Antiviral activity of *Colobanthus quitensis* (Kunth) Bartl. natural plant extract against transmissible gastroenteritis coronavirus *in vitro*

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Abstract

The primary goal of our study was to investigate the antiviral potential of natural extract of unique aboriginal Antarctic plant *Colobanthus quitensis*. The aqueous-ethanolic extract was assessed *in vitro* using MDCK (Madin-Darby Canine Kidney) and PEK (Porcine Embryonic Kidney) cell cultures, challenged with Porcine Coronavirus (TGEV). The observed antiviral properties were juxtaposed with those of synthetic flavonoid compounds, namely apigenin and luteolin. Ultimately, the data show that *C. quitensis* extracts exhibit *in vitro* potent antiviral activity against TGEV coronavirus. The composition of natural *C. quitensis* extracts was investigated using MALDI mass spectrometry method.

Key words: *Colobunthus quitensis* extracts, antiviral activity, polyphenolic compounds, flavonoids, MALDI mass spektrometry

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Introduction

Viral infections pose a significant threat to global health and the world economy due to their ability to cause epidemics and pandemics (Dai et al. 2024). RNA viruses, being the main initiators of infectious diseases in humans, are particularly dangerous. Their high mutation rate leads to the constant emergence of new viral subtypes and genotypes that are resistant to existing treatments, posing a constant threat of new outbreaks (Du et al. 2024). For example, SARS-CoV-2, which belongs to the Coronaviridae family and has a single-stranded RNA genome that encodes about 29 proteins, caused the COVID-19 pandemic, which has led to more than seven million deaths worldwide (WHO 2025[1]).

Despite the availability of licensed antiviral drugs, RNA viruses can evolve rapidly (through recombination and point mutations), developing resistance to traditional treatments. This highlights the urgent need to develop new antiviral agents (Ribeiro et al. 2025). This is why medicinal plants are an important subject of research. They contain a huge reserve of biologically active compounds that could form the basis for the discovery of new antiviral drugs (Ma et al. 2021). These compounds, mostly secondary metabolites, are isolated, purified, and identified from crude extracts of various plant parts. Their wide structural and chemical diversity allows them to interact with various biological and viral targets (Iketani et al. 2023).

As the only dicotyledonous species among Antarctic extremophile plants, *Colobanthus quitensis* (Kunth) Bartl. (Caryophyllaceae) is known to produce polyphenolic compounds possessing a wide range of biological activities (Ozheredova et al. 2015). Analysis of the plant's natural extracts (Laguta et al. 2024) revealed that its phenolic antioxidant profile is highly dominated by apigenin, luteolin, and luteolin methyl ester glycosides, which comprise roughly 90% of the total polyphenolic content, with hydroxybenzoic and hydroxycinnamic acids, which make up about 10%.

Colobanthus quitensis, one of the two vascular plants native to the Antarctic region, occurs primarily along ice-free coastal areas of the Maritime Antarctic, including King George Island, Livingston Island (Byers Peninsula), and surrounding South Shetland Islands, but its range extends northward into subantarctic islands and the high-altitude regions of southern South America, including Patagonia and the Andes. Historical records of its presence on these islands date back to early 20th-century and mid-20th-century British and international botanical surveys, which systematically documented Antarctic vascular flora. Notable censuses include British Antarctic Survey collections from the 1940s–1960s, which mapped occurrences on King George and Livingston Islands; later detailed surveys on Byers Peninsula (1970s–1980s) quantified population sizes and reproductive status; and contemporary studies (2000s–2020s) continued longitudinal monitoring, recording distribution, abundance, and colonization of newly ice-free areas, providing a continuous dataset tracing the species' persistence and expansion under changing climatic conditions (Edwards 1975, Fowbert and Lewis-Smith 1994, Vera 2011, Ivannikov et al. 2023).

In this research, we investigated the antiviral activity of the natural extract from *C. quitensis* from the maritime Antarctic and provided detailed description of its biochemical composition.

Material and Methods

To study antiviral activity, a natural extract was taken from the above-ground part of *C. quitensis* plants (*see* Fig. 1) (old locus Galindez, Galindez Island, Argentine Islands, Graham Coast, Antarctica, -65.247967°, -64.242600°) collected during the 27th Ukrainian Antarctic Expedition in 2023.

Dried plants were grounded into powder and treated with 45% ethanol at the ratio of 10 ml per 1 g of raw material, for 7 days at room temperature. The original 5 ml extract was evaporated using a rotary evaporator, and the resulting dry residue was dissolved in sterile distilled water to the initial volume.

The following continuous cell lines were used: PEK – Porcine Embryonic Kidney cells.

The viruses used in the study: TGEV (Transmissible GastroEnteritis Virus) – porcine coronavirus, etiologic agents of porcine transmissible gastroenteritis. D52-5 (BRE79) strain is highly pathogenic for the pigs of any age. The virus used in the study was obtained after 5 passages in ST cells (fibroblast-like cells isolated from testicle of a pig). The strain of TGEV was kindly provided by Dr. Hubert Laude from Molecular Virology and Immunology Laboratory of INRA Biotechnological Center, Jouy-en-Josas, France.

The infectivity of virus was assessed by two methods. The technique of the end point dilution was based on estimating cytopathic effect (CPE) in cell culture. The infectious titer was calculated by Kerber-Ashmarin and expressed as tissue cytopathic dose $(TCD)_{50}$/mL. The analysis of the negative plaques (S marker) was performed in 1.35% agar (Difco-Bacto) and the infectious titer was expressed in plaque-forming units (PFU)/mL. The results were registered following 120-h culture at 38°C.

50% cytotoxic concentration (CC_{50}) of the extracts under study was assessed by CPE in MDCK and PEK cells. The cells were seeded in a 96-well plate and various dissolution of the assayed extracts were added in triplicate. The cells were incubated for 5 days at 37°C in a 5% CO_2-humidified incubator. The plates were viewed daily for detecting CPE presence or absence. CPE (cell rounding, degeneration, cell detachment from the surface of the wells) was assessed by scoring the cell layer by 5-point scale such as follows:

"–" – degeneration is absent

"+" – damage of cell layer by not more than 25%

"++" – damage of cell layer by not more than 50%

"+++" – damage of cell layer by not more than 75%

"++++" – complete degeneration of cell layer.

50% cytotoxic concentration (CC_{50}) was then calculated as the compound concentration required for the reduction of cell viability by 50%.

For assaying antiviral activity of the substances, 50% effective concentration (EC_{50}) was estimated as the compound concentration exerting half-maximal protective effect assessed by CPE inhibition and reduction of the infectious titer by not less than 2 lg. For assessing EC_{50}, test virus was added to cells grown in 96-well plate in a dose of 100 TCD_{50}/0.1 mL. Upon absorption of virus (60 min, 37°C), the cells were washed and the maintenance medium (RPMI-1640 with 2% of fetal calf serum) was added. Then the assayed substances were added in different concentrations. The protection against virus-induced CPE with the reduction of infectious titer by not less than 2 lg allowed calculating EC_{50} of the substance under study.

The selectivity index (SI) was calculated as CC_{50} to EC_{50} ratio.

Anti-coronavirus activity was assayed in PEK cells infected with TGEV at a dose of 100 TCD_{50}. The infected cells treated with the assayed substances were cultured for 3 days, and then the culture medium was collected for the assessment of TGEV infectious titer (Rybalko et al. 2024)

Statistical analysis: The data obtained were statistically processed by Microsoft Excel software. The significance of the difference was calculated by Student's t-test. The difference was considered as significant at $p < 0.05$. EC_{50}, CC_{50} and SI were calculated using nonlinear regression analysis (Rybalko et al. 2024).

Qualitative analysis of the extract composition was performed using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI MS). Mass spectra were recorded in positive and negative ion modes using an Autoflex II mass spectrometer (Bruker Daltonics Inc., Germany) equipped with a nitrogen laser (337 nm) (Laguta et al. 2024).

Fig. 1. *Colobanthus quitensis* from old population of Galindez Island.

Results and Discussion

The study of the cytotoxic effects of *in situ C. quitensis* extracts, apigenin and luteolin in PEK cells demonstrated in Table 1.

The plant extract from *C. quitensis* had lower toxicity to normal cells compared to synthetic apigenin and luteolin, which can be considered as its greatest advantage.

The data on the assessment of the EC_{50} of the substances in the models of TGEV are given in Figs. 2-4.

The data obtained indicate that the studied natural extract of *C. quitensis*, apigenin, and luteolin in particular effectively inhibit the reproduction of the TGEV virus in dilutions up to 1:12800. The calculated selectivity index is given in Table 2.

Extract	Cell culture
	PEK
	Extract dilution corresponding to CC_{50}
Colobanthus quitensis	1/5
Apigenin	1/32
Luteolin	1/64

Table 1. Cytotoxic concentration (CC_{50}) of *C. quitensis* extracts, apigenin and luteolin in PEK cells.

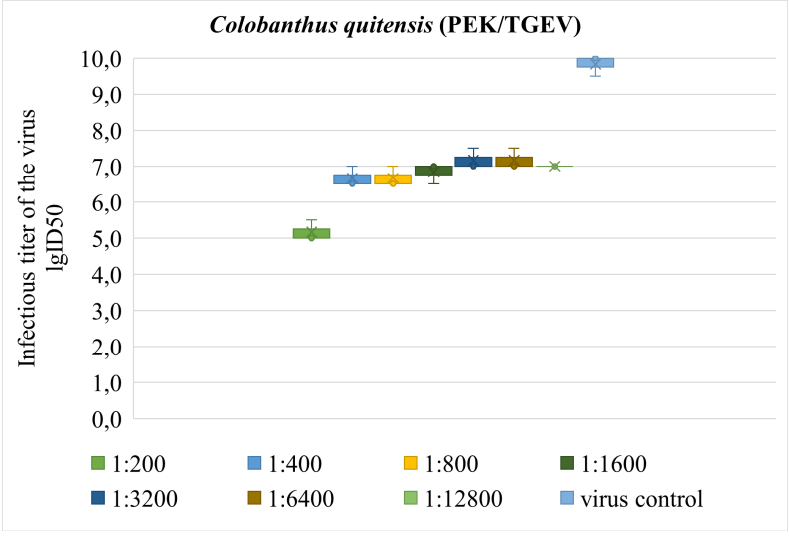

Fig. 2. Infectious titer of TGEV in PEK cells treated with the *C. quitensis* extract.

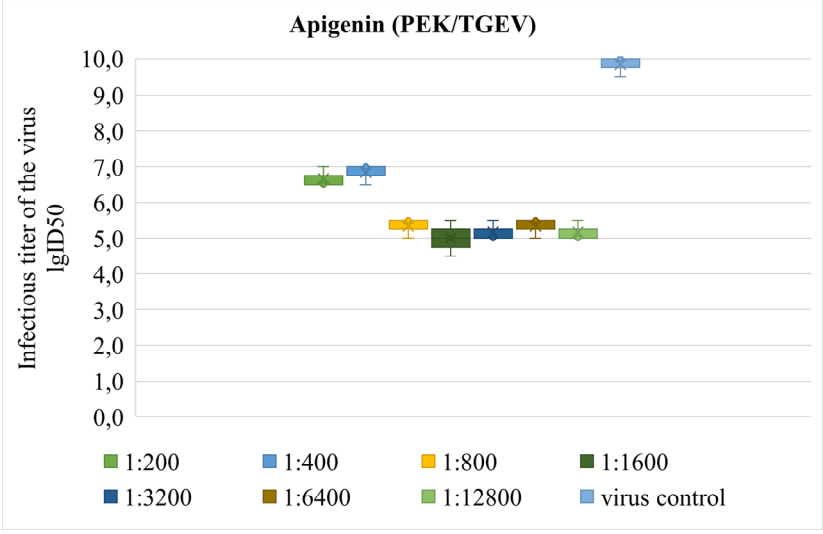

Fig. 3. Infectious titer of TGEV in PEK cells treated with synthetic apigenin.

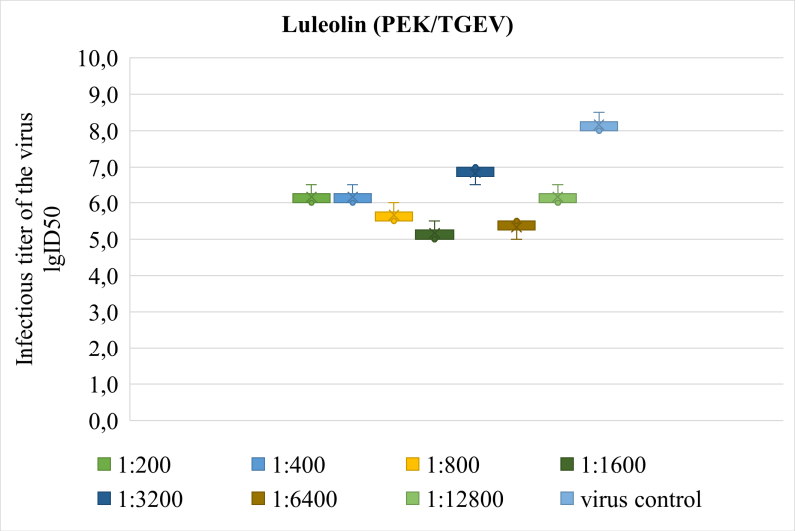

Fig. 4. Infectious titer of TGEV in PEK cells treated with synthetic luteolin.

Virus	Extract	CC_{50}, mkg/ml	EC_{50}, mkg/ml	SI
Coronavirus TGEV	*Colobanthus quitensis*	1:5	1:12800	2560
	Apigenin	1:32	1:12800	400
	Luteolin	1:64	1:12800	200

Table 2. Selectivity index (SI), cytotoxic concentration (CC_{50}) and effective concentration (EC_{50}) for the assayed extract of *C. quitensis*, synthetic apigenin and luteolin for Coronavirus TGEV.

Selectivity Index for the extract exceeds the value of 16 set as acceptance criterion for assessing prospecting substances with antiviral activity.

Thus, the selectivity index of the *C. quitensis* plant extract from nature, as determined by us, exceeds the acceptable criterion for antiviral activity against the TGEV coronavirus by 160 times. Synthetic apigenin and luteolin exceed this indicator by 25 and 12.5 times, respectively.

The results of interpretation of analytically important peaks registered in both the positive- and negative-ion MALDI mass spectra, after exclusion of obvious matrix-related signals, are shown in Table 3.

The most intense signals in the mass spectra of the extract were identified as those belonging to ions of carbohydrates, phenolic acids, and flavonoids (mainly flavones in glycosidic forms) which is consistent with recent (Rubilar et al. 2025) and earlier study (Ivannikov et al. 2023) High content of phenolic compounds is reported for *C. quitensis* as well (Contreras et al. 2025). The spectra also show signals attributed to chlorophylls, carotenoids, phospholipids, and carboxylic acids. Moreover, the extracts from *C. quitensis* plants are characterized by a high sucrose content.

Mode	m/z	I, a.u.	I_{rel},%	Attributed ion(s)	Assigned compound(s) and/or classes
+	138.1	6074	66.5	$C_7H_6O_3^{\bullet+}$	Hydroxybenzoic acids
+	147.1	4076	44.6	$[(C_9H_8O_3\text{-}H_2O)+H]^+$	p-Coumaric acid (I)
+	154.0	798	8.7	$C_7H_6O_4^{\bullet+}$	Dihydroxybenzoic acids
+	160.0	2033	22.2	$C_6H_8O_5^{\bullet+}$	Carboxylic acids
+	175.1	9140	100.0	$[(C_{11}H_{12}O_3\text{-}H_2O)+H]^+$	Ethyl ester of p-coumaric acid
+	176.0	6418	70.2	$C_6H_8O_6^{\bullet+}$	Glucuronic acid derivatives
+	178.1	2773	30.3	$C_6H_{10}O_6^{\bullet+}$	Glucuronic acid derivatives
+	184.1	460	5.0	$C_{10}H_{16}O_3^{\bullet+}$	C_7-carboxylic acid derivatives
+	185.0	1745	19.1	$[(C_9H_8O_3\text{-}H_2O)+K]^+$	p-Coumaric acid (I)
-	191.1	265	13.9	$[C_{11}H_{12}O_3\text{-}H]^-$	Ethyl ester of p-coumaric acid
+	194.1	4106	44.9	$C_6H_{10}O_7^{\bullet+}$ / $C_7H_{14}O_6^{\bullet+}$	Glucuronic acid / (*D-pinitol / ononitol)**
+	203.1	229	2.5	$[C_6H_{12}O_6+Na]^+$	Monosaccharides (*glucose / fructose / galactose)**
+	217.1	346	3.8	$[C_6H_{10}O_7+Na]^+$ / $[C_7H_{14}O_6+Na]^+$	Glucuronic acid / *(D-pinitol / ononitol)**
+	219.0	251	2.8	$[C_6H_{12}O_6+K]^+$	Monosaccharides (*glucose / fructose / galactose**)
+	223.1	1019	11.2	$[C_{11}H_{10}O_5+H]^+$	p-Coumaroyl glycolic acid
-	225.1	1917	100.0	$[(C_{11}H_{12}O_4+H_2O)\text{-}H]^-$	Methyl ester of glucuronic acid
+	233.0	651	7.1	$[C_6H_{10}O_7+K]^+$ / $[C_7H_{14}O_6+K]^+$	Glucuronic acid / *(D-pinitol / ononitol)**
+	238.1	406	4.4	$C_{15}H_{10}O_3^{\bullet+}$	Flavones
-	257.1	473	24.7	$[C_{15}H_{14}O_4\text{-}H]^-$	Trihydroxyflavan (apigeniflavan)
+	280.1	792	8.7	$C_{17}H_{12}O_4^{\bullet+}$	Isoflavonoid(s)
+	283.0	307	3.4	$[C_{16}H_{10}O_5+H]^+$	Isoflavonoid(s)
+	296.1	1698	18.6	$C_{18}H_{16}O_4^{\bullet+}$	Hydroxyflavone derivatives
+	301.1	203	2.2	$[C_{16}H_{12}O_6+H]^+$	Methoxyluteolin
+	317.1	681	7.5	$[C_{16}H_{12}O_7+H]^+$	Hydroxyluteolin derivatives
-	318.1	778	40.6	$C_{16}H_{14}O_7^{\bullet-}$	Flavanone derivatives
+	343.1	352	3.9	$[C_{12}H_{22}O_{11}+H]^+$	Disaccharides (*sucrose**)
+	365.1	4376	47.9	$[C_{12}H_{22}O_{11}+Na]^+$	Disaccharides (*sucrose**)
+	381.1	6042	66.1	$[C_{12}H_{22}O_{11}+K]^+$	Disaccharides (*sucrose**)
+	411.1	1090	11.9	$[C_{20}H_{20}O_7+K]^+$	Cynosetin (OMe-derivatives of hydroxyluteolin)
-	425.0	975	50.9	$[C_{17}H_{14}O_{11}S\text{-}H]^-$	Flavonol derivatives
+	433.1	1321	14.5	$[C_{21}H_{20}O_{10}+H]^+$	Apigenin/luteolin glycoside(s) (flavones)
-	447.1	318	16.6	$[C_{21}H_{20}O_{11}\text{-}H]^-$	Orientin (8C-glucoside of luteolin)
+	449.1	1273	13.9	$[C_{21}H_{20}O_{11}+H]^+$	Orientin (8C-glucoside of luteolin)
-	461.1	245	12. 8	$[C_{22}H_{22}O_{11}\text{-}H]^-$	Swertiajaponin (II)
+	463.1	5115	56.0	$[C_{22}H_{22}O_{11}+H]^+$	Swertiajaponin (II)
+	471.1	323	3.5	$[C_{21}H_{20}O_{10}+K]^+$	Apigenin/luteolin glycoside(s)
+	485.1	774	8.5	$[C_{22}H_{22}O_{11}+Na]^+$	Swertiajaponin (II)
+	501.1	913	10.0	$[C_{22}H_{22}O_{11}+K]^+$	Swertiajaponin (II)
-	525.2	591	30.8	$[C_{32}H_{30}O_7\text{-}H]^-$	Flavanone derivatives
+	527.2	1342	14.7	$[C_{18}H_{32}O_{16}+Na]^+$	Oligosaccharides (*raffinose**)
+	543.1	1929	21.1	$[C_{18}H_{32}O_{16}+K]^+$	Oligosaccharides (*raffinose**)
+	558.3	286	3.1	$C_{30}H_{38}O_{10}^{\bullet+}$	Secoisolariciresinol sesquiterpene
-	563.1	1213	63. 8	$[C_{26}H_{28}O_{14}\text{-}H]^-$	Schaftoside (III) / Neoschaftoside (IV)
+	565.2	2361	25.8	$[C_{26}H_{28}O_{14}+H]^+$	Schaftoside (III) / Neoschaftoside (IV)
-	577.1	407	21.3	$[C_{30}H_{26}O_{12}\text{-}H]^-$	Apigenin/luteolin glycoside(s)

Table 3. Interpretation of the main peaks of MALDI mass spectra of natural *C. quitensis* extract.

Mode	m/z	I, a.u.	I_{rel},%	Attributed ion(s)	Assigned compound(s) and/or classes
+	581.1	668	7.3	$[C_{26}H_{28}O_{15}+H]^+$	Orientin 2"-O-β-arabinopyranoside
+	587.1	1021	11.2	$[C_{28}H_{26}O_{14}+H]^+$	Glycoside(s) of naringenin (flavanones)
-	593.2	607	31.7	$[C_{27}H_{30}O_{15}-H]^-$	(Iso)Swertiajaponin 2"-O-β-arabinopyranoside
+	593.2	525	5.7	$[C_{28}H_{32}O_{14}+H]^+$	Glycosides of apigenin derivatives (flavones)
+	595.2	1847	20.2	$[C_{27}H_{30}O_{15}+H]^+$	(Iso)Swertiajaponin 2"-O-β-arabinopyranoside
-	601.1	143	7.5	$[C_{28}H_{26}O_{15}-H]^-$	Flavanone glycoside(s)
+	603.1	2227	24.4	$[C_{26}H_{28}O_{14}+K]^+$	Schaftoside (III) / Neoschaftoside (IV)
-	617.1	139	7.3	$[C_{28}H_{26}O_{16}-H]^-$	Dihydroflavonol glycoside(s)
+	617.1	914	10.0	$[C_{27}H_{30}O_{14}+K]^+$	Isoswertisin 2"-O-β-arabinoside
+	619.1	753	8.2	$[C_{28}H_{26}O_{16}+H]^+$	Dihydroflavonol glycoside(s)
+	625.1	824	9.0	$[C_{28}H_{26}O_{14}+K]^+$	Naringin glycoside(s) (flavanones)
+	629.2	609	6.7	$[C_{27}H_{32}O_{17}+H]^+$	Dihydroflavonol glycoside(s)
+	633.1	1687	18.5	$[C_{27}H_{30}O_{15}+K]^+$	(Iso)Swertiajaponin 2"-O-β-arabinoside
-	635.2	210	11.0	$[C_{29}H_{32}O_{16}-H]^-$	(Iso)Swertiajaponin 2"-O-β-arabinoside acylated
+	637.2	1499	16.4	$[C_{29}H_{32}O_{16}+H]^+$	(Iso)Swertiajaponin 2"-O-β-arabinoside acylated
+	641.1	658	7.2	$[C_{28}H_{32}O_{17}+H]^+$	Glycosides of methyl derivatives of hydroxyluteolin
+	645.1	1175	12.9	$[C_{28}H_{30}O_{15}+K]^+$	Glycoside(s) of apigenin (flavones)
+	655.1	315	3.5	$[C_{27}H_{26}O_{19}+H]^+$	Flavone glycoside(s)
+	659.1	760	8.3	$[C_{29}H_{32}O_{15}+K]^+$	Isoswertisin 2"-O-β-arabinoside acylated
+	667.1	214	2.3	$[C_{27}H_{32}O_{17}+K]^+$	Dihydroflavonol glycoside(s)
+	671.1	377	4.1	$[C_{27}H_{26}O_{20}+H]^+$	Myricetin glycosides (flavonols)
+	675.1	1419	15.5	$[C_{29}H_{32}O_{16}+K]^+$ / $[C_{30}H_{36}O_{15}+K]^+$	Apigenin / methoxy luteolin glycosides (flavones)
+	689.2	2372	26.0	$[C_{24}H_{42}O_{21}+Na]^+$	Oligosaccharides (*stachyose / (iso)lichnose)**
+	697.2	261	2.9	$[C_{31}H_{36}O_{18}+H]^+$	Apigenin glycoside(s) (flavones)
+	705.2	3175	34.7	$[C_{24}H_{42}O_{21}+K]^+$	Oligosaccharides (*stachyose / (iso)lichnose)**
-	724.2	853	44.5	$C_{39}H_{32}O_{14}^{\bullet-}$	Apigenin glycoside(s) (flavones)
+	780.5	359	3.9	$[C_{40}H_{72}NO_{10}P+Na]^+$ / $[C_{42}H_{80}NO_8P+Na]^+$	PS(16:0/18:3) / PS(16:1/18:2) (*phospholipids***) / PC(16:0/18:2) / PC(16:1/18:1) (*phospholipids***)
+	794.5	280	3.1	$[C_{40}H_{70}NO_{10}P+K]^+$ / $[C_{42}H_{78}NO_8P+K]^+$	PS(16:1/18:3) (*phospholipids***) / PC(16:0/18:3) (*phospholipids***)
+	796.5	564	6.2	$[C_{40}H_{72}NO_{10}P+K]^+$ / $[C_{42}H_{80}NO_8P+K]^+$	PS(16:0/18:3) / PS(16:1/18:2) (*phospholipids***) / PC(16:0/18:2) / PC(16:1/18:1) (*phospholipids***)
+	818.4	367	4.0	$[C_{42}H_{70}NO_{10}P+K]^+$	PS(18:3/18:3) (*phospholipids***)
+	820.5	549	6.0	$[C_{42}H_{72}NO_{10}P+K]^+$ / $[C_{44}H_{80}NO_8P+K]^+$	PS(18:3/18:3) (*phospholipids***) / PC(18:1/18:3) / PC(18:2/18:2) (*phospholipids***)

-	833.5	153	8.0	$[C_{44}H_{80}NO_8P\text{-}H]^-$	PI(16:0/18:2) / PI(16:1/18:1) (*phospholipids***)
+	851.1	571	6.2	$[C_{35}H_{40}O_{23}+Na]^+$	Luteolin glycoside(s)
+	867.1	767	8.4	$[C_{35}H_{40}O_{23}+K]^+$	Luteolin glycoside(s)
+	871.6	1568	17.2	$[C_{55}H_{74}O_5N_4+H]^+$	Theophylline a
+	893.5	859	9.4	$[C_{55}H_{72}O_5N_4Mg+H]^+$	Chlorophyll a
+	909.5	864	9.5	$[C_{55}H_{74}O_5N_4+K]^+$	Theophylline a
+	931.5	245	2.7	$[C_{55}H_{72}O_5N_4Mg+K]^+$	Chlorophyll a
+	959.6	245	2.7	$[C_{51}H_{84}O_{15}+Na]^+$	DGDG(18:3/18:3) (*glycerolipids***)
+	975.6	500	5.5	$[C_{51}H_{84}O_{15}+K]^+$	DGDG(18:3/18:3) (*glycerolipids***)

Table 3. Interpretation of the main peaks of MALDI mass spectra of natural *C. quitensis* extract (continued).
Note:
* – carbohydrates found in *C. quitensis* (Piotrowicz-Cieślak et al. 2005);
** – fatty acid components (C_{16}, C_{18}) for lipids identification were taken from Zúñiga et al. (1994).

Such high sucrose content is consistent with the literature data (Bravo et al. 2001) on its highest accumulation in Antarctic plants during the Antarctic summer (the longest days), when the plant samples were collected for analysis. High sucrose content in *C. quitensis* is, however, generally attributed to low temperature effect. Due to sucrose-phosphate synthase (SPS) which is more active in cold than warm conditions (Bascuñán-Godoy et al. 2006), sucrose is accumulated in leaves serving as antifreezing agens.

In MALDI mass spectra of natural extract of *C. quitensis*, the signals corresponding to 8 out of 11 polyphenolic components, identified in Contreras et al. (2019) during the analysis of secondary metabolites of *C. quitensis* plants, were found, namely: p-coumaric acid (I), apigenin (II), naringenin (III), naringenin chalcone (IV), luteolin (V), swertiajaponin (VI), schaftoside (VII), and neoschaftoside (VIII). The high antiviral activity of the studied extract can be explained by the presence of polyphenols detected in it (Chojnacka et al. 2021).

Conclusion

In our study, we represent first data about antiviral activity of a natural plant extract of *C. quitensis*. This extract showed exceptionally high antiviral action against the TGEV coronavirus in laboratory tests (*in vitro*), outperforming synthetic analogues such as apigenin and luteolin. Furthermore, it is safe, as it possesses extremely low toxicity to normal cells.

Analysis of *C. quitensis* extract using MALDI MS showed that the main components are polyphenols (phenolic acids and flavones, mainly in the form of glycosides), carbohydrates, and chlorophylls. The high antiviral activity of the extract can be explained by the presence of polyphenols.

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