SUPERFOODS AND MEDICINAL PLANTS - SOURCE OF SUGARS, INULIN AND LOW-MOLECULAR FRUCTANS

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Abstract
Superfoods are a rich source of nutrient foods (such as vitamins, minerals, fiber), and other beneficial compounds that can promote overall health and potentially reduce the risk of disease. Therefore, the aim of the current investigation was to evaluate some superfoods and medicinal plants as a potential source of sugars and inulin. The selected plants were considered as superfoods and supplied as food supplemants: the root powder flours from shatavari (Asparagus racemosus), suma (Pfaffia paniculata), maca (Lepidium meyenii), Siberian ginseng (Eleutherococcus senticosus), costus (Saussurea lappa), ashwagandha (Withania somnifera), while the leaves and roots from Siberian wild echinacea, and flowering heads of cotton thistle were medicinal plants. The superfoods and medicial plants were commercially available. The water extracts were obtained from the plant materials by ultrasound-assisted extraction. The extracts were analysed for the content of total fructans by resorcinol based spectrophotometric method. Inulin and sugars content were evaluated by high-performance liquid chromatography with refractive index detection. Inulin was detected in the root powder of shatavari, suma, costus, as well as in leaves and roots of Siberian wild echinacea and flowering heads of cotton thistle. Inulin was detected in the root powder of shatavari, suma, costus, as well as in leaves and roots of Siberian wild echinacea and flowering heads of cotton thistle. Shatavari root powder was evaluated as the richest source of fructans, as inulin content reached up to 29.7 g/100g dw. Inulin in suma, costus and cotton thistle were between 2.9 to 1.35 g/100 g dw. Siberian ginseng, ashvaganda and maca roots did not contain fructans only sugars, as maca root powder demonstrated the highest values of sucrose – 18 g/100 g. The current study revealed the nutritional potential of some superfoods and medicinal plants to be used as a source of dietary fibers, especially flour of shatavari roots.
Keywords: superfoods, fructans, inulin, medicinal, plants, dietary, fibres, sugars.

INTRODUCTION

"Superfoods" is a mainly marketing term, there are not official definition, i.e., there is not a scientific, regulatory, or legal description proposed by food safety regulations. It comprises foods dense of nutrients that have claimed health benefits due to their high values of essential amino acids, vitamins, minerals, antioxidants, and other bioactive compounds. Some authors defined this food as foods beyond the diet, but before the drugs. In most of the definitions superfoods improve overall health, boosting the immune system, increasing the production of serotonin and other hormones, and promoting the smooth operation of organic systems of the human body. According some authors in superfoods roots and tubers can be included as maca, ashvaganda and ginseng, not only fruits and fruit products, vegetables and vegetable products (including fungi family), grains and grains-based products, legumes, nuts and seeds, and herbs, spices and condiments. Nowadays after pandemic has

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increased interest in foods capable of boosting immunity and protecting against pathogens. The list of superfoods was enlarged by including foods such as ginseng (*Panax* sp. pl.), eleuthero (*Eleutherococcus senticosus*, also known as *Siberian ginseng* or devil's bush), echinacea (*Echinacea* sp. pl.), goji berries (*Lycium barbarum*), aloe (*Aloe vera*), turmeric (*Curcuma longa*), gingko (*Ginko biloba*), or individual molecules such as quercetin and chloroquine. These foods are considered as potential panaceas in extreme situations. In this context, superfoods can represent not only a nutritional potential, but also a way to address public health challenges [1,2,3,4].

Therefore, knowledge about their nutritional potential is important for consumers. In some on-line shops (www.zoya.bg) it was recommended to apply some superfoods (flour of suma, shatavari and maca) in preparation of dishes as energy bars, yogurt, smoothies, shakes, muesli or use to make ice creams, creams, etc. due to its rich fiber content. The recommended daily dose is 1 teaspoon or 1-3 g of powder.

Another supperfood is winter cherry (*Withania somnifera*), also known as Ashwagandha supplied as dry extract, roots or supplements. This plant demonstrated many healthy effects (as anti-inflammatory, antimicrobial, cardioprotective and anti-diabetic properties) on human health (adaptogenic effects, neuroprotective, sedative and and effects on sleep). Its root has been used as an aphrodisiac similar to shatavari and maca roots. Ashwagandha supplementation may exhibit neuroprotective activity, be helpful in obsessive-compulsive disorder, and exhibit anti-inflammatory, immunomodulatory and antibacterial properties [5]. Ashvagandhaa roots are rich source of alkaloids, amino acids, steroids, volatile oil, starch, crude fibre 21.0 to 25.0 %,, total sugars 2.52 to 9.52 mg/g reducing sugars (0.15 to 2.10 mg/g) and glycosides [6].

Some medicinal plants have also attract attention because of their beneficial effect, due to fructan content, especially inulin, as potential prebiotic, immunomodulator and soluble dietary fibers [7] Shatavari, Echinacea, suma, costus and cotton thistle are example of such plants. The traditional usage of the aerial part of *Onopordum acanthium*, which is an edible plant, a source of honey, and an anti-inflammatory, antitumor, and cardiotonic remedy, demonstrates the safety and non-toxicity of this plant [8].

Saussurea lappa roots (Synonym-Kuth, *S. costus (*Falc.) Lipsch,) used in traditional Chinese medicine to treat headache, loss of appetite, diarrhea, and abdominal pain are reported to contains carbohydrate 75.25% , as inulin (18%) and minor content sugars (mainly glucose)[9,10].

In earlier research was demonstrated that fructan content reached up to 4 g/100g [11], in cotton thistle and suma [12], up to 25 g/100 g in echinacea roots [13]. However, the detailed composition of some superfoods and medicinal herbs remained unrevealed. Until now there are many gaps or insufficient data in scientific reports about the presence of inulin, fructose and sugar content in many superfoods and some medicinal plants considered as superfoods. Therefore, the aim of this study was to elucidate the carbohydrate composition in some superfoods and medicinal plants as a potential source of sugars, inulin and low-molecular fructans.

EXPOSITION

Materials and methods

Plant material

The plant material and superfoods were purchased from suppliers and on-line shop distributors. The detailed information was listed in Table 1. The root flours of shatavari, maca, suma and costus were used as they were obtained, while the other plant material was finely ground to powder in a laboratory homogenizer BN1200AL (Gorenje) and sieve through 0.5 mm before analysis.

Table. 1. *Superfoods and medicinal plants used for analysis*

№	Plant material	Latin name	Plant parts	Supplier
1	Organic shatavari powder	*Asparagus racemosus*	Root powder	Futunatura, Slovenia
2.	Suma root powder (Brazilian ginseng)	*Pfaffia paniculata*	Roots	Brazil, AUTO9D2M, Zoya, Bulgaria
3	Suma root poweder	*Pfaffia paniculata*	Root powder	FutuNatura, Slovania
4	Maca	*Lipidium meyenii*	Roots	Burel organics Ltd., Bulgaria
5	Ashwagandha (Indian ginseng)	*Withania somnifera* (L.) Dunal	Roots	Bilki Ltd, Sofia, Bulgaria
5.	Siberian wild echinacea	*Ehinacea purpurea* Moench.	Leaves and roots	OOO "Tselebnie Travie Altaja, *Russia* L 18-81
6.	Korean ginseng	*Panax ginseng* C.A.Mey.	Roots	Bilki Ltd, Sofia, Bulgaria
7.	Siberian ginseng or taiga root	*Eleutherococcus senticosus* (Rupr. & Maxim.) Maxim	Roots	OOO "Tselebnie Travie Altaja ", Russia L 25851
8.	Costus (Indian costus)	*Saussurea lappa*	Root poweder	HERBSWORLD, India, Amazon
9.	Cotton thistle	*Onopordum acanthium* L.	Flowering baskets	Bilki Ltd, Sofia, Bulgaria

Moisture content

The moisture content in all plant materials was analyzed on moisture analyzer balance Kern DAB 100-3 (Germany) and express as %.

Preparation of the aqueous extracts

The plant materials were weighed in a plastic graduated centrifuge tube (50 mL) and extracted with distilled H_2O in solid to liquid ratio 1:10 (w/v) for dry samples. The extraction was performed in an ultrasonic bath (IsoLab 621.05.001, Germany, with frequency 40 kHz and power 60W) for 20 mins, at 75°C. The extraction was performed in duplicate. Both extracts were combined and used for further analysis.

Analysis of total fructans

The fructans content in water extracts expressed as fructose equivalent was defined spectrophotometrically by resorcinol-thiourea reagent [14]. Hundred microliters extract were mixed with 100 µL resorcinol (1% ethanol solution), 100 µL thiourea (0.1% ethanol solution), 800 µL 95 % ethanol and 900 µL HCl and heated 8 min at 80°C, cooled and filled with water until 10 mL. Then the absorbance was measured at 480 nm against a blank sample [14].

Thin layer chromatography (TLC)

TLC analysis was performed to detect the presence of mono-, di-, fructooligosaccharides (FOS) and inulin in water extracts. The samples (10 µl) were spotted on a TLC plate silica gel 60 F_{254} (Merck, Germany) and place in a glass chamber with mobile phase n-BuOH:i-Pro:H_2O:CH_3COOH (7:5:4:2)(v/v/v/v). The TLC plate was dipped for 20 seconds in diphenylamine-aniline-H_3PO_4–acetone and then dried for 5 min at 120°C. The standards glucose, fructose, sucrose, fructo-oligosacchides and inulin from chicory (Beneo, Orafti, Belgium) were used for TLC analysis [15].

HPLC-RID analysis of sugars, fructooligosacharides and inulin

The sugars, FOSs and inulin content extracts were analysed by HPLC-RID method. Chromatographic separation was performed on HPLC Elite Chrome Hitachi, with refractive index detector Chromaster 5450 and a column Shodex® Sugar SP0810(300 mm × 8.0 mm i.d.) with $Pb^{2+}$and a guard column Shodex SP - G (5 µm , 6 × 50 mm) operating at 85°C. The mobile phase was distilled water with a flow rate of 1.0 mL min-1 and the injection volume was 20 µL [14].

Statistical analysis

The presented results were average from two independent experiments carried out in triplicates. The data were expressed as mean ± SD and statistically analyzed using MS Excel software.

Results and discussion

The results for the total fructans, inulin and sugars composition in shatavari, suma, maca and ashwagandha were summarized in Table 2. From the obtained results the highest content of fructans 15.25 g/100 g dry weight was detected in the organic shatavari root powder, as inulin content reached 12.66 g/100 g dry weight. In suma flour the content of fructans and inulin was very low, as the sample suma root –Zoya showed the highest values – 1.35 g/100 g dry weight. In maca and ashwagandha inlin were not detected. In all samples sucrose and fructose were detected. The highest content of sucrose was found in maca flour 14.36 g/100 g dw. In ashwagandha roots only sucrose, glucose and fructose were detected. In earlier research it was reported that the total fructan content in shatavari roots was 24 g/100 g dw, as 21.22 g/100 g dw was inulin, 1-kestose (2.91 g/100 g), sucrose, glucose and fructose [7]. Other research mentioned that inulin content in *A. racemosus* reached 10 − 15 g/100 g fw (average 11.83 % on a fresh weight basis), and around 28% fructans on a dry weight basis. Therefore, inulin is the dominating polysaccharide in shatavari roots [16,17].

In suma root flour, inulin content was the lowest in powder form Futunatura – 0.33 g/100 g dw, while in another sample reached 1.35 g/100 g. dw (Table 2). In early reports inulin extracted from the roots of *P. glomerata* reached yield 11 % and characterized as short-chained fructan with degree of polymerization 13 and good prebiotic activity that stimulated growth of genera *Lactobacillus* and *Bifidobacterium* [18]. The low content of inulin and total fructans in Brazilian ginseng (suma) - 3.46% and 4.25%, respectively was reported earlier by our team [12]. However, in the current study this value for inulin content was the lowest one. Therefore, among the investigated superfood samples suma flours were distinguished as the lowest carbohydrate composition, especially sucrose content. It presents dietary supplement with low sugars content and small soluble dietary fibers (inulin).

Sample	Organic shatavari powder	Suma root powder, FutuNatura	Suma root, Zoya	Maca	Ashwagandha
Total fructans	15.25 ±0.23	0.65±0.11	2.52±0.02	8.01±0.12	2.03±0.43
Inulin	12.66±0.02	0.33±0.01	1.35±0.05	n.d.	n.d
Nystose	n.d	n.d	traces	n.d	n.d
1-Kestose	n.d	n.d	traces	n.d	n.d
Sucrose	1.48±0.02	0.15±0.02	0.33± 0.01	14.36±0.02	3.53±0.04
Glucose	n.d	0.11±0.02	0.22± 0.02	2.72±0.02	2.23±0.02
Fructose	1.12±0.05	0.15±0.01	0.30± 0.04	2.07±0.02	0.23±0.01

Table. 2. *Total fructans, inulin and sugars composition in some superfoods, g/100 g dry weight.*

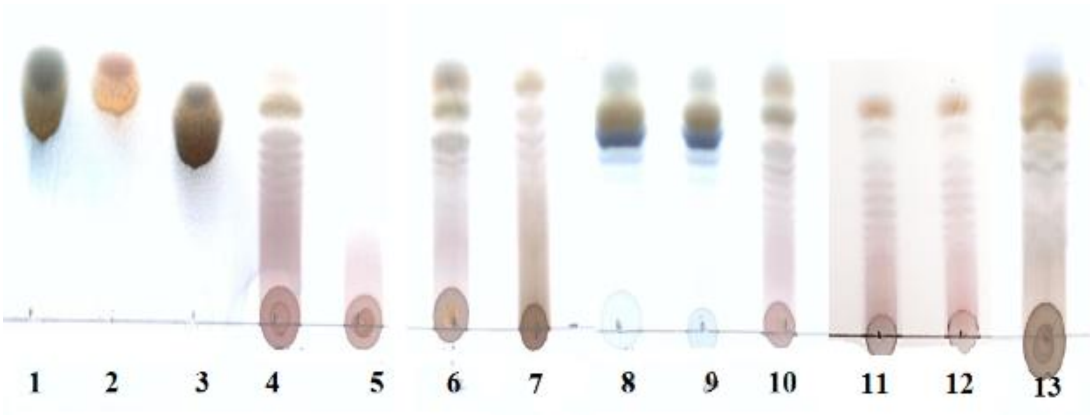

Fig. 1. *TLC chromatograms of aqueous extracts of investigated plant material, where: 1-glucose, 2-fructose; 3-sucrose, 4.FOS Frutafit CLR (DP 9-12), 5 and 10-inulin standard, 6-shatawari, 7- costus, 8-ashwagandha, 9-Korean ginseng, 11 and 12-Brazilian ginseng (suma) and 13-echinacea.*

The obtained TLC chromatograms of aqueous extracts of medicinal plants (Figure 1) showed that the roots of shatawari, costus, Brazilian ginseng, as well as echinacea contain sugars (glucose, fructose and sucrose), fructooligosaccrides and inulin. Inulin is absent only in the roots of Korean ginseng and ashwagandha. Characteristics for these aqueous extracts are the content of glucose, fructose and sucrose. The detailed profile of carbohydrates was also presented by HPLC-RID chromatograms (Figure 2). In suma flour only inulin, sucrose, glucose and fructose were found, while in maca flour only sucrose, glucose and fructose were detected.

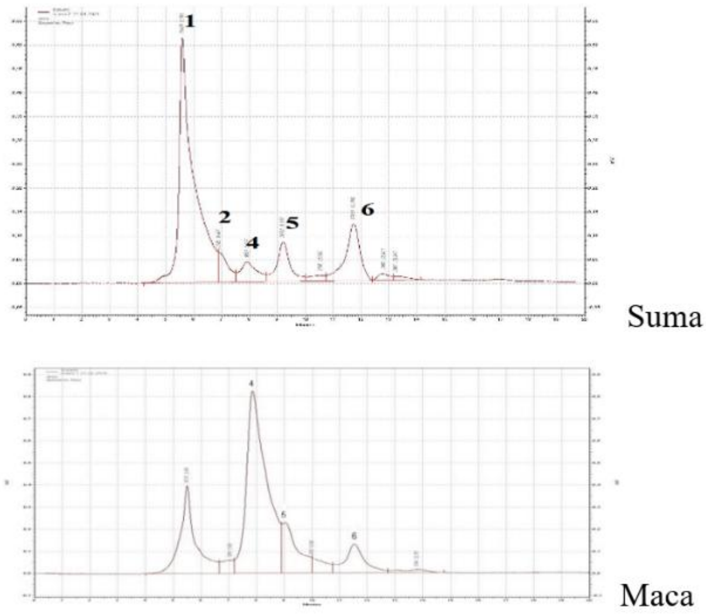

Fig. 2. *HPLC-RID chromatograms of aqueous extracts of investigated plant material, where: 1-inulin, 2-nystose, 3. 1-kestose, 4. sucrose, 5. glucose and 6.-fructose.*

The results for total fructans, inulin and individual sugar composition of the investigated medicinal plants were summarized in Table 3. Inulin was detected only in three samples as its content decreased in the following order costus> cotton thistle> Siberian wild echinacea (*Ehinacea purpurea* Moench). The detected inulin content in *Saussurea lappa* root flour was 2.96 g/100 g. This level of inulin was lower than the previous report of some authors who reported inulin content 18% [19] The content of alcohol-soluble GFr in *S. lappa* roots was according to spectro-photometric analysis (resorcinol method) 107.35–383.42 mg/g; of water-soluble GFr, 245.21–430.57; total GFr content, 476.97–578.27 [8]. However, only in this sample of *Saussurea lappa* 1-kestose was detected 0.29 g/100 g dw, as the only one representative of fructooligosacchrides., while among sugars sucrose was in the dominating content - 2.01 g/100 g dw.

The presence of inulin in the flower heads of cotton thistle (*Onopordum acanthium* L.) was mentioned without details from some authors [20]. Petkova and Mihaylova [11] reported the detailed fructan content in *Onopordum tauricum* of 7.90 ± 0.34 g/100 g and inulin of 4.5 g/100 g. Parzhanova et al. [21] found 0.84 ± 0.17 g/100 g total fructans in the aqueous infusions of flowering heads of *Onopordum acanthium* L. However, in the present study the total fructan content in water extract from commercial samples of cotton thistle reached 5.53 g/100 g, half of which was due to the presence of inulin (2.57 g/100 g dry matter). Fructose was the second most abandoned representative of sugars in cotton thistle extract - 1.14 g/100g dw. The results obtained in current study for fructose, inulin and fructans in cotton thistle coincided with results reported earlier [26], however kestose and nystose were not found in aqueous extracts in this research (Table 3). The possible explanation for the variation of carbohydrate composition in cotton thistle water extracts is type of extraction, as well as harvest time of flowering heads. In general cotton thistle water extracts present average source of soluble dietary fibers (inulin) in daily meals if they were applied as infusion.

The lowest carbohydrate composition was detected in Siberian ginseng root (Table 3). Only glucose was found at low level 0.82 g/100g dw. Pure fructose and sucrose were not detected in water extract. In an earlier study it was reported that the content of alkaline and water-soluble polysaccharides in this plant was estimated at 2–8% and 2.3–5.7%, as in this plant the sugars presented are glucose, galactose, xylose, arabinose, manose [23]. Therefore, water extract of Siberian ginseng root could be considered as extract with the low calorie and sucrose free. However, Korean ginseng root water extract demonstrated high sucrose levels 5.5 g/100g dw. In this extract sucrose and fructose were detected. In earlier study it was mentioned that the total water-soluble sugar content in five-year-old first-grade Korean ginseng root was 35.2% and 35.4% [24]. The nutritional components of Korean ginseng root include glucose, fructose, sucrose, and maltose which are in bulk, and in addition, various amino acids are contained. The major amino-sugars are arginine-fructose-glucose (AFG) and arginine-fructose (AF), which are produced by the thermal reaction of arginine and maltose or glucose during steam processing of red Korean ginseng root. The content of Arg-Fru-Glc (AFG) can reached 1.1-1.5 % [25]. The detected levels of total fructans express as fructose equivalent of Korean ginseng roots reached 9.12 g/100 dw, which can be due to fructose containing sugars.

Table. 3. *Total fructans, inulin and sugars in medicinal plants, g/100 g dry weight (n.d. Not detected).*

№	Sample	Familly	Total fructans	Inulin	Nys	1-Kes	Suc	Glc	Fruc
1	Siberian wild echinacea (*Ehinacea purpurea* Moench)	Asteraceae	7.39±1.78	0.71±0.05	n.d.	n.d.	1.91±0.02	0.50±0.01	0,81±0.02
2.	Korean ginseng	Araliaceae	9.12±0.67	n.d.	n.d.	n.d.	5.50±1.61	n.d.	0.44±0.28
3.	Siberian ginseng (*Eleutherococcus senticosus*)	Amaranthaceae	n.d.	n.d.	n.d.	n.d.	n.d.	0.82±0.01	n.d
4.	Costus (*Saussurea lappa*)	Costaceae	4.86±1.92	2.96±0.51	n.d	0.29±0.01	2.01±0.02	0.12±0.05	0.79±0.02
5.	Cotton thistle (*Onopordum acanthium* L.)	Asteraceae	5.53±0.03	2.57±0.12	n.d.	n.d.	0.42 ± 0.02	0.33±0.01	1.14±0.08

CONCLUSION

The current study revealed the nutritional potential of some superfoods and medicinal plants to be used as a source of dietary fibres, especially flour of shatavari roots. Shatavari root powder demonstrated the highest value of inulin and fructooligosacchrides and was evaluated as potential prebiotic. Inulin was detected in small amounts (2-3 g/100 g dry weight) in costus roots and cotton thistle heads and below 1 g/100 g dry weight in suma roots and and Siberian wild echinacea leave and root mixture. Maca root flour was evaluated as the best source of sugars, mainly sucrose as it content reached up to 14 g/100 g dry weight. The lowest sugar content was found in Siberian ginseng, where only glucose was detected below 1 g/100 g dw.

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