

Chemical composition, antioxidant and antimicrobial activities of *Vaccinium macrocarpon* (Ericaceae) and *Camellia sinensis* (Theaceae) extracts

O. Maslov*, M. Komisarenko*, S. Ponomarenko**, S. Kolisnyk*, T. Osolodchenko**, M. Golik*

*National University of Pharmacy, Kharkiv, Ukraine

**I. Mechnikov Institute of Microbiology and Immunology National Academy of Medical Sciences of Ukraine, Kharkiv, Ukraine

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National University of Pharmacy,
Pushkinskaya st., 53,
Kharkiv, 61001, Ukraine.
Tel.: +380-66-425-72-24.
E-mail: alexmaslov392@gmail.com

I. Mechnikov Institute of
Microbiology and Immunology
National Academy of Medical
Sciences of Ukraine,
Pushkinskaya st., 53,
Kharkiv, 61001, Ukraine.
Tel.: +380-50-597-43-85.
E-mail: svponomarenko@i.ua

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In the modern scientific community, considerable attention is given to studying the pharmacological activity of catechin and anthocyanin derivatives. However, a comparative analysis of the antioxidant and antimicrobial activities of extracts rich in anthocyanins and catechins has not been previously conducted. So, the purpose of this work was to study and compare phytochemical composition, antimicrobial and antioxidant potential of *Vaccinium macrocarpon* L., Ericaceae fruit thick and *Camellia sinensis* L., Theaceae leaf liquid extracts. The quantification of biologically active substances (BAS) was accomplished with spectrophotometric, titrimetric and HPLC methods of analysis; antioxidant activity was determined by the potentiometric method; antimicrobial and anti-fungi effects was evaluated by the well method and minimum inhibition concentration. The total content of phenolic compounds was 0.47% and 10.10%, organic acids – 4.27% and 1.60% for *V. macrocarpon* fruit thick and *C. sinensis* leaf extract. The total content of catechins in the *C. sinensis* leaf extract was 105,000 mg/kg, where epicatechin-3-O-gallate dominated (37300 mg/kg). The total content of anthocyanins in the *V. macrocarpon* fruit thick extract was 1280 mg/kg, where peonidin-3-O-galactoside dominated (408 mg/kg). Both extracts possessed a high antioxidant potential, and effective antimicrobial and anti-fungi effects. The antioxidant, antimicrobial and anti-fungi activity of *V. macrocarpon* fruit extract was higher than *C. sinensis* leaf extract. In addition, we assumed that anthocyanins had higher antioxidant, antimicrobial and anti-fungi properties than catechins. These findings would promote application of *V. macrocarpon* fruits extract as pharmaceuticals and nutraceuticals.

Keywords: anthocyanins; catechins; fruit; growth inhibition zone; leaf.

Introduction

Nowadays, the problem of bacterial infection is still relevant. According to recent statistical studies, it has been found that every year 13.7 million people per year die from bacterial infections in the world. The mortality rate for all ages was 99.6 deaths per 100,000 of the population. Of the pathogens studied, the Staphylococcaceae family: *Staphylococcus aureus*; the Enterobacteriaceae family: *Escherichia coli*, *Klebsiella pneumoniae*; the Pseudomonadaceae family: *Pseudomonas aeruginosa*; and the Streptococcaceae family: *Streptococcus pneumoniae* accounted for 54.9% of the 7.7 million deaths, with *S. aureus* being associated with more than 1.1 million deaths. *S. aureus* was the leading bacterial cause of death in 135 countries and was associated with the largest number of deaths among people over 15 years of age (940,000) (Ikuta, 2019). In addition, an important threat to human populations is fungal infection. According to the latest statistics, every year 1,433,000 people suffer from systemic candidal infections, of which approximately 611 thousand people die annually (Denning, 2020). Thus, this situation affects all areas of active use of antibiotics, including the treatment of urinary tract infections.

The most overspread type of bacterial infection is urinary tract infections (UTI). The risk of disease is about 50% in women and 12% in men as well as 40% of recurrence after a half of year. UTI affect the upper part of the urinary tract (ureters and kidneys) causing pyelonephritis, and UTI affect the urethra, the bladder causing cystitis and urethritis (Gonzales et al., 2020). A major share of UTI (85%) are caused by Gram-negative pathogens *E. coli*, while other strains as *P. aeruginosa*, *S. aureus*, *K. pneumoniae* are involved in low percentages (Arsene et al., 2022).

Today, medical plants, which contain flavan-3-ols, anthocyanins, and hydroquinone derivatives, are receiving considerable attention from scientific society (Chiorcea-Paquim, 2023). Above all, this relates to the fact that some resistance pathogens are more sensitive to natural products (Odabas et al., 2023), secondly, natural compounds have potent antioxidant effect (Alferi et al., 2022) and moreover, the side effects occur more rarely after application of natural compounds than after synthetic drugs (Palchykov et al., 2019; Zazharskyi et al., 2019, 2020; Baier & Szyszka, 2020; Khromykh et al., 2022).

Vaccinium macrocarpon fruits were chosen as a promising source of anthocyanins, while *C. sinensis* leaves are a source of catechins. *Vaccinium macrocarpon* L. is an evergreen shrub of the Ericaceae family, with low-lying vines that bear slim, wiry stems, which can reach lengths of up to 2 meters and heights between 5 and 20 cm, its leaves are elliptical, measuring up to 22 mm in length and 9 mm in width (Raal, 2023). *Vaccinium macrocarpon* fruit is colored in dark red, whereas not matured fruits have a pale pink or white color. *V. macrocarpon* in the wild is cultivated in North America mainly in the Canadian provinces of British Columbia and Quebec. However, *V. macrocarpon* is cultivated in Finland, Russia, the Balkan countries, Poland, Ukraine (Koshovyi et al., 2023).

The composition of *V. macrocarpon* is represented by a diversity of chemical constituents: anthocyanins (peonidin-3-O-galactoside), phenolic acids (p-coumaric acid), organic acids (citric acid), flavonols (myricetin-3-O-galactoside) and triterpenoids (ursolic acid) (Nemzer et al., 2022). *Camellia sinensis* L. is rich in derivatives of catechins (epigallocatechin-3-O-gallate, epicatechin, (+)-catechin, epigallocatechin), organic acids (oxalic acid), flavonoids (rutin) and hydroxycinnamic acids (caffeic acid) (Huang

et al., 2020; Shirai et al., 2021). There is numerous research investigating the pharmacological activity of *V. macrocarpon* fruit and *C. sinensis* leaf extracts. It is known that anthocyanins from *V. macrocarpon* fruit and *C. sinensis* leaves possess: anti-inflammatory, antimicrobial, antiviral, cardioprotective, and anticancer effects (Jurikova et al., 2018). Besides, in folk medicine *V. macrocarpon* are traditionally applied to treat fever, urinary and skin infections, cancers and liver diseases (Bodel et al., 2008) whereas *C. sinensis* leaves are applied for treating diabetes, atherosclerosis, ulcer diseases (Sinija et al., 2008). In our view, the anthocyanins and catechins are potentially useful for the development of new antimicrobial, anti-fungi and antioxidant pharmaceuticals.

Therefore, the purpose of the study was to assess the antimicrobial and antioxidant potential of *V. macrocarpon* fruit thick and *C. sinensis* leaf liquid extracts and provide phytochemical analysis of obtained extracts.

Materials and methods

Vaccinium macrocarpon L. fruits was collected in autumn during fruiting period in Kyiv region, (Pereyaslav suburbs, 50°10'31" N, 31°46'15" E). *Camellia sinensis* L. leaf was cultivated in Anhui province, China (30°63'41" N, 116°33'25" E).

Acetic acid, acetonitrile, methanol, and phosphoric acid were purchased from "AllChem" (China). Peonidin-3-O-glucoside, peonidine-3-O-arabinoside, cyanidin-3-O-galactoside, epigallocatechin, cyanidin-3-O-glucoside, epigallocatechin-3-O-gallate, epicatechin, (+)-catechin and peonidin-3-O-galactosid were bought from Sigma Aldrich Company (Lublin, Poland).

We prepared *V. macrocarpon* fruits thick extract by juice extraction then withdrew polysaccharides with a threefold amount of ethanol, followed by filtration and concentration of the filtrate with a vacuum-evaporator to humidity of the extract is 25%.

Camellia sinensis extract was prepared by extraction 60% ethanol solution at water bath, temperature – 80 °C, time – 1 hour, ratio leaf/extraction agent – 1/20, number of extraction – two times, concentration of the obtained tincture was at ratio of extract to raw material 1:2.

A Folin-Ciocalteu assay was applied for quantification of the content of polyphenolic compounds (Lucas et al., 2022). The sum of catechins derivatives was found by a vanillin reagent assay (Kalidass et al., 2021). The sum of anthocyanin derivatives was determined with a molecular adsorption analysis (Wabaidur et al., 2020). The sum of organic acids was quantified with alkalimetric titration (Maslov et al., 2021a).

A potentiometric assay was applied for evaluation of the antioxidant effect (Maslov et al., 2021b) as standards were a standardized *C. sinensis* leaf extract and epigallocatechin-3-O-gallate.

HPLC-UV analysis of catechins profile in *C. sinensis* was conducted by a following assay (Khodakov, 2013; Umarov et al., 2021).

Anthocyanin content in *V. macrocarpon* extract was quantified by a HPLC with C18 LiChrospher®100 RP column (Merck, Germany). As eluents we used an aqueous solution of phosphoric acid, the elution was carried out in a gradient mode. A UV-detection of anthocyanin was carried out at 520 wavelengths. We used a Hewlett Packard 1100 MS (Agilent Technologies, USA) mass spectrometer, detection of compounds was performed by electrical ionization at nitrogen atmospheric pressure.

Table 1

Quantitative content of total phenolic compounds, anthocyanin and organic acids ($\bar{x} \pm SD$, $n = 4$)

Sample	Total phenolic compounds, %	Total anthocyanin, %	Total catechin, %	Total of organic acids, %
<i>V. macrocarpon</i> fruit thick extract	0.47 ± 0.02	0.130 ± 0.002	not carried out	4.27 ± 0.17
<i>C. sinensis</i> leaf extract	10.10 ± 0.25	not carried out	10.47 ± 0.25	1.60 ± 0.10

Table 2

Chemical composition of catechins in *C. sinensis* leaf extract by HPLC-UV analysis ($\bar{x} \pm SD$, $n = 4$)

No.	Catechins	Retention time, min	Similarity index, I _r	Content of catechins in <i>C. sinensis</i> leaf extract, mg/kg of extract	Share of total catechins
1	Epigallocatechin	13.013	0.875	27600 ± 552	26.3
2	(+)-catechin	13.780	0.996	2100 ± 42	2.0
3	Epicatechin	16.494	0.851	10100 ± 202	9.6
4	Epigallocatechin-3-O-gallate	17.686	0.990	37300 ± 746	35.5
5	Epicatechin-3-O-gallate	20.754	0.814	27880 ± 558	26.6
	The total catechins	–	–	105000	–

Antibacterial activity was provided against 2 Gram (+) test strains: *Bacillus subtilis* ATCC 6538, *Staphylococcus aureus* ATCC 25923; and 3 Gram(-) test strains: *Proteus vulgaris* NTCS 4636, *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853. Anti-fungi activity was conducted against 1 fungi strain: *Candida albicans* ATCC 885/653.

Antibacterial activity was performed by the diffusion method of the drug into agar that was carried out using the method – "wells" (Volyanskiy et al., 2006). The microbial load was 0.5 units on the McFarland scale. 18–24 hour cultures of microorganisms were used. During the studies, Mueller-Hinton medium, MPA and Sabouraud agar were used. When assessing the antimicrobial activity of the studied drugs, the following criteria were used: from 0 to 10 mm indicated that the microorganisms were not sensitive to the drug; from 10 to 15 mm indicated that microorganisms are slightly sensitive to the drug; from 15 to 25 mm indicated that microorganisms are sensitive to the drug; from 25 mm – indicated that the microorganisms are highly sensitive to the drug (Boyko et al., 2020).

The MIC (minimum inhibition concentration) of the different extracts was assessed using the broth microdilution method (Mbarga et al., 2021).

Antimicrobial and quantitative content of compounds were expressed as mean (\bar{x}) ± standard deviation (SD). A one-way analysis of variance (ANOVA) test was applied for leaf length considering $P < 0.05$ as statistically significant.

Results

According to obtained results shown in Table 1, the *C. sinensis* leaf extract (10.10 ± 0.25%) had higher content of phenolic compounds, than in *V. macrocarpon* fruit thick extract (0.47 ± 0.02%). Table 2 demonstrates that the total content of anthocyanin in *V. macrocarpon* fruit thick extract was 0.130 ± 0.002%, whereas in *C. sinensis* leaf extract anthocyanin was not present. The percentage of anthocyanin out of total polyphenols was 27.6% in *V. macrocarpon* extract.

The highest amount of organic acids was determined in *V. macrocarpon* fruit thick extract (4.27 ± 0.50%), whereas in the *C. sinensis* leaf extract it was lower 62.5% (1.60 ± 0.10%). In *V. macrocarpon* extract, the total organic acids were 9 times higher than polyphenols, whereas in the *C. sinensis* leaf, the total organic acids were 6.3 times lower than polyphenols (Table 1). The HPLC method was used to carry out a qualitative and quantitative analysis of catechins and anthocyanins in the obtained extracts of *C. sinensis* leaf and *V. macrocarpon* fruits extract. According to the results of the study, 5 catechins were identified in *C. sinensis* leaf extract (Fig. 1, 2), whereas in *V. macrocarpon* fruits extract 6 anthocyanins were identified (Fig. 3, 4).

The total content of catechins in the obtained *C. sinensis* leaf extract was 105,000 mg/kg. Among catechins, epigallocatechin-3-O-gallate dominated – 37300 ± 746 mg/kg (35.5% part of the total catechins), whereas the lowest content was (+)-catechin 2100 ± 42 mg/kg (2.0% part of the total catechins, Table 2). As shown in Table 4, cyanidin-3-O-galactoside dominated among all anthocyanins (79.9% part of the total anthocyanins), cyanidin-3-O-arabinoside (13.1% part of the total anthocyanins) was in second place, and the lowest content was cyanidin-3-O-(acetyl)glucoside (0.10% part of the total anthocyanins).

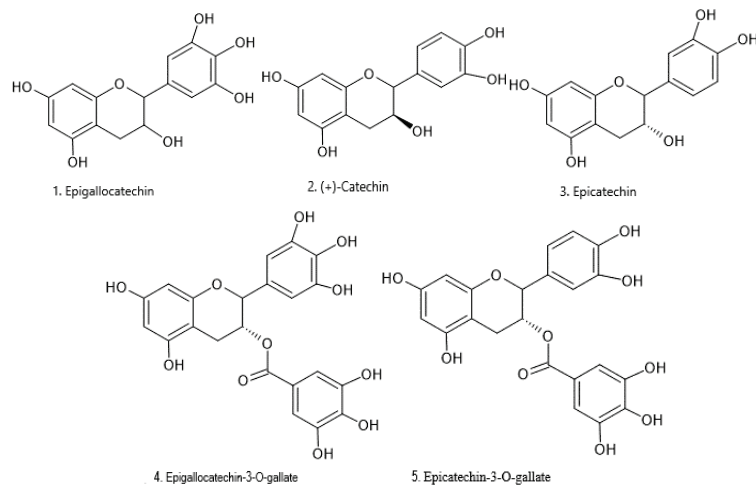


Fig 1. Chemical structure of identified catechins in the *C. sinensis* leaf

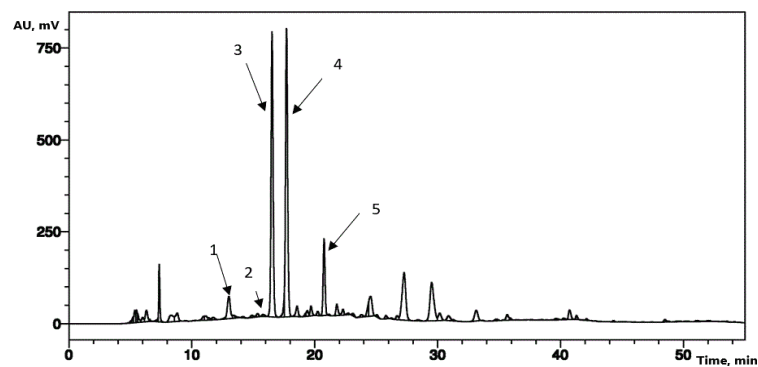


Fig. 2. HPLC fingerprint (255 nm) of the *C. sinensis* leaf extract

Table 3

Chemical composition of anthocyanins in *V. macrocarpon* fruit thick extract by HPLC-UV/MS analysis ($\bar{x} \pm SD$, $n = 4$)

No.	Anthocyanins	Retention time, min	Content of anthocyanins in extract, mg/kg of extract	Part of total anthocyanins
1	Cyanidin-3-O-galactoside	3.251	303.3 \pm 6.1	23.7
2	Cyanidin-3-glucoside	3.710	15.4 \pm 0.3	1.2
3	Cyanidin-3-O-arabinoside	4.351	277.7 \pm 5.6	21.7
4	Peonidin-3-O-galactoside	5.260	408.2 \pm 8.2	31.9
5	Peonidin-3-O-glucoside	6.110	65.2 \pm 1.3	5.1
6	Peonidine-3-O-arabinoside	6.910	210.0 \pm 4.2	16.4
The total anthocyanins			1280	—

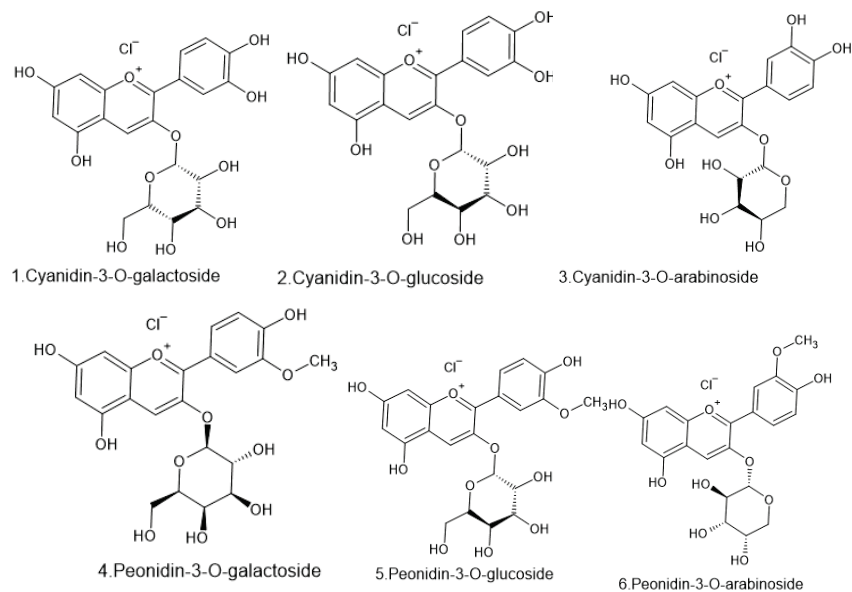


Fig. 3. Chemical structure of identified anthocyanins in the *V. macrocarpon* fruit thick extract

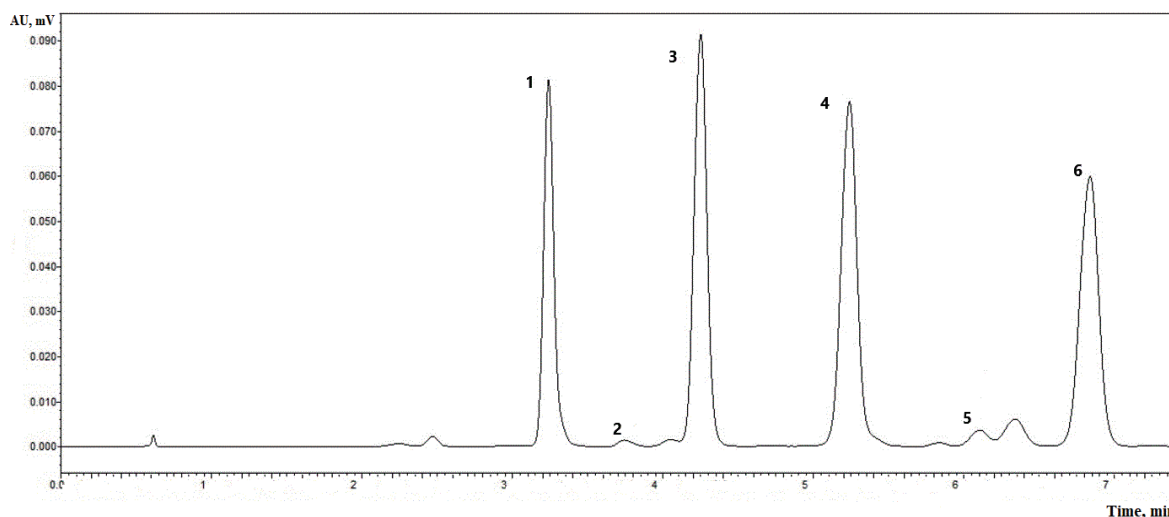


Fig. 4. HPLC fingerprint (520 nm) of the *V. macrocarpon* fruit thick extract

A potentiometric method for determining antioxidant activity was used to evaluate the effect of the obtained extracts. Table 4 shows that the level of antioxidant activity of *V. macrocarpon* fruits extract is significantly inferior to the *C. sinensis* leaf extract. The antioxidant activity of *C. sinensis* leaf is higher by 6.2 times than *V. macrocarpon* extract.

In light of the data obtained, it can be established that the *C. sinensis* leaf extract has the highest level of antioxidant activity. According to the modern classification of antioxidant activity, which was previously developed by us (Maslov et al., 2021c), it was found that all extracts obtained have a high level of antioxidant activity. Moreover, a comparative analysis of the “strength” of antioxidant activity was carried out with the gold standard *C. sinensis* leaf. Further, we prepared solutions (in terms of the amount of polyphenols expressed as gallic acid) of extracts with 0.03 M concentration of *V. macrocarpon* thick fruits extract, *C. sinensis* leaf and epigallocatechin-3-O-gallate. As a result of the study, it was found that the level of antioxidant activity of *V. macrocarpon* extract was higher by 65.1% than the *C. sinensis* leaf extract and higher by 68.8% than epigallocatechin-3-O-gallate (Table 5).

Table 4
Antioxidant activity of *V. macrocarpon* fruit thick extract, *C. sinensis* leaf extract ($x \pm SD, n = 4$)

Sample	Antioxidant activity, mmol-equiv./m _{AVRES}	Conditional term of antioxidant level
<i>V. macrocarpon</i> fruit thick extract	88.3 ± 0.9	high level
<i>C. sinensis</i> leaf extract	548.8 ± 10.1	very high level

Table 5
Antioxidant activity of *V. macrocarpon* fruit thick extract, *C. sinensis* leaf extract and standard epigallocatechin-3-O-gallate at concentration 0.03 mol/L ($x \pm SD, n = 4$)

Sample	Antioxidant activity, mmol-equiv./m _{AVRES}
<i>V. macrocarpon</i> fruit thick extract	88.3 ± 0.9
<i>C. sinensis</i> leaf extract	27.5 ± 0.3
Epigallocatechin-3-O-gallate	30.8 ± 0.3

Table 6
Inhibition diameter (mm) resulting from the screening of antimicrobial activity by well diffusion method with of *V. macrocarpon* thick extract, *C. sinensis* leaf extract and standards: gentamycin, fluconazole ($x \pm SD, n = 4$)

Sample	Concentration, mM	Diameter of the growth retention zone					
		Gramm-positive			Gramm-negative		
		<i>S. aureus</i> ATCC 25923	<i>B. subtilis</i> ATCC 6633	<i>E. coli</i> ATCC 25922	<i>P. vulgaris</i> ATCC 4636	<i>P. aeruginosa</i> ATCC 27853	Fungi <i>C. albicans</i> ATCC 653/885
<i>V. macrocarpon</i> fruit thick extract	0.009 ^a	28.0 ± 0.7	34.0 ± 0.5	30.0 ± 0.6	23.0 ± 0.8	24.0 ± 0.8	24.0 ± 0.7
<i>C. sinensis</i> leaf extract	0.009 ^a	29.0 ± 0.6	26.0 ± 0.8	21.0 ± 0.9	24.0 ± 0.7	28.0 ± 0.6	21.0 ± 0.9
Control Gentamycin	0.003	22.0 ± 0.9	24.0 ± 0.7	25.3 ± 0.8	25.0 ± 0.8	25.7 ± 0.7	12.0 ± 1.0
Control Fluconazole	0.003	18.0 ± 0.7	12.0 ± 0.8	14.3 ± 0.9	12.3 ± 1.0	10.0 ± 0.9	20.0 ± 0.9

Note: ^a – molar concentration of *V. macrocarpon* fruit thick extract and *C. sinensis* leaf extract was calculated as total phenolic compounds expressed as gallic acid.

In this research work, the antimicrobial and antifungal activity of the obtained *V. macrocarpon* fruits and *C. sinensis* leaf extract was investigated against the following strains of *S. aureus*, *B. subtilis*, *E. coli*, *P. vulgaris*, *P. aeruginosa*, as well as a strain of the fungus *C. albicans*. According to the obtained results, extracts obtained from the *V. macrocarpon* fruit and *C. sinensis* leaf had an effective antimicrobial and antifungal effect.

Among Gram-positive bacterial strains, *V. macrocarpon* fruits extracts were the most active against *B. subtilis* strains (34.0 ± 0.5 mm), whereas in the case of Gram-negative strains, *V. macrocarpon* fruits extract inhibited *E. coli* strains the most. *P. vulgaris* was the most resistant bacteria to the action of *V. macrocarpon* fruits extract (23.0 ± 0.8 mm). Comparing results with *C. sinensis* leaf extract, it was determined that *V. macrocarpon* fruits extract was 23.5% and 30.0% better at inhibiting bacterial strains of *B. subtilis* and *E. coli* than *C. sinensis* leaf extract, respectively. Whereas, *C. sinensis* leaf extract showed 3.3%, 4.2% and 14.2% higher inhibition of growth of *S. aureus*, *P. vulgaris* and *P. aeruginosa*, respectively. Comparing the obtained results with reference standard gentamycin, it was found that *S. aureus*, *B. subtilis* and *E. coli* were 21.4%, 23.5% and 15.6% more sensitive to *V. macrocarpon* fruits extract than gentamycin. Whereas, strains of *P. vulgaris*, *P. aeruginosa* were 3%, 4% more sensitive to gentamycin, respectively.

Anti-fungal investigation against *C. albicans* showed that *V. macrocarpon* fruits extract 12.5% and 16.6% more actively inhibited the growth of fungi than *C. sinensis* leaf and fluconazole, respectively.

The investigated extracts significantly inhibited the bacterial and fungi strains with MIC. In the previously above conducted antimicrobial study, the extract of *V. macrocarpon* fruits was the most active independently of the tested strains. Table 7 shows, the *V. macrocarpon* fruit extract with MIC value of 0.14 μM was the most active against *S. aureus*, and *B. subtilis*, whereas *C. sinensis* leaf extract MIC values were 80% lower. The highest MIC value of *C. sinensis* leaf extract was against fungi pathogens *C. albicans*. The MIC value of *V. macrocarpon* fruit extract against pathogens *E. coli*, *P. vulgaris* and *P. aeruginosa* was significantly lower than in the case of *C. sinensis* leaf extract.

Table 7Minimal inhibitory concentration (µM) of the different *V. macrocarpon* fruit thick extract, and *C. sinensis* leaf extract against the 6 references pathogens

Sample	<i>S. aureus</i> ATCC 25923	<i>B. subtilis</i> ATCC 6633	<i>E. coli</i> ATCC 25922	<i>P. vulgaris</i> ATCC 25922	<i>P. aeruginosa</i> ATCC 27853	<i>C. albicans</i> ATCC 653/885
<i>V. macrocarpon</i> fruit thick extract	0.14	0.14	0.28	1.13	0.56	1.13
<i>C. sinensis</i> leaf extract	0.70	0.70	2.80	2.80	2.80	5.60

Discussion

The content of BAS in *V. macrocarpon* fruit and *C. sinensis* leaf extracts was determined by spectrophotometric, titrimetric and HPLC methods of analysis. The organic acids were present in both extracts, where a higher content of organic acids was determined in *V. macrocarpon* fruit extract than in *C. sinensis* leaf extract. In our view, it relates to different purposes of accumulation of organic acids. The organic acids are precursors for biosynthesis of sugars in fruits, whereas in leaves, organic acids only play a role in photosynthesis. As a result there is no purpose in high accumulation organic acids in the leaf (Arená et al., 2023). Urbstaite et al. (2022) investigated anthocyanin content of *V. macrocarpon* juice by the HPLC method. According to their results, the following anthocyanins were detected (mg/kg per dry raw material): cyanidin-3-O-galactoside (490 mg/kg), cyanidin-3-glucoside (25 mg/kg), and cyanidin-3-O-arabinoside (450 mg/kg), peonidin-3-O-galactoside (660 mg/kg), peonidin-3-O-glucoside (110 mg/kg) and peonidine-3-O-arabinoside (340 mg/kg). Comparing our results, the content of anthocyanins in our research was lower, but peonidin-3-O-galactoside dominated in both extracts. The chemical composition of fruit changed during its development and ripening, and in different cultivars.

At first glance, the *C. sinensis* leaf extract had significantly higher antioxidant potential than *V. macrocarpon* fruit extract. However, comparing extracts at the same molar concentration, it was found that *V. macrocarpon* fruit extract had 3 times higher the level of antioxidant activity than *C. sinensis* leaf extract. In our view, this relates to the fact that anthocyanins are more potent antioxidants than catechins. Lapidot et al. (1999) determined antioxidant activity of malvidin-3-glucoside, catechin, malvidin and resveratrol by the method of oxidation myoglobin with H₂O₂. It was shown that inhibition efficiency of the antioxidant decreased in the following order: malvidin-3-glucoside > catechin > malvidin > resveratrol. In the research of Muselik et al. (2007), evaluation was carried out of the level of antioxidant activity of derivatives of catechins: epicatechin, (+)-catechin, epicatechin, epicatechin-3-O-gallate, galocatechin; and anthocyanins: cyanidin-galactoside, malvidin-3-glucoside and delphinidin-3-glucoside by ferric reducing antioxidant power assay. It was found that the level of antioxidant activity decreased in the following order: epicatechin-3-O-gallate > delphinidin-3-glucoside > cyanidin-galactoside > galocatechin > malvidin-3-glucoside > epicatechin > catechin. The antioxidant activity of epicatechin-3-O-gallate had the highest antioxidant power whereas the catechin – the lowest one, where cyanidin-3-galactoside interferes with epicatechin-3-O-gallate, but remains greater than other derivatives of catechins. The major part of composition of *C. sinensis* leaf is presented by epicatechin-3-O-gallate and a low amount – epicatechin and (+)-catechin. However, it is quite difficult to evaluate the contribution of each compound to the total antioxidant power of the extract while it still is unknown whether catechins interact by synergistic way or antagonistic way. Thus, the level of antioxidant activity of an extract depends not only on composition of extract, but also, on ration and interaction of compounds.

The analyzed *V. macrocarpon* fruit and *C. sinensis* leaf extracts showed high antimicrobial and antifungal activity against the following strains of *S. aureus*, *P. aeruginosa*, *P. vulgaris*, *B. subtilis* and *C. albicans*. According to the obtained data, at first glance it can be considered that the antimicrobial and antifungal activity of *V. macrocarpon* fruit and *C. sinensis* leaf extracts is significantly inferior to the action of gentamicin and fluconazole, because their concentration of solutions was in 3 times lower than the content of polyphenols in the extract. However, we would like to note that gentamicin has serious toxicity to the auditory nerve, kidneys and liver, which can lead to serious complications. Comparing the antifungal effects of fluconazole and *V. macrocarpon* fruit and *C. sinensis* leaf extracts, it was found that they inhibited the growth of the fungal strain at the

same level, while the concentration of fluconazole was also lower, like gentamicin. We can declare that fluconazole is a leader as anti-fungi medicine, but at the same time it weakly inhibits the growth of gram-negative and gram-positive bacteria, but both strains of bacteria and fungus are sensitive to *V. macrocarpon* fruit and *C. sinensis* leaf extracts. Thus, *V. macrocarpon* fruit and *C. sinensis* leaf extracts are a combined pharmaceutical that affects different mechanisms of vital activity of bacteria and fungi, thereby having a wide spectrum of action against different strains of bacteria and fungi, and at the same time not possessing serious toxicity.

The *V. macrocarpon* fruit is a rich source of anthocyanins, whereas *C. sinensis* leaf is a source of catechins. It is well known that the anthocyanins biosynthesis pathway is based on chemical conversion of catechins. Li et al. (2022) declared that at the beginning of ripening period the content of anthocyanin started increasing, whereas the content of catechins began to decrease. However, the question which of this group of flavonoids possess higher antimicrobial and anti-fungi activity is still relevant for today. In our research, we compared the antimicrobial potential of *V. macrocarpon* fruit and *C. sinensis* leaf extracts. In the antimicrobial and anti-fungi tests, which were carried out by the method of well, it was shown that the *V. macrocarpon* fruit extract was more active against pathogens *E. coli*, *B. subtilis* and *C. albicans*, whereas *C. sinensis* leaf extract was more inhibitory for pathogens *P. vulgaris*, and *P. aeruginosa*. *S. aureus* was sensitive to both extracts practically at the same level. Furthermore, MIC values for both extracts were determined, as result *V. macrocarpon* fruit extract had better results than *C. sinensis* leaf extract. Therefore, based on the above-mentioned results, it was assumed that antimicrobial and anti-fungi activity of anthocyanins was higher than catechins. However, both extracts had a high content of organic acids whose presence should not be neglected. Further in our research, we planned to answer the question of whether organic acids impact on antimicrobial potential or not.

Conclusions

It was found that total phenolic compounds were higher in *C. sinensis* leaf extract, whereas total organic acids were higher in *V. macrocarpon* fruit thick extract. Both extracts possessed a high antioxidant potential, and effective antimicrobial and anti-fungi effects. However, we assumed that anthocyanins had higher antioxidant, antimicrobial and anti-fungi properties than catechins. In future studies, the hypothesized impact of organic acids on antimicrobial and anti-fungi effects should be verified by isolation of organic acids from both extracts.

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