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# Inulin-Benefits and Scope of Use in Dairy Products

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**A B S T R A C T**

Health has become the prime importance for consumers with the ongoing pandemic situations. They are in search of food solutions that meet their requirements of health and nutrition along with taste. Inulin is one such dietary fibre which when added to food imparts various health benefits. Inulin is mainly known for its prebiotic effect. Several studies have proved its role in influencing lipid metabolism, enhanced bio availability of minerals and prevention of cancer and tumor growth. Inulin acts has wide scope in dairy products and recently many researches are exploiting inulin as a prebiotic source, a bulking agent and/or calorie reducing agent, a fat replacer and a texture modifier in various dairy products thus providing consumers guilt free traditional dairy products with enhanced nutritional properties and similar taste.

## Introduction

Dietary fibre, is a term introduced by nutritionist E.H. Hipsley to symbolize intake of the indigestible components of plant cell walls (Hipsley, 1953). According to the American Association of Cereal Chemists (AACC) Dietary Fiber Definition Committee, dietary fiber is defined as the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber mainly includes lignin, oligosaccharides, polysaccharides, and associated plant substances are known to boost beneficial physiological effects including blood cholesterol attenuation, laxation, and/or blood glucose attenuation (AACC, 2003). As stated by Flamm *et al.*, 2001, the five basic attributes of dietary fibre are:

Component of edible plant cell
Carbohydrate (both oligosaccharide and polysaccharides)

Resistance to hydrolysis by human alimentary enzymes
Resistance to absorb in small intestine
Hydrolysis and fermentation by bacteria in the large intestine

The recommended daily dose of dietary fiber is 25g for persons consuming 2000 kcal daily and 30 g per day for those consuming 2500 kcal for a healthy diet (Redgwell, 2005). WHO recommends 16-24g/d of non-starch polysaccharides or 27-40g/d of total dietary fiber.

Dietary fibres are broadly divided into two categories (Truswell, 1995):

-water-soluble or gel forming viscous fibers
-water insoluble fibers

Insoluble fibers consist mainly of cell wall components such as cellulose, lignin, and hemicelluloses present mainly in wheat, most grain products, and vegetables. Soluble fiber consists of noncellulosic polysaccharide such as pectin, gums and mucilages found in fruits, oat, barley, dried beans, and legumes. Soluble dietary fibers are highly fermentable and are associated with carbohydrate and lipid metabolism and have been shown to exhibit hypocholesterolemic properties, (Delzenne *et al.,* 2000) while, insoluble fibers contribute to fecal bulk and transit times and have little or no effect on cholesterol metabolism (Madar and Odes, 1990).

Inulin is classified as a soluble carbohydrate of fructan family with β (2→1) linked fructosyl residues mostly ending with a glucose residue, and it is present as a storage carbohydrate in more than 36,000 plant species (Carpita *et al.,* 1989) including bananas, onion, wheat, garlic and chicory (Niness, 1999). Inulin is produced commercially mostly from chicory roots in powdered form (Franck, 2002) or synthesized from sucrose. The root of the *Cichorium intybus* plant contains 15–20% inulin stored as reserve carbohydrate in the fleshy taproot (Gupta, 1985). Physically, it is colorless and odorless, and has a pleasant, slightly sweet taste with moderate solubility in water, dependent on temperature.

## Nutritional value

Inulin is officially recognized as a natural food ingredient in all European Union and has a self-affirmed Generally Recognized as Safe (GRAS) status in United States. The average daily consumption of inulin has been estimated to be 1–4 g in the United States and 3–11 g in Europe (Van Loo *et al.,* 1995). However, no such study has been made in India. The unique aspect of the structure of inulin is its β-(2→1) bonds. These linkages prevent inulin from being digested like a typical carbohydrate and are responsible for its reduced caloric value and dietary fiber effects (Niness, 1999). Several studies revealed that in a normal gastrointestinal tract, the transfer of inulin and oligofructose into the colon is likely to be quantitative (100%) (Bach Knudsen and Hessov 1994, Ellega¨rd *et al.,* 1997) and is fermented in the large intestine (Roberfroid *et al.,* 1998). Roberfroid *et al.,* (1993) have calculated that the caloric value of inulin and oligofructose to be between 1.5–1.7 kcal/g or 6.3–7.3 kJ/g. Another study by Hosoya *et al.,* 1988 using $^{14}C$- labelled molecular weight inulin type fructans revealed the calorific value of 1.5 kcal/g or 6.3 kJ/g. Inulin and oligofructose have been thus used in many countries to replace fat or sugar and reduce the calories of foods such as ice cream, dairy products, confections and baked goods.

## Health benefits

Inulin and FOS are considered functional food ingredient, since they affect physiological and biochemical processes, resulting in better health and reduction in the risk of many diseases (Karimi *et al.*, 2015).Beneficial effects on interesting health properties depend on the average chain length of the fructans consumed. Some studies have observed that a combination of short-chain and long-chain fructans is physiologically more active than the individual fractions (Van Loo, 2004). Table 1 shows the various health benefits of inulin in a nut shell.

## Prebiotic effect of inulin

Prebiotics can be defined as a nondigestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or the activity of one or a limited number of bacteria in the colon, and thus improves health (Gibson, 2004). It has been demonstrated by various in vivo and in vitro studies that in humans, fermentation of fructans and inulin leads to the selective stimulation of growth of the bifidobacteria population (Cummings *et al.,* 2001). The normal recommendation for supplementation of inulin for the increase of healthy bacterial microflora, is a daily dose of 2.5–10 g. As it happens in a dose-dependent manner, 2.5–5 g daily seems to be low for bifidogenic effects (Kelly, 2009). It has been reported that both *Lactobacillus casei* and *Bifidobacterium lactis* are able to grow in a basal medium supplemented with FOS or inulin (Su *et al.*, 2007).They are often used in combination with ‘‘probiotics‘‘ or live bacteria that are added to the host’s diet to promote health.

The combinations of pre- and probiotics have synergistic effects referred to as synbiotics, because in addition to the action of prebiotics that promote the growth of existing strains of beneficial bacteria in the colon, inulin and oligofructose also act to improve the survival, implantation and growth of newly added probiotic strains.

## Influence of Inulin on lipid metabolism

Certain studies wherein inulin was incorporated into the diet of saturated fat fed rats, a significant reduction of the triglyceride content of blood and liver were observed (Kaur *et al.,* 1988). Trautwein, 1998 had studied that when male golden Syrian hamsters were fed with 16% inulin diets for five weeks, they experienced lower VLDL production by alteration in the hepatic lipid metabolism. A significant reduction in plasma total cholesterol by 29% was also detected. Causey *et al.,* (2000) in his recent study proved that in healthy individuals with normal blood lipid concentrations given with rice breakfast cereal incorporated with 9 g/d of inulin showed significant reduction in total cholesterol (5%) and LDL cholesterol levels over the 4-week intervention. A double blind crossover human study using 18g/d chicory inulin (in ice cream) in 12 moderate hyperlipidaemic men over a three-week treatment period. The serum triglyceride reduction of 40mg/dL was noticed. Total serum cholesterol was also decreased to 11 mg/dL. LDL cholesterol also showed reduction, albeit, not significant. However, no change in HDL was noticed 9Brighenti, 1999).

## Enhancement of mineral bioavailability

Human clinical studies showed that the incorporation of inulin in the diet makes the digestive system more efficient at absorbing calcium, thus significantly increasing the absorption of calcium (Schulz *et al.*, 1993 and Campbell *et al.*, 1997). The remarkable effect of inulin to enhance solubility and bioavailability of mineral may be due to the osmostic effect of inulin that transfers water into large intestine; thus it allows it to become more soluble (Roberfroid, 1998). Furthermore, it reduces the colon pH (due to the short chain carboxylic acids produced);

and it forms soluble calcium and magnesium salts of these acids and hypertrophy of the colon wall. Levrat and coworkers,1991 formulated the hypothesis that the cecal pool for calcium, magnesium, and phosphate improved when 10% inulin was supplemented in the diet of rats.

## Effect of inulin on cancer and tumor growth

Increased consumption of fiber is associated with a reduced risk of developing cancer particularly colon cancer (McIntosh, 2004). Several hypothetical mechanisms may be involved in the inhibitory and/or anticarcinogenic effect of inulin on tumor growth. Rumney and Rowland, 1995 suggested that production of toxic metabolites may be attenuated by increasing the proportion of healthier colonic microflora, which compete with putrefactive and pathogenic bacteria to reduce the levels of toxin and carcinogenic producing enzymes. These alterations in bacterial enzymes may interfere with the conversion of procarcinogens to its carcinogens, thereby reducing cancer risk.

## Scope of use in dairy products

Inulin has wide applications in various types of foods because of their large number of health-promoting functions. Dairy products represent one of the most highly studied food matrices for supplementation of inulin. Incorporation of inulin in a variety of foods, especially dairy products is mostly due to two reasons. One reason can be attributed towards the various physiological functions which confer to the consumer (i.e. dietary fibre, prebiotic etc). Other reason is the different technological properties of inulin and its functionality in the food matrix (i.e. mimic texture modifier etc). The technological reasons for adding inulin to foods relate to its capacity to act as fat and sugar replacer as well as emulsifier, thickener and stabilizer. The functions vary with the nature of the inulin (e.g. chain length), its concentration in a food and the food itself. The technological reasons relate to the dispersing properties of inulin in particular its ability to mimic fat droplets dispersed in water. This dispersion can then be used in food to replacer fat or to impart texture qualities in foods. The amount of inulin derived substance used for these purposes will vary depending on the technological purpose to be fulfilled. Since addition of inulin does not contribute to any viscosity, it can be regarded as an invisible way of incorporating fiber to foods. The high solubility of this functional ingredient when compared to classical fibers makes it relevant to fortify dairy products such as milk drinks, yogurt, cheese, and desserts, which have been traditionally difficult to fortify (Franck, 2002 and Murphy, 2001).Inulin is also found to improve the stability of foams and emulsions such as in aerated desserts, ice creams, table spreads, and sauces and therefore, it can be used to replace other stabilizers in food (Franck, 1997).

Today’s consumers hold high standards for the foods they consume. They demand foods that taste great, are fat- and/or calorie-reduced, and they are interested in foods that provide added health benefits. Consequently they are looking for foods to provide multiple benefits as well as good taste. Inulin is mostly used in dairy industry as a prebiotic source, a fat replacer and/or texture modifier.

Cardarelli *et al.,* (2008) investigated the influence of inulin, oligofructose and oligosaccharides on the probiotic viable count of symbiotic petit-suisse cheese containing *Bifidobacterium lactis* and *Lactobacillus acidophilus*. They found that probiotic populations varied between 7.20 and 7.69 log CFU/g for *Bifidobacterium lactis* and 6.08

and 6.99 log CFU/g for *Lactobacillus acidophilus*. Akin *et al.,* (2007) observed that the addition of inulin in probiotic ice cream increased *Lactobacillus acidophilus* and *Bifidobacterium lactis* counts. In another study the effect of 3% inulin addition on the survival of probiotic *Lactobacillus acidophilus* in synbiotic ice cream was assessed (Pandiyan *et al.,* 2012). The efficiency of prebiotics in enhancing the viability of probiotics namely *Lactobacillus acidophilus, Lactobacillus casei*, *Lactobacillus rhamnosus* and *Bifidobacterium* spp. was evaluated in yoghurt by Kolida *et al.,* (2002).

The presence of fat in dairy products plays an important role for their physical, rheological, and textural properties (Barclay *et al.,* 2010 and Dave, 2012). Fat, apart from its nutritional significance in cheese, contributes to the sensory and functional properties of dairy products (Miocinovic *et al.,* 2011). Consumers are increasingly demanding foods with dietetic and functional properties, such as those with low calories, low or reduced fat and health benefits. Low-fat food plans have been recommended for weight loss and maintenance (Carmichael *et al.,* 1998 and Peterson *et al.,* 1999). Low-fat or reduced fat foods are less desirable because they have poor organoleptic qualities (Hamilton *et al.,* 2000). There are some reviews about specific applications and potential effects of fat replacers (Ognean *et al.,* 2006). The challenge of using fat replacers in cheese while keeping the same functional and organoleptic properties as full fat cheeses has attracted great attention (Kebary, 2002). Inulin is widely used as texturizing agents in low-fat foods, particularly in the European Union and increasingly in the U.S.A. and Australia (Devereux *et al.,* 2003). Inulin seems particularly suitable for fat replacement in low-fat cheeses, as it may contribute to an improved mouth feel (Meyer *et al.,* 2011). A creamy mouth feel is achieved when inulin is used as a fat replacer in dairy products due to its interactions with whey protein and caseinate (Karaca *et al.,* 2009). High performance (HP) inulin with long chain and high molecular weight is most desirable as a fat replacer. Longer chain lengths reduce the solubility of inulin type fructans and result in the formation of inulin micro crystals when mixed with water or milk. These microcrystals are not discretely perceptible and have a smooth, creamy mouth feel. The fat mimetic property of HP inulin is double than standard inulin, while it has no sweetness (Niness, 1999). The different functional attributes of inulin and oligofructose are due to the difference in their chain lengths. As noted above, due to its longer chain length, inulin is less soluble than oligofructose, and has the ability to form inulin microcrystal when sheared in water or milk. Inulin has therefore been used successfully to replace fat in dairy products (Kaur and Gupta, 2002). The ability of inulin as fat replacer is not only related to the modification of rheological behavior or the thickness or hardness of the product, but also to changes in other mouth feel attributes, such as creaminess or smoothness (Meyer *et al.,* 2011). To obtain low-fat products with rheology and thickness closer to those of full fat products, higher concentrations of inulin are needed than is necessary to merely mimic their creaminess or smoothness (Meyer *et al.,* 2011). Fadaei *et al.,* (2012) studied the chemical characteristics of low-fat whey less cream cheese containing inulin as a fat replacer. No significant difference was found in the pH and salt values of cream cheeses. They indicated that an inulin proportion of 10% was enough to obtain a low-fat cream cheese with chemical attributes near to those of high fat cream cheese that does not contain inulin. They also reported that inulin has an excellent water binding capacity which inhibits syneresis in spreads and fresh cheeses (Fadaei *et al.,* 2012). It is expected that long chain inulin versus short chain has considerable water binding/retention capacity and capability to prevent syneresis. Wadhwani *et al.,* (2011) conducted several preliminary studies to select the most efficient fiber type from four inulin fibers; low methoxy pectin, polydextrose and resistant starch–to improve the quality of low-fat Mozzarella and Cheddar cheeses (Wadhwani, 2011). Results from their preliminary studies indicated that inulin had better efficacy in cheese systems than the other three fibers. They also found that incorporating inulin led to improved texture in low-fat cheese by decreasing hardness and gumminess while maintaining cohesiveness, adhesiveness and springiness (Wadhwani, 2011). Overall, studies have shown that the effect of fat replacement on cheese texture depends on the nature of the fat being replaced (Lobatocalleros, 1998).

Highly soluble fibers are highly branched and those that are relatively short chain polymers, such as inulin, have low viscosities. They are generally used to modify texture or rheology, manage water migration, influence the colligative properties of the food system and enhance the food product's taste, mouth feel and shelf life without significantly altering its specific application characteristics and improve its marketability as a health promoting or functional food product. As inulin content increases, its effect on the product's structure and texture becomes important, because at higher levels of inulin, the physic-chemical properties can modify the texture of dairy products and may significantly influence their sensory quality. It has been observed that the viscosity of the products increases with increasing levels of inulin (Akin *et al.,* 2007), Hennelly *et al.,* (2006) compared the use of shear induced inulin gels and heated inulin solutions to replace 63% of the fat in imitation cheese. They also found that at equivalent moisture levels, the inulin cheeses had significantly higher hardness values than the control sample with fat. However, there was no difference in hardness among the cheeses containing different levels of inulin (5% or 13.75%). Cheeses manufactured with 3% of inulin were characterized by a more compact structure, denser protein matrix and more uniform disposition of protein chains and the pores between them compared to other cheeses (Miocinovic *et al.,* 2011). It has been speculated that inulin may become part of the protein structural network by complexion with protein aggregates if inulin is present during fermentation and coagulation (Kip *et al.,* 2006) or if water phase insoluble submicron crystalline inulin particles form a particle gel network (Franck, 2002). According to the study of Juan *et al.,* (2013) on the sensorial properties of reduced fat fresh cheese, the addition of 5% inulin in milk resulted in a retention of 3% of inulin in the resulting cheeses. They found that the pH and microbiological quality of cheeses were not affected by the presence of inulin. In their study, cheeses produced with inulin were less hard, springy, cohesive and chewy than reduced fat cheeses. Inulin's water retention capacity could increase the water available for salvation of the protein chains, resulting in a softer, more easily deformed cheese (Creamer, 1982). Alnemr *et al.,* (2013) investigated the effect of adding texturizing inulin at levels 2 and 4% on physicochemical properties of Karish cheese. The use of inulin significantly enhanced the yield of cheese and moisture content compared to control. They related the increase in yield to the form of a gel network and increase of the ability of water holding in cheese containing inulin. It was found that the pH values of Karish cheese with inulin were higher than that of the control cheese during the storage. Higher addition of inulin led to decrease in hardness of Karish cheese.

**Table.1** Physiological effects of inulin on body (Karimi *et al.*, 2015)

| **Sl.no.** | **Application area** | **Effects** | **Reference** |
|---|---|---|---|
| **1** | Intestine | Stimulating the body's immune system<br>Decreasing the levels of pathogenic bacteria<br>Enhancing resistance to infections<br>Relieving constipation<br>Reducing the incidence of colon cancer<br>Decreasing the symptom of irritable bowel syndrome<br>Increasing the stool frequency<br>Decreasing β glucuronidase activity | Lomax and Calder, 2009<br>Buddinngton and Donahoo, 2002<br>Hond *et al.*, 2000<br>Kato, 2000<br>Paineau *et al.*, 2008<br>Kapiki *et al.*, 2007<br>Van dokkum *et al.*, 1999 |
| **2** | Cardiovascular system | Reducing the risk of atherosclerosis<br>Reducing the incidence of cardiovascular disease | Rault- Naina *et al.*, 2006<br>Larsson *et al.*, 2009 |
| **3** | Blood | Lowering blood urea and uric-acid levels<br>Lowering blood-serum lipids | Younes *et al.*, 1997<br>Brighenti, 2007 |
| **4** | Bone | Decreasing the risk of osteoporosis<br>Increasing the calcium, magnesium, copper, iron & zinc absorption | Coxam, 2007<br>Meyer and Stasse, 2006<br>Tahiri *et al.*, 2001<br>Ducros *et al.*, 2005<br>Meyer *et al.*, 2005<br>Yap *et al.*, 2005 |
| **5** | Skin | Improving the severity of atopic dermatitis | Rahmati *et al.*, 2014 |
| **6** | Weight management | Increasing feelings of satiety<br>Smaller increase in body mass index | Parnell and Reimer, 2009<br>Abrams *et al.*, 2007<br>Balcazar *et al.*, 2003 |
| **7** | Lipid metabolism | Decreasing the total cholesterol, LDL-, VLDL-cholesterol and triglycerides<br>Lowering the synthesis of triglycerides and fatty acids in the liver<br>Favourable impact on lipid and glucose metabolism<br>Decreasing aspartate aminotransferase | Delzenne and Kok, 1999<br>Boutron *et al.*, 2005<br>Daubioul *et al.*, 2005 |

In conclusion, inulin has many interesting health benefits that are useful in formulating the food of today and tomorrow. Quick solution for consumers in today's fast paced life can be met by incorporation of inulin into various products especially widely consumed dairy products. Usage of inulin has still lots of scope and further studies and researches on the same can yield fruitful results.

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