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FUNCTIONAL FOODS BASED ON JERUSALEM ARTICHOKE

V. Pavlova

Faculty of Technology and Technical Science - Veles, St. Kliment Ohridski University - Bitola, Petre Prlickov 42, 1400 Veles, Republic of Macedonia

Abstract. The paper presents facts, as provided in the scientific literature, concerning the current tendencies in the manufacture of functional foods enriched with natural nutrients of plant origin. It focuses on the chemical composition of Jerusalem artichoke and its incorporation in healthy diets and nutrition therapy.

Keywords: Jerusalem artichoke, functional foods

I. Introduction

Functional foods are among the latest developments in food science. A foodstuff can be regarded as functional if it has a beneficial effect on one or several bodily functions as a complement to normal eating habits, by means of which it contributes to general health and/or reduces the susceptibility to disease [16, 17].

As far back in time as the 1980s, the Japanese developed the concept of functional foods and defined them on the basis of their natural nutrient content [32]. Recent years have witnessed the application of various approaches to functional foods having to do with their production, the improvement of foodstuff composition in view of raising the nutritive value and the increase in biologically active substances in foods [18, 22]. Some approaches have concentrated on the regulation of the amount of specific components of plant origin whose content is affected by the manner and conditions under which the plant is cultivated. For instance, some authors reveal data testifying to the fact that soil fertilization accounts for changes in the presence of some chemical substances, such as vitamin C and zinc, in plants [29]. Due to the dynamic developments in the manufacture of low-calorie foods and beverages as well as of sweet sugar-free foods and beverages, sugar substitutes are widely used. From the point of view of food safety, polyols are preferred, e.g.: sorbitol, or other sugar substitutes of plant origin, such as agave syrup [21, 33]. The production of functional and healthy foods has profited significantly from the use of various unconventional plant raw materials, e.g.: sweet chestnut (Castanea sativa), Jerusalem artichoke (Helianthus tuberosus), etc. Gluten-free bread, bakery and confectionery products are extremely important to people suffering from coeliac disease or gluten enteropathy. In this respect, sweet chestnut flour is a very suitable alternative since it is not only gluten-free but it also has a beneficial chemical composition: it is low in fat, high in potassium, phosphorus, iron, vitamin C, B-complex vitamins, including folic acid, dietary fibre, etc. [25].

Jerusalem artichoke has been used for hundreds of years. Recently, the interest in Jerusalem artichoke has been growing steadily on the part of the food industry and cooking because the plant is rich in dietary fibre and its tubers are high in inulin, a prebiotic [2].

The focus of the present paper is on the summary and analysis of literature sources dealing with the chemical composition, healthy benefits and possibilities of using Jerusalem artichoke in functional food and beverage manufacture.

II. Biological and commercial importance of Jerusalem artichoke

Jerusalem artichoke (Helianthus tuberosus L.) is a herbaceous perennial tuber plant belonging to the Asteraceae family. The plant has a 3-4-metre tall shoot system above ground [28]. The tubers, its root system, are a major source of inulin, a polysaccharide [6]. Jerusalem artichoke has a number of important properties which make it a valuable plant with various applications: it is modest as regards soil, climate and cultivation; it can be planted in the spring and in the autumn, which allows for the rapid and dynamic growth of a big plantation; it gives good yield; the food industry can use the plant as a raw material in the manufacture of functional foods and beverages; it is an important raw material in the production of alcohol; it is also applied in phytotherapy and medicinal cosmetics; it paves the way for the production of cheap high-quality fodder and silage for farm animals [2]. Last but not least, Jerusalem artichoke is valuable as a honey plant. Bees use it in the late summer and autumn when flowering honey plants are scarce. Jerusalem artichoke honey has a golden yellow colour and a pleasant flavour recalling that of the sunflower [14].
III. Chemical composition of Jerusalem artichoke

Table 1 presents some data on the chemical composition of Jerusalem artichoke tubers.

Proteins. The protein content amounts to the average range of 1.6 – 2.4 g/100 g of fresh material [28]. Jerusalem artichoke contains all essential amino acids in a desirable ratio.

Table 1. Chemical composition of Jerusalem artichoke tubers [2]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy, kcal</td>
<td>70</td>
</tr>
<tr>
<td>Protein, %</td>
<td>2.0</td>
</tr>
<tr>
<td>Fat, %</td>
<td>0.3</td>
</tr>
<tr>
<td>Total carbohydrate (in %), of which:</td>
<td>17.5</td>
</tr>
<tr>
<td>Inulin, %</td>
<td>12</td>
</tr>
<tr>
<td>Pectins, %</td>
<td>1.5</td>
</tr>
<tr>
<td>Cellulose, %</td>
<td>2.0</td>
</tr>
<tr>
<td>Hemicellulose, %</td>
<td>1.0</td>
</tr>
<tr>
<td>Mono- and oligosaccharides, %</td>
<td>1.0</td>
</tr>
<tr>
<td>Ash, mg/100g</td>
<td>1.2</td>
</tr>
<tr>
<td>Potassium, mg/100g</td>
<td>420</td>
</tr>
<tr>
<td>Sodium, mg/100g</td>
<td>3.2</td>
</tr>
<tr>
<td>Calcium, mg/100g</td>
<td>24.1</td>
</tr>
<tr>
<td>Magnesium, mg/100g</td>
<td>17.0</td>
</tr>
<tr>
<td>Phosphorus, mg/100g</td>
<td>75.0</td>
</tr>
<tr>
<td>Zinc, mg/100g</td>
<td>0.22</td>
</tr>
<tr>
<td>Chromium, µg/100g</td>
<td>7.4</td>
</tr>
</tbody>
</table>

The proteins in Jerusalem artichoke tubers are richer in lysine and methionine compared to the protein content of many other plants and the general opinion is that this is a high-quality protein which can be used for food and animal feed [24, 34].

Fat. The scarcity of fat in Jerusalem artichoke plants is attributed to trace amounts of mono- and polyunsaturated fatty acids whereas there are no saturated fats [36]. Polyunsaturated fatty acids – the presence of linoleic acid (18:2, n-6) and linolenic acid (18:3, n-3) – has been estimated in the following amounts: 24 mg and 36 mg/100 g, respectively, in raw tubers [26].

Carbohydrates. Jerusalem artichoke is high in carbohydrates. The major monosaccharides are fructose and glucose and the basic oligo- and polysaccharides are fructooligosaccharides, inulin, pectin, cellulose and hemicellulose [28]. The polyfructan inulin is a dominant component of Jerusalem artichoke tubers. It is a prebiotic component belonging to the group of soluble dietary fibre [30]. As a result of its beneficial effect on the human organism, inulin is being increasingly incorporated into foods and the interest in its manufacture has grown considerably [7]. For industrial uses, inulin is usually extracted from chicory roots or Jerusalem artichoke tubers by means of hot water extraction followed by clarification and concentration of the liquor and spray-drying. In general, the inulin manufacture technology resembles the industrial extraction of sugar from sugar beet [3, 5]. From the point of view of chemistry, inulin is a linear polymer composed of D-fructose residues joined by (2→1)-glycosidic bond. One end of the chain also contains α-D-glucose joined by a (1-2)-glycosidic bond [5, 15]:

Delchev et al. [4] point out that the flowers, leaves, and stems of Jerusalem artichoke plants contain the following sugars: glucose, fructose, galactose, mannose, arabinose, sucrose, kestose, and nystose. It is worth mentioning that the latter two oligosaccharides demonstrate a prebiotic effect comparable to that of inulin. Of all polysaccharides in Jerusalem artichoke flowers, the authors [ibid.] talk about the presence of pentosans (~ 6,78 % adm*), pectins (~ 10-11 % adm), cellulose (~ 21,08 % adm), polysaccharides which are difficult to hydrolyse (23,75 %) and polysaccharides that are easy to hydrolyse (17,54 % adm).

Other components. Jerusalem artichoke tubers contain large amounts of minerals as well as many biologically active substances such as organic acids – 0,1 % [19], enzymes – inulinase (EC 3.2.1.7), inulinsucrase (EC 2.4.1.9), polyphenol oxidase (EC 1.10.3.1), peroxidase (EC 1.11.1.7), etc. [2]. The aroma of the tubers that have not been heat-processed is mainly due to the sesquiterpene β-bisabolene and small amounts of saturated long-chain hydrocarbons.

Jerusalem artichoke tubers also contain heliangine (which regulates plant growth), spermine (a common component of plants participating in protein synthesis), 2,5-dihydroxybenzoic acid (with a bactericidal and antiviral effect), 4-hydroxybenzoic acid, caffeic acid, ferulic acid, chlorogenic acid, p-
coumaric acid and vanillic acid. Polyphenol compounds play a major role in tuber browning under technological processing [1, 28].

IV. Health effects of Jerusalem artichoke

The health effects of Jerusalem artichoke are due to the great variety of biologically active substances and, most of all, to the high amounts of dietary fibre. By definition, dietary fibre is not absorbed by digestion system organs [20]. Its physiological effect has to do with its physico-chemical properties. Dietary fibre increases the volume of food and leaves a feeling of satiety. It affects digestion, resorption and nutrient metabolism via water and bile acid absorption, gel formation, cation exchange, etc. Dietary fibre alters the assimilation of glucose, cholesterol, medicinal drugs and toxins and it also normalizes the intestinal microflora. Its breakdown leaves acidic by-products which protect the mucous membrane against malignant growth and help in the elimination of mutagenic substances and the free ammonia in the intestine, etc. [2, 11]. It is widely believed that insufficient dietary fibre intake contributes to an increased risk of many diseases, such as obesity, diabetes mellitus, gout, coronary heart disease, cholelithiasis, etc. [20].

The hypolipidemic function of various dietary fibres has been well documented. For instance, pectin substances possess a marked hypcholesterolemic effect attributable to their high sorption capacity. They contribute to the feeling of satiety and their normalizing effect on glucose tolerance is bigger compared to other types of dietary fibre. What is more, pectins have significant immunostimulating activity and their ability to bind metal ions and radioactive isotopes is used in protective job-oriented diets [10, 11, 12].

Inulin is a major representative of the dietary fibre in Jerusalem artichoke tubers. In addition to the above-mentioned physiological effects of dietary fibre, inulin can enhance the assimilation of some important minerals like calcium [35]. The absorption of this bioelement from food is accomplished by active transportation in the upper parts of the small intestine. With normal eating habits, about 30% of calcium is usually absorbed. In the large bowel, most of the calcium is in the form of insoluble complexes. Here, under the influence of the short-chain fatty acids produced in the intestinal fermentation of inulin, calcium solubility rises, which stimulates the assimilation of calcium via passive diffusion [5].

Phytotherapy utilizes Jerusalem artichoke in metabolism normalization in cases of obesity, some kidney diseases, in the improvement of the secretary and peristaltic functions of digestion system organs and especially of the bile secretion with patients suffering from atherosclerosis, diabetes mellitus, etc. [9, 13].

V. Application of Jerusalem artichoke in the manufacture of functional foods and beverages

In recent years, Jerusalem artichoke has been increasingly used in the food and flavour industry for the production of foods, beverages and food supplements. It has been used as a basic ingredient by various technologies and methods in the manufacture of inulin, fructose, glucose-fructose syrups, cellulose, ethyl alcohol, bakery and dairy products, canned food, drinks, etc. Owing to its beneficial effects on health, Jerusalem artichoke is also present on the market in the form of powder (flour) to be incorporated in cooked meals during their heat processing or in the form of tablets as a source of dietary fibre. The flowers and leaves of Jerusalem artichoke, alone or in combination with other medicinal plants, are used in the production of herbal tea and food supplements while the whole shoot system of the plant can serve as fodder for farm animals [2, 8, 9].

As a food ingredient, Jerusalem artichoke has the following effects:
- it enriches foods with dietary fibre (pectin, inulin, cellulose, etc.);
- it has a prebiotic effect (mainly due to inulin);
- it enriches foods with trace elements, vitamins and other biologically active substances;
- it improves the organoleptic parameters (taste, smell, consistency, etc.) of the product;
- it has a desirable effect on the functions of the human digestive system, the cardiovascular system and the urinary system due to its rich chemical composition and indisputable health effects.

Table 2 outlines the opportunities for the application of Jerusalem artichoke plants in the manufacture of healthy and functional foods.

Under the action of certain enzymes (inulinase, cellulase, etc.), the polysaccharides in Helianthus tuberosus L. are hydrolyzed to lower-molecular-weight sugars. The latter may ferment under the influence of some microorganisms, which is why Jerusalem artichoke turns out to be a valuable raw material in the production of bioethanol [23]. Research shows that the pre-processed and pre-hydrolyzed flours from Jerusalem artichoke tubers and stems are suitable for the alcohol fermentation brought about by Saccharomyces cerevisiae. Under the action of the microorganism, the fermentable sugars are completely used up within 24 h [27].
Table 2. Jerusalem artichoke application in the manufacture of functional foods.

<table>
<thead>
<tr>
<th>Jerusalem artichoke</th>
<th>Application (usage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh tubers</td>
<td>Direct consumption, canned products, preparation of vegetable and meat-and-vegetable meals.</td>
</tr>
<tr>
<td>Tuber juice</td>
<td>Production of functional beverages, canned products, soups, sauces/dips, dressings, etc.</td>
</tr>
<tr>
<td>Mashed tubers</td>
<td>Canned functional food, cooked food, sauces/dips, dressings, dairy products, etc.</td>
</tr>
<tr>
<td>Tuber flour</td>
<td>Food supplements, bread and bakery products, cakes and confectionery, cereal foods, etc.</td>
</tr>
<tr>
<td>Flowers and leaves</td>
<td>Herbal tea, herbal extracts, food supplements, functional foods and beverages.</td>
</tr>
</tbody>
</table>

It should also be pointed out that the inulin isolated from Jerusalem artichoke finds great application in the manufacture of functional foods, beverages and other products based on this plant. Since most food products undergo heat processing in their production, it is also necessary to obtain information on the heat stability of the polysaccharide. Panchev et al. claim that the threshold of inulin heat stability is in the 152 - 158°C range [31].

VI. Conclusion

The paper presents data concerning the chemical composition and application of Jerusalem artichoke plants in the manufacture of functional foods. The analysis illustrates that the latter is extremely rich in dietary fibre and other biologically active substances, including the prebiotic inulin. The paper also outlines the beneficial physiological effects of Jerusalem artichoke and its dietary fibre which determine the usage of the plant in the production of healthy and functional foods and beverages.

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Project "Step into a new educational future of electronic forms of distance learning"

Title: "Step into a new educational future of electronic forms of distance learning"

Scheme: BG051PO001-4.3.04 "Development of electronic forms of distance learning in higher education" in OP, Human Resources Development "financed by the European Union through the European Social Fund.

Value: 515 770.97 lev

Duration: from 10.10.2012 to 10.10.2014, the d (24 months)