Review paper
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NUTRITIONAL AND HEALTH BENEFITS OF INULIN AS FUNCTIONAL FOOD AND PREBIOTIC

Nadica Ilievska[1], Valentina Pavlova[1*], Vera Kirovska[1], Jovana Ilievska[2], Martina Pavlovska[3]

[1]Faculty of Technology and Technical sciences, University St. Kliment Ohridski - Bitola, Dimitar Vlahov bb, 1400 Veles, Republic of Macedonia
[2]Institute of Biology, Faculty of Natural Sciences and Mathematics, "Ss. Cyril and Methodius" University, Arhimedova 3, 1000 Skopje, Republic of Macedonia
[3]Faculty of Agricultures Sciences and Food, "Ss. Cyril and Methodius" University, 16-ta Makedonska brigada 3, 1000 Skopje, Republic of Macedonia

[*]e-mail: valentina.pavlova2@gmail.com

Abstract

Inulin is a complex carbohydrate that belongs to a class of compounds known as fructans. Inulin has been consumed from plant sources by mankind for centuries, and is most concentrated in chicory, jerusalem artichoke, garlic, leek and onion. This review summarizes and categorizes the nutritional benefits of its intake as part of the human nutrition.

Inulin is thought to share many of the properties of soluble dietary fibers, such as the ability to lower blood lipids and stabilize blood glucose. Additionally, inulin has been shown to enhance the growth of bifidobacteria and lactobacilli and enhance the gut environment by inhibiting growth or activities of some pathogenic bacteria. There is some scientific evidence that inulin decreases risk of coronary heart disease and haves immunomodulation effects. Because of its properties inulin-type fructans are gaining attention in recent years. This review focuses on nutritional properties of inulin as functional food and prebiotic, and health benefits from its inclusion in daily diet.

In conclusion the published data shows that intake of inulin has beneficial properties to the overall health and most notably it has positive influence on maintaining a healthy gut flora. Inulin is food ingredient with potential health-promoting effects.

Key words*: Inulin, Prebiotic, Dietary fibers, Nutrition, Health.*

1. Introduction

Inulin is a natural storage polysaccharide of various plants which are mostly part of the *Compositae* family including chicory and Jerusalem artichoke. Other natural sources of inulin are: asparagus, leek, onion, banana, wheat and garlic. Among these sources, in industrial production of inulin, chicory is the most common source. The inulin content in the roots of chicory is more than 70% on dry substance [1]. The industrial production process of inulin involves the extraction of the naturally occurring inulin from chicory roots by diffusion in hot water, followed by purification and then spray-drying.

Inulin has been a part of human dietary food intake for centuries, contributing to nutritional properties and exhibits technological benefits. In fact it has been estimated that Americans consume on average 1 - 4 g of inulin and oligofructose per day, and Europeans average 1 - 10 g [2].

Inulin is prebiotic dietary fiber showing excellent properties as a carbohydrate-based fat substitute in relation to its ability to increase viscosity, form gels, provides texture and to increase water-holding capacity, and thus presenting a good application potential in various food product formulations. Additionally, the incorporation of inulin in foods is known to reduce the risk of many diseases in human beings thus promoting health effects, and it has to be considered as functional food [3].

2. Nutritional and health benefits of inulin as functional food and prebiotic

2.1 Chemical structure and physicochemical properties of inulin

Inulin polymer consists of a long chain made up of 2 - 60 fructose molecules, which are connected by β-(2-1) bonds. The terminate fructose molecule is linked with a glucose molecule by α-(1-2) bond [4]. The degree of polymerization and branches gave an effect on the functionality of inulin. Generally, plant inulins are found to have chains incorporating 2 - 100 or more fructose units. When inulin is extracted from the chicory root, it comprises a family of identical linear structures that differ in their degree of polymerization, ranging from 3 to 60 [5].

The chemical structure of an inulin polymer is presented in Figure 1.

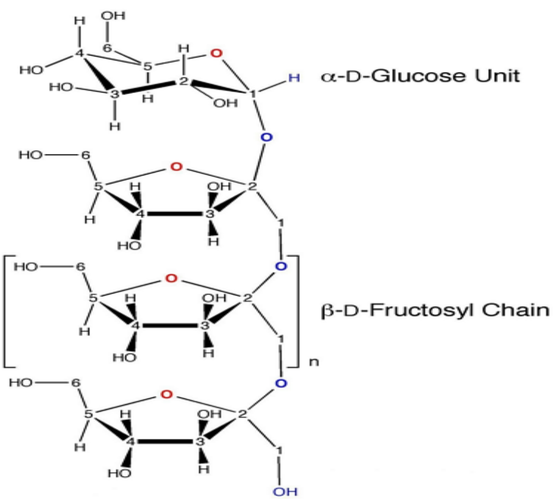

Figure 1. Inulin polymer (α-D-glucopyranosyl-[β-D-fructofuranosyl] (n-1)- D-fructofranoside)

Chicory inulin is white, odorless powder with a high purity and well-known chemical composition. Inulin has a bland neutral taste, without any off-flavour or aftertaste. Standard inulin has a slight sweetness (10% compared to sugar) but still easily combines with other food ingredients.

2.2 Functional properties

Because of its longer chain length, inulin is less soluble than oligofrustose and has ability to form inulin microcrystals when sheared with water or milk. These crystals are not discretely perceptible in the mouth, but they interact to form smooth creamy texture and provide a fat-like mouthfeel. Inulin has been used successfully to replace fat in table spreads, baked goods, fillings, dairy products, frozen desserts and dressings.

Inulin is used worldwide to add fiber to food products. Unlike other fibers it has no "off flavors" and may be used to add fiber without contributing viscosity. These properties allow the formulation of high fiber foods that look and taste like standard food formulations. It is an invisible way to add fiber to foods.

2.3 Nutritional properties and health benefits

Perhaps the most interesting and exciting aspects of inulin are its nutritional properties. Inulin have been used to replace fat or sugar and reduce the calories of foods such as ice cream, dairy products, and baked goods. Inulin have lower caloric value than typical carbohydrates due to the β(2-1) bonds linking the fructose molecules. These bonds render them non-digestible by human intestinal enzymes, thus inulin pass through the mouth, stomach and small intestine without being metabolized. This has been proven by many scientific studies [6, 7, and 8]. These studies indicate that almost all of the inulin or oligofructose ingested enters the colon where it is totally fermented by the colonic microflora. The energy derivated from fermentation is largely a result of the production of short- chain fatty acids and lactate, which are metabolized and contribute 1,5 kcal/g of useful energy for both oligofructose and inulin. Due to the non-digestibility of inulin, it was found to be suitable for consumption by diabetics. Researchers found no influence on serum glucose, no stimulation of insulin secretion and no influence on glucagon secretion [9]. Inulin has a long history of use by diabetics and in fact has been reported to benefit diabetic patients in high doses (40 - 100 g/d) [10].

Some studies have suggested that chicory inulin as a soluble fiber may increase the body absorption of calcium, improve bone mineral density, and reduce the risk of osteoporosis development. Increased calcium absorption could be due to its increased availability by transfer of calcium from small intestine into large intestine and the osmotic effect of inulin that transfers water into the large intestine, thus allowing it to become more soluble [11].

Human diets containing inulin-type fructans had lower serum levels and/or hepatic triglycerides [12]. Considering that the newly synthesized fatty acids are preferentially secreted with very low density lipoprotein, it has been hypothesized that the consumption of inulin-type fructans reduces the *de novo* synthesis of fatty acids in the liver [13]. According to investigation the consumption of inulin is not capable of increasing hepatic lipid catabolism, since it does not alter the activity of the enzyme carnitine palmitoyl-transferase-1. This finds support that consumption of inulin is associated with reduced serum triglycerides by increased extrahepatic lipid catabolism [14, 15].

Perhaps the best-known nutritional effects of inulin are its actions to stimulate bifidobacteria growth in the intestine. The colon is known to be a complex ecosystem with more than 400 different types of bacteria. Some strains have pathogenic effects such as the production of toxins and carcinogens, whereas other are considered to provide a health promoting function. Nourishing beneficial bacteria with inulin allows them to "outcompete" potential detrimental organisms and thereby potentially contribute to the health of host. The bifidogenic effect of inulin has been well proven [16, 17]. Inulin has been termed "prebiotic" [16], because they are non-digestible food ingredients that selectively stimulate growth and/or activity of a number of potentially health-stimulating intestinal bacteria.

2.4 Inulin as functional food

A food can be said to be "functional" if it meets at list one of these criteria: 1) It contains a food component (nutrient or not) which affects one or a limited number of function(s) in the body in a target way and have positive effects [18]; 2) It has physiological effect beyond the traditional nutritional effect [19].

Functional food should have a relevant effect on well-being and health or result in a reduction in disease risk. The component that makes the food "functional" can be an essential macronutrient if it has specific physiologic effect, or an essential micronutrient if its intake is over and above the daily recommendations. Also it could be a food component even though some of its nutritive value is not listed as "essential" or it is even nonnutritive value. The positive effects of a functional food can be either maintenance and/or improvement of a state of well-being and health, or reduction of the risk of a disease. There is sufficient scientific evidence for inulin to be considered as a functional food:

1) Classification of inulin as dietary fiber based on their resistance to digestion, followed by fermentation in the colon leading to improvement of colonic functions [16];

2) Stimulation of bifidobacteria growth in the colonic microbiota to support their classification as prebiotic [17];

3) Increased bioavailability of minerals, in particular, calcium [11];

4) Effect on lipid metabolism.

The functional food science development is opportunity to contribute the improvement of the quality of food and human health. In that context, inulins are natural products that may be classified as functional food ingredients.

3. Conclusions

- Inulin is a type of soluble fiber found in many plants. It is a "fructan" - meaning that it is made up of chains of fructose molecules that are linked together in a way that cannot be digested by small intestine. Instead, it travels to the lower gut, where it functions as a prebiotic, or food source for the beneficial bacteria that live there.

- The gut bacteria convert inulin and other prebiotics into short-chain fatty acids, which nourish colon cells and provide various other health benefits. Inulin is relatively low in calories, providing 1.5 calories per gram. People can take inulin for a variety of reasons. It may improve digestive health, relieve constipation, promote weight loss and help control diabetes.

- There is some evidence that consumption of inulin, may help other health conditions, although the evidence is not as strong. This includes benefits for heart health, mineral prevention of osteoporosis, colon cancer and inflammatory bowel disease.

- Inulin is widely used in functional foods for their health promoting and technological properties. Inulin have to be considered as ingredient of the future that meet the needs of the food industry and the human needs for optimal health and disease prevention.

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