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Review

Inulin: Properties, health benefits and food applications

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ABSTRACT

Inulin is a water soluble storage polysaccharide and belongs to a group of non-digestible carbohydrates called fructans. Inulin has attained the GRAS status in USA and is extensively available in about 36,000 species of plants, amongst, chicory roots are considered as the richest source of inulin. Commonly, inulin is used as a prebiotic, fat replacer, sugar replacer, texture modifier and for the development of functional foods in order to improve health due to its beneficial role in gastric health. This review provides a deep insight about its production, physicochemical properties, role in combating various kinds of metabolic and diet related diseases and utilization as a functional ingredient in novel product development.

Contents

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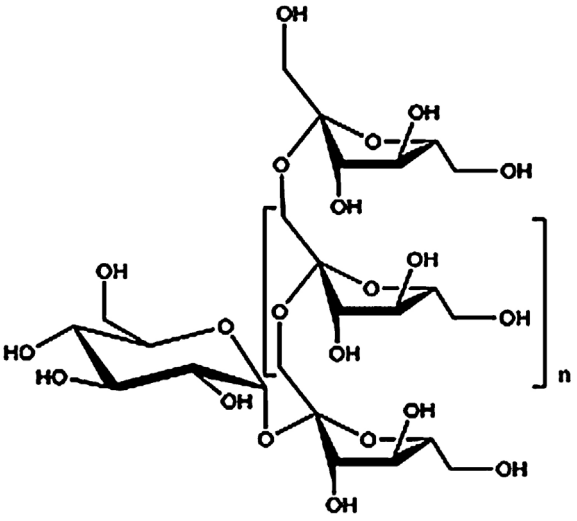

Fig. 1. Chemical chair structure of inulin [GFn].

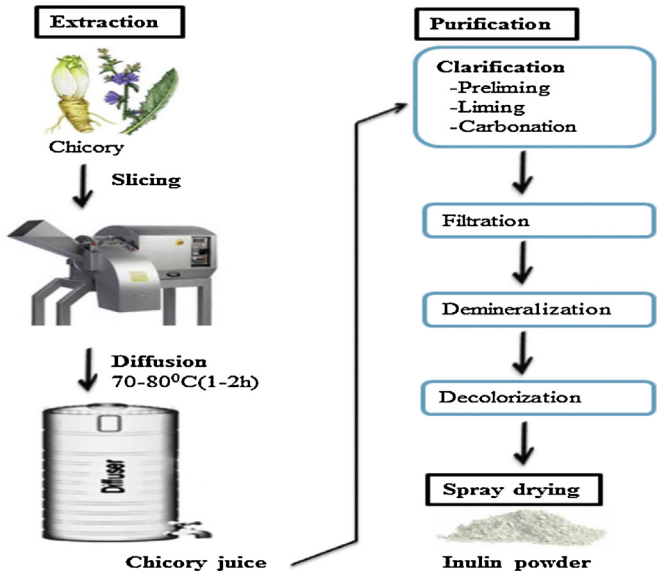

Fig. 2. Production line of inulin from chicory roots. Adopted from (Zhu et al., 2016).

1. Introduction

Inulin, owing to its presence in over 3000 vegetables, is considered to be extensively distributed in various plants, being present (Wichienchot et al., 2011). It has been a part of our daily food intake for centuries contributing to nutritional properties and exhibits significant technological benefits (Giarnetti, Paradiso, Caponio, Summo, & Pasqualone, 2015; Kalyani Nair, Kharb, & Thompkinson, 2010). In the early 1800s, a German scientist named Valentine Rose discovered inulin from the roots of Elecampane (*Inula helenium)* and was later on named inulin by Thomson in 1817. Inulin spherocrystals were detected in dahlia, Jerusalem artichoke and elecampane by Julius Sachs in 1864. Natural sources of inulin include chicory roots, Jerusalem artichoke, dahlia tubers, yacon, asparagus, leek, onion, banana, wheat and garlic (Table 1) (Bornet, 2008; Roberfroid, 2007). Synthetically, inulin type fructans are prepared from sucrose (Cooper et al., 2015). Inulin is widely used in the processed foods as a fat or sugar replacer or to impart desirable characteristics and it gives only 25–35% energy as compared to digestible carbohydrates. The sweetness level of inulin is about 10% of the sucrose. It is a versatile ingredient owing to its health benefits, specifically increased mineral absorption and also considered as Fermentable Oligo-,Di-, Monosaccharides and Polyols (FODMAP), group of carbohydrates which are readily digested in the colon by drawing water into colon to manage constipation and related ailments. It also promotes the growth of micro-flora in digestive tract and is considered as an appropriate ingredient to prepare low caloric foods for diabetics to manage blood sugar levels.

1.1. Chemical structure

β-(2-1)-D-frutosyl fructose bonds are present between the fructose units of inulin and β-configuration of anomeric carbon, making it indigestible in human small intestine, however, can be fermented in large intestine by the intestinal micro-flora (Apolinario et al., 2014). Inulin-type fructan consists of linear (2 → 1)-linked β-D-fructosyl units attached to the fructosyl moiety of sucrose. G represents glucose unit, F denotes units of fructose, whereas n denotes number of fructose units. In chicory inulin, the number of fructose unit vary from 2 to 60 indicating a combination of oligomers and polymers (Roberfroid, 2005). Fig. 1. shows the chemical structure of inulin compounds.

The DP (Degree of polymerization) and branches have an effect on the functionality of the inulin. Plants inulin have relatively low DP (maximally < 200) which depends on plant species, climatic conditions and the plant's physical condition. Inulin present in bacteria has a very high DP, ranging from 10,000 to above 100,000; furthermore, a bacterial inulin is 15% more branched than the plant inulin (Cho & Samuel, 2009).

1.2. Production

Commercially most of the inulin is produced from chicory, however, dahlia and Jerusalem artichoke are also considered as good sources for industrial production in temperate areas (Flamm, Glinsmann, Kritchevsky, Prosky, & Roberfroid, 2001). Besides, this some new plants with high inline contents have been reported (Table 1). Chicory is a bi-yearly plant belonging to the *Asteraceae* family. During the first year of growth, chicory plants persist in the vegetative phase and form only leaves, taproots and fibrous roots. The root stocks have resemblance with small oblong sugar beets (Boeckner, Schnepf, & Tungland, 2001; Kelly, 2008). Inulin production goes through two stages. In the first phase extraction and initial purification of raw syrup is done, which is further refined to produce commercial product (above 99.5%) during second phase of processing. Some advanced technologies like, supercritical carbon dioxide (CO_2) (Mendes, Cataldo, da Silva, Nogueira, & Freitas, 2005) ultrasound (Lingyun et al., 2007) simultaneous ultrasonic/microwave (Lou, Wang, Wang, & Zhang, 2009) and pulsed electric field (PEF) (Loginova, Shynkaryk, Lebovka, & Vorobiev, 2010) are also being implicated in the inulin extraction process for getting higher yields of purified final product with less energy consumption. But in the classical purification process in order to remove impurities from the extracted juice, clarification requires multiple steps (pre-liming, liming and carbonation) at relatively high temperature (80–90 °C) as shown in Fig. 2 (Franck & De Leenheer, 2005). This may lead to the hydrolysis of inulin molecules in the extracted juice and may also introduce additional calcium ions into clarified juice which requires further purification treatments (Kim, Faqih, & Wang, 2001). Membrane based technologies like microfiltration and ultrafiltration are also reported to ease these laborious and time consuming steps. The resultant inulin having DP ranging between 3 and 60 imitates the original DP present in chicory. A high quality long chain inulin with DP more than 23 is also attainable (Cho & Samuel, 2009).