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Molecular properties and prebiotic effect of inulin obtained from artichoke (*Cynara scolymus* L.)

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Abstract

A high molecular weight inulin has been prepared from artichoke (*Cynara scolymus* L.) agroindustrial wastes using environmentally benign aqueous extraction procedures. Physico-chemical analysis of the properties of artichoke inulin was carried out. Its average degree of polymerization was 46, which is higher than for Jerusalem artichoke, chicory, and dahlia inulins. GC–MS confirmed that the main constituent monosaccharide in artichoke inulin was fructose and its degradation by inulinase indicated that it contained the expected β-2,1-fructan bonds. The FT-IR spectrum was identical to that of chicory inulin. These data indicate that artichoke inulin will be suitable for use in a wide range of food applications. The health-promoting prebiotic effects of artichoke inulin were demonstrated in an extensive microbiological study showing a long lasting bifidogenic effect on *Bifidobacterium bifidum* ATCC 29521 cultures and also in mixed cultures of colonic bacteria.

Keywords: Inulin; Artichoke; Bifidobacteria; Prebiotic effect; Inulinase

1. Introduction

Inulin is a plant-derived carbohydrate with the benefits of soluble dietary fiber. It is not digested or absorbed in the small intestine, but is fermented in the colon by beneficial bacteria. Functioning as a prebiotic, inulin has been associated with enhancing the gastrointestinal system and immune system. In addition, it has been shown to increase the absorption of calcium and magnesium, influence the formation of blood glucose, and reduce the levels of cholesterol and serum lipids (Coudray et al., 1997; Niness, 1999). Therefore, inulin obtained from several Compositae (Jerusalem artichoke, artichokes, chicory, dahlias, and dandelions) is a subject of interest in many food research programs (Mitchell and Mitchell, 1995; Smits and Hermans, 1998; Silver and Brinks, 2000; Heyer et al., 1998; van Loo and Hermans, 2000). Inulin is not simply one molecule; it is a polydisperse β-2,1 fructan (Phelps, 1965). The fructose units (F) in this mixture of linear fructose polymers and oligomers are each linked by β-2,1 bonds. A glucose molecule (G) typically resides at the end of each fructose chain and is linked by an α-1,2 bond, as in sucrose. The unique aspect of the structure of inulin is its β-2,1 bonds.

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These linkages prevent inulin from being digested like a typical carbohydrate and are responsible for its reduced caloric value and dietary fibre effects.

Inulins obtained from different plants differ in their degree of polymerization (DP). As inulin is a polydisperse mixture of oligomers with varying DPs, inulin samples are characterized by their average degree of polymerization, DP_n. The differences in DP_n between different inulins account for their distinctly different functional attributes. Long chain length inulins are less soluble, and they have the ability to form inulin microcrystals when sheared in water or milk. These crystals are not discretely perceptible in the mouth, but they interact to form a smooth creamy texture and provide a fat-like mouth sensation. Inulin has been used successfully to replace fat in table spreads, baked goods, fillings, dairy products, frozen desserts and dressings.

Globe artichokes (*Cynara scolymus* L.) are perennial, frost sensitive, thistle-like plants with edible flower buds, which sprout from the terminal portion of the main stem and on lateral stems. Each unopened flower bud resembles a deep green pine cone, 7–10 cm in diameter, round, but slightly elongated. Several pointed, leathery green bracts fold around a purple-blue flower. The base of each bract is the fleshy edible portion, along with the fleshy centre of the artichoke on which the flower and bracts are borne. Commercially available inulins are obtained mainly from chicory, Jerusalem artichoke, and dahlia. They are distributed with several trade names such as Raftiline or Fibruline. Although artichokes possess high inulin content [3% of fresh weight (van Loo et al., 1995)] its properties and possible applications are less well known than those from other sources probably because the flowers of the plant are usually eaten as a vegetable. Our research group in collaboration with the Spanish company Artbiochem, S.L., has designed a protocol for the isolation and purification of inulin from artichoke waste materials (bracts) from the canning industry. The artichoke canning industry, an active sector in our local area, generates large amounts of industrial waste, consisting mainly of the stems and external parts of the flowers (bracts) of the artichoke plant, which are not suitable for human consumption. For example, 70% of the weight of the artichoke flower corresponds to waste. Said wastes are generally used in the production of animal feed, particularly silage. Therefore, isolation of a by-product with high added value, such as inulin, from these industrial wastes is of commercial interest. The process we have developed is carried out exclusively in aqueous medium, without the addition of any organic solvents, which is environmentally friendly in itself and could be of importance for the use of this inulin in foods. Therefore, in this study we have characterized artichoke inulin and explored its possible application as a prebiotic agent. Moreover, further investigations are in progress to determine the possible inclusion of this inulin in other applications including diagnostic reagents, preparation of specific drug carriers and its use as an anticarcinogenic agent (Hughes and Rowland, 2001; Chourasia and Jain, 2003).

2. Results and discussion

2.1. Extraction of artichoke inulin

The initial inulin extract was obtained from milled artichoke bracts in aqueous solution. The liquid extract was filtered and concentrated by ultrafiltration using a 10000 NMWCO membrane to obtain a high molecular weight fraction of artichoke inulin. At this stage most of the acid components, pigments, and dyes were removed from the crude precipitate by ion-exchange chromatography, yielding a colourless material. The concentrated extract was then submitted to a precipitation process at low temperature and subsequent phase splitting by centrifugation. Variables involving inulin precipitation yield (w/w) were identified and studied: time for precipitation, precipitation temperature (from −24 to 16 °C), centrifugation velocity (from 6000 to 10,000*g*) and centrifugation time (from 15 to 45 min). The results showed a tendency to increased inulin precipitation mass yield when precipitation time increased and temperature decreased, independently of centrifugation velocity and time. The time-course of inulin precipitation showed maximal yield after 12 h at −24 °C. The final lyophilized white powder was subjected to several characterization techniques.

2.2. Physico-chemical properties of artichoke inulin

The physico-chemical characteristics of artichoke inulin are compared with samples of standard and high performance chicory inulin in Table 1. Artichoke inulin is moderately soluble in water (maximum 5% at room temperature), it has a bland neutral taste, without any off-flavour or aftertaste, and is not sweet. Therefore, it combines easily with other ingredients without modifying delicate flavours. For reasons of growing interest in the food and pet food industries, the short chain inulins have to be separated from their long chain analogues, because their properties (digestibility, prebiotic activity and health promoting potential, caloric value, sweetening power, water binding capacity, etc.) differ substantially (van Loo and Hermans, 2000; van Leeuwen et al., 1997; De Gennaro et al., 2000). The method applied here for artichoke inulin preparation produced high molecular weigh fractions of the polymer, and made further fractionation procedures (Moerman et al., 2004) by precipitation from water/solvent