

Potential application of inulin in food industry; A review

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ABSTRACT

Inulin is a polyfructans which is widely used as prebiotic, sugar replacer, fat replacer and texture modifier. It is a significant ingredient used in food industry by virtue of its diversified nutritional and functional properties. Inulin, cellulose, starch, pectin, carrageenan and xanthan gum are of great attention because of their nutritional and technological properties. The inulin concentration enhances product texture; at high concentration inulin can alter the texture profile of products because of its physico-chemical significance. Inulin may also significantly affect the sensory attributes of many products. The physico-chemical significance of inulin is associated with its degree of polymerization. The short chain fraction of inulin possess more solubility and also contain much more sweetness than the long chain oligosaccharides. It can improve the mouth feel due to its properties which directly relate with those of other sugars. In correlation with the existing increase in obesity food industry is required to produce such food products which have pleasant taste with less caloric values. The development of such product is feasible through reducing the sugar or fat content. The decrease in fat content of food not only alters formation and texture but also modifies the relation among various constituents of the foodstuff. The addition of inulin increases the total solids in the fermented liquid dairy products and also enhances its acidity. The supplementation of inulin in dairy foods modifies its structure and composition as well as the probable relation among components, giving rise to perceptible changes in flavor, color and particularly in texture.

Keywords: inulin, prebiotic, oligofructose, food industry, application

INTRODUCTION

Inulin belongs to a class of carbohydrates known as fructans. Inulin is found in dahlia, garlic, onion, banana and chicory roots (Table 1). The main sources of inulin and oligofructose that are used in the food industry are Chicory and Jerusalem artichoke. Inulin and oligofructose are considered as functional food ingredients since they affect physiological and biochemical processes in human beings, resulting in better health and reduction in the risk of many diseases. Fructans are a group of nutritionary substances that comprehends plant oligo and polysaccharides in which one or more fructosyl-fructose linkages comprise the most of glycosidic bonds. It is compulsory for fructans to include $\beta(2-1)$ glycosidic linkage (fructosyl-fructose) to become an "inulin-type". Inulin has peculiar physiological and structural properties that make it more resistant to hydrolysis by small intestinal and human salivary enzymes. Inulin type fructans can be obtained from plants or prepared with basic molecule (sucrose). Inulin is indigestible carbohydrates because β -

configuration of the anomeric Carbon No.2 makes inulin resistant to digestion by the enzymes in small intestine. Inulin decreases the pathogens in small intestine thereby increasing the prebiotic count. Fructans also mask positive effects on the mucin profile, crypts growth and the concentration of polyamine. In additions, it also improves the absorption of magnesium, calcium and meliorates bowl habit. It also effects to reduce the carcinogenesis in colon, effect lipid metabolism and regulate the immune system. Fructans are dietary fibers and nutritional they are low calories carbohydrates (1.5 kcal/g).

Inulin and its products of enzymatic hydrolysis comprised of GF_n and F_m types which are $\beta(2-1)$ linked fructans, G denotes glucosyl moiety, F refers to fructosyl moiety and the number of fructosyl moieties are indicated by n and m. The value of n varies between two and sixty for the inulin from dahlia and for dahlia oligofructose it differs between two to seven. ORAFTI manufacture inulin as Raftiline ST because inulin is present in tubers of dahlia and commercially extracted from the fresh tubers of the

dahlia plant by using hot water extraction technique (Gibson *et al.*, 1994). The inulin extracted by this technique have 92% fructo-oligosaccharides and mostly of GF_n type (98%), with 10 hexose units as mean degree of polymerization. The (degree of polymerization) DP of almost 10% frutans varies between 2 and 5. Inulin yields Oligofructose (Raftilose) by enzymatic hydrolysis which comprise of GF_n and F_m type oligomers having the DP in the range of 4-5. Oligomers with a DP from 2 to 5 characterize about 70% of the total FOS. The synthetic (fructo-oligosaccharides) FOS (Paris, France, Actilight, BMI,) have GF_n type fructo-oligosaccharides, having the DP of 3.7 as an average.

Table 1. Inulin content in (%) from different sources

Source	Inulin content (%)
Asparagus root	10-15
Garlic	15-20
Jerusalem artichoke	15-20
Salisfy	15-20
Chicory root	15-20
Dahlia tubers	15-20

Functional properties of inulin

Inulin is presented as an odorless white powder. The oligofructose as powder and viscous syrup is colorless having 75% dry substance is available with a great purity and an eminent chemical constitution. Inulin has an insipid neutral taste without any aftertaste. The standard inulin is somewhat sweet having 10% sweetness as compared to sugar. It can easily combines with other ingredients without flavor modification. It has very less solubility in water (10% at room temperature) and possess less viscosity. On the other side, the inulin has a significant property to replace fat. It produces a particle gel network having a tiny spreadable texture when carefully mixed with water or other aqueous liquid. It can be incorporated in foods for 100% fat replacement (Franck, 1993). This gel like structure is comprised of a three dimensional complex of impenetrable submicron crystalline particles of inulin in water. Too much water is blocked in this complex that ensures its physical strength. In the context of fat replacement, high functioning patent protected inulin shows almost twice the performance of inulin. Using a specific spray drying process,

particular qualities which do not need shearing to provide stable homogenous gels can also have synthesized. Most of the gelling agents work in synergy with inulin e.g. alginate, gelatine and k-carrageenans, maltodextrins and gellan gum. It also improves the stability of emulsions and foams like ice creams, aerated desserts, sauces and table spreads. Therefore, inulin can substitute other stabilizers in different other food items.

Inulin is less soluble than oligofructose. It has a sweetness of about 35% as compared to sucrose in the pure form. The sweetening role of inulin closely approaches to that of sugar. Its taste is extremely clean without any persistent effect and also heightens fruit flavors. It gives attractive mixtures by providing a rounder mouthfeel, better persistent flavor with minimal after sensation and improved stability. In the combined effect with intense sweeteners like acesulfame K and aspartame, oligofructose exhibit a considerable quantitative synergy (Wiedmann and Jager, 1997). If the beta bond is hydrolysed between the fructose units, the oligofructose shows excellent stability during food processes even in very acidic conditions. A fructose is formed in this process that is very pronounced in low pH, less dry matter conditions and high temperature. The oligofructose also adds in mouthfeel improvement and **lowers the water activity** that ensures high microbial strength. It shows the properties of **humectants** and also affects the freezing and boiling points. In fact its technological properties closely relates with those of glucose syrup and sugar (Crittenden and Playne, 1996).

Long chain oligosaccharides and short chain synthetic fructo-oligosaccharides proceed to large intestine and are not considered as major energy source (Oku *et al.*, 1984). Moreover, in model of rats there were no hydrolytic adjustments of enzymes over long term intake of such factors. FOS contributes to the energy group due to the fermentation by bacteria that takes place in colon. The calorific value of inulin is measured between 1 to 1.5kcal/g or between 30-40% of a digested fructose molecules (Roberfroid *et al.*, 1993). A caloric value for oligofructose is 1.48kcal/g. By using young rats as the test model they calculated usable value of energy on the basis of conversion efficiency of gross to net food energy i.e. carcass energy. The energy value of FOS is further defined as 44% for GF₂; 46% for GF₃; and 10% for GF₄ by using six subjects of healthy human. Roberfroid (1999) suggests that oligofructose and inulin and all indigestible oligosaccharides should have a caloric value 1.5 kcal/g for the purposes of nutrition labeling.

Inulin have been used to substitute sugar, fat and to reduce the calories of foods stuff such as dairy products, ice cream, baked products and confectionary produduts. Oligofructose, fructose and inulin have lesser caloric values than a characteristic carbohydrate. The human intestinal enzymes cannot break these bonds and makes them indigestible. Therefore oligofructose and inulin pass without being metabolized throughout the mouth and small intestine. It shows that colonic fermentation of all the ingested oligofructose and inulin results in lactate and SCFA production. The energy derived from fermentation in very high. Bacterial biomass and gases are the other byproducts of fermentation which are finally excreted. Inulin was considered more appropriate for the patients of diabetes due to their indigestibility. Inulin has no effect on serum glucose, no influence on secretion of glucagon and has not any stimulation regarding secretion of insulin (Sanno *et al.*, 1984; Beringer and Wenger, 1995). There is a long history of inulin to be used by diabetic patients (Lewis, 1912) and its high doses been reported to benefit greatly in diabetics.

Fermentation of inulin

The carbohydrates which failed to be digested by small intestine reached in gut where microflora will partially or completely degrade them. Short chain fatty acids (SCFAs) mainly propionic acid, acetic acid, butyric acid and gases are produced during this fermentation (Macfarlane and Cummings, 1991). Fermentation of simply fermentable carbohydrates will produce a set of short chain fatty acids. The butyric acid is crucial factor in regulation of colonic mucosa, while the propionic acid is progressively associated with valuable influences on metabolism of lipids. SCFA may influence motility of colon. Various SCFA patterns are developed by different non-digestible carbohydrates, as stated by Berggren *et al.* (1993). It is not much easy to analyse the SCFA production, various methodologies are applied to measure the formation of SCFA. Humans Studies focus on the fecal SCFA but not at actual fermentation site. Therefore, relevant experimental models are required for the evaluation of SCFA production from various substrates. Vitro incubations with animal or human feces are examples of such models. While the rats studies mostly focus on SCFA.

Technological properties of inulin

1. Inulin as texture modifier

Boeckner *et al.* (2000) stated that for commercial production of inulin the dahlia tubers are preferably

utilized. Its production commenced in Netherlands and the Belgium in the 1990 and the production volume has been increasing from that time. This indigestible carbohydrate is applied in an increasing number of food applications. For instance, it can be employed in bakery and dairy products, ice cream, low fat spreads, beverages, confectionary and in cereals food items. Inulin is also significant in non food applications as binder (Eissens *et al.*, 2002) and feed of pets as described by Van Loo *et al.*, 2007 in additions to food applications. In industrial applications the inulin differentials are utilized. For instance, in waste water treatment carboxymethyl inulin functions as descaling agent (Martinod *et al.*, 2009).

Due to its unique technological and nutritional properties inulin finds its extensive applications in food industry. Inulin is significant not only due to its dietary fibre properties, as having the optimistic effect in bowel habit but also important as prebiotic as stated by Tungland and Meyer (2002). Gibson *et al.* (2004) concludes that the particular shift in the constitution of the microbiota of colon is due to inulin which has helpful significances for human. This particular rise in bifidogenic action is present in all humans age group (Meyer and Stasse-Wolthuis, 2009) and associated with different useful physiological significances.

Inulin includes positive effects for bone health by increasing calcium absorption, improved bowel habits and reduction of serum lipids for heart fitness. It also has a good effect on satiety for weight control, enhance infectious resistance and stimulate the immune system. Technological properties of inulin are based on its effects as sugar replacer, as texture modifier and fat replacer. Particularly, inulin is suitable because it contributes to an improved mouthfeel in low fat dairy products. Several researchers showed that creaminess can be enhanced by the addition of long chained inulin in yoghurt having low fat concentration. While according to others, the same action also occurs in less fat custards. When inulin is incorporated in low concentrations to the food, the product sensory qualities and rheological properties will not be affected due to its slight sweet or neutral taste and minimal effect on viscosity (Kalyani Nair *et al.*, 2010). Because of its unique properties, inulin influence significant affects on the texture of dairy product. It influence texture modification and also improves the sensory attributes of dairy products as stated by Tungland and Meyer (2002).

The unique characteristics of inulin related to its extent of polymerization. The long chain oligofructose is less sweet and have less solubility than a native short chain oligofructose. Inulin can enhance mouthfeel as it

posses sugar like characteristics. Native inulin product is more viscous and more soluble than a long-chain inulin, and also functions as texture improvers in dairy products (Wada *et al.*, 2005). DP also effect the other physico-chemical properties that includes the melting temperature (Blecker *et al.*, 2003), transition temperature of glass capability of gel formation, successive gel vigor (Meyer and Blaauwhoed, 2009), relations with different food ingredients like hydrocolloids. Such characteristics are obviously linked with technological functions of inulin especially its use as texture improver. The production of a good taste and less caloric products is a prime requirement for food industry in relation to the present rise in obesity. Thus reducing the sugar or fat contents is an appropriate way for a product development. The fat reduction and elimination however not only changes their structure but also brings up changes in the relations among the different ingredients. It causes clearly perceptible modifications in flavor, texture and color.

Application of fat replacers to recompense texture shortcomings is the most important strategy. It is possible with such type of ingredient to imitate the product rheology. However it has not any significant feature of relating the texture in the sense of creaminess. Although rheological and mechanical characteristics are major stimulator for texture sensing but the others related to structure and surface properties and have a prime function in textural properties of different food products (Foegeding *et al.*, 2010). The other characteristics such as smoothness, creaminess and fattiness are also very important for mouthfeel in additions to hardness or thickness in dairy products (De Wijk *et al.*, 2006). The rheological properties clarify the conffliction between hardness and thickness but the relationship of textural properties i.e. smoothness, roughness and creaminess is much less clear with rheological properties.

It is conclude from the presented data that not only the concentration but also DP of the inulin affects the rheological and texture behavior in certain dairy products. On the basis of composition and structure of every product, the addition of inulin as fat replacer in dairy product masks various effects on texture and rheology. Every dairy product is strongly regulated by its structure and composition i.e. fat contents, concentration and type of the other carbohydrates and the interactions of inulin with other constituents. The product structure and the incidence of the different components particularly the hydro-colloids can alter the extent or rate of inulin crystallization and consequently manipulate its fat replacing properties.

In some cases, the rheology of the product is largely determined by the other ingredients such as with k-carrageenan or starch with minor inulin effects. While at some definite concentrations of the long chain inulin a predominant function is imparted. The moisture competition is a factor to determine whether inulin can dissolve completely as it makes aggregates or complete gelatinization of starch. As the association between the parameters of bulk rheology and creaminess is not always clear so the bulk rheology measurements may not constantly be sufficient. Supplementary information could be given by calculation of additional parameters of friction. Therefore, such kind of information is of great importance for better understanding of inulin effects on oral and structural breakdown of dairy products (Foegeding *et al.*, 2010). Meanwhile, it is depicted that for proper replacement of fat, not only subsequent texture and structure should be optimum but also have to understand the flavor release (De Wijk *et al.*, 2003). In various dairy products inulin can perform as an excellent fat replacer. The fat replacement features of inulin are not only linked with the rheological modification (hardness or thickness) but also related to modifications of other characters i.e. mouthfeel, smoothness and creaminess. Generally, higher concentration of inulin is needed to mimic the smoothness or creaminess in low-fat dairy products having the thickness and rheology close to those of the full fat dairy food items. By the influence of inulin as fat replacer becomes more feasible to develop and design good sensory attributes of inulin enriched low fat products. Thus, inulin application as texture improver in different dairy products is the most important area of applications. The fat mimic feature of inulin is linked to alter the products rheology.

2. Inulin as prebiotics

Prebiotic is an indigestible ingredient of food that selectively stimulates the activity and growth of one or confined number of colon bacteria by affecting the host beneficially and also improves the health of the host. Additionally, prebiotic may suppress the pathogen's growth (Roberfroid, 2002). The oligofructose and inulin can be digested only through the bacterial activity. They can modify the composition of gut flora of human by a particular fermentation that consequently produce a bifidobacterial community (Wang and Gibson, 1993). According to Menne *et al.* (2000) Fn type fructans have prebiotic effect like oligofructose of GFn type. The oligofructose is resistant to enzymatic hydrolysis due to beta configuration of anomeric carbon 2 in their fructose monomers. These are explicated for the

glycosidic bonds and assorted as indigestible oligosaccharides on the basis of in vivo and vitro data. Since there is a limited physiological significance of inulin hydrolysis in stomach and these products pass from the upper gastrointestinal tract into colon without being digested.

It has been further confirmed by studies of humans and rats in vivo. The application of the ileostomy is the most compelling studies that substitute for the analysis of human digestive physiology and quantification of nutrients (particularly carbohydrates) excretion from small intestine. Coudray *et al.* (1997) found that in the effluent of ileostomy, 88% of dosage 11, 18, 31 g of oligofructose and inulin had been regained which endorsed the idea of oligofructose or inulin indigestibility in human small intestine. There is a little loss in the passage of small intestine as a result of microbial fermentation of the food ingredients by the ileum colonized microflora. Thus the microbial population of ileostomists is 100 times higher than ordinary individuals. Before and after the inulin intake in the ileostomy effluents, the end yield of the anaerobic fermentation of the carbohydrates (short chain carboxylic acids and lactic acid) revealed that 13% fructans lost in bowl. Acidic and enzymatic hydrolysis of fructans with less molecular weight showed that they are highly sensitive to hydrolysis in small intestine and stomach as compared to higher molecular weight ingredients (Coudray *et al.*, 1997).

3. Fat replacer

Various inulin mixes have functions as impending fat mimics in certain food products. Inulin can be mixed in water to produce fat like mouth feel and texture by using a particular processing technique. The inulin can be used as a fat replacer in liquid dairy foods but fails to mask the same effect in dry food products. Inulin HP is the very important as a fat replacer due to its higher molecular weight and long chain structure. The solubility of inulin is reduced by longer chain lengths. They result in the formation of inulin microcrystals when mixed with the foods that are not discretely detectable (water or milk) and have a smooth creamy mouthfeel as described by Niness (1999). Niness (1999) stated that inulin HP has almost two times greater fat replacing characteristics than a standard inulin without contribution of any sweetness. Inulin HP is preferably used when prebiotics are used to manufacture low fat spreads due to lack of sweetness and greater fat mimetic individuality.

4. Application as a Sugar Replacer

The properties of inulin type fructans are best suited as sugar substitute. The higher molecular weight and longer chain inulin type prebiotics are less soluble while lower molecular weight, shorter chain, FOS, oligofructose are ideal sugar replacers. The solubility of these short chain oligomers is greater than sucrose. They acquire functional characteristics similar to glucose syrup or sugar and possess 35 to 55 % sweetness of sucrose. Inulin can be extracted from dahlia tubers by using hot water extraction technique and produces about 8-10% sugars having a slight sweet taste. Other processing techniques should also be applied to manufacture a good sweet product that can be utilized as a good sugar replacer. Enzymatic hydrolysis of inulin can produce a powder or oligofructose syrup having additional free sugars. FOS from the sucrose produces a sweet inulin type prebiotic mix. Classically, oligofructose syrups and oligofructose powders have less sweetness than a table sugar. So, in order to obtain a desired sweetness level they are used in mixture with intense sweeteners. The most frequent practices of oligofructose in foods applications is their combined effect with the intense sweeteners. Therefore, it advances sweetness profiles of intense sweeteners and also removes their aftertaste. This point is further restated by Niness (1999) that combination of inulin with intense sweeteners is frequently used to substitute sugar. It provides a balanced profile of sweetness and dissembles the aftertaste of acesulfame-K or aspartame. Therefore, the objective of the product containing FOS or oligofructose influence the consumers that they are using somewhat unusual than sugar. In case of inulin type prebiotics, the free sugars are responsible for sweet taste. Food producers can lawfully publicize the prebiotic health benefits because food labeling does not require the label discrimination i.e. whether the free sugars contain high or low level of FOS.

5. Inulin as dietary fibre

The inulin is a carbohydrate that is resistant to digestion in small intestine. They improve the bowel habits by increasing the faecal water content and biomass. Due to such characteristics, these are indisputably part of dietary fibre as stated by Roberfroid (1993). These are carbohydrates and components of vegetal plant cell. Inulin shows hydrolytic resistance to alimentary enzymes of mammals and resistant to absorption in small intestine. These are summarized as carbohydrates and resistant to digestion by digestive enzymes of the mammals and absorption in the small intestine. But they can be hydrolyzed and fermented by colonic microflora to some extent. In consumer food products they should

be labeled as dietary fibre. They have particular features that are unusual from other fibres due to their peculiar fermentation significances. Therefore, by escalating the contents of dietary fibre they may add in considerable approach to balanced diet. They may also helps in the improvement of various sources of fibre and their effects on different intestinal functions i.e. intestine microflora, mucosal functions, mineral absorption and endocrine activities.

CONCLUSION

Application of various plant-derived, indigestible carbohydrates has potential as a prebiotic, sugar replacer, fat replacer and texture modifier by regulating the desirable sensory quality and technological characteristics of product. Inulin is a storage polysaccharide, commonly found in chicory Jerusalem artichoke tubers, dahlia tubers, asparagus root, burdock, onions, wheat, oat, rye, banana, Chinese chives, garlic, pine and honey. The wide applications of inulin in the food industry are based on their nutritional and technological properties. Inulin is significant not only as dietary fibre for positive results on bowel habit but also for its prebiotic importance and texture improvers. It is used in food industry by virtue of its diversified nutritional and functional properties.

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