flavours which will match with the yellowish-greenish colour, for example lemon flavor.
Table 1 The dietary fiber content of some selected foods

<table>
<thead>
<tr>
<th>Source of Dietary Fiber</th>
<th>TS (%)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>TDF (%)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>ISF (%)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>SF (%)&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vegetables:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottle gourd</td>
<td>3.90</td>
<td>(2.00)</td>
<td>(1.70)</td>
<td>(0.30)</td>
</tr>
<tr>
<td>Carrots, raw</td>
<td>12.21&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.00</td>
<td>1.50</td>
<td>1.50</td>
</tr>
<tr>
<td>Coriander leaf, fresh</td>
<td>13.70</td>
<td>2.77</td>
<td>1.04</td>
<td>1.73</td>
</tr>
<tr>
<td>Cucumber</td>
<td>3.70</td>
<td>0.79</td>
<td>0.59</td>
<td>0.20</td>
</tr>
<tr>
<td>Peas, green</td>
<td>27.90</td>
<td>(8.60)</td>
<td>(7.20)</td>
<td>(1.4)</td>
</tr>
<tr>
<td>Potato, boiled without skin</td>
<td>22.54&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.80</td>
<td>0.76</td>
<td>1.03</td>
</tr>
<tr>
<td>Sweet potato, cooked</td>
<td>27.15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.00</td>
<td>1.89</td>
<td>1.10</td>
</tr>
<tr>
<td>Yam, cooked</td>
<td>30.10</td>
<td>3.00</td>
<td>1.89</td>
<td>1.10</td>
</tr>
<tr>
<td><strong>Cereals:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bajra</td>
<td>87.60</td>
<td>(11.30)</td>
<td>(9.10)</td>
<td>(2.20)</td>
</tr>
<tr>
<td>Bran, corn, dry</td>
<td>95.29&lt;sup&gt;c&lt;/sup&gt;</td>
<td>85.48</td>
<td>81.05</td>
<td>2.10</td>
</tr>
<tr>
<td>Bran, oat, dry</td>
<td>93.45&lt;sup&gt;c&lt;/sup&gt;</td>
<td>15.40</td>
<td>8.20</td>
<td>7.20</td>
</tr>
<tr>
<td>Bran, rice, dry</td>
<td>89.00</td>
<td>21.00</td>
<td>18.29</td>
<td>2.70</td>
</tr>
<tr>
<td>Bran, wheat, unprocessed</td>
<td>90.11&lt;sup&gt;c&lt;/sup&gt;</td>
<td>42.76</td>
<td>39.45</td>
<td>3.31</td>
</tr>
<tr>
<td>Flour, corn</td>
<td>89.09&lt;sup&gt;c&lt;/sup&gt;</td>
<td>9.59</td>
<td>5.34</td>
<td>4.26</td>
</tr>
<tr>
<td>Flour, rice, brown</td>
<td>88.03&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.60</td>
<td>3.91</td>
<td>0.679</td>
</tr>
<tr>
<td>Flour, rice, white</td>
<td>88.11&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.39</td>
<td>1.86</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>86.90</td>
<td>(11.50)</td>
<td>(9.90)</td>
<td>(1.60)</td>
</tr>
<tr>
<td>Ragi</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghum (Jowar)</td>
<td>88.10</td>
<td>13.80</td>
<td>9.61</td>
<td>4.19</td>
</tr>
<tr>
<td>Wheat (whole)</td>
<td>87.2</td>
<td>(12.50)</td>
<td>(9.60)</td>
<td>(2.90)</td>
</tr>
<tr>
<td><strong>Fruits:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple, fresh with skin</td>
<td>15.40</td>
<td>2.70</td>
<td>2.00</td>
<td>0.70</td>
</tr>
<tr>
<td>Apricot, fresh</td>
<td>80.60</td>
<td>2.40</td>
<td>1.09</td>
<td>1.29</td>
</tr>
<tr>
<td>Banana, fresh or ripe</td>
<td>29.90</td>
<td>2.39</td>
<td>1.79</td>
<td>0.60</td>
</tr>
<tr>
<td>Dates (fresh)</td>
<td>40.80</td>
<td>(7.70)</td>
<td>(6.90)</td>
<td>(0.80)</td>
</tr>
<tr>
<td>Dates (dry)</td>
<td>84.70</td>
<td>(8.30)</td>
<td>(6.90)</td>
<td>(1.40)</td>
</tr>
<tr>
<td>Grapes, fresh</td>
<td>20.80</td>
<td>1.00</td>
<td>0.60</td>
<td>0.40</td>
</tr>
<tr>
<td>Mango, fresh</td>
<td>19.00</td>
<td>1.80</td>
<td>1.05</td>
<td>0.73</td>
</tr>
<tr>
<td>Orange, fresh</td>
<td>2.30</td>
<td>(1.10)</td>
<td>(0.60)</td>
<td>(0.50)</td>
</tr>
<tr>
<td>Papaya, fresh</td>
<td>9.20</td>
<td>1.80</td>
<td>0.90</td>
<td>0.89</td>
</tr>
<tr>
<td>Peach, fresh</td>
<td>14.00</td>
<td>2.00</td>
<td>1.20</td>
<td>0.79</td>
</tr>
<tr>
<td>Pear, fresh</td>
<td>14.00</td>
<td>2.39</td>
<td>1.10</td>
<td>1.30</td>
</tr>
<tr>
<td>Pineapple, fresh</td>
<td>12.20</td>
<td>1.20</td>
<td>1.09</td>
<td>0.09</td>
</tr>
<tr>
<td>Raisins, uncooked</td>
<td>79.80</td>
<td>4.00</td>
<td>2.89</td>
<td>1.09</td>
</tr>
<tr>
<td>Raspberries, fresh</td>
<td>15.20</td>
<td>6.79</td>
<td>6.09</td>
<td>0.69</td>
</tr>
<tr>
<td>Sapota (chiku)</td>
<td>26.30</td>
<td>(10.90)</td>
<td>(9.10)</td>
<td>(1.80)</td>
</tr>
<tr>
<td>Strawberries, fresh</td>
<td>12.20</td>
<td>2.29</td>
<td>1.70</td>
<td>0.59</td>
</tr>
<tr>
<td><strong>Nuts and seeds:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Almonds</td>
<td>94.80</td>
<td>11.19</td>
<td>10.09</td>
<td>1.09</td>
</tr>
</tbody>
</table>
Replacement of fat or for some technological benefits

Between the two kinds of DF, soluble fiber has been used extensively in the research studies as well as in the market products to replace the fat content of milk and milk products. Among the several soluble fibers, inulin or oligo-fructose have found the most successful applications in dairy products such as skim milk based drink, fermented milk/drink, cheese, dessert and ice cream. Several studies are available in the literature with regards to the effect of inulin addition on physical and sensory properties of dairy products. Villegas and Costell (2007) reported that the addition of inulin (@4–6%) to skimmed milk beverages was found to increase the viscosity, approximating it to that of 3.1% fat beverages. Similar effect was also observed upon addition of 6% inulin to low-fat custard with low starch concentration (2.5 and 3.25%) (Tarrega and Costell, 2006). Tomas et al. (2008) studied the effect of long-chain inulin incorporation on the visco-elastic properties of low and full-fat desserts and reported that low impact of inulin (@ 2.5 to 7.5%) on the visco-elasticity of whole-milk desserts. Long-chain inulin (@3%) was found to improve the creamy mouth-feel of low-fat stirred yoghurt by exerting a beneficial effect on the airy, thickness as well as stickiness attributes (Kip et al., 2006). Aryana et al. (2007) also reported that chain length of inulin (small, medium or long) affects the pH and syneresis of yogurt, inulin being helping the survival of L. acidophilus in the dairy product. However, Guven et al. (2005) found that the use of inulin (Raftiline HP) had no effect on the pH values but it negatively influenced some physical properties including whey separation, consistency and organoleptic properties of fat-free yogurt. Higest consistency was found in yogurt containing 1% inulin. Bayarri et al. (2010) studied the effect of carrageenan and a blend (50:50) of short and long-chain inulin addition on the rheological behaviour as well as sensory properties of low-fat carboxymethyl cellulose semi-solid dairy desserts. The samples with 0.03% carrageenan or with 9% of the inulin blend displayed identical rheological behaviour as compared to the full-fat control sample showing similar thickness, creaminess and smoothness values. However, the substitution of fat by carrageenan or inulin affected the sweetness and flavor sensory values.

Guggisberg et al. (2009) showed that firmness, yield stress and creaminess of low-fat set yoghurt increased with increase in inulin and fat contents; however, the highest inulin level considered (4%) was not found sufficient to imitate whole-milk yoghurt. In contrast, Paseephol et al. (2008) reported that 4% inulin addition to non-fat set yoghurt resulted in lower yield stress and gel stiffness similar to that of the full-fat yoghurt. Addition of 5% inulin to low-fat fresh Kashar cheese also enhanced the texture and other sensory properties (Koca and Metin, 2004). The low-fat cheese containing inulin as well as full-fat cheese were not as hard, elastic or gummy as the low fat cheese.

---

<table>
<thead>
<tr>
<th>Substance</th>
<th>TS</th>
<th>ISF</th>
<th>SF</th>
<th>TDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cashew</td>
<td>94.10</td>
<td>3.80</td>
<td>3.46</td>
<td>0.33</td>
</tr>
<tr>
<td>Coconut, fresh</td>
<td>63.70</td>
<td>(13.60)</td>
<td>(12.70)</td>
<td>(0.90)</td>
</tr>
<tr>
<td>Gingely (sesame)</td>
<td>94.70</td>
<td>(13.60)</td>
<td>(13.60)</td>
<td>(3.20)</td>
</tr>
<tr>
<td>Mustard seeds</td>
<td>91.50</td>
<td>(13.60)</td>
<td>(10.20)</td>
<td>(3.40)</td>
</tr>
<tr>
<td>Peanuts</td>
<td>97.00</td>
<td>(11.0)</td>
<td>(8.50)</td>
<td>(2.50)</td>
</tr>
<tr>
<td>Poppy seeds</td>
<td>95.70</td>
<td>(33.60)</td>
<td>(22.40)</td>
<td>(11.20)</td>
</tr>
<tr>
<td>Walnuts</td>
<td>95.50</td>
<td>4.80</td>
<td>3.30</td>
<td>1.50</td>
</tr>
<tr>
<td>Milk</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

TS: Total solids, TDF: Total dietary fiber, ISF: Insoluble dietary fiber, SF : Soluble dietary fiber. aGopalan et al. (2004) (values for the edible portion), b calculated from Spiller, 2001; figures in parentheses are from Gopalan et al. (2004), c calculated from Cho et al. (1999).
and showed greater meltability. Cardarelli et al. (2008) found the best combination of petit-suisse cheese in terms of technological and sensory acceptability added with oligofructose in combination with inulin (5% each) and showing good viable counts of L. acidophilus and Bifidobacterium animalis subsp. lactis. Kantha (2005) developed a low fat soy fiber and inulin added paneer and reported that paneer developed from milk with 2.5% fat and 0.56% soy fiber or 1.8% fat and 4.5% inulin had similar sensory attributes to that prepared from full cream milk (6% fat). Product type and composition affect viscosity with the inclusion of long-chain inulin in a similar fashion to that of fat globules. In the case of reduced-fat ice-cream, addition of long-chain inulin was found to increase hardness and viscosity, and also lowered the freezing point with improved sensory attributes (Schaller-Povolny and Smith, 1999). Use of inulin as fat substitute has also found beneficial for various physico-chemical and sensory properties of low-fat ice creams (Aykan et al., 2008; Kaur et al., 2007; Singh et al., 2006; Devereux et al., 2003; El-Nagar et al., 2002). Inulin has also been used as corn syrup replacer in reduced-fat ice cream (Povolny and Smith, 1999, 2001, 2002). It also improves the physical and sensory properties of low-fat set yoghurt (Srisuvor et al., 2013). Isik et al. (2011) developed frozen yoghurt fortified with 6.5% inulin and 6.5% isomalt with no added sugar and found it similar to the control. Polydextrose (@5.0%), as bulking agent, along with the mixture of artificial sweeteners (aspartane and acesulfame-k, @0.065%) was used in the study.

Dietary fibers in the form of resistant starch (RS) have also been used as fat replacers in various dairy products. Herrero et al. (2006) added N330 (Novelose330, retrograded resistant starch) in imitation cheese to reduce the fat content and achieved high levels of fiber inclusion without much impairing the physico-chemical properties (texture, rheology, meltability and microstructure). Noronha et al. (2007) developed imitation cheese with added Novelose 240 (native resistant starch). Fat replacement in high-moisture cheeses resulted in the production of a firm cheese. RS up to a level of 43.2% dry matter has been found suitable for incorporation into cheeses with acceptable functional properties.

β-glucan is known for its beneficial physiological effects such as reduction of blood cholesterol and smooth mouth-feel and reduced calorie input. Addition of 0.5% barley β-glucan or inulin and guar gum (>2%) was effective in improving serum retention and visco-elastic properties in low-fat yogurt (Brennan and Tudorica 2008). Oatrim is one of the carbohydrate-based fat substitutes obtained by treating the oat flour with enzyme and is a nearly tasteless white powder consisting primarily amylodextrins and soluble fiber (β-glucan, usually at 5–10% by weight). It has been used as a fat substitute in several foods including muffins, cookies, candies, salad and dressings, margarine, and breakfast cereals. It can be used in skim milk to provide 0.8 g DF per 240 ml serving to overcome the bland mouth-feel, watery appearance and for cholesterol-lowering properties (Pszczola, 1996). About 50% level of fat replacement in butterfat with oatrim is possible without impeding the physical, textural, and sensory properties of oatmeal cookies (Wekwete and Navder, 2008).

Gums are the major class of viscous soluble fibers. For decades the several gums like carrageenan, sodium alginate, xanthan gum, locust bean gum and gelatin, carboxymethyl cellulose etc. are used to improve the textural properties of ice cream, provide a uniformly smooth bulk, desirable resistance to melting, and improved handling properties primarily by retarding crystal growth during temperature fluctuations (Regand and Goff, 2003). Voulasiki and Zerfiridis (1990) produced
functional yogurt-ice cream containing xanthan gum (0.2%) or guar gum (0.3%) or a commercial stabilizer (0.5%) while Soukoulis and Tzia (2008) used different hydrocolloids (xanthan gum, guar gum and carboxy methyl cellulose) and skim milk powder or whey powder to standardize the recipe for frozen yoghurt. Xanthan gum (at 0.2%) along with the partial substitution of skim milk powder by whey powder was reported to increase the overall acceptance and creaminess of the frozen yoghurt. Recently, Soukoulis et al. (2009) also showed the potential use of oat, wheat, apple and inulin as DF sources to control crystallization and recrystallisation in frozen dairy products, particularly ice cream.

**Probiotic or synbiotic effect**

Soluble fiber preparations have gained tremendous popularity over the years as a fiber ingredient for use in various dairy products for their physiological and functional roles. In recent years, yogurts containing probiotics have gained popularity. These products contain *Lactobacillus* and *Bifidobacterium* species at $10^6$ viable cells per millilitre of the product at the time of consumption (Arunachalam, 1999). As such, there is no RDA of prebiotics, but doses in the range of 4-20 g/d are required to show health benefits (Tuohy et al., 2003). Glucans, fructans and mannans are common prebiotics. Among the fructans, inulin and oligofructoses are commonly used (Oliveira et al., 2009). Correa-Matos et al. (2003) reported that the milk formula with added fermentable fiber enhanced the intestinal function and reduced the severity of induced infection by *Salmonella typhimurium* in piglets. Addition of fermentable fiber to the milk compositions is a cost-effective way to overcome the severity of infection-associated symptoms in infants. Euler et al. (2005) found a statistically significant increase in Bifidobacteria after seven days of oligofructose feeding in milk formula to infants, which was however, not maintained after discontinuation of oligofructose-fortified milk formula. It suggests the importance of continual use of oligofructose. Brunser et al. (2006) also conducted a similar study where 113 young children (1-2 years old) were fed a milk formula with or without oligofructose-enriched inulin for three weeks following cessation of amoxicillin (amoxicillin decreased total fecal bacteria by 30% and increased *E. coli*), and the results were compared to the period prior to the antibiotic. Administration of oligofructose-enriched inulin was found to significantly increase *Bifidobacteria*, whereas, the total fecal bacterial counts in terms of of *E. coli* rapidly returned to pre-antibiotic levels independent of prebiotic administration within one week of cessation of the antibiotic. Inulin has been found by many researchers to go well with the milk products because of its slightly sweet taste, white colour, good solubility and lesser viscosity in comparison to other soluble fibers. Miremadi and Shah (2012) reviewed the effect of inulin and probiotics on colonic microbiota and efficiency of functional attributes of synbiotic foods in formulation and development of new dairy products. Recent trend for incorporating DF into yoghurt is also accompanied with the addition of the probiotic cultures (this is known as synbiotic) and the effect of DF on the probiotic culture is studied. One such study was performed by Gonzalez, Adhikari and Madriz (2011). They found significant differences in 8 out of the 12 attributes of the drinking yogurt because of the addition of prebiotic (fructo-oligosaccharide, Raftilose P 95 @1.4%) or synbiotic (fructo-oligosaccharide @1.4% and *Lactobacillus acidophilus* Lafti-L10). The synbiotic samples had higher intensities of sour and yeasty aroma and lower sweetness as compared to the control samples and the samples containing only prebiotic. The consumer results indicated more liking of the whole milk based yogurt beverages over the skim milk yogurt beverages, the whole milk beverage containing the prebiotic being the most liked. When wheat bran was added at the rate of 15% to milk before incubation with 4% yoghurt culture (Costmagna and Rossi, 1977), it was
found that the wheat bran addition did not retard the growth of *Streptococcus thermophilus* and showed beneficial effects on the growth of *Lactobacillus bulgaricus*. Ozer et al. (2005) observed that the addition of inulin caused a substantial increase in the cell counts of *Bifidobacterium bifidum* BB-02, being about 4.6 and 7.5 fold for the inulin added samples at levels of 0.5% and 1.0%, respectively. Allgeyer et al. (2010) assessed the sensory attributes of drinkable yogurts prepared using prebiotics and probiotics as well as soluble corn fiber, polydextrose, and (5 g of fiber/serving, each) or (2.5 g of fiber/serving, each). The results of principal component analysis revealed that the yogurt drinks containing soluble corn fiber and inulin varied by the sweet versus sour attributes and yogurt drinks containing polydextrose varied by the mouth-feel attributes. Polydextrose treatment was found an acceptable vehicle to deliver the probiotic health effects at the end of the 30-d storage time period.

**Bulking agent along with artificial sweeteners or micronutrient premixes**

Some DF, e.g., polyfructan, has been suggested for use by Harada et al. (1993) as a low-energy bulking agent. It can be used along with sweeteners, such as aspartame, or as a fat substitute in ice cream as well as in baked cheese cakes. Polydextrose has been found to provide good bulking ability in terms of textural properties as compared to aspartame sweetened frozen dessert (Specter and Setser, 1994). However, the use of polydextrose was not found as suitable as maltodextrin for the preparation of artificially sweetened misti dahi (a fermented dairy product of India) (Raju and Pal, 2011). The combination of polydextrose with aspartame was found to be comparable to sucrose. In another study, it was found that when aspartame and acesulfame-K were used singly to sweeten plain low-fat yoghurt along with polydextrose as bulking agent, aspartame containing yoghurt yielded high flavor sensory scores than its acesulfame-K sweetened counterpart (Keating and White, 1990).

**Traditionally produced value-added dairy Foods**

The beneficial effects of fiber-rich diet are beyond doubt. While most dairy products do not contain DF, in India there are certain traditionally made dairy products, which contain several non-dairy ingredients contributing varying amounts of fiber (Patel and Arora, 2005b). Also, several milk products occur traditionally in different parts of the World which carry fruits, vegetables, nuts and cereals as a non-dairy ingredient complementing milk with the much devoid entity, the DF e.g., milk-based porridges or fruit smoothies and milk shakes and are highly acceptable to human palate.

3. Conclusion

DF, an extrinsic additive to milk, is known to have wide ranging beneficial effects on human health. The fortification of milk and milk products with DF may be the result of four main reasons, firstly from the considerable work done by various researchers/product developers in order to either enhance the fiber content of the product or replacement of fat for the obvious health benefits, secondly, to achieve some of the technological benefits e.g., improvement in the texture, thirdly, as cheap bulking agent along with artificial sweeteners or micronutrient premixes, and fourth reason may be the enhanced sensory benefits, as fiber rich dairy foods produced traditionally. By all means, fiber fortification is advantageous to the consumer because of its proven role for health
benefits and its use for fortification can definitely improve the flabby image of milk products due to their saturated fat and cholesterol contents. Due to the growing double burden of diseases because of under nutrition on one hand and the over nutrition on the other, it is becoming essential to develop DF fortified milk and milk products on large scale. Such innovations in product development will probably help the people and the governments to address the problem of malnutrition and several metabolic diseases. Among the commercially available concentrated source of DF, inulin is the most searched one primarily because of its solubility, colour and taste. There are still some untapped potentials in this emerging field of knowledge and application which need to be practically harvested together with the planned endeavours of the food and dairy technologists using the underutilized sources of DF into dairy mainly insoluble ones and soluble ones with proven health benefits e.g., beta-glucan and psyllium husk.

References


http://dx.doi.org/10.1016/j.idairyj.2006.09.007

http://dx.doi.org/10.1111/j.1365-2621.1990.tb05211.x

http://dx.doi.org/10.1111/j.1745-4557.2008.00191.x
