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ARTICLE

Phytochemical and Pharmacological Research in Galenic Remedies of *Solidago canadensis* L. Herb

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ABSTRACT

Canadian goldenrod (*Solidago canadensis* L.) is a rhizomatous plant of the Asteraceae family. In folk medicine, *Solidago* galenic remedies are used for diseases of the kidneys, urinary tract, liver, etc. Externally, goldenrod is used to treat purulent wounds, furunculosis, and gum abscesses as washes and compresses. The aims of this research were to study the yield and chemical composition of essential oil (EO), the anti-inflammatory activity of *S. canadensis* dry extracts based on its decoction and tincture. In EO (2.8 mL/kg) of *S. canadensis* were identified and quantified 34 compounds. The principal compounds of the EO from flowering tops of *S. canadensis* were α-pinene (20.36%), β-copaene (16.16%), bornyl acetate (10.45%), D-limonene (8.21%), and β-elemene (6.80%). In the *S. canadensis* dry extracts were identified and quantified 20 phenolics (10 flavonoids, 8 hydroxycinnamic acids and 2 phenolic acids) and 14 amino acids, 7 of which are essential. The dominant hydroxycinnamic acids were neochlorogenic and chlorogenic acids, and 4,5-dicaffeoylquinic, 3,5-dicafeylquinic and 3,4-dicafeylquinic acids. The main flavonoids were rutin and isoquercitrin. The main amino acids (more than 1 mg/g) were proline, histidine, serine, alanine, aspartic acid, lysine and glutamic acid. The extracts of *S. canadensis* were characterized as practically non-toxic substances (toxicity class V). The extracts act on the exudative phase of inflammation. The antiexudative effect of the dry aqueous-alcohol *S. canadensis* extract was 23.59%, and for the aqueous one –19.26%. The dry aqueous-alcohol *S. canadensis* extract showed promising anti-inflammatory activity.

KEYWORDS

Solidago canadensis; extract; essential oil; terpenoids; phenolics; amino acid; anti-inflammatory activity

1 Introduction

Solidago canadensis L. is a perennial rhizomatous plant that belongs to *Asteraceae* family. In the *Solidago* genus there are about 190 species and 330 taxons [1]. In Europe, both *S. canadensis* L. and

S. virgaurea L. are the most widely spread species and have a long tradition of use in folk and official medicine [2,3]. They are considered as invasive weeds [2,4].

Thus, *S. canadensis* is a very common species and can be found everywhere because of its wide and rapid distribution. It is undemanding to soils but develops better on relatively heavy and rich soils with average moisture. It is also easily cultivated, so the raw material base of this plant is significant. Considering the long and successful use of folk medicine in many countries, it is interesting to expand scientific knowledge, and its wider use in official medicine is promising.

The Canadian goldenrod's remedies are implemented for the treatment of cystitis, chronic nephritis, and urolithiasis, and as an antiphlogistic drug [5,6] and as a mouth rinse in the treatment of inflammations of the mouth and throat [7,8]. The antibacterial, antioxidative, anti-inflammatory and antimutagenic effects have been proved for *Solidago* remedies and are connected to flavonoids, terpenoids, and saponins [9,10].

S. canadensis essential oil (EO) were studied previously and their chemical composition was presented in some publications [5,7,11,12]. Germacrene D, α-pinene, β-elemene, limonene, and bornyl acetate predominated [13,14].

The European Pharmacopoeia monograph "*Solidago* herba" regards flavonoids as quality markers, and there must be at least 0.5% and a maximum of 1.5% in the calculation to hyperoside [15]. The *Solidago* flavonoids are represented by quercetin and kaempferol glycosides [16–18]. The *S. canadensis* herb also contains polyphenolic acids (vanillic, gallic, ferulic, caffeic, and chlorogenic acids) [19] and oleanane-type triterpene saponins [1,5]. Considering the rich composition of phenolic compounds, especially flavonoids and hydrocinnamic acids, using *S. canadensis* raw material in inflammatory urinary tract diseases, possibly in prostate adenoma and chronic prostatitis, is promising.

In Ukraine dry extracts of *S. canadensis* are part of complex medicines: Marelin, Phytolysin, Prostamed [20]. In folk medicine, *Solidago* galenic remedies are used for diseases of the urinary tract, kidneys, liver, etc. Externally, it also helps to treat purulent wounds, gum abscesses and furunculosis [21,22]. Considering this, it is advisable to investigate the chemical composition and pharmacological activity of the main galenic remedies of *S. canadensis* herb to establish the prospects of their use for developing modern dosage forms and implementation in medical and pharmaceutical practice.

This research aimed to study the chemical composition of essential oil, phenolic compounds, amino acids and the anti-inflammatory activity of *S. canadensis* dry extracts based on its decoction and tincture for use as promising agents in medicinal and pharmaceutical practice. As *S. virgaurea* is the most well-studied species, *S. canadensis* can be considered as its analogue after obtaining this new knowledge. To the best of our knowledge, this work is the first to analyze the amino acid content of *S. canadensis* herb and investigate the anti-inflammatory activity of this plant extract.

2 Material and Methods

2.1 Materials

The flowering tops of *S. canadensis* were harvested in Tartu (58.36277085085124, 26.747175570884128) in July 2023 and dried for 14 days at room temperature in a well-ventilated area. The plant species were identified by Professor Andriy Grytsyk according to the botanical catalogue [23]. Voucher specimens No. 455–457 were deposited at the Department of Pharmaceutical Management, Drug Technology and Pharmacognosy, Ivano-Frankivsk National Medical University (IFNMU, Ivano-Frankivsk, Ukraine). It was stored in paper bags.

The EO hydrodistilled from the dried flowering tops of *S. canadensis* using the method described in the European Pharmacopoeia [15]. It lacks a verb in the yellow-shaded sentence.

The flowering tops of *S. canadensis* (20 g) with 400 mL of purified water were distilated in a 1000 mL round-bottom flask during 2 h (3–4 mL/min). Hexane (0.5 mL) was added to a graduated tube to remove the distilled oil.

100.0 g of the *S. canadensis* herb was filled with 1000 mL of water, heated to 100°C for 15 min and macerated overnight. The liquid extract was filtrated and evaporated with a vacuum rotary evaporator and finally dried in the lyophilic dryer Scanvac Coolsafe 55-4 Pro (LaboGene ApS, Lillerød, Denmark).

100.0 g of the *S. canadensis* herb was filled with 70% ethanol (1000 mL) and macerated over 7 days at room temperature. The liquid extract was separated by filtration and evaporated with a vacuum rotary evaporator and finally dried with the same lyophilic dryer.

2.2 Gas Chromatography/Mass Spectrometry

The samples of EO were analyzed by gas chromatography with mass detections (GC/MS), using an Agilent 6890/5973 GCMS system controlled by mass spectrometry detectors (MSD) Chemstation. 1 µL of the sample was injected at an injector temperature of 280°C in split mode (150:1), using He as the carrier gas onto Agilent HP-5MSI column (30 m length, 0.25 mm inner diameter, 0.25 µm film thickness). The carrier gas was held at the constant flow rate of 1 mL/min. The oven was held at 50°C for 2 min, followed by a ramp of 4 °C/min to a final temperature of 280°C and held at 280°C for 5 min.

The MSD was operated in EI mode at 70 eV. Mass spectra were recorded in the range of 29–400 m/z with a delay time of 4 min and a scan speed of 3.8 scans per second. The data were analyzed by the deconvolution algorithm of Agilent Masshunter Software package using different window size factors. Obtained compounds were identified by using NIST20 library with Match Factor ≥90 and by retention indexes (relative to *n*-alkanes C8–C20) either made available in the literature [7,14] or obtained by the analysis of the reference compounds. The area percentages of each peak were calculated from the total areas in the chromatograms without using correction factors.

2.3 Spectrophotometric Analysis of Phenolic Compounds

The Spectrophotometric assay of sum of hydroxycinnamic acids, polyphenols, and flavonoids in the dry *S. canadensis* herb extracts was conducted with Shimadzu UV-1800 (Shimadzu Corporation, Kyoto, Japan). The sum of hydroxycinnamic acids was measured in calcilation to chlorogenic acid after a reaction with sodium molybdate and sodium nitrite at 525 nm [15]. The sum of flavonoids was determined regarding rutin after a reaction with aluminium chloride at 417 nm [24]. The content of total polyphenolic compounds was assayed in terms of gallic acid at 270 nm [25]. The repeatability of the experiments was three times for statistical validity.

2.4 UPLC-MS/MS Analysis of Phenolic

Identification and quantification of phenolic compounds in the *S. canadensis* extracts was established by UPLC-MS/MS. on Acquity H-class UPLC chromatograph (Waters, Milford, MA, USA) with column YMC Triart C18 (100 mm × 2.0 mm 1.9 µm) at such conditions: column temperature –40°C; the mobile phase flow rate 0.5 mL/min.

Solvent A was formic acid (0.1% aqueous solution). Gradient elution was: solvent B (pure acetonitrile) from 0 to 1 min at 5%, 1 to 5 min. to 30% of solvent B, 5 to 7 min., linear decrease to 50%, 7.5 to 8 min. just solvent B, and 8.1 to 10 min balance column to initial conditions of 5% of solvent B. The chemical structure analysis of phenolics was performed with a triple quadrupole tandem mass spectrometer (Xevo, Waters, USA). Negative electrospray ionization [ESI] was used to create ions and receive MS/MS data. The MS/MS analysis were carried out at such conditions: a capillary voltage 2 kV, the nitrogen gas temperature 400°C, a flow rate 700 L/h, the gas flow rate –20 L/h, and the ion source temperature 150°C.

The phenolic compounds was determined by comparing their MS/MS data and retention times with the standards and using standard dilution method and linear regression fit models [26,27].

2.5 UPLC-MS/MS Analysis of Amino Acids

Aa assay of amino acids in the *S. canadensis* extracts was conducted on Acquity H-class (Waters, Milford, MA, USA) UPLC system with mass spectrometerXevo TQD (Waters, Milford, MA, USA) using a BEH Amide (150 mm × 2.1 mm, 1.7 μm) column (Waters, Milford, MA, USA) at 25°C. The mobile phase consist of eluent A (10 mmol ammonium formate with 0.125% formic acid) and eluent B (acetonitrile) and was used at such conditions: 0 to 1 min. 95% B; 1–3.9 min, 70% B; 3.9–5.1 min, 30% B; 5.1–6.4 min, the column was washed with eluent A, 70%; at 6.5 to 10 min. the initial composition was used. The mobile phase flow rate was 0.6 mL/min. For the analysys 1 μL of the extracts were used. The MS/MS analysis were carried out at such conditions: positive electrospray ionization + 3.5 kV, cone voltage 30 V, desolvation gas flow 800 L/h, and temperature 400°C, the ion source temperature 120°C. The assay of amino acids was determined by comparing their MS/MS data and retention times with the standards and using linear regression fit models [28].

2.6 The Acute Toxicity of the Extracts

A study of the acute toxicity of the *S. canadensis* extracts herb was carried out according to the methodology of preclinical studies of the harmlessness of medicinal products [29]. The mice were divided into 3 groups of 6 animals each: Group 1–the intact group of mice, who consumed purified water; Group 2–the mice consumed the dry aqueous extract of *S. canadensis*; Group 3–the mice consumed the dry extract of *S. canadensis*, obtained with 70% ethanol solution. Animals were under surveillance for 14 days. The degree of extracts' toxicity was considered based on the mortality rate and changes in the general condition of animals. The toxicity class was established according to the generally accepted classification [29]. The study used non-linear white mice that were born and raised in the IFNMU's vivarium.

2.7 Anti-Inflammatory Activity of the Extracts

The anti-inflammatory activity of the *S. canadensis* extracts was determined using a model of formalin oedema on rats [24,29]. The diclofenac sodium was a reference drug and its recommended dose is 0.8 mg [29]. The concentration of phenolic substances in the *S. canadensis* extract is around 12%, so, considering this, 10 mg of the extracts were used for analysis, as a comparable dose to the reference medicine. The study used non-linear white rats that were born and raised in the IFNMU's vivarium.

2.8 Statistical Calculations

All practical data is processed using variational statistics, which calculates the arithmetic mean and standard deviation. The reliability of the compared values was assessed according to the Student's test, and the probability level was accepted as $p \leq 0.05$. Statistical processing of the obtained results was carried out using a package of Windows application programs-MS Excel 2007 according to the methodology of the State Pharmacopoeia of Ukraine [30,31].

3 Results and Discussion

S. canadensis EO was an oily liquid with a slightly yellowish tint, yielding 2.80 mL/kg on dry mass. The yield of the dry aqueous extract was 22.77% and the dry aqueous-alcohol extract was 16.82%. The dry *S. canadensis* aqueous extract was a light brown powder with a specific smell.

Using GC-MS, the *S. canadensis* EO was analyzed (Table 1, Fig. 1).

Table 1: The content of essential oil of *Solidago canadensis* flowering tops, %

No.	Retention index	Compound	Area, %
1	927	α-Phellandrene	0.04
2	935	**α-Pinene**	**20.36**
3	948	Camphene	1.35
4	973	β-Phellandrene	0.64
5	976	β-Pinene	3.11
6	991	β-Myrcene	3.57
7	1029	**D-Limonene**	**8.21**
8	1067	m-Tolualdehyde	0.33
9	1080	p-Tolualdehyde	0.18
10	1126	α-Campholenal	0.39
11	1138	Isopinocarveol	0.36
12	1145	(*E*)-Verbenol	1.43
13	1163	Pinocarvone	0.45
14	1196	(−)-Myrtenal	0.62
15	1209	D-Verbenone	0.53
16	1219	*(Z)*-Carveol	0.31
17	1244	(−)-Carvone	0.30
18	1288	**Bornyl acetate***	**10.45**
19	1307	Undecanal	0.07
20	1339	d-Elemene	0.24
21	1387	(−)-β-Bourbonene	1.91
22	1395	**β-Elemene***	**6.80**
23	1422	β-Caryophyllene	0.88
24	1447	β-Copaene isomer	0.14
25	1457	Humulene	0.49
26	1486	**β-Copaene isomer**	**16.16**
27	1490	β-Selinene*	0.95
28	1509	Elemene isomer	1.53
29	1526	Cedrene/b-Funebrene	0.69
30	1561	β-Germacrene	0.91
31	1586	Caryophyllene oxide	0.33
32	1632	Isospathulenol	1.08
33	1676	Spatulenol	0.53
34	1760	Ylangenol	0.58

Note: *Identified by GC-MS/NIST and literature [7,32]. Bold: >5%.

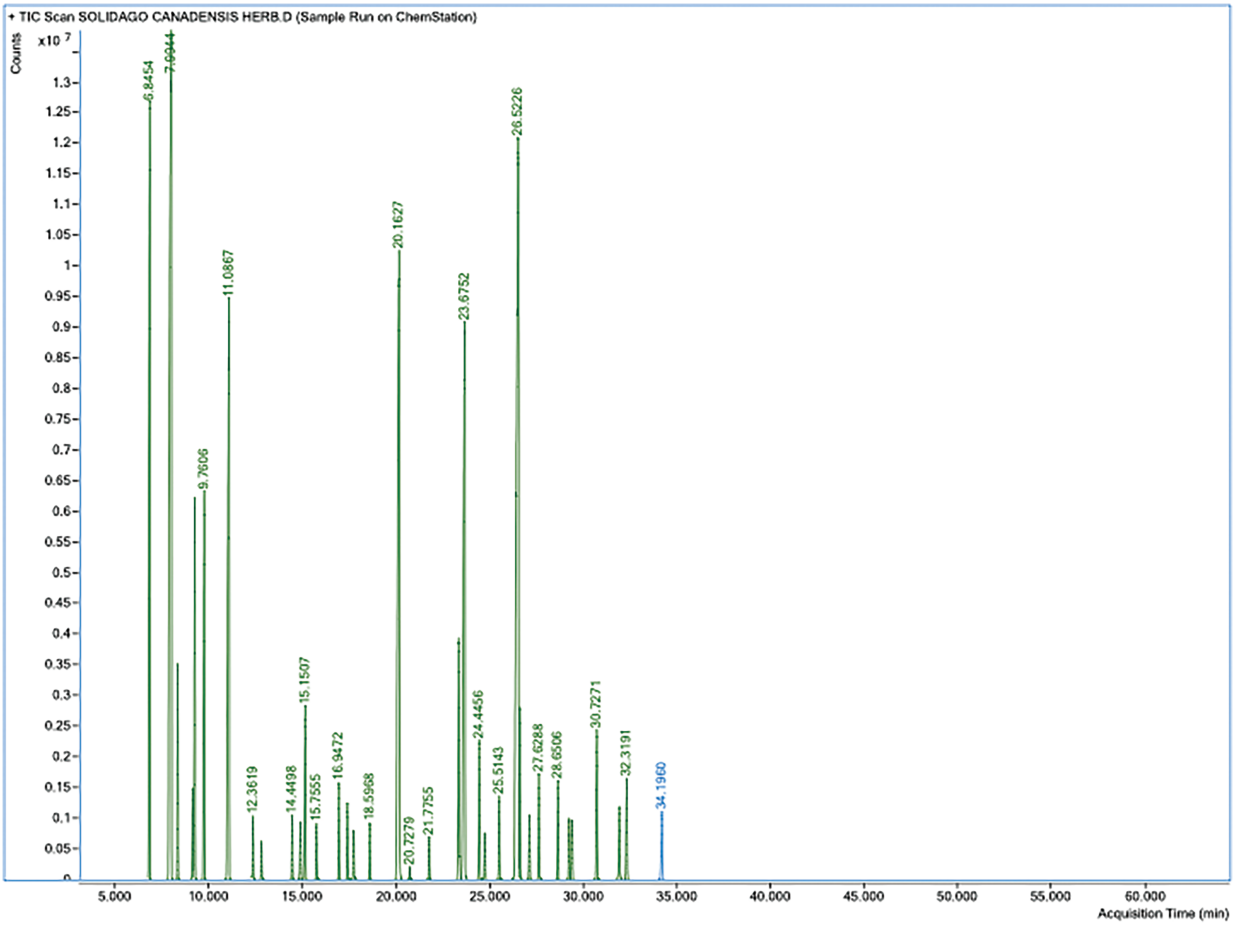

Figure 1: The GC-MS chromatogram of the essential oil from *S. canadensis* flowering herb with retention times. The main compounds (>5%): 7.99–α-pinene, 11.09–D-limonene, 20.16–bornyl acetate, 23.67–β-elemene, 26.52–β-copaene isomer (other in Table 1)

In total, 34 components were isolated in the studied EO, which makes up 86.01% of all components found in the oil studied. The concentrations of most unidentified components were only in the 0.01%–0.20% range. The principal compounds of the EO from flowering tops of *S. canadensis* were α-pinene (20.36%), β-copaene (16.16%), bornyl acetate (10.45%), D-limonene (8.21%), and β-elemene (6.80%). Pinene and limonene have been mentioned among the main constituents of *S. canadensis* EO in previous studies [5,11,33]. At the same time, the contents of β-cubenene and germacrene D showed the highest concentrations, respectively. Germacrene D is also found to be one of the main compounds in the oil of *S. virgaurea* [4]. In the comparative study of four *Solidago* species, α-pinene, germacrene D, bornyl acetate, and E-verbenol were mentioned as principal compounds of EOs [7]. The contents of *S. canadensis* and *S. virgaurea* oils showed more similar concentrations of main compounds than the EOs distilled from *S.* × *niederederi* and *S. gigantea*. Thus, the results of our study are rather similar to the already published papers mentioned below.

The research in phenolics was carried out by UPLC-MS/MS and spectrophotometry (Table 2, Fig. 2).

Totally in the *S. canadensis*, dry extracts were identified and quantified 20 phenolics (2 phenolic and 8 hydroxycinnamic acids, and 10 flavonoids): 20 compounds in the aqueous extract and 19 in the aqueous-alcohol extract. The dominant hydroxycinnamic acids are neochlorogenic and chlorogenic acids,

4,5-dicaffeoylquinic, 3,5-dicaffeoylquinic and 3,4-dicaffeoylquinic acids. The main flavonoids were rutin and isoquercitrin. Previously, it was reported that in *S. canadensis* predominated flavonols such as quercetin and its glycosides, kaempferol and its glycosides were also found in a significant amount [16]; the data about quercetin compounds corresponded to our results, but the content of kaempferol derivatives is quite lower. It was reported that caffeoylquinic acid esters such as 5-O-caffeoylquinic acid (neochlorogenic acid) accompanied by several mono-, di-caffeoylquinic and feruoylquinic acids also predominated among phenolic compounds [16]. Still, in our extracts, the major compounds were 3,4-dicaffeoylquinic acid, 3,5-dicaffeoylquinic acid, 4,5-dicaffeoylquinic acid, chlorogenic acid (in order of increasing concentrations), and ferulic acid derivatives were not detected. The European Pharmacopoeia monograph for *Solidago* herba regards flavonoids in terms of hyperoside as quality markers [15], but rutin is predominated, and a high content of hydroxycinnamic acids is observed. Therefore, in the standardising of the dry extracts, it's advisable to consider these two groups of biologically active substances.

Table 2: Chemical composition of phenolics in the *Solidago canadensis* dry extracts

Compound	Retention time, min	Content in the dry extract, mg/g	
		Aqueous extract	Aqueous-alcohol extract
Neochlorogenic acid	2.88	5.95 ± 0.19	0.86 ± 0.08
Kaempferol-3-O-rutinoside	5.66	4.22 ± 0.21	0.21 ± 0.08
Isoquercitrin	5.46	10.13 ± 0.35	8.07 ± 0.24
Chlorogenic acid	3.90	8.65 ± 0.38	11.87 ± 0.42
Quercetin	7.00	1.34 ± 0.04	8.43 ± 0.19
Isorhamnetin-3-O-rutinoside	5.74	3.26 ± 0.11	2.98 ± 0.21
p-Coumaric acid	5.26	0.09 ± 0.01	0.05 ± 0.01
Ferulic acid	5.57	0.05 ± 0.01	0.05 ± 0.01
Isorhamnetin-3-glucoside	6.08	0.52 ± 0.03	0
Vanilic acid	4.28	0.18 ± 0.01	0.21 ± 0.03
Caffeic acid	4.32	0.55 ± 0.03	0.19 ± 0.01
Kaempherol	7.78	0.34 ± 0.02	2.67 ± 0.35
3,4-Dihydroxyphenyl-acetic acid	2.50	0.64 ± 0.04	1.71 ± 0.11
Isorhamnetin	7.89	0.24 ± 0.01	1.08 ± 0.18
Kaempherol-3-O-glucoside	5.94	1.22 ± 0.08	0
Rutin	5.29	24.13 ± 0.52	28.23 ± 0.42
Hyperoside	5.41	0.33 ± 0.03	0.42 ± 0.05
4,5-Dicaffeoylquinic acid	5.60	15.51 ± 0.04	3.06 ± 0.31
3,5-Dicaffeoylquinic acid	5.97	12.09 ± 0.49	4.86 ± 0.27
3,4-Dicaffeoylquinic acid	5.78	10.01 ± 0.55	25.42 ± 0.53
Spectrophotometry, %			
Hydroxycinnamic acids		5.81 ± 0.38	5.34 ± 0.42
Flavonoids		8.84 ± 0.06	9.68 ± 0.14
Total phenolic compounds		12.47 ± 0.28	11.56 ± 0.28

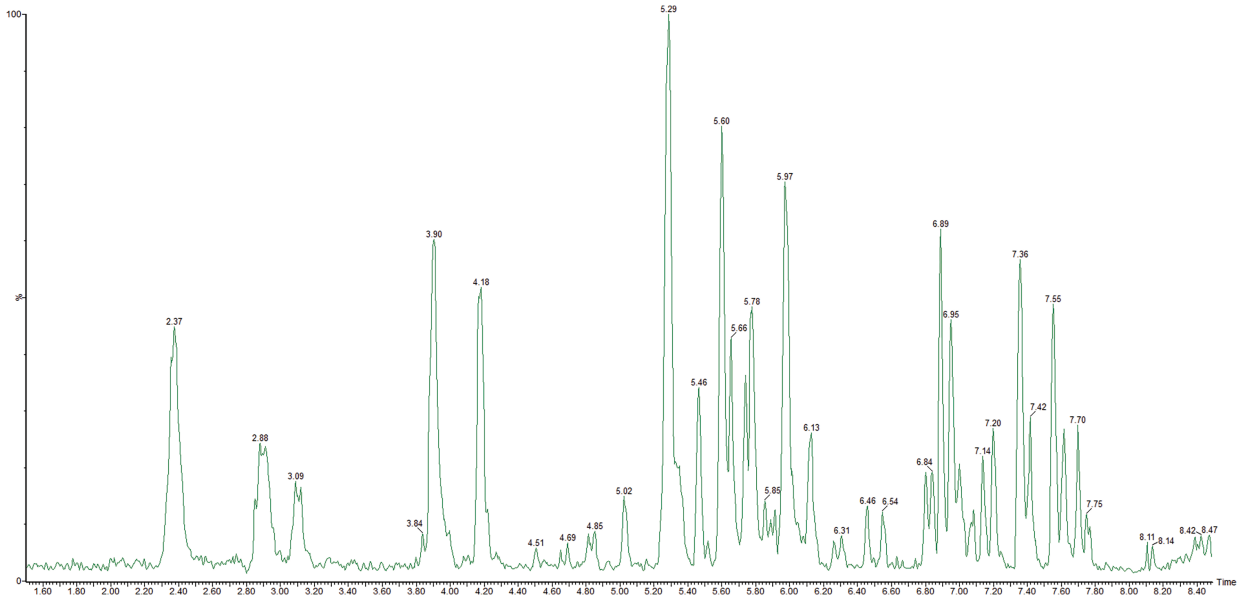

Figure 2: UPLC-MS negative scan chromatogram of *Solidago* herb sample (Aqueous-alcohol extract). The main compounds (>10%): 5.29–rutin, 5.46–isoquercitrin, 5.60–4,5-dicaffeoylquinic acid, 5.78–3,4-dicaffeoylquinic acid, 5.97–3,5-dicaffeoylquinic acid (other in Table 2)

The study results on the amino acid composition of the *S. canadensis* dry extracts are presented in Table 3 and Fig. 3.

Table 3: Chemical composition of amino acids in the *Solidago canadensis* dry extracts

Compound	Retention time, min	Content in the dry extract, mg/g	
		Aqueous extract	Aqueous-alcohol extract
Alanine	4.97	1.35 ± 0.04	2.09 ± 0.07
Arginine	5.74	0.97 ± 0.08	1.72 ± 0.05
Aspartic acid	5.31	1.27 ± 0.13	2.26 ± 0.08
Glutamic acid	5.24	1.15 ± 0.08	2.01 ± 0.11
Glycine	5.13	0.27 ± 0.06	0.32 ± 0.04
Histidine	5.75	2.29 ± 0.03	1.12 ± 0.03
Isoleucine	5.34	0.32 ± 0.03	0.87 ± 0.04
Leucine	5.24	0.35 ± 0.02	0.79 ± 0.02
Lysine	5.74	1.20 ± 0.04	1.31 ± 0.05
Phenylalanine	4.24	0.57 ± 0.03	1.54 ± 0.06
Proline	4.59	6.00 ± 0.06	7.32 ± 0.07
Serine	5.26	1.50 ± 0.04	1.76 ± 0.02
Threonine	5.10	0.81 ± 0.07	0.75 ± 0.03
Valine	4.58	0.54 ± 0.05	0.95 ± 0.04

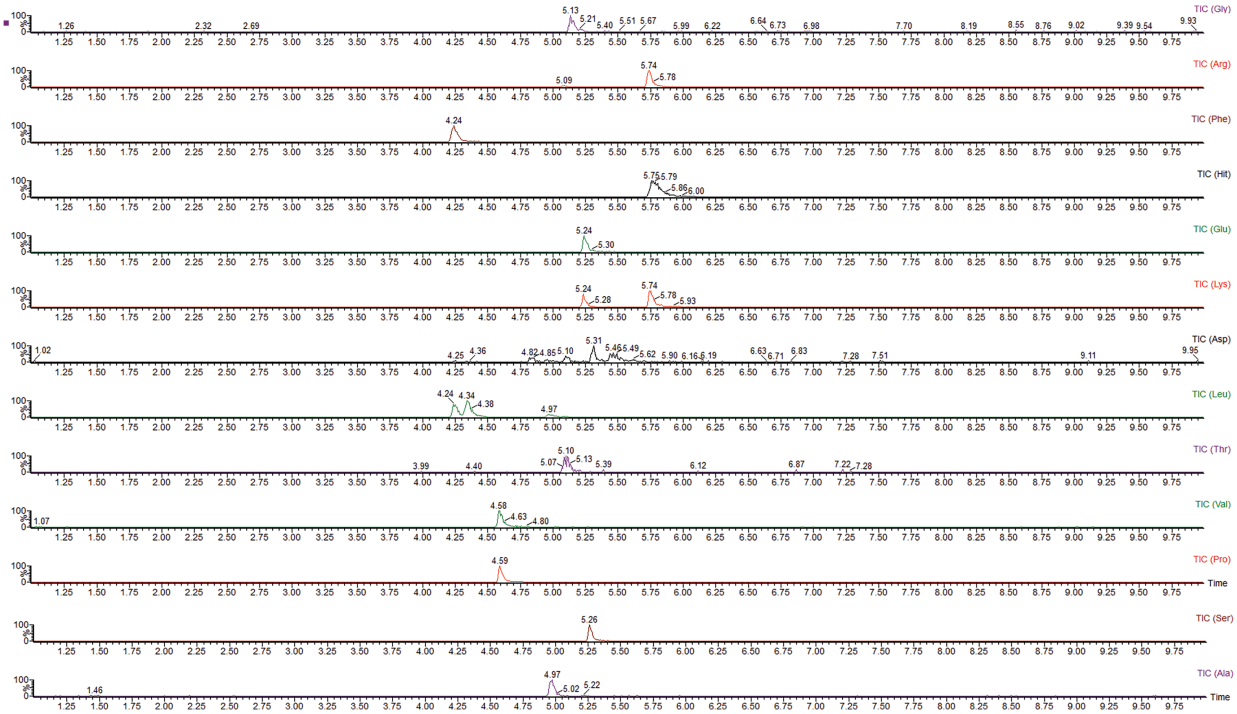

Figure 3: UPLC-MS/MS chromatograms of amino acids of *Solidago* herb sample (Aqueous-alcohol extract)

In the *S. canadensis* dry extracts were identified and quantified 14 amino acids, 7 of which are essential. The main amino acids (more than 1 mg/g) are proline, histidine, serine, alanine, aspartic acid, lysine and glutamic acid. There is no available data about the amino acid composition of *S. canadensis* raw material and its extracts in scientific literary sources, so these data might be considered novel.

The study of acute toxicity of the *S. canadensis* dry extracts was carried out on white non-linear sexually mature male mice weighing 19–21 g, grown in the nursery of the vivarium of the IFNMU. The conducted studies showed that after the intragastric administration of the extracts of *S. canadensis* herb at a dose of 6000 mg/kg, no deaths were observed: the animals were tidy, had a satisfactory appetite, reacted normally to light and sound stimuli, the processes of defecation and urination were normal, breathing disorders and seizures were not observed. Thus, the extracts were characterized as practically non-toxic (toxicity class V, LD50 > 5000 mg/kg).

The anti-inflammatory activity of the studied extracts was assessed by their ability to inhibit the development of formalin-induced oedema in the paw of rats compared to animals of the control group (Table 4).

The obtained data indicate the effect of the extracts on the exudative phase of inflammation. The antiexudative effect of sodium diclofenac in 5 h was 26.11%. At the same level acted the dry aqueous-alcohol *S. canadensis* extract (23.59%), and a little bit less was the effect of the aqueous extract (19.26%). It's interesting and advisable to establish the dose-effect relationship of *S. canadensis* extract in the future, but we took only a single dose, as it was preliminary research. A comparable dosage of the extracts to diclofenac sodium (0.8 mg) was 10 mg, as the concentration of phenolic substances in the extract is around 12%. Anyway, this single dose has proven the anti-inflammatory activity of the extracts and galenic remedies from which they originated. The anti-inflammatory effect of the *S. canadensis* extracts is due to both the phenolic compounds and the EO terpenes. Thus, pronounced antioxidant and anti-inflammatory activity is inherent in phenolics of the *S. canadensis*, such as isoquercitrin and rutin,

chlorogenic and dicaffeoylquinic acids. Isoquercitrin also displays several chemoprotective effects against oxidative stress, cardiovascular disorders, diabetes, allergic reactions and cancer [34]. Rutin also has anti-carcinogenic, cardioprotective, anti-thrombotic, and neuroprotective activities [35]. Chlorogenic acid exhibits strong antioxidant and anti-inflammatory effects [36]. Previously, it was only reported about the anti-inflammatory activity of *S. virguarea* extracts and pure substances, such as a a triterpene saponin fraction (1.25–2.5 mg/kg) [37]. In the experiment of a carrageenan-induced oedema model in rats, *S. virguarea* extract showed the anti-exudative effect at the level of 27% (after 2 h) and 54% (after 5 h) [38]. Aqueous and ethanolic extracts of *S. virgaurea* reduced paw oedema and arthritic paw volume in rat models [39]. Also it was proved that *Solidago* hydroalcoholic extract can inhibit dihydrofolate reductase and contribute *S. virgaurea* extracts anti-inflammatory activity [1,40]. However, there is no data about the anti-inflammatory activity of *S. canadensis* extract in available scientific literary sources, so these data might be considered quite novel.

Table 4: Anti-inflammatory activity of the dry *S. canadensis* extracts

A group of animals	Dose, mg/100 g	The increase in the volume of the rat's paw, c.u.: $\bar{x} \pm \Delta\bar{x}$, n = 6 (Inhibition of the inflammatory reaction to the control group, %)		
		In a 1 h	In 3 h	In 5 h
Control	–	123.10 ± 2.73	135.30 ± 2.12	152.30 ± 4.40
Aqueous extract	10	113.07 ± 2.11*/** (8.15 %)	116.80 ± 3.35*/** (13.67%)	122.97 ± 1.34*/** (19.26%)
Aqueous-alcohol extract	10	107.60 ± 2.96* (12.59%)	109.83 ± 2.02*/** (18.82%)	116.37 ± 2.81*/** (23.59%)
Diclofenac sodium	0.8	105.60 ± 1.59* (14.22%)	107.15 ± 1.45* (20.81%)	112.53 ± 1.43* (26.11%)

Note. *Reliability of deviations in relation to the control group ($p \leq 0.05$); **Reliability of deviations in relation to the animal group that received diclofenac sodium ($p \leq 0.05$).

It is important to interrelate results and the composition of the *S. canadensis* extracts. The anti-exudative effect was stronger in the aqueous-alcohol *S. canadensis* extract than in the aqueous one. Caffeic, ferulic and *p*-coumaric acids exhibit anti-inflammatory activity [24] but their content in *S. canadensis* extracts was low (less than 0.6 mg/g). The aqueous-alcohol extract contained more caffeic acid than the aqueous extract (0.55 and 0.19 mg/g, respectively). The main polyphenol of *S. canadensis* extract, rutin, has antioxidant activity [41], and its concentration in both extracts was similar.

4 Conclusions

Phytochemical and pharmacological research in the galenic remedies of *S. canadensis* L. herb indicates possible perspectives of their use for developing novel dosage forms. 34 compounds of EO, 20 phenolics (10 flavonoids, 8 hydroxycinnamic acids and 2 phenolic acids) and 14 amino acids were found and quantified in *S. canadensis* galenic remedies. The extracts of *S. canadensis* were characterized as practically non-toxic substances (toxicity class V). The dry aqueous-alcohol *S. canadensis* extract shows promising anti-inflammatory activity. The mechanisms of action of pharmacological effect need to be elucidated in further work, as does the relationship of the biological activities to the chemical composition of the plant material.

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