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Research Article

Analysis of inulin and fructans in *Taraxacum officinale* L. roots as the main inulin-containing component of antidiabetic herbal mixture

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Abstract

Herbs and their combinations due to the wide range of biologically active substances can influence on various links of the pathogenetic mechanism of development of diabetes mellitus and its complications. One of such combinations is an antidiabetic herbal mixture with established hypoglycemic, hypolipidemic, antioxidant, hepatoprotective, pancreatoprotective activity in previous pharmacological study in vivo that including an inulin-containing component – *Taraxacum officinale* L. roots. Thus, the aim of this study was to determine the quantitative content of inulin and fructans in *Taraxacum officinale* L. Quantity content of inulin was determined by the difference between fructose as a product of enzymatic hydrolysis and *D*-fructose, a constituent of sucrose and free *D*-fructose, taking into account the empirical factor for the conversion of *D*-fructose from inulin. Carbohydrates used in the calculation of inulin were separated by gas chromatography-mass spectrometry after conversion into volatile derivatives as aldononitrile acetate. According to the results, *Taraxacum officinale* L. roots contain 436.29 mg/g of inulin. Total content of fructans was determined by spectrophotometric analysis as a product of acid hydrolysis of 5-(hydroxymethyl)furfural. The results show that *Taraxacum officinale* L. roots contain 39.49% of fructans. The obtained results are evidence that this plant component should be included in the herbal antidiabetic mixture, because due to the presence of fructans and inulin causes hypoglycemic, hypolipidemic and detoxification activity.

Keywords

Diabetes mellitus, fructans, herbal mixture, inulin, GC-MS, spectrophotometric assay, *Taraxacum officinale* L. roots

Introduction

Diabetes mellitus is one of World Health Organization priorities matters, which requires immediate solutions, as the epidemiological situation is alarming – the number of patients is growing rapidly each year, leading to increased disability and mortality due to the development of macro- and microangiopathies (Harding et al. 2019; American Diabetes Association 2021). According to the official information of International Diabetes Federation (2019) the number of diabetics will increase to 700 million by 2045. Therefore, the implementation of pharmacotherapy optimization, the search and study of new drugs for the prevention and treatment of this disease and its dangerous complications is a topical issue of pharmacy and medicine.

Modern pharmacotherapy is increasingly taking into account the centuries-old experience of folk medicine using phytomedicines as monotherapy and in combination with synthetic drugs. It became quite justified, after all as phytotherapy has a number of advantages over traditional therapy with using synthetic agents, namely, it is low-toxic, has a mild pharmacological effect and possibility to be used for long periods of time without significant side effects and is well combined with synthetic drugs (Gothai et al. 2016; Governa et al. 2018). In addition, herbal preparations usually have a wide range of pharmacological properties, which is realized through various groups of phytochemicals (Oh and Jun 2014; Kooti et al. 2016). Particular attention deserve the combinations of different medicinal plants, because such herbal mixtures will have more biologically active substances that will influence on the all links of the pathogenetic mechanism of development of diabetes mellitus and its complications (Savych et al. 2020a, b, c, d, e, f; Savych et al. 2021a, b, c, d, e, f, g).

One of such combinations is an antidiabetic herbal mixture (*Urtica dioica* L. leaf, *Taraxacum officinale* L. roots, *Vaccinium myrtillus* L. leaf, *Rosa majalis* L. fruits, *Mentha piperita* L. herb) with established hypoglycemic, hypolipidemic, antioxidant, hepatoprotective, pancreatoprotective activity in pharmacological study in vivo (Savych et al. 2020b, c, d, e, f) and the defined phytochemical composition that determines such pharmacodynamics (Savych et al. 2020a; Savych et al. 2021a, b, c, d, e, f, g).

Biologically active substances of plant origin have a wide range of pharmacological action and a variety of mechanisms of influencing on the development of diabetes and its angiopathies (Oh and Jun 2014; Kooti et al. 2016; Skyler et al. 2017). One of the most influential phytochemical components is fructans, in particular inulin because it has the ability to regulate the lipid metabolism, a disorder of which occurs in diabetes and leads to the development of cardiovascular diseases and microcirculatory complications – diabetic nephropathy, neuropathy and retinopathy, the formation of diabetic foot. Important influence of inulin on lipid metabolism is manifested by a decrease in triglycerides and cholesterol (Hiel et al. 2018; Mistry et al. 2018).

Inulin as a representative of fructans has hypoglycemic activity due to its ability to increase glucagon-like peptide-1 (GLP-1), which increases the secretion of insulin, inhibits the secretion of glucagon and somatostatin, causes the proliferation and neogenesis of β-cells and increases the response of β-cells to glucose (Kietsiriroje et al. 2018; Paternoster and Falasca 2018).

Fructans, including inulin, have a powerful detoxifying effect due to the formation of a healthy intra-intestinal environment that protects against pathogens, toxins and free radicals resulting from lipid peroxidation. This is achieved by stimulating the growth of beneficial bacteria in the colon, including *Bifidobacteria* and *Lactobacilli* (Shang et al. 2018; Hoffman et al. 2019).

The main plant component in the studied mixture containing fructans and inulin, according to the literature, is *Taraxacum officinale* L. roots (Wirngo et al. 2016). As for other components of the herbal mixture, such as *Urtica dioica* L. leaf, *Vaccinium myrtillus* L. leaf, *Rosa majalis* L. fruits and *Mentha piperita* L. herb, no literature data were found on the presence of inulin in them, so these components were not considered by us as objects of this study.

Aim of the research

The aim of this study was to determine the quantitative content of inulin and fructans in *Taraxacum officinale* L. roots, as the main inulin-containing component of antidiabetic herbal mixture.

Materials and methods

Plant materials

It was used the herbal raw materials of *Taraxacum officinale* L. harvested from September to October 2020 in Ternopil region (Ukraine) during the study. The raw materials were then dried, crushed and stored according to the general GACP requirements (WHO 2003). The plant was identified at the Department of Pharmacognosy with Medical Botany, Ivan Horbachevsky Ternopil National Medical University, Ternopil, Ukraine. Sample of herbal raw materials has been deposited in Departmental Herbarium for future record.

Chemicals and standards

All applied reagents were of analytical grade (≥ 99% purity). Chemical reference substances (CRS) of carbohydrates including *D*-arabinose, *D*-glucose, *D*-fructose and saccharose were purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). Water used in the studies was produced by MilliQ Gradient water deionization system (Millipore, Bedford, MA, USA). Inulinase, acetate buffer, methanol, hydroxylamine hydrochloride, pyridine, dichloroethane, hydrochloric acid, heptanes, ethyl acetate were purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA).

Chromatographic condition

Quantity content of inulin in *Taraxacum officinale* L. roots was studied by GC-MS method with small modifications (Marchyshyn et al. 2020). Chromatographic separation was performed on a gas chromato-mass spectrometric system model 6890N/5973inert (Agilent Technologies, USA) using a capillary column HP-5ms (30 m × 0.25 mm × 0.25 mm, Agilent Technologies, USA). Evaporator temperature was 250 °C, the interface temperature – 280 °C. Separation was performed in the mode of temperature programming – the oven temperature was initially at 160 °C, held for 8 min, then ramped at the rate of 5 °C/min to 240 °C and finally held at this temperature for 6 min. Samples 1 μL were administered in a 1:50 flow divider

mode. Detection was held in the SCAN mode in the range of (38–400 m/z). Carrier gas flow rate through a column was 1.2 mL/min.

Sample preparation for GC-MS

Sample of herbal raw materials was grinded into a powder by laboratory mill, then about 50–80 mg (accurately weighed mass) was placed in a glass vial and 4 mL of 0.1 M acetate buffer (pH 4.5) was added. Extraction of inulin was performed in ultrasonic bath at 80 °C for 3 hours. Resulting extract was centrifuged at 3000 rpm for 10 min and the supernatant was evaporated to dryness on a rotary evaporator. One part of an extract was used for enzymatic hydrolysis of inulin with 100 μL of inulinase at 60 °C for 30 min (Vendrell-Pascuas et al. 2000). Rest of an extract of *Taraxacum officinale* L. roots was used for the determination of free *D*-fructose (Guan et al. 2010).

Pre-column derivatization

Aliquots of 0.6 mL from extracts were taken and 0.3 mL of a derivatizing reagent (32 mg/mL of hydroxylamine hydrochloride in the mixture of pyridine/ methanol (4:1, v/v)) was added to obtain an aldonitrile monosaccharide derivatives. Sample was incubated in a preheated water bath shaker at 75 °C for 25 min. After incubation 1.0 mL of acetic anhydride was subsequently added to the sample and incubated at 75 °C for 15 min. 2 mL of dichloromethane was added to the mixture, the excess of the derivatization reagents was removed by the double extraction with 1 M hydrochloric acid solution and water. Dichloromethane layer was dried and dissolved into 300 μL of the mixture of heptane/ethyl acetate (1:1, v/v) (Chen et al. 2009).

Identification and calculation for GC-MS

Identification of enzymatic hydrolysis products, free monosaccharides and disaccharide – sucrose was performed by comparing of retention time (t_R) of the mixture of CRS and using the NIST 02 mass spectrum library. Quantitative analysis was performed by adding a solution of internal standard – arabinose 0.25 mg in 2 mL of pyridine into test samples. Under normal conditions of derivatization, the ketone carbohydrate (*D*-fructose) is converted into an aldo carbohydrate (*D*-glucose) (Agius et al. 2018). According to this technique, *D*-fructose in derivatization gives two peaks, which are summed up during calculations.

Concentration of total *D*-fructose (C_1, mg/mL), free *D*-fructose (C_2, mg/mL) and sucrose (C_{sucr}, mg/mL) was determined by the method of internal standards according to the formula:

$$C = \frac{S_x \times m_{st} \times V_{sol}}{S_{st} \times m_x \times V_{extr}} \times 1000$$

where S_x –peak area of studied substance;
m_{st} – mass of internal standard injected into the sample, mg;
S_{st} – peak area of internal standard;
m_x – mass of the sample of raw materials, mg;
V_{sol} – volume of solvent for extraction, mL;
V_{extr} – volume of extract for derivatization, mL.

Concentration (C_3, mg/mL) of *D*-fructose released from sucrose was calculated by the formula:

$$C_3 = \frac{C_{\text{sucr}}}{B}$$

where C_{sucr} –concentration of sucrose, mg/mL;
B – empirical factor for the conversion of *D*-fructose from sucrose (2.13).

Quantitative content (*X*, mg/g) of inulin was determined as the subtraction from total content of *D*-fructose after enzymatic hydrolysis, free *D*- fructose and *D*-fructose released by decomposition of sucrose according to the formula:

$$X = \frac{A \times (C_1 - C_2 - C_3)}{m_1}$$

where C_1 – concentration of total *D*-fructose, mg/mL;
C_2 – concentration of free *D*-fructose, mg/mL;
C_3 – concentration of *D*-fructose released from sucrose, mg/mL;
A – empirical factor for the conversion of *D*-fructose from inulin (1.03);
m_1 – mass of raw materials on which was calculated, g.

Empirical factor for the conversion of *D*-fructose from inulin and sucrose (factor of conversion of inulin to *D*-fructose and sucrose to *D*-fructose) was determined by sequential processing of samples with different amounts of inulinase using *D*-arabinose as an internal standard and determining an amount of *D*-fructose released (Vendrell-Pascuas et al. 2000).

Spectrophotometric condition

Quantitative content of fructans in *Taraxacum officinale* roots L. was determined by spectrophotometric methods, using spectrophotometer Shimadzu 1800-UV (Japan).

Exrtact: 3.00 g (accurately mass) of powdered herbal raw materials were extracted by 100 mL of water at the water bath under reflux at 80 °C for 1 hour.

Stock solution: an extract was cooled, filtered and the volume was completed to 100 mL by water.

Test solution: 2 mL of stock solution was placed into 100 mL volumetric flask and 50 mL of 5% hydrochloric acid solution was added. Obtained solution was hydrolyzed at the water bath under reflux for 2 hours. Then 2.0 mL of cooled hydrolyzate was placed into 50 mL volumetric flask and solution of 5% hydrochloric acid was added to the mark.

Reference solution: 2 mL of stock solution was placed into 50 mL volumetric flask and solution of 5% hydrochloric acid was added to the mark.

The absorbance of the test solution was measured at wavelength (λmax) of 284 nm relative to the blank.

The total content of fructans in *Taraxacum officinale* L. roots was calculated, as a product of acid hydrolysis of 5-(hydroxymethyl)furfural (5-HMF) (Marchyshyn et al. 2020).

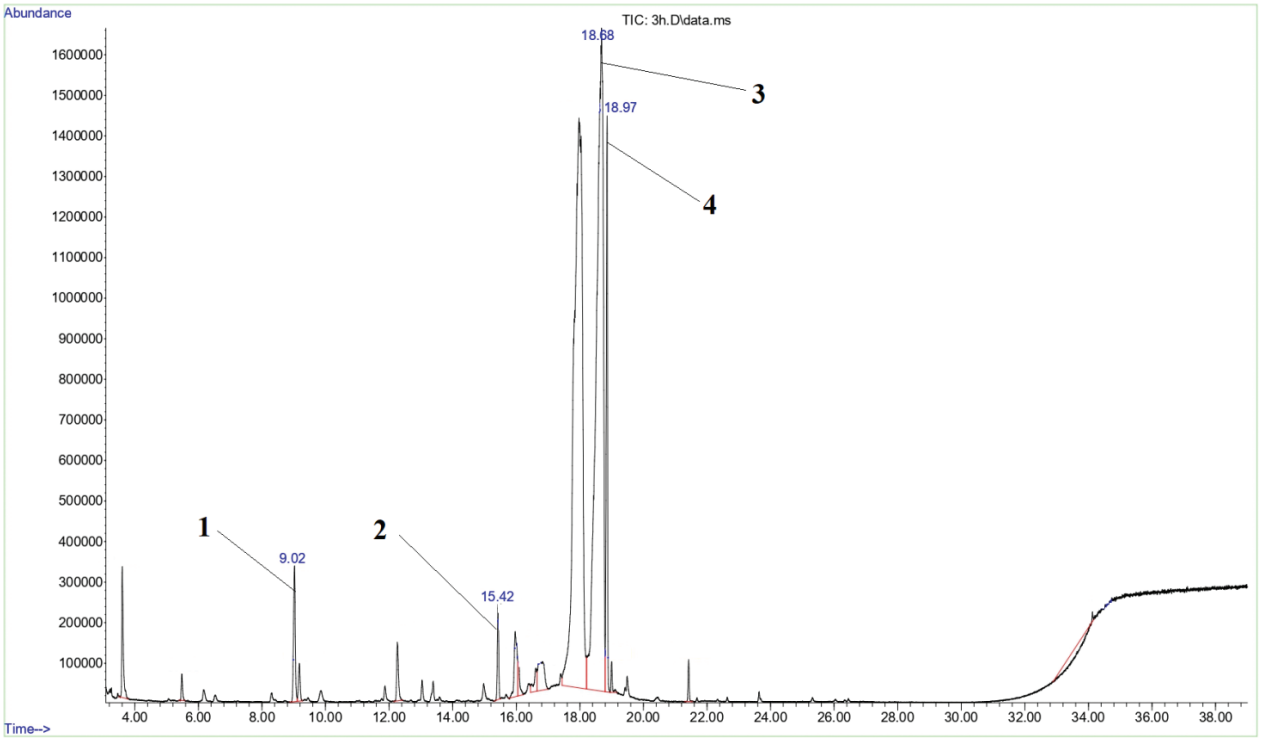

Figure 1. GC-MS chromatogram of carbohydrates formed as a result of enzymatic hydrolysis in *Taraxacum officinale* roots (1 – *D*-arabinose, internal standard; 2 – *D*-glucose; 3, 4 – *D*-fructose).

Results and discussion

During GC-MS analysis it was detected an inulin by the products of its enzymatic hydrolysis after conversion into volatile derivatives as aldononitrile acetate in *Taraxacum officinale* L. roots, which was the main inulin-containing component of antidiabetic herbal mixture (Fig. 1). However, chromatographic determination of free carbohydrates, in particular *D*-fructose and sucrose, was performed to exclude their content from the total amount of enzymatic hydrolysis products by inulinase (Fig. 2).

Result of quantitative determination of carbohydrates formed due to enzymatic hydrolysis, free *D*-fructose, *D*-glucose and sucrose in *Taraxacum officinale* L. roots has showed in Table 1. It was established that content of inulin was 436.29 mg/g in *Taraxacum officinale* L. roots by a number of calculations.

After acid hydrolysis of an aqueous extract of *Taraxacum officinale* L. roots by a solution of 5% hydrochloric acid was formed 5-HMF, which was confirmed by the absorption spectrum at λmax 284 nm (Fig. 3). During spectrophotometric analysis it was found that the *Taraxacum officinale* L. roots contain 39.49% of fructans.

The obtained results are an important stage of phytochemical study of antidiabetic herbal mixture and its plant components, because it allows already establish a correlation between biologically active substances and its pharmacodynamics. Fructans and their representative – inulin have a leading position in the prevention and treatment of diabetes, as confirmed by numerous preclinical and clinical studies (Kietsiriroje et al. 2018; Mistry et al. 2018; Shang et al. 2018; Hoffman et al. 2019). Inulin-type fructans help control glycemia in type 2 diabetes and prediabetes by a variety of mechanisms, including by reducing insulin resistance, increasing glucagon-like peptide (GLP-1), and glucagon-like peptide 2 (GLP-2) (Kietsiriroje et al. 2018; Paternoster and Falasca 2018). In addition, the hypoglycemic effect of inulin is realized by delaying the rate of gastric

Table 1. Result of the GC-MS analysis of carbohydrates, which are taken into account when calculating the inulin content in *Taraxacum officinale* L. roots.

No. of peak	t_R, min (SD±0.008)	Identified substance	Derivatization products	Content, mg/g
CARBOHYDRATES AFTER HYDROLISIS				
1.	9.02	*D*-arabinose	2,3,4,5-tetra-O-acetyl-D-arabinononitrile	Internal standard
2.	15.42	*D*-glucose	2,3,4,5,6-penta-O-acetyl-D-gluconitrile	10.86±0.56
3.	18.68	*D*-fructose	naphthalene-1-carboxylic acid, 4-butylamino-6,7-dimethoxy-2-methyl-ethyl ester	394.66±1.87
4.	18.94	*D*-fructose	1-nitro-4-phenoxyanthraquinone	65.74±0.83
FREE CARBOHYDRATES				
1.	9.02	*D*-arabinose	2,3,4,5-tetra- O-acetyl-D-arabinononitrile	Internal standard
2.	15.42	*D*-glucose	2,3,4,5,6-penta-O-acetyl-D-gluconitrile	3.58±0.25
3.	18.68	*D*-fructose	naphthalene-1-carboxylic acid, 4-butylamino-6,7-dimethoxy-2-methyl-ethyl ester	7.10±0.29
4.	18.97	*D*-fructose	1-nitro-4-phenoxyanthraquinone	2.39±0.19
5.	34.05	sucrose	sucrose octaacetate	58.19±0.64

Note: Values are expressed as mean ± SD (n = 5).

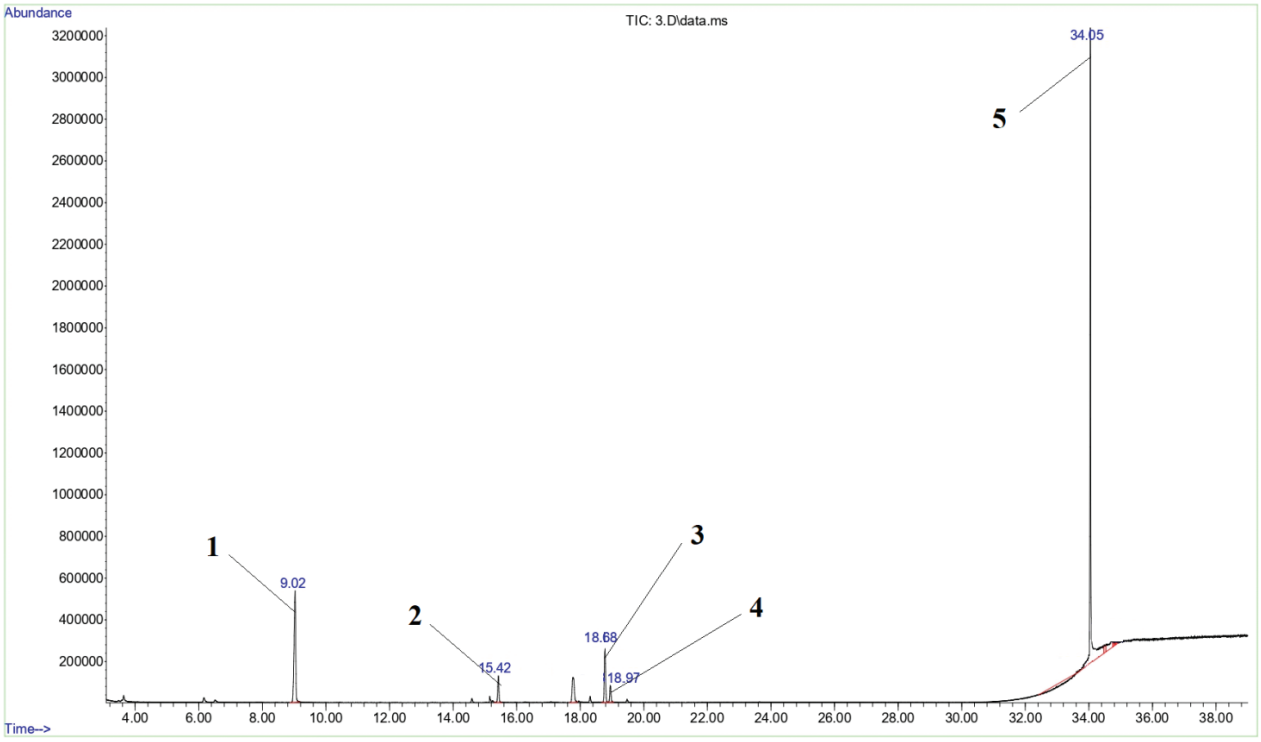

Figure 2. GC-MS chromatogram of free carbohydrates in *Taraxacum officinale* roots (1 – *D*-arabinose, internal standard; 2 – *D*-glucose; 3, 4 – *D*-fructose; 5 – sucrose).

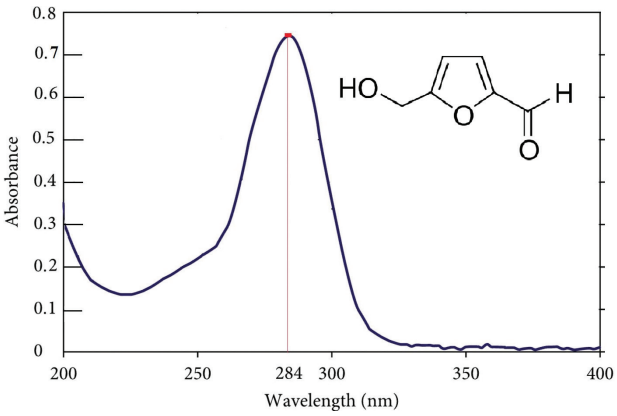

Figure 3. UV spectrum of 5-HMF in *Taraxacum officinale* L. roots, λmax 284 nm, Mean ± SD (n = 5).

emptying, thereby slowing the flow of glucose into the blood and reducing the degree of alimentary hyperglycemia that occurs after meals (Hiel et al. 2018). Fructans as probiotics have many health benefits, such as improving immune function, lowering blood pressure, improving blood lipids and reducing inflammation (Mistry et al. 2018).

That is why the phytochemical study of the content of inulin and total content of fructans confirms the feasibility of introducing *Taraxacum officinale* L. roots into the antidiabetic herbal mixture with established hypoglycemic, hypolipidemic, antioxidant, hepatoprotective, pancreatoprotective activity in pharmacological study in vivo (Savych et al. 2020b, c, d, e, f).

Conclusion

We established the quantity content of inulin in *Taraxacum officinale* L. roots as the main inulin-containing component of antidiabetic herbal mixture with hypoglycemic, hypolipidemic, antioxidant, hepatoprotective, pancreatoprotective activity and defined phytochemical composition by GC-MS method. The inulin content was 436.29 mg/g. During spectrophotometric analysis it was detected that the *Taraxacum officinale* L. roots contain 39.49% of fructans, as a product of acid hydrolysis of 5-(hydroxymethyl)furfural. The obtained results are evidence that this plant component should be included in the herbal antidiabetic mixture, because due to the presence of fructans and inulin causes hypoglycemic, hypolipidemic and detoxification activity.

References

Agius C, Tucher S, Poppenberger, Rozhon W (2018) Quantification of sugars and organic acids in tomato fruits. Methods X 5: 537–550. https://doi.org/10.1016/j.mex.2018.05.014

American Diabetes Association (2021) Introduction: Standards of Medical Care in Diabetes-2021. Diabetes Care 44(1): 1–2. https://doi.org/10.2337/dc21-Sint

Chen Y1, Xie MY, Wang YX, Nie SP, Li C (2009) Analysis of the monosaccharide composition of purified polysaccharides in Ganoderma atrum by capillary gas chromatography. Phytochemical Analisis 20(6): 503–510. https://doi.org/10.1002/pca.1153

Gothai S, Ganesan P, Park S, Fakurazi, S, Choi D, Arulselvan P (2016) Natural phyto-bioactive compounds for the treatment of type 2 diabetes: inflammation as a target. Nutrients 8(8): e461. https://doi.org/10.3390/nu8080461

Governa P, Baini G, Borgonetti V, Cettolin G, Giachetti D, Magnano AR, Miraldi E, Biagi M (2018) Phytotherapy in the Management of Diabetes: A Review. Molecules (Basel, Switzerland) 23(1): e105. https://doi.org/10.3390/molecules23010105

Guan J, Yang FQ, Li SP (2010) Evaluation of carbohydrates in natural and cultured Cordyceps by pressurized liquid extraction and gas chromatography coupled with mass spectrometry. Molecules 15: 4227–4241. https://doi.org/10.3390/molecules15064227

Harding JL, Pavkov ME, Magliano DJ, Shaw JE, Gregg EW (2019) Global trends in diabetes complications: a review of current evidence. Diabetologia 62(1): 3–16. https://doi.org/10.1007/s00125-018-4711-2

Hiel S, Neyrinck AM, Rodriguez J, Pachikian BD, Bouzin C, Thissen JP, Cani PD, Bindels LB, Delzenne NM (2018) Inulin improves postprandial hypertriglyceridemia by modulating gene expression in the small intestine. Nutrients 10(5): e532. https://doi.org/10.3390/nu10050532

Hoffman JD, Yanckello LM, Chlipala G, Hammond TC, McCulloch SD, Parikh I, Sun S, Morganti JM, Green SJ, Lin AL (2019) Dietary inulin alters the gut microbiome, enhances systemic metabolism and reduces neuroinflammation in an APOE4 mouse model. PLoS ONE 14(8): e0221828. https://doi.org/10.1371/journal.pone.0221828

International Diabetes Federation (2019) IDF Diabetes Atlas. 9th edn., Brussels. http://www.diabetesatlas.org

Kietsiriroje N, Kanjanahirun K, Kwankaew J, Ponrak R, Soonthornpun S (2018) Phytosterols and inulin-enriched soymilk increases glucagon-like peptide-1 secretion in healthy men: double-blind randomized controlled trial, subgroup study. BMC Research Notes 11(1): e844. https://doi.org/10.1186/s13104-018-3958-5

Kooti W, Farokhipour M, Asadzadeh Z, Ashtary-Larky D, Asadi-Samani M (2016) The role of medicinal plants in the treatment of diabetes: a systematic review. Electronic Physician 8(1): 1832–1842. https://doi.org/10.19082/1832

Marchyshyn S, Polonets O, Savych A, Nakonechna S (2020) Determination of carbohydrates of *Chrysanthemum morifolium L.* leaves and flowers by GC-MS. Pharmakeftiki Journal 32(4): 202–212.

Mistry RH, Gu F, Schols HA, Verkade HJ, Tietge U (2018) Effect of the prebiotic fiber inulin on cholesterol metabolism in wildtype mice. Scientific Reports 8(1): e13238. https://doi.org/10.1038/s41598-018-31698-7

Oh YS, Jun HS (2014) Role of bioactive food components in diabetes prevention: effects on beta-cell function and preservation. Nutrition and Metabolic Insights 7: 51–59. https://doi.org/10.4137/NMI.S13589

Paternoster S, Falasca M (2018) Dissecting the physiology and pathophysiology of glucagon-like peptide-1. Frontiers in Endocrinology 9: e584. https://doi.org/10.3389/fendo.2018.00584

Savych A, Marchyshyn S, Basaraba R (2020a) Determination of fatty acid composition content in the herbal antidiabetic collections. Pharmacia 67(3): 153–159. https://doi.org/10.3897/pharmacia.67.e51812

Savych A, Marchyshyn S, Basaraba R (2020b) Screening study of hypoglycemic activity of the herbal mixtures (Message 1). Scientific Journal "ScienceRise: Pharmaceutical Science" 4(26): 40–46. https://doi.org/10.15587/2519-4852.2020.210734

Savych A, Marchyshyn S, Basaraba R, Lukanyuk M (2020c) Antihyperglycemic, hypolipidemic and antioxidant properties of the herbal mixtures in dexamethasone-induced insulin resistant rats. PharmacologyOnLine 2: 73–82.

Savych A, Marchyshyn S, Doroshenko O (2020d) Screening of hypoglycemic activity of herbal mixtures (Message 2). Ukrainian biopharmaceutical journal 3(64): 22–29. https://doi.org/10.24959/ubphj.20.281

Savych AO, Marchyshyn SM, Basaraba RY (2020e) Determination of hypoglycemic activity of the herbal mixtures in screening study. Pharmacology and Drug Toxicology 14(5): 344–351. https://doi.org/10.33250/14.05.344

Savych AO, Marchyshyn SM, Milian II (2020f) Screening study of hypoglycemic activity of herbal mixtures (Presentation 3). Clinical Pharmacy 24(4): 38–46. https://doi.org/10.24959/cphj.20.1537

Savych A, Marchyshyn S, Harnyk M, Kudria V, Ocheretniuk A (2021a) Determination of amino acids content in two samples of the plant mixtures by GC-MS. Pharmacia 68(1): 283–289. https://doi.org/10.3897/pharmacia.68.e63453

Savych AO, Marchyshyn S, Kozyr H, Yarema N (2021b) Determination of inulin in the herbal mixtures by GC-MS method. Pharmacia 68(1): 181–187. https://doi.org/10.3897/pharmacia.68.e55051

Savych A, Marchyshyn S, Milian I (2021c) Determination of carbohydrates in the herbal antidiabetic mixtures by GC-MC. Acta Pharmaceutica 71(3): 429–443. https://doi.org/10.2478/acph-2021-0026

Savych A, Basaraba R, Muzyka N, Ilashchuk P (2021d) Analysis of fatty acid composition content in the plant components of antidiabetic herbal mixture by GC-MS. Pharmacia 68(2): 433–439. https://doi.org/10.3897/pharmacia.68.e66693

Savych A, Marchyshyn S, Basaraba R, Kryskiw L (2021e) Determination of carboxylic acids content in the herbal mixtures by HPLC. ScienceRise: Pharmaceutical Science: 2(30): 33–39. https://doi.org/10.15587/2519-4852.2021.229132

Savych A, Marchyshyn S, Nakonechna S (2021f) Influence of some herbal mixtures on insulin resistance and glucose tolerance in rats. PharmacologyOnLine 1: 356–364.

Savych A, Marchyshyn S, Kyryliv M, Bekus I (2021g) Cinnamic acid and its derivatives in the herbal mixtures and their antidiabetic activity. Farmacia 69(3): 595–601. https://doi.org/10.31925/farmacia.2021.3.23

Shang HM, Zhou HZ, Yang JY, Li R, Song H, Wu HX (2018) In vitro and in vivo antioxidant activities of inulin. PLoS ONE 13(2): e0192273. https://doi.org/10.1371/journal.pone.0192273

Skyler JS, Bakris GL, Bonifacio E, Darsow T, Eckel RH, Groop L, Groop PH, Handelsman Y, Inse RA, Mathieu C, McElvaine AT, Palmer JP, Pugliese A, Schatz DA, Sosenko JM, Wilding JP, Ratner RE (2017) Differentiation of diabetes by pathophysiology, natural history, and prognosis. Diabetes 66(2): 241–255. https://doi.org/10.2337/db16-0806

Vendrell-Pascuas S, Castellote-Bargalló A, López-Sabater M (2000) Determination of inulin in meat products by high-performance liquid chromatography with refractive index detection. Journal of Chromatography A 881(1–2): 591–597. https://doi.org/10.1016/S0021-9673(00)00351-4

WHO [World Health Organization] (2003) WHO guidelines on good agricultural and mixture practices (GACP) for medicinal plants. World Health Organization, Geneva, 72 pp. https://apps.who.int/iris/handle/10665/42783

Wirngo FE, Lambert MN, Jeppesen PB (2016) The physiological effects of dandelion (*Taraxacum officinale*) in type 2 diabetes. The Review of Diabetic Studies 13(2–3): 113–131. https://doi.org/10.1900/RDS.2016.13.113