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12. Inulin: Wonder Fiber – Health, Nutritional and Technological Aspects

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Abstract:

In recent times, there has been an increased interest to adapt healthy diets, which help in preventing diseases, improved nutrition, and as a consequence, the study and development of new functional foods have gained much importance. Dietary fibers are found naturally in the plants that we eat. They do not break down in our stomachs, and instead pass through our system undigested. All fibers either soluble or insoluble are equally important for health. (Guarner, 2005). Inulin, a soluble fibre extracted from chicory roots, is accumulating value in the functional food market, as ongoing research finds the ingredient has several health, nutritional and technological benefits. These physiological responses to fiber consumption are the basis for associating high fiber diets with reduced risk of chronic diseases, diabetes and intestinal cancer (Kelly, 2009). Inulin attracts water and form a gel, which slows down digestion. It delays the emptying of your stomach and makes you feel full, which helps control weight. Slower stomach emptying may also affect blood sugar levels and have a beneficial effect on insulin sensitivity, which may help control diabetes (Tako et al., 2007). The benefits of inulin ingestion are not only limited to its condition as a dietetic fibre, but also include aspects related to its prebiotic (stimulation of growth of health-promoting bacteria e.g. bifidobacteria) nature, and the regulation of intestinal flora in the colon (Kaur & Gupta, 2002). In addition inulin has unique technological properties such as fat, sugar substitute, texture agent etc. The benefits of inulin on human health coupled with interesting technological properties have focused the research in this ingredient, to be used for incorporation in many dairy and food products including pharmaceutical products (Roberfroid, 2007). Therefore, this review focuses to promote the uses of inulin in various dairy as well as functional foods.

Keywords:

Dietary fiber, Dairy, Functional foods, Inulin, Fat replacer, Probiotic.

12.1 Introduction:

A. Dietary Fiber:

Dietary fibers are found naturally in the plants that we eat. They are parts of plant that do not break down in our stomachs, and instead pass through our system undigested. All dietary fibers are either soluble or insoluble. Both types of fiber are equally important for health, digestion, and preventing conditions such as heart disease, diabetes, obesity, diverticulitis, and constipation. All dietary fibers are either soluble or insoluble.

B. Insoluble Fibers:

Insoluble fibers are considered gut-healthy fiber because they have a laxative effect and add bulk to the diet, help to prevent constipation. These fibers do not dissolve in water, so they pass through the gastrointestinal tract relatively intact, and speed up the passage of food and waste through your gut. Insoluble fibers are mainly found in whole grains and vegetables. Various sources of insoluble fibers are whole wheat, whole grains, wheat bran, corn bran, seeds, nuts, barley, couscous, brown rice, bulgur, zucchini, celery, broccoli, cabbage, onions, tomatoes, carrots, cucumbers, green beans, dark leafy vegetables, raisins, grapes, fruit, and root vegetable skins **(**Kathleen, 2013**).**

C. Soluble Fibers:

Soluble fibers attract water and form a gel, which slows down digestion. Soluble fiber delays the emptying of your stomach and makes you feel full, which helps control weight. Slower stomach emptying may also affect blood sugar levels and have a beneficial effect on insulin sensitivity, which may help control diabetes. Soluble fibers can also help lower LDL (“bad”) blood cholesterol by interfering with the absorption of dietary cholesterol. Various sources of soluble fiber are oatmeal, oat cereal, lentils, apples, oranges, pears, oat bran, strawberries, nuts, flaxseeds, beans, dried peas, blueberries, psyllium, cucumbers, celery, and carrots **(**Kathleen, 2013**)**.

Soluble fiber absorbs water to become a gelatinous, viscous substance and is fermented by bacteria in the digestive tract. Insoluble fiber has bulking action and is not fermented (Eastwood, 2005).

Chemically, dietary fiber consists of non-starch polysaccharides such as arabinoxylans, cellulose, and many other plant components such as resistant dextrins, inulin, lignin, waxes, chitins, pectins, beta-glucans, and oligosaccharides. A novel position has been adopted by the US Department of Agriculture to include *functional fibers* as isolated fiber sources that may be included in the diet. The term "fiber" is something of a misnomer, since many types of so-called dietary fiber are not actually fibrous.

Advantages of consuming fiber are the production of healthful compounds during the fermentation of soluble fiber, and insoluble fiber's ability (via its passive hygroscopic properties) to increase bulk, soften stool, and shorten transit time through the intestinal tract (Anderson, 2009).

12.2 Inulin:

Inulin, a nondigestible carbohydrate, is a fructan that is not only found in many plants as a storage carbohydrate, but has also been part of man's daily diet for several centuries. It is present in many regularly consumed vegetables, fruits and cereals, including leek, onion, garlic, wheat, chicory, artichoke, and banana. Industrially, inulin is obtained from chicory roots, and is used as a functional food ingredient that offers a unique combination of interesting nutritional properties and important technological benefits. In food formulations, inulin significantly improves the organoleptic characteristics, allowing an upgrading of both taste and mouthfeel in a wide range of applications. In particular, this taste-free fructan increases the stability of foams and emulsions, as well as showing an exceptional fat-like behavior when used in the form of a gel in water. By contrast, as an ever-increasing amount of information becomes available on inulin, its nutritional attributes continue to amaze both researchers and nutritionists alike. Consequently, fat and carbohydrate replacement with inulin offers the advantage of not having to compromise on taste and texture, while delivering further nutritional benefits. Hence, inulin represents a key ingredient that offers new opportunities to a food industry which is constantly seeking well balanced, yet better tasting, products of the future (http://www.wileych.de/books/biopoly/pdf_v06/ bpol6014_439 _448.pdf). Inulin is a group of naturally occurring polysaccharides produced by many types of plants. They belong to a class of fibers known as fructans. Inulin is used by some plants as a means of storing energy and is typically found in roots or rhizomes. Most plants that synthesize and store inulin do not store other materials such as starch. Unlike most carbohydrates, inulin is non-digestible. This allows it to pass through the small intestine and ferment in the large intestine (Roberfroid M., 2005).

12.3 Definition:

Inulin falls under the general class of carbohydrates called fructans, those polymers containing fructose. Fructans serve as storage polymers in many members such as *Cichorium intybus* (chicory), *Inula helenium* (elecampane), *Taraxacum officinalis* (dandelion), and *Helianthus tuberosus* (Jerusalem artichoke). Inulin extracted from chicory is a natural polydisperse carbohydrate.

12.4 Historical Origin:

Inulin was discovered by Rose, a German scientist, who in 1804 found "a peculiar substance" from plant origin in a boiling water extract from the roots of *Inula helenium*, a genus of perennial herbs of the group Composite, natives of the temperate regions of Europe, Asia, and Africa. The substance was named inulin but was also identified by other names such as helenin, alantin, meniantin, dahlin, sinanternin, and sinisterin. The biochemical production was elucidated around the middle of the 19th century (Goudberg, 1913).

The German plant physiologist Julius Sachs (1864) was the pioneer in fructan research and, by using only a microscope, was able to detect the spherocrystals of inulin in the tubers of Dahlia, Helianthus tuberosus and Inula helenium after ethanol precipitation. Although today, chicory is the major crop used for the industrial production of inulin, the first reference to chicory being consumed by humans was made during the first century by Pedanios Dioscoride who, as a physician in the Roman army, praised the plant for its beneficial effects on the stomach, liver, and kidneys (http://www.wiley-vch.de/books/biopoly/pdf_v06/bpol6014_439 _448.pdf).

Much later, in about 1850, Jerusalem artichoke (Helianthus tuberosus) pulp, when prepared by cooking and drying the tubers, was added in a 50:50 ratio to flour when baking bread to provide cheap food for laborers (Franck, 2002).

12.5 Structure:

It is known as a fructan consisting predominately of linear chains of 1,2-β-linked d-fructofuranose units bound by a (α_1- β_2) type linkage (as in sucrose) to a terminal glucose moiety. The gross molecular formula of inulin is GF_n, with G being a terminal glucosyl unit, F representing the fructosyl units and "n" representing the number of fructosyl units. The basic structure of inulin shown in Figure 1 (Tungland and Meyer, 2002).

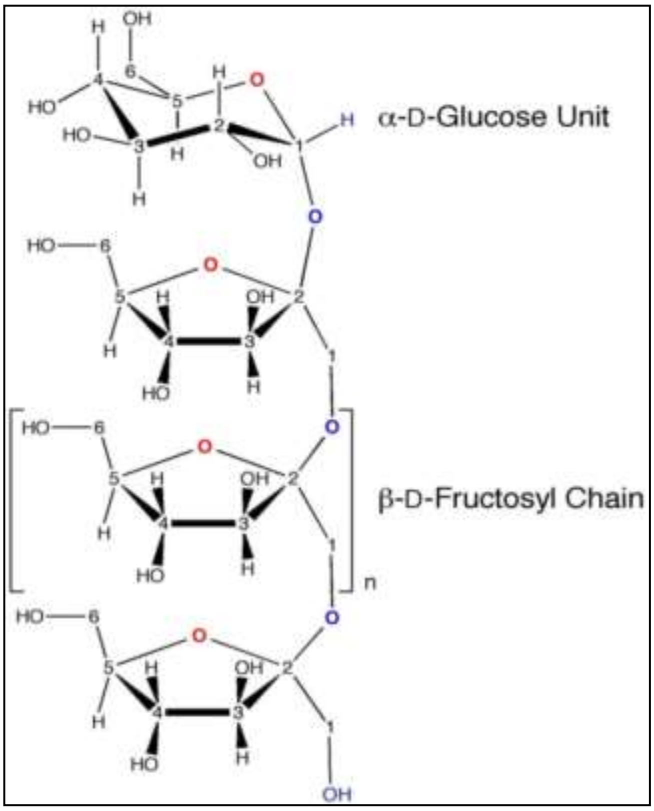

Figure 12.1: Chemical Structure of Inulin

Sources: Inulin belongs to the group of naturally-occurring carbohydrates known as non-digestible oligosaccharides (NDO). It is produced naturally in over 36,000 plants worldwide, including 1,200 native grasses belonging to 10 families. After starch, they are the most plentiful carbohydrates occurring in the plant kingdom (Carpita *et al.*, 1989 and Marchetti, 1993). It has been estimated that as much as one third of the total vegetation on earth consists of plants that contain fructans. Inulin-type carbohydrates obtained from fungal fermentation have been reported in commercial use but the predominant commercial source for Inulin/FOS is of chicory root origin shown in Table 12.1 (Van Loo *et al.*, 1995).

Table 12.1: Inulin content of plants that are commonly used in Human nutrition

Source	Edible parts	Dry solid content (per cent)	Inulin content (per cent)
Onion	Bulb	6	2
Jerusalem artichoke	Tuber	19	14
Chicory	Root	20	15
Leek	Bulb	15	3
Garlic	Bulb	40	9
Artichoke	Leaves-heart	14	3
Banana	Fruit	24	0.3
Rye	Cereal	88	0.5
Barley	Cereal	NA	0.5
Dandelion	Leaves	50	12
Burdock	Root	21	3.5
Camas	Bulb	31	12
Murnong	Root	25	8
Yacon	Root	13	3
Salsify	Root	20	4

NA, data not available.

Chicory Roots: Chicory (*Chicorium intybus* var. *sativum*) is a herb with its unique blue flowers, found in many parts of India. Chicory has many uses in current cuisine and commonly in coffee substitute, or coffee additive. Chicory ***inulin*** can be extracted from the root shown in Figure 2.3 and used as an ideal ingredient in functional foods

(http://www.chicoryindia.net/main.php).

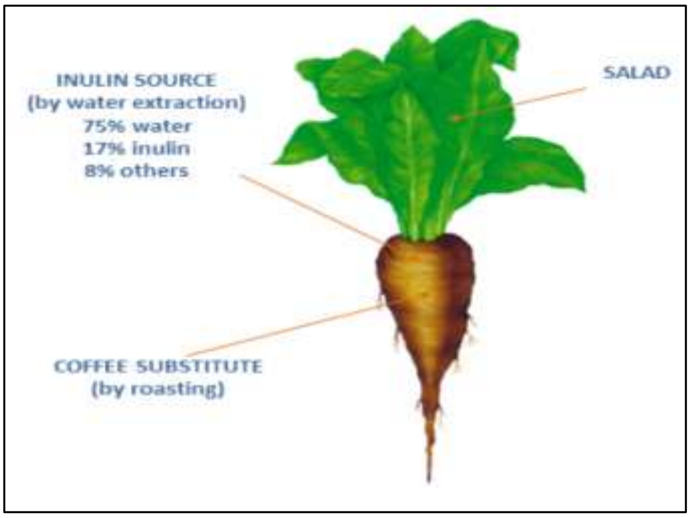

Figure 12.2: Chicory Root *(Chichorium Intybus)*

Chicory root inulin is not synthesized or modified during the extraction process. Acquiring inulin from the root of the chicory involves processing steps where the inulin is extracted, purified, and then spray-dried. However, the extracted inulin is chemically indistinguishable from "native" inulin. Though the inulin cannot be considered unprocessed, the process is completely natural (http://www.prebiotic.ca/inulin.html).

12.6 Industrial Production of Inulin:

Inulin as a pure compound was not produced economically on an industrial scale and was not available as a food ingredient for human consumption. It was produced on a pilot scale in Deutsche Kulorfabrik in the early 1920s (Sloane, 1920), and later was extracted on an industrial scale. The inulin can be extracted by two methods and shown in Figure 3 and 4 respectively.

a. Natural Extraction (http://www.foodingredientsfirst.com/newsmaker_article.asp).
b. Industrial Production Process (http://www.prebiotic.ca/inulin.html)

The industrial production process involved following steps

a. extraction of raw inulin with hot water,
b. purification of the raw inulin and
c. spray drying of the purified juice to a pure inulin powder.

Although inulin is spray dried, the molecule is quite flexible, and crystallizes easily (French, 1989).

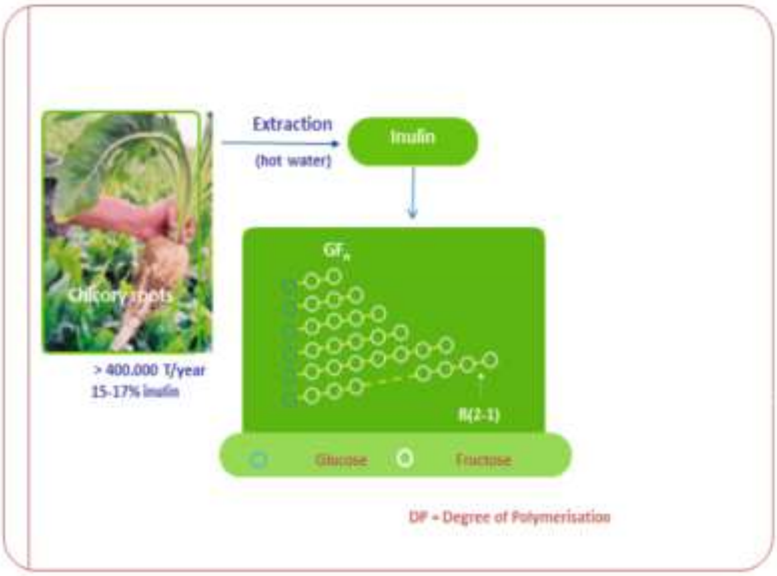

Figure 12.3: Natural Extraction Process

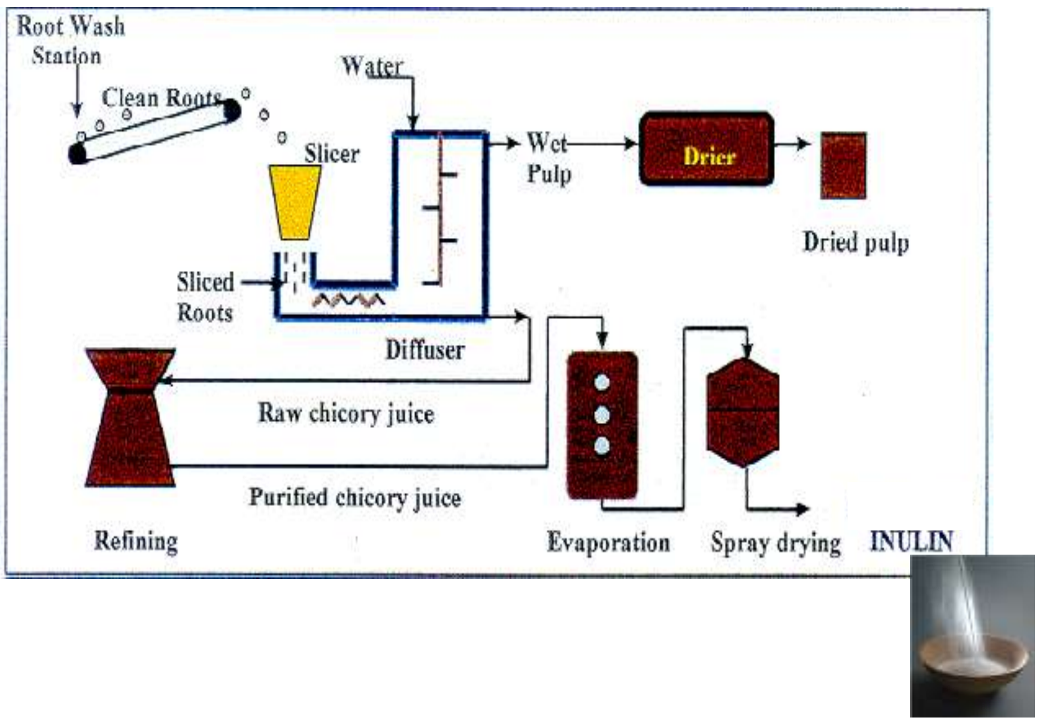

Figure 12.4: Inulin Production Process

Physicochemical Properties and various forms of inulin

The various physico chemical properties of inulin are shown in Table 2.

Table 12.2: Physicochemical Properties of Inulin

Properties	Standard inulin	High Performance
Chemical Structure	GFn	GFn
Dry Matter (%)	95	95
Inulin Content (%on d.m.)	92	99.5
Sugars Content (%on d.m.)	8	0.5
p^H (10% w/w)	5-7	5-7
Heavy Metals (ppm on d.m.)	<0.2	<0.2
Appearance	White Powder	White Powder
Taste	Neutral	Neutral
Sweetness (v. sucrose=100%)	10%	None
Solubility in water at 25°C (g/l)	120	25
Viscosity in water (5%) at 10°C (mPas)	1.6	2.4
Functionality in foods	Fat as well as Sugar Replacer	Fat as well as Sugar Replacer

(Source: Franck, 2002)

12.7 Health Benefits:

A. Anti Colon Cancer Activity:

Barclay (2010) reported that dietary inulin inhibits development of colon cancers. Similarly tumor inhibitory effects are seen with fermentation products of inulin, particularly the short chain fatty acids, butyric and propionic acids, both of which inhibit growth of colon cancer cells and might reduce risk of cardiovascular disease. A recent report on human trial showed that dietary inulin reduced serum concentrations of the proatherogenic molecule, p-cresyl sulphate, in haemodialysis patients (Meijers *et al.,* 2010).

Life-long ingestion of inulin (10% diet) also reduced the number of colonic tumours in azoxymethane (AOM) treated rats (Verghese *et al.,* 2002). The higher the number of aberrant crypts per foci (ACF), the greater likelihood of tumour development and this might be taken as an indicator of relative cancer risk (Pretlow *et al.*, 1992 and Magnuson *et al.*, 1993). Several studies have confirmed the ability of inulin (fed at 10% w/w diet) to reduce the number of ACF in the colon of AOM treated rats (Rowland 1998; Reddy *et al.,* 1997 and Rao *et al.*, 1998).

B. Antitumor Activity:

Butyrate, the anion of the short-chain fatty acid (butyric acid), is produced by bacterial fermentation of inulin in the colon. Some studies suggested that butyrate might induce growth arrest, cell differentiation and upregulate apoptosis, three activities that could be significant for antitumor activity.

C. Hypolipidemic Activity:

Kelly (2009) reported that administration of inulin might lower cholesterol levels in some type 2 diabetes and might be attributed via decreased triglyceride synthesis in liver. The consumption of inulin and FOS has been linked to a modification of the serum levels of triglycerides and cholesterol in rodents (Delzenna and Williams, 2002). Due to the complexity of human lipid metabolism, comprehensive studies are difficult to undertake and few in number. Results between studies are often conflicting. Williams and Jackson (2002) have discussed possible bias in various experimental approaches. Available data tend showed either no effect or a slight decrease in circulating tricylglycerols and plasma cholesterol concentrations following the ingestion of inulin and FOS. The possible mechanisms of action of prebiotic on lipid metabolism have been reviewed by Pereira and Gibson (2002).

D. Antiosteoporotic Activity:

Inulins, similar to dietary fiber, might bind such minerals like calcium and magnesium in the small intestine. The short-chain fatty acids (acetate, propionate, and butyrate) formed from the bacterial fermentation of inulin in the intestinal tract could facilitate the colonic absorption of calcium and possibly also magnesium ions. This could be beneficial in preventing osteoporosis and osteopenia (http://www.jn.nutrition.org).

F. Inulin as a Prebiotic:

The term *prebiotic* was introduced by Gibson and Roberfroid (1995), who exchanged "pro" for "pre," which means "before" or "for." They defined prebiotics as "a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon."A prebiotic is a non-viable food component that confers a health benefit on the host associated with modulation of the microflora. Prebiotics are as substances that trigger the growth of bacteria having favourable effects on the intestinal flora. They remain intact throughout the digestive process, and deliver healthy bacteria directly to the large intestine. By consuming a non-digestible ingredient, it allows for growth of bio-cultures by reaching the intestine unaffected by the digestion process. This can provide good digestive health. A prebiotic effect occurs when there is an increase in the activity of healthy bacteria in the human intestine. The prebiotics stimulate the growth of healthy bacteria such as bifidobacteria and lactobacilli in the gut and increase resistance to invading pathogens. This effect is induced by consuming functional foods that contain prebiotics. These foods induce metabolic activity, leading to health improvements. Healthy bacteria in the intestine can combat unwanted bacteria, providing a number of health benefits (Cummings *et al.,* 1987).

The most common type of prebiotic is from the soluble dietary fibre inulin. Inulin is common in many plants containing fructan. Furthermore, many of these plants are frequently eaten as vegetables - asparagus, garlic, leek, onion, artichoke – and are an excellent source of inulin. However, as the need for functional foods rises, prebiotics are being added to many every day food choices such as cereals, biscuits, breads, table spreads, drinks, and yoghurts (http://www.prebiotic.ca/inulin.html).

12.8 Nutritional Benefits:

Kaur and Gupta (2002) reported that inulin improved the mineral absorption and balance. It may also aid in increasing the concentrations of calcium and magnesium in the colon. Dietary inulin has also been shown to increased calcium, magnesium and iron absorption, and bone mineralization in young adolescents, reduced bone loss and improved bone density.

Although the site of absorption of minerals is primarily the small intestine, oligosaccharides, and specifically, inulin and fructo-oligosaccharides have been linked to an improvement in the mineral absorption in the large bowel (Roberfroid, 2000). Enhanced absorption of calcium and magnesium has been demonstrated in ovariectomized rats fed FOS (50g/kg diet). This rodent model simulated bone demineralisation occurring during post-menopausal hormonal changes. Enhanced calcium uptake, observed in this animal model was correlated with an improvement of bone mineralization (Scholz-Ahrens and Schrezenmeir, 2000). The increase in butyrate production and pH acidification, resulting from the fermentation of oligosaccharides, were thought to be responsible for enhanced uptake of calcium by the colonic mucosa (Trinidad *et al.,* 1996). In human subjects, an improvement in mineral status is more difficult to observe. A double-blind, placebo-controlled, cross-over study using a stable isotope of calcium investigated the effect of fructo-oligosaccharide supplementation in post-menauposal women. An improvement of calcium uptake was only apparent in subjects at the late menopause phase (Tahiri *et al.,* 2003). The effect of bone mineralization at puberty has also been investigated in a human trial using dual stable isotopes of calcium as markers. A significant increase in calcium absorption was measured in adolescent girls who were given a drink fortified with FOS and inulin (4g/day) and a daily supplementation of calcium (1.5g/day) (Griffin *et al.,* 2002). An increase of magnesium absorption was also repeatedly observed in humans and animals following the consumption of oligosaccharides, and the mechanism of action of oligosaccharides in the metabolism of magnesium was recently reviewed (Coudray, 2003). Animal experiments showed that metabolism of other minerals such as iron, zinc, copper and phosphorous might be affected to a lesser extent by the supplementation of oligosaccharides in the diet (Scholz-Ahrens *et al.,* 2001).

12.9 Technological Benefits:

FDA approved use of inulin in food/dairy for human consumption. It is a fat as well as sugar replacer and used in various dairy products. Inulin does not have taste but enhances the flavor of the food with which it is mixed or blended. Its granulated form, has the “mouth feel” of sugar (Patton, 2005). It serves as a preservative when mixed with other foods (such as muffins or breads). Pure form of inulin has a long shelf life. It provides steady energy up to 4 to 12 hours, depending on the blend and the metabolism of the individual.

Inulin is an extremely versatile product for fiber fortification into beverages, such as meal replacements, dairy-based beverages and dry mixes. As a soluble source of fiber, it can be easily incorporated into dairy products, including yogurt, ice cream etc. A wide array of bakery products, including breads, cookies, cakes and crackers, can be developed with inulin. Longer chain inulin, can improve the body and texture of various food products. It is capable of forming a gel and can be successfully used for fat replacement and calorie reduction. (http://www.cargill.com/food/na/en/index.jsp)

In spreadable cheeses and low calorie sauces and dressings, it functions as a fat replacer, imparting a desirable creamy mouthfeel. It can also be used to improve the texture and mouthfeel of low fat dairy products. In fillings and confectionery products, including coatings, sugar and calorie reduction can be achieved through the addition of inulin. Inulin is also approved for use in meat applications (http://www.springerlink.com/)

Inulin may act as a useful fat replacer and texture enhancer in dairy products, said a new review from ingredient company Sensus and CSIC in Spain. The review, published in Food Hydrocolloids, investigated the uses of inulin in dairy systems as a fat replacer, exploring how the soluble fibre ingredient could be used to replace fats by mimic the features such as mouth feel and creaminess – and how these effects might be related to changes in rheology of the food system in liquid, semi-solid and solid dairy products. The reviewers said the inclusion of long-chain inulin in a dairy product as fat replacer "can have different effects on the rheological properties and on texture depending on the structure and composition of each product" (Meyer *et al.*, 2011).

12.10 Dosage and Administration:

Inulins are available in the form of Tablets,Powder or as Functional foods. Dosing is variable and ranges from 4 to 10 grams daily. Those who use more than 10 grams daily should split the dosage throughout the day. Doses higher than 30 grams daily may cause significant gastrointestinal discomfort. as flatulence, bloating and diarrhea (http://www.gettingwell.com /drug_info/ nmdrugprofiles/nutsupdrugs/inu_html)

12.11 Conclusions:

Rapidly expanding market, inulin has the advantage of the multiple functions. Growing awareness of the consumers and the increasing cost of the health care, lead to a lot of attraction from the dairy and food industry for products with healthy image. Inulin has the ability to create new business opportunity for Dairy/Food industry with special health oriented products as well as low and light products.

12.12 References:

1. Akalin, A.S. and Erisir, D. 2008. Effects of inulin and oligofructose on the rheological characteristic and probiotic culture survival in low-fat probiotic ice cream. *Journal Of Food Science* doi: 10.1111/j.1750-3841.2008.00728.x
2. Anderson, J.W., Baird P., Davis R.H. 2009. Health benefits of dietary fiber. *Nutr Rev.*, 67 (4): 188–205. doi:10.1111/j.1753-4887.2009.00189.x. PMID 19335713.

3. Aryana, K.J., plausche, S., Rao, R.M., McGrew, P. and Shah, N.P. 2007. Fat free plain yoghurt manufactured with inulin of various chain lengths and *Lactobacillus acidophilus. J. Food Sci*, **72**:M79-84.
4. Barclay, Thomas; Milena Ginic-Markovica, Peter Cooperb, C., Nikolai Petrovskyc, D., 2010. Inulin - a versatile polysaccharide with multiple pharmaceuticaland food chemical uses. *J. Excipients and Food Chem, **1** (3): 27-50.*
5. Bowman, S.A. 2002. Beverage choices of young females: Changes and impact on nutrient intakes. *J Am Diet Assoc*, **102**:1234-1239.
6. Carpita, N.C., Kanabus, J., & Housley, T.L. 1989. Linkage structure of fiuctans and fiuctan oligomers from Triticum aestivum and Festuca arundinacea leaves. *J. Plant Physiol,.* 134:162-168.
7. Choonhahirun, Anchan and Akesowan, Adisak. 2012. Partial fat and sugar replacement with soy milk, inulin and sucralose on quality of Thai *Pandanus* custard. *African Journal of Biotechnology*. , **11** (20):4611-4619. DOI: 10.5897/AJB11.4192
8. Coudray, C., Demigne, C., Rayssiguier, Y. 2003. Effects of dietary fibers on magnesium absorption in animals and humans. *J Nut.*, **133**: 1- 4.
9. Cummings, J.H., Pomare, E.W., Branch, W.J., Naylor, C.P.E., Macfarlane, G.T. 1987. Short chain fatty acids in human large intestine, portal, hepatic and venous blood. *Gut.*, **28**:1221-7.
10. Davidson, M.H., Maki, K.C., Synecki, C. 1998. Evaluation of the influence of dietary inulin on serum lipids in adults with hypercholesterolemia.
11. Franck, A. 2002. Technological functionality of inulin and oligofructose. *British Journal of Nutrition*, **87**(2): 287–291.
12. Gibson, G.R. and Roberfroid, M.B. 1995. Dietary modulation of the human colonic microbiota. Introducing the concept of prebiotics. *J Nutr*, **125**:1401–12.
13. Goldberg, A. 1913. The utilization of inulin in the metabolism for nutritional cures. *Z. Exp. Path. They*, **13**:310-325,ciited by: http://www.prebiotic.ca/inulin.html
14. http://www.cargill.com/food/na/en/index.jsp
15. http://www.chicoryindia.net/main.php
16. http://www.jn.nutrition.org
17. http://www.prebiotic.ca/inulin.html
18. Kathleen, M. Zelman. 2013. The Benefits of Fiber: For Your Heart, Weight, and Energy. Skip to Article Content Fiber for Weight Control Fiber fills you up and helps you lose weight. How can you get more in your diet.
21. Kaur, N. and Gupta, A. K. 2009. Applications of inulin and oligofructose in health and nutrition. Journal of Biosciences, **27**: 703–714.
22. Kelly, Greg. 2009. Inulin-Type Prebiotics: A Review (Part 2). *Alternative Medicine Review Volume*, **14**(1): 36-55.
23. Kolida, S., Tuohy, K. and Gibson, G.R. 2002. Prebiotic effects of inulin and oligofructose. *British Journal of Nutrition*, **87**(2):193–197.
24. Megala1, P. and Hymavathi, T.V. 2011. Inulin and Fructooligosaccharides Incorporated Functional Fruit Bars. World Academy of Science, Engineering and Technology, **59**: 600-605.
25. Meijers, B.K.I. 2010. *P-Cresyl Sulfate Serum* Concentrations in Haemodialysis Patients Are Reduced by the Prebiotic Oligofructose-Enriched Inulin. *Nephrology Dialysis Transplantatio,* **25**: 219-224.
26. Patton, Dominique. 2005. Inulin gaining in health benefits by: http://www.nutraingredients.com/Industry.

27. Pierre, F., Perrin, P., Champ. M., Bornet, F., Meflah, K. and Menanteau, J. 1997. Short-chain fructo oligosaccharides reduce the occurrence of colon tumours and develop gut associated lymphoid tisseu in Min mice. *Cancer Research*, **57**: 225-8.
28. Rao, C.V., Chou, D., Simi, B., Ku, H. and Reddy, B.S. 1998. Prevention of colonic aberrant crypt foci and modulation of large bowel microbial activity by dietary coffee fiber, inulin, and pectin. Carcinogenesis, **19**:1815-1819.
29. Reddy, B.S., Hamid, R. and Rao, C.V. 1997. Effect of dietary oligofructose and inulin on colonic preneoplastic aberrant crypt foci inhibition. Carcinogenesis, **18**:1371-4.
30. Roberfroid, M.B. 2000. Prebiotics and probiotics: are they functional foods?. *Am J Clin Nut.*, **71**:1682S-7S.
31. Roberfroid, M.B. 2007. "Inulin-type fructans: functional food ingredients". *J Nutr.* **137** (11): 2493–2502.
32. Scholz-Ahrens, K. and Schrezenmeir, J. 2000. Inulin, oligofructose and mineral metabolism - experimental data and mechanism. *British Journal of Nutrition,* **87**:S186-S219.
33. Scholz-Ahrens, K.E., Schaafsma, G., van den Heuvel, E.G. and Schrezenmeir, J. 2001. Effects of prebiotics on mineral metabolism. *Am J Clin Nut.,* **73**:459S-64S.
34. Tahiri, M., Tressol, J.C., Arnaud, J., Bornet, F.R.J., Bouteloup-Demange, C. and Feillet-Coudray, C. 2003. Effect of short chain fructo oligosaccharides on intestinal calcium absorption and calcium status in postmenauposal women: a stable-isotope study. *Am J Clin Nut.,* **77**:449-57.
35. Tako, E., Glahn, R.P., Welch, R.M., Lei, X., Yasuda, K. and Miller, D.D. 2007. Dietary inulin affects the expression of intestinal enterocyte iron transporters, receptors and storage protein and alters the microbiota in the pig intestine. *Br J Nutr.*, **99**(9):1–9. http://www.ncbi.nlm.nih.gov/pubmed/17868492.
36. Tungland, B. C., and Meyer, D. 2002. Non digestible oligo-and polysaccharides (dietary fiber): Their physiology and role in human health and food. *Comprehensive Reviews in Food Science and Food Safety*, **1**:73–92.
37. Van Loo, J., Coussement, P., de Leenheer, L., Hoebregs H., and Smits, G. 1995. On the presence of inulin and oligofr|uctose as natural ingredients in the western diet. *Crit. Rev. Food Sci. Nutr.*, **35**(6):525-552.
38. Verghese, M., Rao, D.R., Chawan, C.B., Williams, L.L. and Shackelford, L. 2002. Dietary inulin suppresses azoxymethane-induced aberrant crypt foci and colon tumors at the promotion stage in young Fischer 344 rats. *J Nutr*., **132**:2809-2813.
39. Williams, C.M. and Jackson, K.G. 2002. Inulin and oligofructose: effects on lipid metabolism from human studies. *Br J Nutr*., **87**:S261-4.