

Inulin Syrup from Dried Jerusalem Artichoke **Inulīna sīrups no kaltēta topinambūra**

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Abstract. Inulin from Jerusalem artichoke tubers is used as a prebiotic ingredient in functional foods. The extract of inulin was obtained from dry or wet Jerusalem artichoke tuber chips: 11 g of dry matter were suspended in 400 mL of water and were stirred at 50 °C for 4 h. Dry chips as raw material proved to be more convenient as nearly all carbohydrates were extracted in 2 h; a 4-h-extraction from dry chips ensured a 1.57 times higher inulin content than that from wet chips. The concentrations of carbohydrates and inulin in the extract, natural apple juice, and their blend showed that inulin (5%) in apple juice preserved well for 10 days at +4 °C. To obtain inulin syrup, the Jerusalem artichoke extract was concentrated by vacuum evaporator at 80 °C for 5.5 hours or by boiling at 100 °C for 2 hours. It was found that boiling ensures more effective evaporation: after vacuum-evaporation of the initial sample of 409 g it was concentrated to 61 g, whereas by boiling – to 38 g. It is essential that inulin was not lost during the evaporation. As to the content of total carbohydrates, it slightly decreased during boiling. This can be explained by Maillard reaction as the content of melanoidins in the vacuum-evaporated syrup was 32.5 mg g⁻¹, but in the boiled sample – 41.0 mg g⁻¹. FT-IR spectroscopy was used to evaluate the biochemical composition and the relative content of total carbohydrates in apple juice and Jerusalem artichoke juice, as well as to evaluate the biochemical composition of syrups.

Key words: inulin syrup, Jerusalem artichoke, Jerusalem artichoke extract, apple juice.

Introduction

Functional foods and beverages are natural products enriched or balanced with biologically active components which offer the potential of enhanced health or reduced risk of disease. The most common functional foods contain specific minerals, vitamins, fatty acids or dietary fiber, or are enriched with biologically active substances such as phytochemicals or other antioxidants and probiotics – live beneficial cultures (Roberfroid, 2005). Inulin in fortified foods and beverages may improve gastrointestinal health and improve calcium absorption, and may affect the physiological and biochemical processes in rats and human beings, beneficially influencing the lipid metabolism, which results in better health and reduction in the risk of many diseases including cardiovascular diseases (Kaur, Gupta, 2002; Balcazar-Munoz et al., 2003). The main sources of inulin used in the food industry are chicory and Jerusalem artichoke. Jerusalem artichoke is rich in inulin – a polydisperse carbohydrate consisting mainly of β (2-1) fructosyl-fructose links (Flamm et al., 2001). Inulin syrup made from chicory or its

commercial form (Raftiline, Orafiti) can be used as a prebiotic ingredient in breadstuffs as well as functional inulin-juice or milk beverages (McDevitt-Pugh, Rooyackers, 2003; Hempel et al., 2007; Villegas, Costell, 2007). Jerusalem artichoke powder with high inulin concentration, which is produced from the local Jerusalem artichoke varieties offered to the market, contains all water soluble components – proteins (15-18% of DM), carbohydrates (62-62% of DM) including inulin (50-60% of DM), K (400-500 mg 100 g⁻¹), P (70-75 mg 100 g⁻¹), vitamins, and plant-origin cholesterol-free lipids and fiber –, thus increasing its functional value (Bekers et al., 2007A).

The Maillard reaction products form specific smell, taste and color of this concentrate which is used to obtain inulin syrup. The thermostability of inulin has been studied, and it has been found that heating of inulin for up to 1 h at temperature between 135 and 195 °C results in a significant degradation of inulin (20-100%) and formation of new products like di-D-fructoze (Bohm et al., 2005). The loss of fructans during baking can reach up to 38-45% (Praznik et al.,

2002). Our previous studies showed that after boiling of the Jerusalem artichoke concentrate suspension for 1 h the loss of inulin made up 8.8%, but sterilization at 120 °C caused even more significant loss of inulin – 26.9%. At these temperatures Maillard reaction products are formed (Bekers et al., 2007b). Functional beverages are a quickly expanding market segment with inulin containing juices as one of lines. A blend of apple and Jerusalem artichoke juice or inulin syrup could enrich the nutritional value and range of the functional drinks. Therefore the aim of this study was to obtain inulin syrup from Jerusalem artichoke chips and to evaluate the stability of inulin in apple juice.

Materials and Methods

Materials. Tubers of Jerusalem artichoke variety ‘DagNeutral’ were obtained from the Horticultural Study Centre “Pure” Ltd (Latvia). Jerusalem artichoke concentrate (JAC) was produced in the farm “Lazdinas” (Latvia) and finally roasted in the plant “Tukuma Kafija” (Latvia) (Bekers et al., 2007a). The chemical composition of JAC is shown in Table 1.

JAC was used as raw material to obtain inulin water extract and syrup. Jerusalem artichoke juice was squeezed out from tubers by a juicer. Natural apple juice was supplied by the farm “Lases” (Latvia) and was a blend of the four most popular apple varieties in Latvia – ‘Safrāna pepiņš’, ‘Mičurina bezsēklu’, ‘Tribu’, and ‘Rudens svītrainais’. Raftiline – the inulin concentrate – was kindly supplied by “Orafti”. The stability of inulin (5% of Raftiline) in natural apple juice was tested after storage at 4 °C for 10 days.

Methods. Inulin extract was obtained from dry or wet Jerusalem artichoke tuber chips: 11 g of DM

were suspended in water at 50 °C and were stirred for 4 h (Bekers et al., 2007b). Evaporation of Jerusalem artichoke extract – 409 g (12.77% of DM) – was carried out either in a vacuum evaporator at 80 °C for 5.5 h or by boiling at 100 °C for 2 hours. The content of reducing substances (RS) – free and after acid hydrolysis – was determined by Lane-Eynon method (Великая et al., 1964). The concentration of glucose and fructose was determined by ENZYTEC™ D-glucose/D fructose method (Schmidt, 1961). The content of inulin was determined according to the AOAC-999.03 and AACC-32.32 methods. FT-IR spectroscopy being a quick and informative method was used to evaluate the biochemical composition and the relative content of total carbohydrates in the abovementioned juices. The FT-IR spectra were registered on a microplate reader HTS-XT (Bruker), absorption mode – 600-4000 cm⁻¹ region, 32 scans, and resolution – 6 cm⁻¹. Data were processed by OPUS 6.0. Quantitative analysis of total carbohydrates was carried out as in Grube et al. (2002). The standard solvent of melanoidins was prepared according to Nursten (2005), and the concentration of melanoidins was determined spectroscopically on a Biochrom Libra S22.

Three series of experiments were conducted in duplicate, and the average data are presented.

Results and Discussion

The FT-IR spectra of apple and Jerusalem artichoke juices (Fig. 1) are quite different indicating the qualitative and quantitative differences in the biochemical composition. In both spectra the main absorption was in the carbohydrate region – 900–1200 cm⁻¹ (CO, CC, stretching vibrations and COH, COC deformation vibrations of carbohydrates)

Table 1

The chemical composition of Jerusalem artichoke concentrate

Component	Concentration, % of dry weight (DW)
Solids	94.60
Total carbohydrates	62.80–64.50
Reducing sugars	4.70–5.00
Inulin	40.00–50.00
Glucose	0.60–0.90
Fructose	0.70–6.00
Sucrose	7.00–10.00
Glucose after hydrolysis	16.70
Fructose after hydrolysis	44.80
Ratio fructose/glucose	2.80
Proteins	17.12
Lipids	1.96
Nucleic acids	2.11

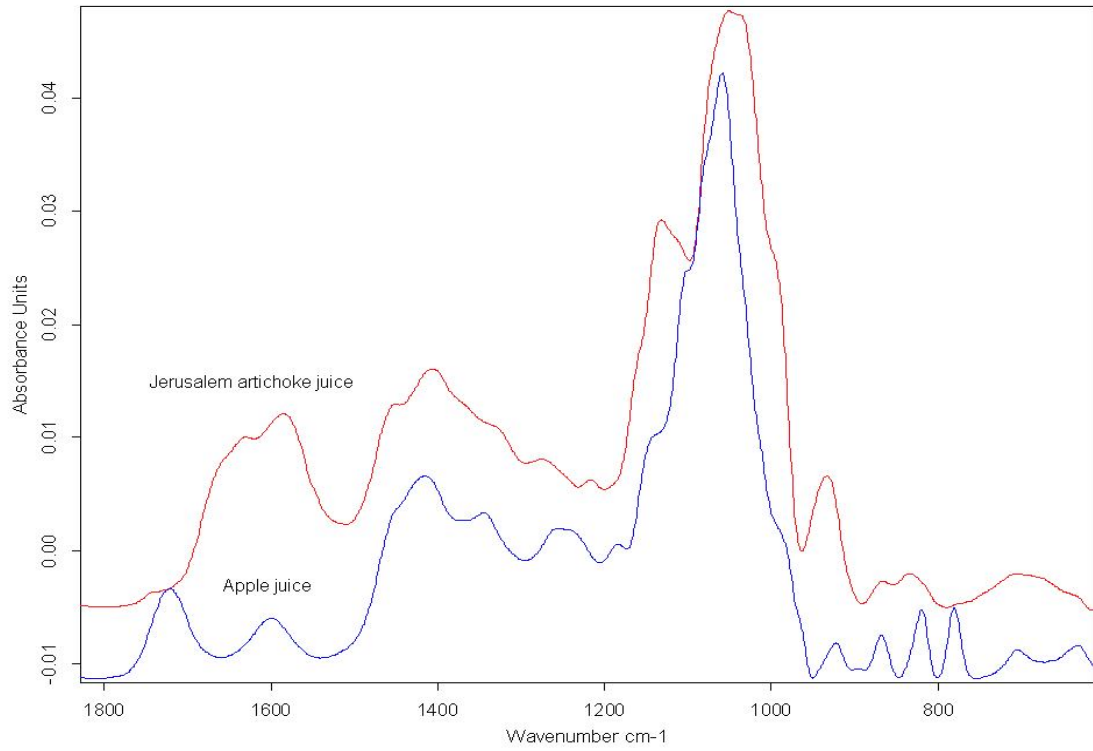


Fig. 1. FT-IR spectra of apple and Jerusalem artichoke juice (data processing – baseline correction and normalization).

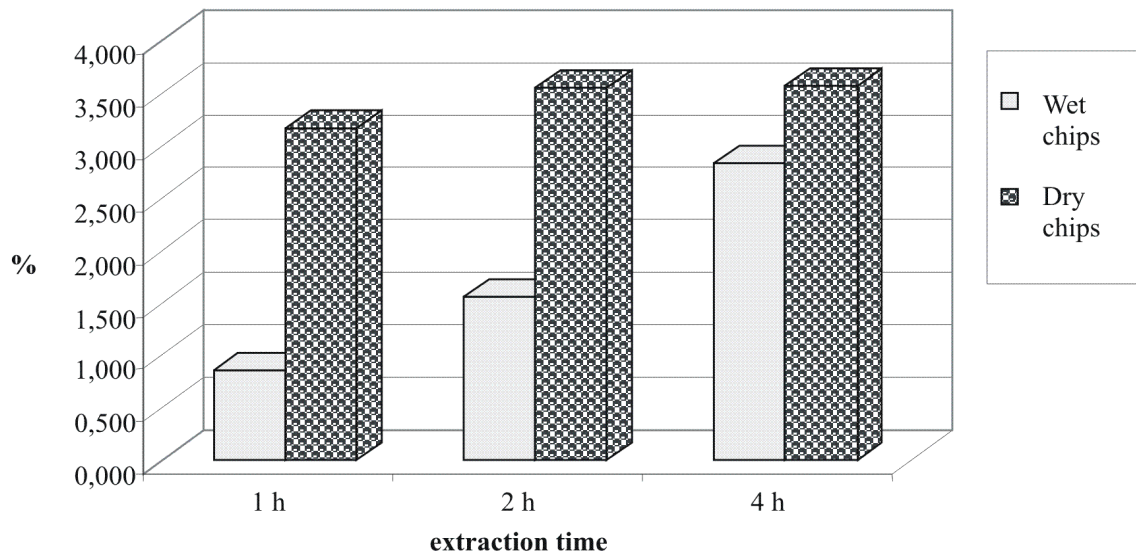


Fig. 2. Extraction of carbohydrates from Jerusalem artichoke chips.

with maximums at 1059 cm^{-1} in apple juice and at 1050 cm^{-1} with a shoulder at 1132 cm^{-1} in Jerusalem artichoke juice. In the spectra of apple juice, the band at 1600 cm^{-1} originates from the COO^- antisymmetrical stretching vibrations of carboxylate in ionized form, and the band at 1721 cm^{-1} – from the acetyl ester groups in pectins (Synytsya et al., 2003). In the spectra of Jerusalem artichoke juice, the band at 933 cm^{-1} was shown to be characteristic for inulin (Bekers et al., 2005). The total carbohydrate content in juices was evaluated and thus the spectra were recorded in the absorption range not exceeding 80%, while the Lambert-Beer law applies and the concentration of the component is directly proportional to the band intensity. The quantitative analysis of carbohydrates showed that the content of carbohydrates in Jerusalem artichoke juice was 85.04% of dry weight (DW) and 86.53% of DW in natural apple juice.

The dynamics of total carbohydrate extraction from dry and wet Jerusalem artichoke chips was studied, and the results are shown in Fig. 2. It can be seen that the extraction rate of carbohydrates was higher from dried chips than from wet ones. Also the extraction of inulin from dried chips was 95.00%, but from wet chips – only 21.69%. After a 4-h-extraction, the concentration of inulin in water extract was 1.73% and 2.38 % in wet and dry chips correspondingly. This study also showed that nearly all carbohydrates

were extracted from dry chips after 2 h. After a 4-h-extraction, the content of inulin in the extract from dry chips was 1.57 times higher than that from wet chips. The study of carbohydrate composition in Jerusalem artichoke extract, natural apple juice, and their mixture showed that the concentration of carbohydrates in apple juice was slightly higher than in Jerusalem artichoke extract, whereas a significant difference was observed in the content of RS (Table 2).

The pH of apple juice and Jerusalem artichoke extract are quite different: 3.5 for juice, and 5.7 for extract. The blend of half apple juice and half Jerusalem artichoke extract would result in a reduced pH and RS, and an inulin-containing functional drink which ensures the daily inulin intake by 200 mL. Therefore the stability of inulin in apple juice is essential and was evaluated in the present study. Storage (for 10 days at +4 °C) of apple juice with inulin additive did not cause a considerable loss of carbohydrates or inulin content (Table 3). The FT-IR absorption spectra of these samples after a 4-h, 7-day, and 10-day storage were recorded and also did not indicate any changes neither in quality nor concentration of inulin; whereas the content of total carbohydrates slightly increased during the storage time.

To obtain inulin syrup, the Jerusalem artichoke extract was evaporated in vacuum or boiled. The

Table 2

Composition of carbohydrates in apple juice and Jerusalem artichoke extract

Component	Apple juice, % DM	Jerusalem artichoke extract, % DM	Apple juice and Jerusalem artichoke extract 1:1 (V:V), % DM
Dry matter	9.85	7.49	8.67
Carbohydrates	79.29	77.70	78.49
RS	66.29	5.74	36.01
Sucrose+fructose	13.00	16.45	14.72
Inulin	0	55.01	27.51

Table 3

Stability of inulin (5% Raftiline) in apple juice during storage at +4 °C

Storage time	pH	DM, %	RS, % DM	Total carbohydrates, % DM	Inulin, % DM
0	3.59	12.77	49.80	91.78	30.71
4 h	3.60	12.26	50.57	94.21	25.86
24 h	3.62	12.86	50.39	88.57	27.52
7 days	3.63	12.47	53.65	90.21	30.55
10 days	3.63	11.64	55.24	96.39	32.56

Table 4

Results of Jerusalem artichoke syrup

Sample	pH	RS, % DM	Carbohydrates, % DM	Inulin, % DM	Melanoidins, mg g ⁻¹	Solids, %
at 80 °C for 5.5 h						
Initially	5.83	5.74	77.70	55.01	–	7.49
After evaporation	5.54	6.35	76.40	56.10	32.50	69.48
at 100 °C for 2 h						
Initially	5.79	5.59	75.81	53.58	–	7.69
After evaporation	5.53	5.80	64.89	55.87	41.00	59.13

– not determined

initial samples of 409 g were concentrated to 61.0 g by vacuum evaporator, but by boiling – to 38.3 g. Analyses of syrups showed that inulin was preserved during both evaporation schemes, whereas the total carbohydrate content slightly decreased after evaporation at 100 °C. This can be indicative to the Maillard reaction as the content of melanoidins in the vacuum “evaporated” syrup was 32.5 mg g⁻¹, but in the “boiled” sample – 41.0 mg g⁻¹ (Table 4). The content of melanoidins in syrup depends on their initial concentration in dried chips of Jerusalem artichoke. The chips obtained at 55 °C contained up to 2 mg g⁻¹ of melanoidins, but those dried at 120 °C for 30 min contained 35-40 mg g⁻¹ of melanoidins; whereas chips used for inulin extraction contained up to 25 mg g⁻¹ of melanoidins.

Although the biochemical composition of both syrups was similar, the evaporation at 100 °C ensured more concentrated syrup in half as much time. The FT-IR absorption spectra of the initial and evaporated samples were evaluated to ensure the possible changes during the treatment; however, no qualitative or considerable quantitative changes were seen. Organoleptic tests showed that the obtained inulin syrup is slightly sweet, with pleasant smell and a bit brown.

Conclusions

1. Dried Jerusalem artichoke concentrate can be used for production of inulin syrup.
2. Boiling ensures more concentrated inulin syrup and is more time-saving process than vacuum evaporation.
3. Subsequent roasting of Jerusalem artichoke chips and evaporation of water extract ensures the formation of Maillard reaction products in syrup and thus the organoleptic properties.
4. FT-IR spectroscopy can serve as a quick method for the process monitoring and assessment of the composition and content of a particular component in juices.

5. The obtained Jerusalem artichoke syrup could be used as an additive in different kinds of functional foods like beverages, cookies, yoghurts, ice creams, and deserts.
6. Further studies should emphasize the formation of Maillard reaction products during processing and should evaluate the significance of variable storage conditions on the quality and nutritive/functional value of inulin-fortified drinks.

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Anotācija

Inulīns tiek plaši izmantots kā prebiotisks un fizioloģiski aktīvs savienojums dažādos funkcionālajos pārtikas produktos. Šī darba mērķis bija izpētīt iespēju iegūt ūdenī šķīstošu inulīna sīrupu, izmantojot kaltētus un grauzdētus vai nekaltētus topinambūra bumbulu čipsus. Šo inulīna produktu varētu izmantot funkcionālo dzērienu ražošanai. No sausiem čipsiem praktiski viss inulīns ekstrahējās pēc divām stundām, bet pēc četrām stundām ekstraktā bija 1.57 reizes vairāk inulīna nekā izmantojot nekaltētus čipsus. Tika noteikts inulīna un kopējo ogļhidrātu daudzums sauso čipsu ekstraktā, ābolu sulā un to maisījumā. Glabājot ābolu sulu ar 5% inulīna piedevu 10 dienas +4 °C, inulīna daudzums būtiski nesamazinājās. Lai iegūtu koncentrētu inulīna sīrupu, topinambūra ekstraktu ietvaicēja vakuumā 5.5 stundas 80 °C vai vārīja 2 stundas 100 °C, attiecīgi iegūstot 69.48% un 59.13% koncentrāta. Ietvaicēšanas veids neietekmēja inulīna koncentrāciju, bet kopējo ogļhidrātu daudzums vārot nedaudz samazinājās. Tas varētu būt saistīts ar Mailarda reakcijas produktu veidošanos, jo melanoidīnu daudzums sīrupā pēc vakuuma ietvaicēšanas bija 32.5 mg g⁻¹, bet pēc vārīšanas – 41.0 mg g⁻¹. Furjē transformācijas infrasarkanā spektroskopija tika izmantota, lai salīdzinātu topinambūra sulas un ābolu sulas bioķīmisko sastāvu un noteiktu kopējo ogļhidrātu daudzumu, kā arī topinambūra sīrupa kvalitatīvās un kvantitatīvās izmaiņas atkarībā no ietvaicēšanas metodes.