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## RESEARCH ARTICLE

### PREBIOTICS AS FAT REPLACERS.

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#### Abstract

Prebiotics are found in several vegetables and fruits and are considered functional food components which present significant technological advantages. Their addition improves sensory characteristics such as taste and texture, and enhances the stability of foams, emulsions and mouthfeel in a large range of food applications like dairy products and bread. Prebiotics which decrease the caloric value of food can be used to solve some physical and sensory problems originating from low fat levels in the final products.

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#### Introduction:-

Prebiotics are non-digestible food components that selectively stimulate the growth or activity of specific indigenous bacteria in the digestive tract in a manner claimed to be beneficial for the host. prebiotics allow desirable changes in the composition as well as the activity of the gastrointestinal microflora and confer health benefits to the host (Kanakupt, Boler, Dunsford, & Fahey, 2011; Nagpal, Yadav, & Marotta, 2014).

Prebiotics are primarily carbohydrates (oligosaccharides and polysaccharides), but may include some non-carbohydrate moieties. Soluble fibres are the most prevailing type of prebiotics. Nevertheless, various other forms of dietary fibre may serve the purpose. In this context, criteria have been established to categorize any food ingredient as a candidate prebiotics: they have the ability to resist gastric hydrolysis by digestive enzymes and remain unabsorbed in the upper gastrointestinal tract; they undergo fermentation by resident microbiota in the large intestine; and they stimulate the activity/growth of potentially beneficial intestinal bacteria (Xiao, Fei, & Pang, 2014).

Prebiotics exhibit imperative technological properties as well as attractive nutritional value. In food formulations, they appreciably upgrade sensory features and improve taste and mouth feel. In order to become part of functional food, prebiotics must be stable to processing conditions like heat, pH and Maillard reaction because degraded mono- and disaccharides are not available for bacterial fermentation. Previous investigations on prebiotics have shown that heating at low pH causes reduction in prebiotic activity whilst other conditions did not alter stability.

Inclusion of prebiotics in food is a natural way to provide healthy ingredients to the consumers. Most of the prebiotics are easily consumable and give desired functionality to the food items (Courtin, Swennen, Verjans, & Delcour, 2009). For instance, short chain prebiotics act like sugars and contribute to crispiness and browning of the end product. Long chain prebiotics work as fat replacer, escalate the texture and mouthfeel. The majority of the prebiotics are not considerably distorted or damaged by processing treatments, thus retaining their functionality.

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throughout the alimentary tract. Contrarily, most of the probiotics in the finished products have been killed due to harsh processing conditions that are required to eradicate microbes for food safety reasons (Bohm et al., 2006).

#### **Types and sources of prebiotics:-**

Non-digestible carbohydrates can be considered as prebiotic if they achieve the following criteria (A) resistance to gastric acidity and mammalian enzymes; (B) susceptibility to fermentation by gut bacteria; and (C) ability to enhance the viability and/or activity of beneficial microorganisms (Rastall & Gibson, 2006). Galactooligosaccharides (GOS), fructooligosaccharides (FOS) and inulin are the prebiotics most commonly known. GOS are non-digestible and are derived from lactose that occurs naturally in mammalian milk and consist of chains of galactose monomers. Inulin and inulin-type fructans, are known soluble dietary fibres (Roberfroid, 2005). Additionally, dietary fibre containing several non-starch polysaccharides, such as cellulose, dextrins, pectins, beta-glucans, waxes, and lignin can adjust the transfer time through the gut, thus offering the same useful effects as those of inulin-type fructans (Napolitano et al., 2009).

#### **Application of inulin as a fat replacer:-**

The presence of fat in dairy products plays an important role in their physical, rheological, and textural properties (Barclay et al., 2010; Brennan & Tudorica, 2008; Dave, 2012). Fat, apart from its nutritional significance in cheese, contributes to the sensory and functional properties of dairy products (Miocinović et al., 2011). However, consumers are increasingly demanding foods with dietetic and functional properties, such as those with low calories, low or reduced fat and health benefits (Gonzalez-Tomás, Coll-Marqués, & Costell, 2009). Also, low-fat food plans have been recommended for weight loss and maintenance (Peterson, Sigman-Grant, Eissenstat, & Kris-Etherton, 1999). On the other hand, there is a widely held view that low-fat or reduced-fat foods are less desirable because they have poor organoleptic qualities (McEwan & Sharp, 2000).

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, Salem, El-Sonbaty, & El-Sissey, 2002). Removal of fat from cheese causes rheological, textural, functional and sensory defects such as rubbery texture, lack of flavor, bitterness, off-flavor, poor meltability and undesirable color (O'Connor & O'Brien, 2011). It is not easy to make low-fat or fat-free cheeses with desirable properties (Fadaei et al., 2012). As fat content decreases, the protein matrix becomes more compact and the cheese texture is more chewy. When fat ingredients are reduced in food formulations, other ingredients are often required to fulfill its functional role in maintaining organoleptic qualities (Mattes, 1998). A strategy proposed for improving the flavor and texture of low-fat cheese is the use of fat replacers (Sandrou & Arvantoyannis, 2000). The Codex Commission on International Trade has set a maximum limit of 50% reduction in fat from a referenced variety for a cheese to be labeled as reduced-fat (FAO/WHO, 2008). In Europe, cheese can be labeled as reduced-fat when the reduction in fat content is at least 30% compared with a similar product (EU, 2006). In the United States, a reduced-fat cheese requires at least a 25% reduction in fat level from the traditional level of the referenced variety. 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 mouthfeel (Meyer et al., 2011). The fat-substituting property of inulin is based on its ability to stabilize the structure of the aqueous phase, which creates an improved creaminess (Ibrahim, Mehanna, & Gad El-Rab, 2004). A creamy mouthfeel is achieved when inulin is used as a fat replacer in dairy products due to its interactions with whey protein and caseinate (Karaca, Güven, Yasar, Kaya, & Kahyaoglu, 2009). High performance (HP) inulin with long chain and high molecular weight is the 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 mouthfeel. HP inulin has an average DP of 25 and a molecular distribution ranging from 11 to 60. Thus, the residual sugars as well as the oligomers have been removed. 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 microcrystals when sheared in water or milk. Inulin has therefore been used successfully to replace fat in dairy products (Kaur & Gupta, 2002), especially cheese (Salvatore et al., 2014). Long-chains of inulin form microcrystals (insoluble sub-micron crystalline) which inter-act with each other forming small aggregates in the water phase (Guggisberg et al., 2009). They cause a smooth and creamy texture through encapsulating a great

amount of water (Bot et al., 2004). Inulin can also form parts of the protein structural network by complexing with protein aggregates (Kip, Meyer, & Jellema, 2006).

Koca and Metin (2004) considered the possibility of obtaining low-fat fresh kashar cheese with a 70% fat reduction using long-chain inulin. They reported that their low-fat control cheese, due to its high protein content, was significantly harder, more elastic, gummier and chewier than the full-fat control cheese. Fat breaks the protein matrix and acts as a lubricant to provide a softer texture. It has been shown that adding 5% inulin to the low-fat cheese resulted in a significantly lower hardness compared to the low-fat control cheese, but slightly higher than that of the full-fat control cheese. This softening effect could be attributed to both the higher ratio of moisture to protein and the increase in filler volume, which decreases the amount of protein matrix. In general, inulin improved the cheese texture until the 30th day of storage, but reduced its shelf life. 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 mouthfeel attributes, such as creaminess or smoothness (Meyer et al., 2011). When inulin is added to food in low concentrations, the rheological properties and the sensory quality of the product will not be affected strongly due to inulin's neutral or slightly sweet taste and its limited effect on viscosity (Kalyani et al., 2010). To obtain low-fat products with rheology and thickness close 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. It is expected that long chain inulin versus short chain has considerable water binding/retention capacity and capability to prevent syneresis.

Salvatore et al. (2014) evaluated the effect of replacing fat with 2, 3 and 7% long-chain inulin on the textural and microstructural properties of a fresh caprine milk cheese. Using scanning electron microscopy and penetrometry, it was shown that cheese samples containing inulin had more open structure compared to full-fat cheese due to the decreased fat distribution in the matrix of protein. Positioning of inulin in casein network appeared as structures embedded in the gel system and the size of which increased with higher concentration of inulin in cheese. Inulin interrupts the casein network, resulting in a softening effect, which increases with increasing levels of inulin to replace fat. According to their findings, samples containing inulin were characterized by lower values for compressive force, stiffness, viscosity and adhesiveness.

Inulin products consisting mainly of long-chain molecules are applied for fat replacement, since in the presence of water they are capable to develop a particulate gel, thus alter the product texture and provide a fat-like mouthfeel (Karimi et al., 2015). In non-fat functional dairy foods inulin can be used as a fat replacer and provides them nearly the same sensory characters as of full fat products (Solowiej et al., 2015). Some scientists have analyzed the effect of long chain inulin addition on physical and sensorial features of dairy foods such as yogurt or custard. Long-chain inulin has been used in low-fat yogurts to replace fat where it was exposed to considerably improve creaminess, mouthfeel and smoothness (Modzelewska-Kapituła & Kle, 2009). Addition of long-chain inulin to low fat custards enhanced creaminess and consistency, also same results were obtained by its addition to full-fat custards (Lobato, Grossmann, & Benassi, 2009).

Fat replacer can additionally be used in meal replacers, meat products, sauces and soups, thus less fat meat products are available having a juicy and creamy mouthfeel and an enhanced firmness due to water control (Cho & Samuel, 2009). The addition of inulin to added-fat containing meat products like sausages could be an attraction to health conscious consumers as they are significant to human nutrition in the situation of dietary guidelines (Selgas et al., 2005). The addition of inulin to sausages results in reduced fat content, improves texture, and sensorial appraisal. Fructan analysis suggested that the inulin remained stable during processing and successive heat treatment (Keenan et al., 2014). Further studies showed that fermented chicken sausages made with inulin as a partial oil replacement persisted stable without any significant loss of physicochemical, microbiological and sensory characteristics during storage at 4°C for 45 days (Menegas et al., 2013). Inulin addition in biscuits to a level of 15% could be used to attain fat replacement and good sensory properties (Laguna, Primo-Martín, Varela, Salvador, Sanz, 2014).

**Effects of prebiotics on the chemical characteristic of yoghurt:-**

The addition of inulin into yoghurt did not influence acetaldehyde, pH and titratable acidity (Güven et al., 2005). Tyrosine and volatile fatty acidity levels were negatively affected by inulin addition. Fat replacers are also used to reduce the fat content of yoghurt such as Simplesse and Dairy-Lo. Simplesse is a microparticulated spray-dried powder that mimics emulsified fat by forming a dispersed phase of particles that are free to move independently. Dairy-Lo is classified as a protein based fat replacer and derived from whey protein concentrate. It is a modified whey protein concentrate that forms a gelled network when heated above the protein denaturation temperature (Yazici & Akgun, 2004). The sample that supplemented with it had higher titratable acidity, fat, and ash than Simplesse supplemented samples. The pre-biotic containing yoghurt had a significantly lower pH than the other yoghurts (Aryana, Plauche, Rao, McGrew, & Shah, 2007).

**Effects of prebiotics on rheological measurements of yoghurt:-**

The addition of inulin at more than 1% increased whey separation from yoghurt and consistency (Güven et al., 2005). The amount of fat replacer and storage time had a significant effect on the physical, chemical, textural, and sensory properties of strained yoghurts (Yazici & Akgun, 2004). Yoghurts containing inulin had less syneresis than the control and had a better body and texture than other yoghurts (Aryana et al., 2007).

The analysis showed that stickiness, airiness, and thickness contributed to the creamy mouthfeel of the yoghurts. Thickness was significantly affected by inulin (Kip et al., 2006). Rheological characterisation was performed by dynamic, shear, and compression extrusion assays and did not show any differences (Dello Staffolo et al., 2004). Fibre incorporation increased the consistency of the yoghurts, especially if the fibre was ethanol extracted and lyophilised. However, there were no significant changes in the viscoelastic behaviour for any of the fibre types (Sanz et al., 2008).

**Effects of prebiotics on the sensory evaluation of yoghurt:-**

With respect to the sensory quality of yoghurt, inulin addition caused a decrease in sensory scores: the control yoghurt had the highest score, and the lowest score was obtained in yoghurt samples containing 3% inulin. Overall, the yoghurt containing 1% inulin was similar in quality characteristics to the control yoghurt made from whole milk (Güven et al., 2005). The inulin containing yoghurt had comparable flavour scores to that of the control (Aryana et al., 2007).

Inulin can be used successfully to improve the creamy mouthfeel of low-fat yoghurts (Kip et al., 2006). Only apple fibre yoghurt showed colour differences compared to the control. Even though fibres modified certain rheological characteristics of the plain yoghurt, panellists found the supplemented yoghurts acceptable (Dello Staffolo et al., 2004). Fibre diminished the clarity and imparted a yellow-greenish colour to the yoghurt, which also varied depending on the method of extraction and drying, the yoghurts with water-extracted fibres being more colourful. The sample most liked according to a consumer test was the yoghurt containing water-extracted and oven-dried fibres for aroma, taste, texture, and overall acceptance, and ethanol-extracted and lyophilised for colour. Fibre obtained by all methods was equally compatible with yoghurt enrichment (Sanz et al., 2008).

**Prebiotic chocolate:-**

Prebiotics can be applied to a variety of foods (Morris & Morris, 2012; Volpini-Rapina et al., 2012). The consumption of foods such as prebiotics that promote wellness, health, and a reduced risk of diseases have grown worldwide. During the past decade, more than 500 new products enriched with prebiotics have been introduced to the market (Da Silveria et al., 2015). Prebiotics have attracted the interest of researchers and the food industry due to their nutritional and economic benefits (Scheid et al., 2013). The nutritional value and the possibility of improving some sensory properties of food formulations make the use of prebiotic ingredients advantageous (De Moraes et al., 2015).

Among the most widely studied and commercially used prebiotics are inulin, fructooligosaccharide (FOS), and galactooligosaccharides (GOS) (Davis et al., 2010). Usage of these beneficial ingredients for enrichment of the corresponding material is also valid for chocolate. Inulin responds to a variety of consumer demands: it is fiber-enriched, prebiotic and low calorie. Fructooligosaccharide products containing mainly short-chain molecules enhance flavor and sweetness and are used to partially substitute of sucrose (Aidoo, Afaokwa, & Dewettinck, 2015).

Major prebiotic substances used in the chocolate production can be stated as inulin and polydextrose. There are limited number of studies in the literature related with GOS and FOS. Polydextrose, a functional food ingredient, is also potentially a prebiotic substance. The rise in diet-related illness has led consumers to take a greater interest in the ingredients of food products. Polydextrose is a functional food additive due to its prebiotic properties (Srisuvor et al., 2013). Polydextrose is a non-digestible, odourless, white-to-cream amorphous powder with virtually no sweetness, low molecular weight, randomly bonded polysaccharides of glucose and a calorie content of 1 kcal/g. Polydextrose comprises mainly glucose in its highly branched polymer, with small quantities of randomly distributed sorbitol and citric acid. This compound has an average degree of polymerisation (DP) of 12 and an average molecular weight of 200 g/mol (Konar et al., 2014). Polydextrose consumption resulted in dose-dependent decrease in Bacteroides, as well as an increase in lactobacilli and bifidobacteria (Slavin, 2013).

Interestingly, instead of prebiotic characteristics of inulin and polydextrose as the mostly studied prebiotics their bulking and sweetener properties have been considered for the production of sugar-free chocolate and their fat substitute characteristics have been considered for the production of calorie- or fat-reduced chocolates. However this situation provides an advantage since they could play a role in reducing fat and sugar contents as well as prebiotic characteristics depending on their concentrations in the formula. These multiple functional properties of inulin and poly-dextrose provide advantageous in using of them in chocolate formulations. The extensive use of inulin (Aidoo et al., 2014; Rezende et al., 2015) and polydextrose in the food industry is based on its nutritional and technological properties. Its use as a body agent in sucrose-free chocolates was studied by some researchers, which reported its effects on rheological, physical (Shah, Jones, & Vasiljevic, 2010), and sensory properties of chocolates (Rezende et al., 2015).

One of the factors taken into consideration during production of functional foods is health claims mentioned on the label of the product and used in the description of the products. In this respect, national regulations, global structure of food market, international legislative regulations and rules should be taken into consideration in order to keep standards of the corresponding material. Although inulin is recognized as efficient fat replacer for use in chocolate, In Europe, the minimum reduction is 30% (EC, 2006). The American regulations do not set a minimum percent reduction for food to be considered light, as long as the nutrient percent reduction in relation to the reference food is informed (FDA, 2009) fiber sources (content 3.0 g fiber/100 g of solid food), as high fiber (content 6.0 g fiber/100 g solid food), (Aidoo et al., 2015; EC, 2006; FDA 2009). Therefore, threshold value for different prebiotics may be accepted as 6.0 g/100 g for chocolates as well as other food products.

Shourideh et al., (2012) reported increase in moisture content with increase in inulin concentrations in their dark chocolate formulations containing different mixtures of D-tagatose and inulin. The authors attributed this to hydrophilic groups present in inulin, which causes increase and preservation of moisture in samples with high content of inulin. The low concentrations of inulin (25%) in chocolate formulations of Rezende et al. (2015) could have thus resulted in the chocolates falling within acceptable moisture limits. Therefore, prebiotic concentration added to the chocolates should be determined considering quality characteristics of the end product.

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