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STUDIES ON THE CHEMICAL COMPOSITION OF FRUITS AND SEEDS OF *PSEUDOCYDONIA SINENSIS* (THOUIN) C.K. SCHNEID.

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ABSTRACT
Pseudocydonia sinensis (Thouin) C. K. Schneid. less known plant species in the Ukraine conditions, but the fruits were widely used in traditional Chinese medicine for the treatment of asthma, colds, sore throat, mastitis, rheumatoid arthritis, and tuberculosis. The content of protein, ash, and lipids in the seeds was found to be greater than in the pulp and peel. Monosaccharide analysis of neutral carbohydrate part showed the presence of two main sugars fructose and sucrose in the seeds, pulp, and peel. There is a higher beta-carotene content in the rind of the fruit than in the seeds and pulp. The total amount of fatty acids varied from sample to sample and contained mainly oleic acid, palmitic acid, linolenic acid, and linoleic acid. Linoleic acid in the seeds was 48.02% of total fatty acids, slightly less in the rind 42.70%. Palmitic acid, oleic acid, and linoleic acid in the pulp samples were 45.38, 21.32, and 14.93%, respectively. The total amount of amino acids found in the seeds was 105.0 $g.kg^{-1}$ DM, including total essential amino acids (32.70 $g.kg^{-1}$ DM). Glutamic acid was found in seeds to be the dominant free amino acid followed by aspartic acid and arginine in the seed. In our study, the antioxidant activity carried out by the DPPH method and measured by molybdenum reducing antioxidant power of peel, pulp and seeds were 9.41, 7.08, 6.21, and 158.81, 92.83, 78.58 mg $TEAC.g^{-1}$ DM, respectively. Micro and macronutrients and amino acids predominated in the seeds, total fatty acids predominated in the pulp. The highest content of bioactive compounds (total polyphenols, flavonoid, and phenolic acid) and antioxidant activity was found in the peel. *P. sinensis* can be considered as a nourishing fruit with a copious potential with health-promoting roles and medicinal properties.

Keywords: Chinese quince; fruit; seed; chemical composition; nutrients

INTRODUCTION
Increasing interest in less know, non-traditional, neglected, and underutilized plant species, which could serve as a valuable source of natural bioactive compounds, has been emerged worldwide and they play important role in procuring food security to improve health and nutrition, ecological sustainability, and livelihoods. These species of rich in valuable biologically active compounds include *Aronia mitschurinii* A. K. Skvortsov & Maitul., *Cornus mas* L., *Chaenomeles* spp., *Diospyros virginiana* L., *Lycium* spp., *Lonicera* spp., *Morus nigra* L., *Ziziphus jujuba* Mill., *Vaccinium* spp., *Sambucus nigra* L. **(Monka et al., 2014; Ivanišová et al., 2017; Klymenko, Grygorieva and Brindza, 2017; Grygorieva et al., 2018; Grygorieva et al., 2020; Klymenko et al., 2019; Horčinová Sedláčková et al., 2018; Horčinová Sedláčková et al., 2019; Szot, Zhurba and Klymenko, 2020; Vinogradova et al., 2020)**. The direction adopted by the European Community towards sustainable crop production intensification involves "growing a wider range of plant species and varieties using combinations, sequences and rotations" **(Save and Grow, 2011)**. It is important to cultivate little-known edible plants more widely, as they are a potential source of new biologically active substances needed for the functioning of the human body.

Pseudocydonia sinensis (Thouin) C. K. Schneid. (Chinese quince) is a less known species of the family Rosaceae Juss. and the only species in the genus *Pseudocydonia* C. K. Schneid., native to eastern Asia in China. This species is closely related to the East Asian genus, *Chaenomeles* Lindl., and to the European genus, *Cydonia* Mill. **(Suzuki, 1994)**. Sometimes it is called *Chaenomeles sinensis*. They are distinguished by the absence of thorns and single, not clustered flowers. *Cydonia oblonga* differs from the *Pseudocydonia sinensis* plant in the presence of toothed leaves and the absence of pubescence on the fruits **(Klymenko, Grygorieva and Brindza, 2017)**.

In Europe, *Pseudocydonia sinensis* is only grown in botanical gardens and arboretums but has already proved to be an annually fruiting crop that is resistant to the climatic conditions of the continent. A more detailed study of the biology of this species will help to introduce it into widespread cultivation more quickly.

Since the fruits of *Pseudocydonia sinensis* are very acidic and tart, they are used only in their raw form; they are used to make marmalades, jams, fruit jellies, candied pulp, syrups and juices, wines, liqueurs, and in the preparation of flour products **(Hamauzu et al., 2006; Monka et al., 2014; Klymenko, Grygorieva and Brindza, 2017)**.

According to literature data, fruits of the studied species contain organic acids, flavonoids (rutin and quercetin), procyanidins, and volatile compounds **(Hamauzu et al., 2005; Hamauzu and Nakamura, 2014)**. The skin of *Pseudocydonia sinensis*' fruits contains the following volatile compounds: (E,E)-α- -farnesene, isobutyl octanoate, ethyl octanoate, isobutyl 7-octanoate, and hexyl hexanoate **(Mihara et al., 1987)**. Aromoactive compounds such as ethyl 2-methylpropanoate, ethyl (E)-2-butenoate, ethyl 2-methyl butanoate, methionyl, (Z)-3-hexenyl acetate, β-ionone, ethylnonanoate, and γ-decalactone were also found in the skin **(Choi et al., 2018)**.

The fruits of the *Pseudocydonia sinensis* were widely used in traditional Chinese medicine for the treatment of asthma, colds, sore throat, mastitis, rheumatoid arthritis, and tuberculosis **(Mihara et al., 1987; Chung, Cho and Song, 1988; Hamauzu and Nakamura, 2014)** as confirmed by their antibacterial, antihemolytic, anti-inflammatory, antipruritic, antioxidant, antiviral, anti-ulcerative, gastroprotective, antitumor, and antimicrobial properties **(Osawa et al., 1997; Osawa et al., 1999; Oku, Ueda and Ishiguro, 2003; Hamauzu et al., 2006; Hamauzu et al., 2007; Hamauzu, Kishida and Yamazaki, 2018; Sawai et al., 2008; Chun et al., 2012; Sawai-Kuroda et al., 2013; Monka et al., 2014; Kabir et al., 2015; Essuman, Nagajyothi and Tettey, 2017; Grygorieva et al., 2020)**.

This work was carried out to determine the chemical composition of fruits and seeds of less known species *Pseudocydonia sinensis* to assess the possibility of using this species in the future.

Scientific Hypothesis

As *Pseudocydonia sinensis* is widely used in Chinese traditional medicine, its fruits and seeds contain bioactive components. When introduced in Ukraine and Slovakia, the amount of beneficial substances in fruits and seeds is not reduced, which makes it possible to recommend this species for wide cultivation.

MATERIAL AND METHODOLOGY

Samples

Pseudocydonia sinensis seeds (Figure 1) and fruits (pulp and peel) (Figure 2) were collected in November 2019 from trees growing in an M.M. Gryshko National Botanical Garden (Kyiv, Ukraine; 197 m a.s.l.).

Figure 1 *Pseudocydonia sinensis* (Thouin) C. K. Schneid.

Figure 2 Fruits (A) and seeds (B) *Pseudocydonia sinensis* (Thouin) C. K. Schneid.

Chemicals

Ethanol (Centralchem s.r.o., Bratislava, Slovakia, p.a.), acetonitrile (Fisher Chemical, Loughborough, UK, HPLC grade), petroleum ether (Sigma-Aldrich,Merck KGaA, Darmstadt, Germany,Sigma Grade, ≥99%), ninhydrin (Ingos, Czech Republic), nitric acid (Analytika Praha Ltd, Czech Republic), hydrochloric acid (Analytika Praha Ltd, Czech Republic), methyl cellosolve (Ingos, Czech Republic), filter with 0.45 μm pore size (Labicom, Czech Republic), tin chloride ($SnCl_2$) (Centralchem s.r.o., Bratislava, Slovakia, p.a.), Folin-Ciocalteu reagent (Sigma-Aldrich,Merck KGaA, Darmstadt, Germany), sodium carbonate (Centralchem s.r.o., Bratislava, Slovakia, p.a.), sodium hydroxide (Centralchem s.r.o., Bratislava, Slovakia, p.a.), gallic acid (Fisher Chemical, Loughborough, UK, HPLC grade), aluminum chloride (Centralchem s.r.o., Bratislava, Slovakia, p.a.), potassium acetate (Centralchem s.r.o., Bratislava, Slovakia, p.a.), quercetin (Fisher Chemical, Loughborough, UK, HPLC grade), Arnova reagent (10% $NaNO_2$+10% Na_2MoO_4) (Sigma-Aldrich,Merck KGaA, Darmstadt, Germany), caffeic acid (Fisher Chemical, Loughborough, UK, HPLC grade).

Instruments

HPLC system with an ELSD detector (Agilent Technologies 1260 Infinity, Santa Clara, CA, USA).

Vacuum degasser (Agilent Technologies, Santa Clara, CA, USA).

Quarterly pump (Agilent Technologies, Santa Clara, CA, USA).

Autosampler (Agilent Technologies, Santa Clara, CA, USA).

HPLC system with ninhydrin and a VIS detector (Model AAA-400 amino acid analyzer, Ingos, Czech Republic).

UV-VIS spectrophotometer (UV Jenway Model 6405, UV/VIS, England).

ICP-OES system (Ultima 2, Horiba Scientific, France).

ES column (Zorbax SB-C18, 4.6x25.0 mm, 5 μm particle size, Agilent, Santa Clara, CA, USA).

Centrifuge (EBA 21, Hettich, Germany).

Magnetic stirrer (Arex-6 Connect Pro, Velp Scientifica, Italy).

Microwave oven (Milestone 1200, Milestone, Italy).

Vertical shake table (GFL, Germany).

Laboratory Methods

Determination of dry matter, ash, and protein content

Total dry matter, ash, and protein content were determined according to the EN method **(CSN EN 12145, 1997)**. Total lipid content was determined according to methods specified in the ISO method **(ISO 659, 1998)**.

Determination of saccharides

For the determination of saccharides, 1 g of sample was extracted with 10 mL of extraction solution (ultrapure water and ethanol mixed in ration 4:1) in a 50 mL centrifugation tube placed on a vertical shake table (GFL, Germany). After 1 h of extraction, samples were centrifuged for 4 min at 6000 rpm in a centrifuge (EBA 21, Hettich, Germany); the supernatant was filtered using a filter with 0.45 μm pore size (Labicom, Czech Republic) and filled up to 50 mL in a volumetric flask with ultrapure water. An Agilent Infinity 1260 liquid chromatography (Agilent Technologies, USA) equipped with an ELSD detector was used for the determination of saccharides. A Prevail Carbohydrates ES column (250/4.6 mm) was used as a stationary phase and acetonitrile (VWR) mixed with water in a 75:25 volume ratio was used as the mobile phase.

Determination of carotenoid

Total carotenoid content expressed as beta-carotene was analyzed at a wavelength of 445 nm spectrophotometrically (VIS spectrophotometer UV Jenway Model 6405 UV/VIS). Sample (1 g) was disrupted with sea sand and extracted with acetone until complete discoloration. Petroleum-ether was added and then water, in purpose to the separation of phases. After the separation, the petroleum ether-carotenoid phase was obtained and the absorbance was measured **(ČSN 560053, 1986)**.

Determination of mineral contents

Sample for elemental analysis was prepared using the wet ashing method in a microwave oven (Milestone 1200, Milestone, Italy). A total of 0.25 g sample matrix was decomposed in a mixture of nitric acid (6 mL) (Analytika Praha Ltd, Czech Republic) and hydrochloric acid (2 mL) (Analytika Praha Ltd, Czech Republic). After the decomposition sample was filtered using a filter with 0.45 μm pore size and filled up to 25 mL in a volumetric flask with ultrapure water. Elemental analysis was performed using ICP-OES (Ultima 2, Horiba Scientific, France) according to the procedure described by **Divis et al. (2015)**.

Determination of amino acids

Amino acids were determined by ion-exchange liquid chromatography (Model AAA-400 amino acid analyzer, Ingos, Czech Republic) using post-column derivatization with ninhydrin and a VIS detector. A glass column (inner diameter 3.7 mm, length 350 mm) was filled manually with a strong cation exchanger in the LG ANB sodium cycle (Laboratory of Spolchemie) with average particles size 12 μM and 8% porosity. The column was tempered within the range of 35 to 95 °C. The elution of the studied amino acids took place at a column temperature set to 74 °C. A double-channel VIS detector with the inner cell volume of 5 μL was set to two wavelengths: 440 and 570 nm. A solution of ninhydrin (Ingos, Czech Republic) was prepared in 75% v/v methyl cellosolve (Ingos, Czech Republic) and in 2% v/v 4 M acetic buffer (pH 5.5). Tin chloride (SnC^{l2}) was used as a reducing agent. The prepared solution of ninhydrin was stored in an inert atmosphere (N^2) in darkness at 4 °C. The flow rate was 0.25 ($mL.min^{-1}$) and the reactor temperature was 120 °C.

Determination of total polyphenol, flavonoid, and phenolic acid content

The total polyphenol content (TPC) was measured by the method of **Singleton and Rossi (1965)** using the Folin-Ciocalteu reagent. A quantity of 0.1 mL of each sample was mixed with 0.1 mL of the Folin-Ciocalteu reagent, 1 mL of 20% (w/v) sodium carbonate, and 8.8 mL of distilled water. After 30 min in darkness, the absorbance at 700 nm was measured with the spectrophotometer Jenway (6405 UV/Vis, England). Gallic acid (25 – 300 $mg.L^{-1}$; R^2 = 0.998) was used as the standard. The results were expressed in $mg.g^{-1}$ DM gallic acid equivalent.

The total flavonoid content (TFC) was determined by the modified method described by **Shafii et al. (2017)**. An aliquot of 0.5 mL of the sample was mixed with 0.1 mL of

10% (w/v) ethanolic solution of aluminum chloride, 0.1 mL of 1 M potassium acetate, and 4.3 mL of distilled water. After 30 min in darkness, the absorbance at 415 nm was measured using the spectrophotometer Jenway (6405 UV/VIS, England). Quercetin (1 – 400 $mg.L^{-1}$; $R^2 = 0.9977$) was used as the standard. The results were expressed in $mg.g^{-1}$ DM quercetin equivalent.

Total phenolic acid (TPA) content was determined using the method of **Farmakopea Polska (1999)**. A 0.5 mL of sample extract was mixed with 0.5 mL of 0.5 M hydrochloric acid, 0.5 mL Arnova reagent (10% $NaNO_2$+10% Na_2MoO_4), 0.5 mL of 1 M sodium hydroxide (w/v) and 0.5 mL of water. Absorbance at 490 nm was measured using the spectrophotometer Jenway (6405 UV/Vis, England). Caffeic acid (1 – 200 $mg.L^{-1}$, $R^2 = 0.999$) was used as a standard and the results were expressed in $mg.g^{-1}$ DM caffeic acid equivalents.

Number of samples analyzed: 15.
Number of repeated analyses: 3.
Number of experiment replication: 1.

Statistical Analysis

Basic statistical analyses were performed using PAST 2.17. Data were analyzed with ANOVA test and differences between means compared through the Tukey-Kramer test (p <0.05). The variability of all these parameters was evaluated using descriptive statistics.

RESULTS AND DISCUSSION

Determining the chemical composition of *Pseudocydonia sinensis* is of great importance in studies into its nutritional aspects and use as raw material for industry. Proteins are macromolecules, structural units of which are called amino acids and play numerous functions that allow an organism to function and reproduce **(Day, 1996)**. The protein content in seeds, pulp, and peel was 13.20, 1.26, and 2.32%, respectively (Table 1). Protein content in *Cydonia oblonga* varied from 0.49 to 0.70 $g.100g^{-1}$ **(Leonel et al., 2016; Rasheed et al., 2018)**.

After the combustion process of the plant sample at high temperatures, the plant raw transforms into a mineral residue that consists of macro- and microelements. The results obtained show the differences between the parts of the plant and are 4.33, 2.42, and 2.46% in the seeds, pulp, and peel. According to **Leonel et al. (2016)** the fruits of different *Cydonia oblonga* cultivars contain between 0.5 and 0.8 $g.100g^{-1}$ ash, and for the results of **Rasheed et al. (2018)**, the ash content in fruits is 0.62 $g.100g^{-1}$.

Lipids are important structural components of membranes, concentrated in different plant parts and responsible for the growth and survival of the organism. There are essential components of food products **(Sebei et al., 2013)**. The content of lipids makes up in seeds, pulp, and peel was 22.95, 0.40, and 3.65%, respectively. Lipid content in the *Cydonia oblonga* was from 1.5 to 2.4 $g.100g^{-1}$ **(Leonel et al., 2016)**. **Rodríguez-Guisado et al. (2009)** reported lipid content in *Cydonia oblonga* similar to those observed in this study, varying from 1.31 to 2.33%.

Monosaccharide analysis of neutral carbohydrate part showed the presence of two main sugars – fructose (3.40, 34.46, and 26.00 $g.kg^{-1}$, respectively) and sucrose (9.65, 7.97, and 17.43 $g.kg^{-1}$, respectively) in the seeds, pulp, and peel, while other saccharides, such as maltose and lactose were found in low amounts only (<0.5 $g.kg^{-1}$).

Rodríguez-Guisado et al. (2009) analyzing the profile of sugars in *Cydonia oblonga* found levels of 5.31 to 10.89% for fructose, 4.08 to 5.44% for glucose, 1.51 to 2.41 of sucrose, and 0.31 to 0.42% for maltose totaling between 11.67 and 16.08% total sugars. **Leonel et al. (2016)** established the amount of total zinc in the range from 9.5 to 11.1 $g.100g^{-1}$. Behind the results of **Rasheed et al. (2018)**, the amount of reducing sugar was 5.15 $g.100g^{-1}$, and the amount of non-reducing sugar was 4.61 $g.100g^{-1}$.

Pseudocydonia sinensis contains beta carotene in seeds, pulp, and peel (0.93, 2.45, and 6.67 $mg.kg^{-1}$, respectively). The major quantitative tocopherol in *Pseudocydonia sinensis* seeds, pulp, and peel was α-tocopherol (67.26, 7.63, and 13.72 $mg.kg^{-1}$ DWP, respectively). The oil contents were 22.95 (seeds), 0.40 (pulp), and 3.65% (peel) dry weight plant material.

Total fatty acid profile demonstrated properties and uses of plant oils. Many plant species are an essential source of valuable fatty acid content **(Burčová et al., 2017; Matemu et al., 2017)**.

Table 1 The contents of some phytochemical compounds of *Pseudocydonia sinensis* (Thouin) C. K. Schneid.

Components	Seeds (*mean ±SD*)	Pulp (*mean ±SD*)	Peel (*mean ±SD*)
Total dry matter (%)	91.67 ±2.65	90.23 ±2.16	92.67 ±1.38
Total content of protein (%)	13.20 ±0.22	1.26 ±0.06	2.32 ±0.11
Total content of ash (%)	4.33 ±0.18	2.42 ±0.09	2.46 ±0.07
Total content of lipids (%)	22.95 ±0.32	0.40 ±0.02	3.65 ±0.11
Beta carotene ($mg.kg^{-1}$)	0.93 ±0.07	2.45 ±0.10	6.67 ±0.15
Saturated fatty acids ($g.100g^{-1}$ oil)	14.40 ±0.10	55.94 ±0.18	27.86 ±0.16
Monounsaturated fatty acids ($g.100g^{-1}$ oil)	28.00 ±0.19	20.40 ±0.21	16.55 ±0.12
Polyunsaturated fatty acids ($g.100g^{-1}$ g oil)	40.65 ±1.20	14.81 ±0.17	37.80 ±0.19
Fructose ($g.kg^{-1}$)	3.40 ±0.08	34.46 ±0.19	26.00 ±0.22
Maltose ($g.kg^{-1}$)	<0.5	<0.5	<0.5
Sucrose ($g.kg^{-1}$)	9.65 ±0.13	7.97 ±0.09	17.43 ±1.10
Lactose ($g.kg^{-1}$)	<0.5	<0.5	<0.5
Vitamin A (retinyl acetate) ($mg.kg^{-1}$)	<0.1	<0.1	<0.1
Vitamin E (α-tocopherol) ($mg.kg^{-1}$)	67.26 ±1.33	7.63 ±0.13	13.72 ±1.14

Note: mean – arithmetic mean; *SD* – standard error of the mean.

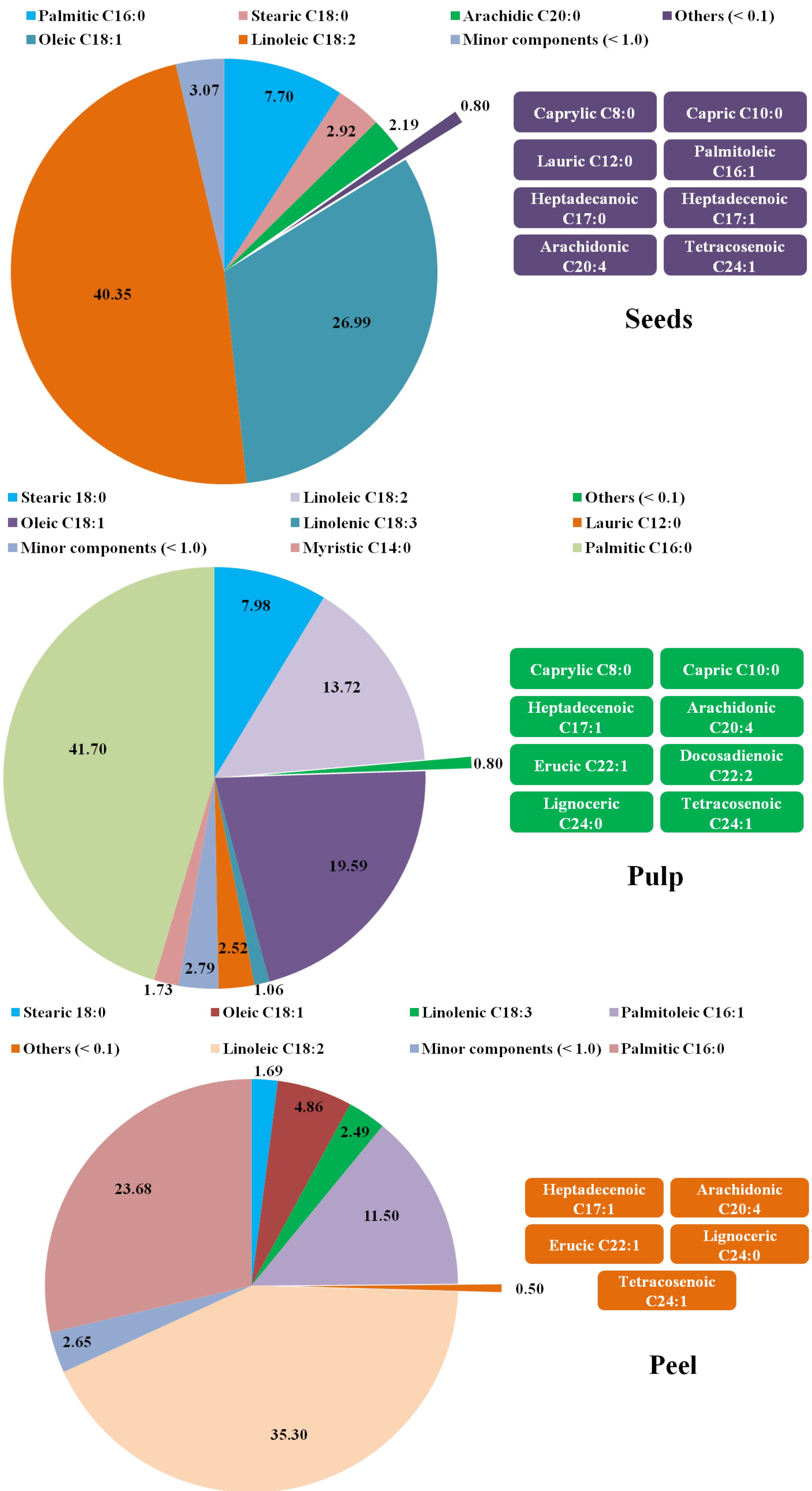

Figure 3 Fatty acid composition of *Pseudocydonia sinensis* (Thouin) C. K. Schneid. Note: Minor components (<1.0): seeds (Myristic C14:0 (0.45); Linolenic C18:3 (0.28); Eicosenoic C20:1 (0.80); Behenic C22:0 (0.55); Erucic C22:1 (0.22); Docosadienoic C22:2 (0.20); Lignoceric C24:0 (0.57) their total amount is 3.07 $g.100g^{-1}$ oil); pulp (Palmitoleic C16:1 (0.28); Heptadecanoic C17:0 (0.73); Arachidic C20:0 (0.60); Eicosenoic C20:1 (0.54); Behenic C22:0 (0.64) their total amount is 2.79 $g.100g^{-1}$ oil); peel (Caprylic C8:0 (0.14); Capric C10:0 (0.10); Lauric C12:0 (0.42); Myristic C14:0 (0.51); Heptadecanoic C17:0 (0.37); Arachidic C20:0 (0.75); Eicosenoic C20:1 (0.10); Behenic C22:0 (0.10); Docosadienoic C22:2 (0.16) their total amount is 2.65 $g.100g^{-1}$ oil).

In this study, total fatty acids varied in different parts of *Pseudocydonia sinensis* and contained oleic acid, palmitic acid, linolenic acid, and linoleic acid. Linoleic acid in seeds accounted for 48.02% of total fatty acids, followed by oleic acid, accounting for 32.12% of total fatty acids (Figure 3). Palmitic acid was the minor fatty acid in leaves, accounting for 9.16% of the total fatty acids. Unsaturated fatty acids were the predominant fatty acids in seeds, accounting for 82.41% of the total fatty acids while saturated fatty acids only accounted for 17.59%.

Palmitic acid, oleic acid, and linoleic acid in the pulp samples were 45.38, 21.32, and 14.93%, respectively. Stearic acid was the minor fatty acid in leaves, accounting for 8.68% of the total fatty acids. Saturated fatty acids were the predominant fatty acids in *Pseudocydonia sinensis* pulp, accounting for 61.16% of the total fatty acids, while unsaturated fatty acids accounted for only 38.84%.

In peel, linoleic acid, palmitic acid, and palmitoleic acid accounted for 42.70, 28.64, and 13.91% of total fatty acids, respectively. Oleic acid was the minor fatty acid in the peel, accounting for 5.88% of the total fatty acids. Unsaturated fatty acids were also predominant in the peel, which accounted for 66.30% of total fatty acid while saturated fatty acids accounted for 33.70%.

According to **Zhou et al. (2020)**, *Pseudocydonia sinensis* fruits were rich in oleanolic acid and ursolic acid, and from the twigs isolated five new oxylipins of chaenomic acid **(Kim et al., 2014)**. Amino acids are structural components of proteins and classified into essential and non-essential. Seeds and fruits are the most analyzed parts of plants for amino acid composition **(Kumar et al., 2019)**. Amino acid content has also been reported in various other fruit plants, namely apples **(Gomis et al., 1990)**, medlar **(Glew et al., 2003)**, quince **(Silva et al., 2004)**, plum **(Ogasanović, 2007)**, cherry **(Cubero et al., 2009)**, pawpaw **(Nam, Jang and Ha Rhee, 2018)**, Chinese chestnut **(Yang et al., 2018)**. There are no reports on free amino acid composition in *Pseudocydonia sinensis* fruits.

Amino acid analysis has shown that the studied *Pseudocydonia sinensis* seeds, pulp, and peel contained 18 amino acids (9 essential and 9 non-essential) (Figure 4).

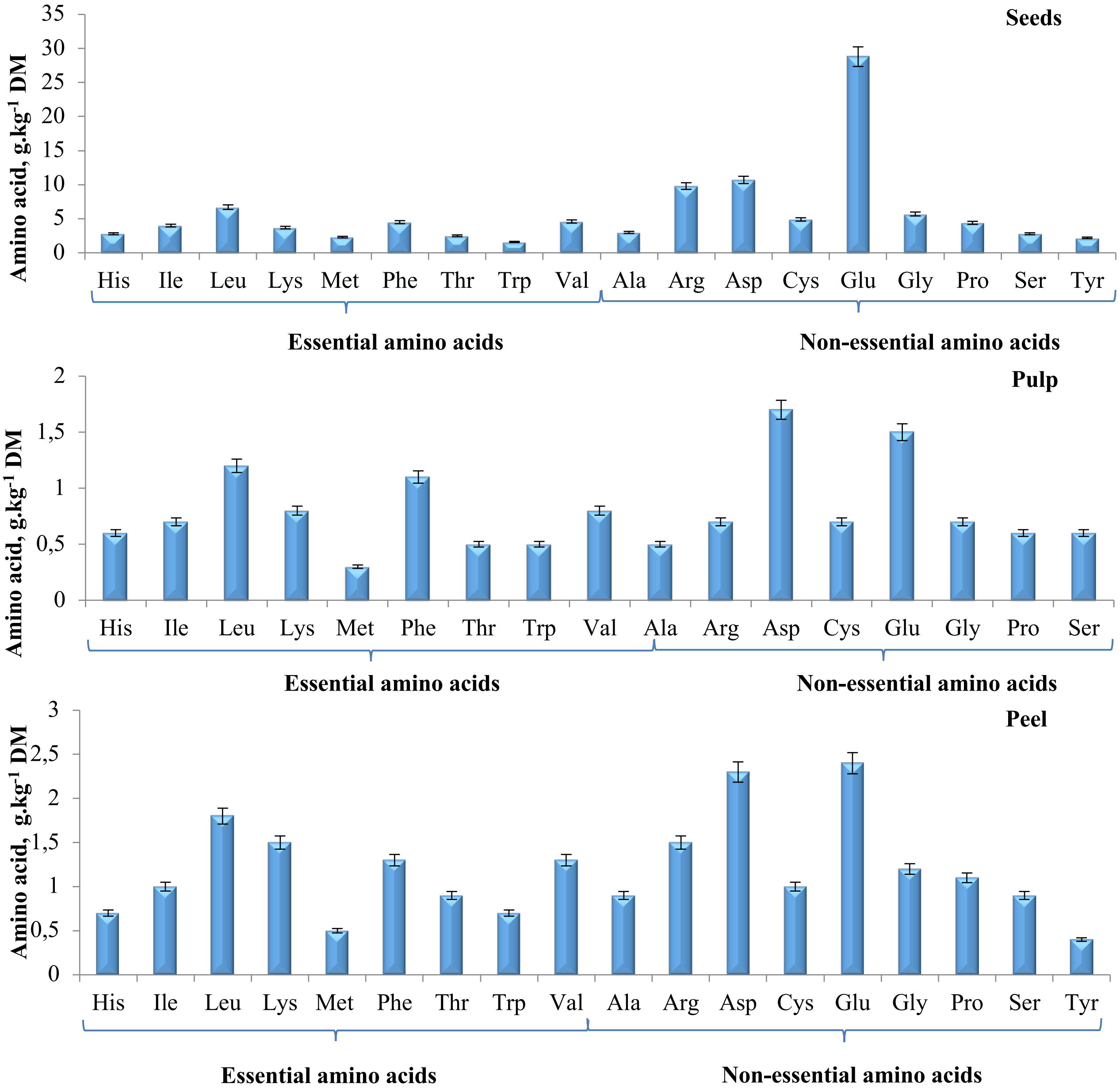

Figure 4 Amino acid composition of *Pseudocydonia sinensis* (Thouin) C.K. Schneid. seeds, pulp and peel (g.kg^{-1} DM).

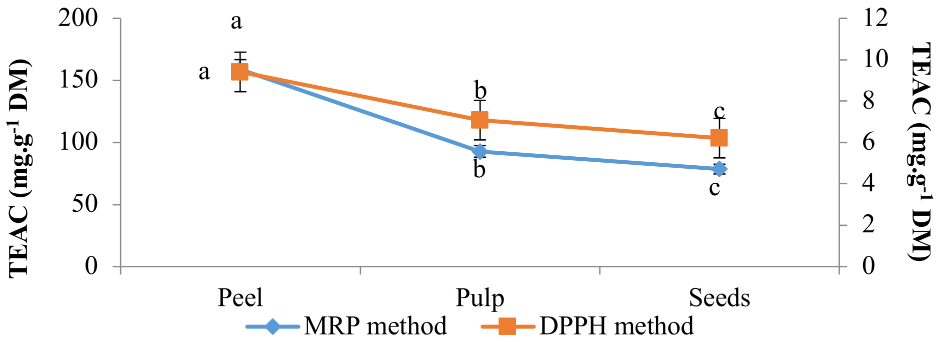

Figure 5 Antioxidant activity of the peel, pulp and seeds of the fruit of *Pseudocydonia sinensis* (Thouin) C. K. Schneid. Note: evaluated by the DPPH method and molybdenum reducing antioxidant power (different superscripts in each column indicate the significant differences in the mean at p <0.05): TEAC – Trolox equivalent antioxidant capacity.

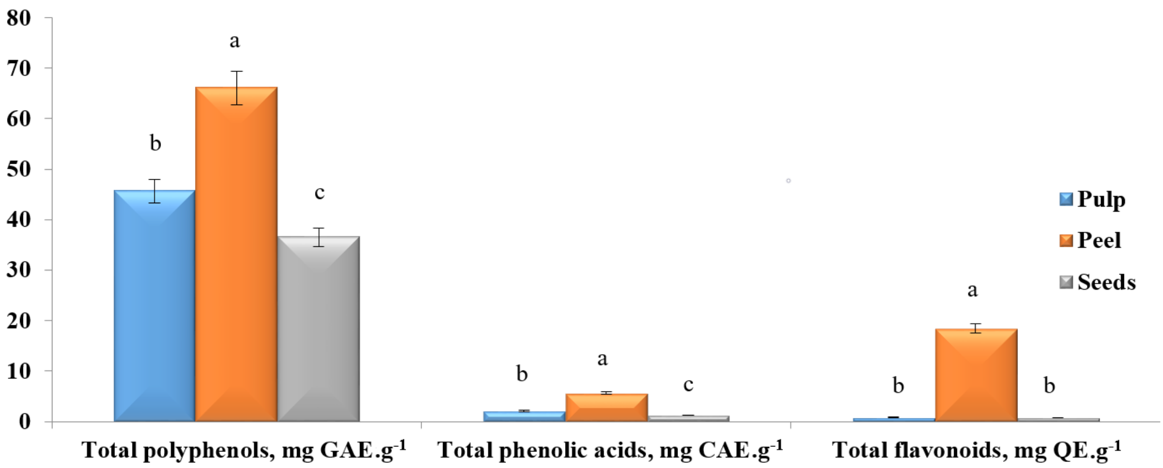

Figure 6 Total polyphenols, phenolic acids and flavonoids of the peel, pulp and seeds of *Pseudocydonia sinensis* (Thouin) C.K. Schneid. Note: different superscripts in each column indicate the significant differences in the mean at p <0.05.

The total amount of amino acids found in the seeds was 105.0 $g.kg^{-1}$ DM, including total essential amino acids (32.70 $g.kg^{-1}$ DM) and percentage of total essential amino acids (31.14%). Glutamic acid was found to be the dominant free amino acid (28.8 $g.kg^{-1}$) in seeds followed by aspartic acid (10.7 $g.kg^{-1}$) and arginine (9.8 $g.kg^{-1}$). In the peel and pulp, the total amino acid content is found much than in the seeds, amounting to 21.4 and 13.7 $g.kg^{-1}$ DM, respectively. The total non-essential amino acids in peel and pulp amounting to 11.7 and 7.2 $g.kg^{-1}$ DM, respectively, and the percentage of total essential amino acids amounting to 9.7 and 6.5%, respectively).

The *Cydonia oblonga* fruits with 21 free amino acids identified. The sum of the 21 free amino acids ranged from approximately 316 to 1357 $mg.kg^{-1}$ for *Cydonia oblonga* pulps and from 512 to 1820 $mg.kg^{-1}$ for *Cydonia oblonga* peels. In what concerns the quince pulps, generally, the three most abundant free amino acids were aspartic acid, hydroxyproline, and asparagine. As a general rule, the three most abundant compounds present in quince peels were glycine, aspartic acid, and asparagine **(Silva et al., 2004)**.

At present, little is known about the levels of trace elements in *Pseudocydonia sinensis* fruits and their parts such as seeds, peel, or pulp. The average contents of the elements in the different parts of *Pseudocydonia sinensis* are shown in Table 2.

Macroelement and trace element concentrations in the seeds samples revealing the following trend: K > P > Mg > Ca > S > Zn > Fe > Cu > Mn > Na > Al > Ni > As > Cr > Se > Pb > Cd > Hg. These elements were also detected in pulp samples according to the following order: K > Ca > P > Mg > S > Fe > Na > Zn > Cu > Al > Mn > Se > Ni > As > Cr > Pb > Cd > Hg. In the peel samples, the following concentrations were observed: K > Ca > P > Mg > S > Fe > Zn > Na > Cu > Al > Mn > Se > Ni > As > Cr > Pb > Cd > Hg.

Among biological activities inherent in plant raw material can be highlighted an antioxidant activity that had widely studied last time. A plant raw is a valuable source of antioxidants with different nature that has a therapeutic value for human health. The study of antioxidant capacity was carried out by different methods **(Gupta, 2015)**.

In our study, the antioxidant activity carried out by the DPPH method of *Pseudocydonia sinensis* peel, pulp and seeds were 9.41, 7.08, and 6.21 mg $TEAC.g^{-1}$ DM, respectively (Figure 5).

Table 2 Mineral composition of *Pseudocydonia sinensis* (Thouin) C.K. Schneid. seeds, pulp and peel (mg.kg^{-1}).

Components	Seeds (*mean ±SD*)	Pulp (*mean ±SD*)	Peel (*mean ±SD*)
P	5189 ±218	1015 ±121	846 ±68
K	10381 ±203	12101 ±236	7572 ±337
Ca	2863 ±95	1285 ±119	3045 ±278
S	1670 ±77	441 ±58	460 ±58
Fe	36.0 ±1.4	36.0 ±1.8	27.0 ±0.4
Mn	13.2 ±0.5	1.7 ±0.05	2.3 ±0.1
Mg	3589 ±68	650 ±97	644 ±68
Na	7.0 ±0.09	10.0 ±0.9	11.0 ±1.1
Al	1.6 ±0.04	2.4 ±0.03	4.7 ±0.2
Cr	<0.2	<0.2	<0.2
Cu	22.0 ±1.8	5.0 ±0.01	6.0 ±0.5
Zn	45.0 ±1.4	9.0 ±1.1	15.0 ±0.9
Se	<0.2	1.03 ±0.01	1.48 ±0.7
As	<0.3	<0.3	<0.3
Cd	0.020 ±0.001	0.017 ±0.001	0.029 ±0.004
Ni	1.35 ±0.01	0.51 ±0.002	0.53 ±0.010
Hg	0.005 ±0.0001	0.005 ±0.0001	0.010 ±0.004
Pb	<0.1	<0.1	<0.1

Note: mean – arithmetic mean; SD – standard error of the mean.

The antioxidant activity of peel, pulp, and seeds extracts measured by molybdenum reducing antioxidant power was from 158.81, 92.83, and 78.58 mg TEAC.g^{-1} DM, respectively.

Earlier in our study **(Grygorieva et al., 2020)** the antioxidant activity of peel and pulp of *Pseudocydonia sinensis* of different genotypes growing in the arboretum (Slovakia) also confirmed the higher antioxidant potential of peel extracts compared to a pulp. Our results were similar according to previous studies that confirmed the higher antioxidant activity of the peel of *Pseudocydonia sinensis* than the pulp **(Monka et al., 2014)**. The higher antioxidant activity of peels of other fruits than pulp has been widely reported, namely mango **(Ajila et al., 2007)**, different varieties of peach **(Liu et al., 2018)**, Chinese jujube **(Xue et al., 2009)**. In a study by other authors, the total antiradical activity of aqueous and methanolic extracts of dry peels was 91.87 – 93.25% and that of dry pulp 80.39 – 84.11% **(Monka et al., 2014)**. In a study by **Baroni et al. (2018)**, the antioxidant activity of *Cydonia oblonga* Mill. pulp, peel, seed, and jam extracts evaluated by the DPPH assay identified that methanolic peel extracts demonstrated the strongest activity, followed by pulp and seed extracts. A study by **Silva et al. (2004)** showed that the phenolic fraction of the seed extracts have stronger antioxidant activity than the peel and pulp extracts. Also, the different studies determined that the antioxidant activity by the DPPH method of methanol extracts of *Malus domestica* Borkh. cultivars were higher in peel extracts (71.7 – 84.9%) than in pulp ones (43.9 – 52.8%) **(Manzoor et al., 2012)**.

Polyphenols are a large group of organic compounds with antioxidant and anti-inflammatory properties that may play a vital role in metabolic processes in the human body **(Cory et al., 2018)**. **Osawa et al. (1999)** and **Oku, Ueda and Ishiguro (2003)** report that the polyphenols of *Pseudocydonia sinensis* are considered to be the most important biologically active ingredients because of their various pharmacological actions and high content. The content of total polyphenols (Figure 6) in the peel, pulp, and seeds was from 66.06, 42.02, and 36.05 mg GAE.g^{-1} DM, respectively.

It was previously reported that the content of total polyphenols in the peel and flesh in different genotypes of *Pseudocydonia sinensis* growing under Slovakian conditions, the content of total polyphenols in the peel and flesh was between 55.61 and 82.02 and between 34.73 and 66.99 mg GAE.g^{-1} DM, respectively **(Grygorieva et al., 2020)**. Studies by **Manzoor et al. (2012)** and **Al-Snafi (2016)** confirmed the high content of phenolic compounds in the rinds of *Malus domestica* and *Cydonia oblonga*.

Flavonoids are a group of natural substances that play variable biological activities as well as other polyphenol compounds such as anti-inflammatory, antimutagenic, anticancer, antioxidative, etc. **(Panche, Diwan and Chandra, 2016)**.

The total flavonoid content in the peel, pulp, and seeds was 18.39, 0.80, and 0.75 mg QE.g^{-1} DM, respectively. The total flavonoid content in the peel and pulp of *Pseudocydonia sinensis* fruits of different genotypes growing in Slovakia was 11.00 to 26.72 and 0.59 to 1.07 mg QE.g^{-1} DM, respectively **(Grygorieva et al., 2020)**. It was previously reported **(Amirahmadi, Abdollahi and Ayyari, 2017)** that the total flavonoid content in fruits of closely related *Cydonia oblonga* species was 6.2 mg QE.g^{-1}.

Phenolic acids are a large group of phenolic compounds that possess numerous biological activities, among which antioxidant action **(Kumar and Goel, 2019)**.

It was found that the total phenolic acid content varies significantly between samples (Figure 6). The content of phenolic acids in the peel, pulp, and seeds was 5.68, 2.08, and 1.23 mg CAE.g^{-1} DM, respectively.

The content of phenolic compounds in the fruit of *Pseudocydonia sinensis* was in agreement with previous research **(Hamauzu et al., 2006; Grygorieva et al., 2020)**. According to our previous studies **(Grygorieva et al., 2020)** of fruits from Slovakia, the total phenolic content in peel and pulp was 4.20 – 8.39 and 1.12 – 3.97 mg CAE.g^{-1} DM. According to **Hamauzu et al.**

(2005), the total content of phenols in fruits of *Pseudocydonia sinensis* was 1280 mg.100g^{-1} FW. This was four and twenty times higher than in *Cydonia oblonga* and *Malus domestica*, respectively. Differences between present and previously conducted studies in the chemical composition of fruit of *Pseudocydonia sinensis* could be attributed to the geographical plant origin and different methods of extraction. This has been previously reported in other plant species, namely *Diospyros virginiana* **(Grygorieva et al., 2018)**, *Sambucus nigra* **(Horčinová Sedláčková et al., 2018; Horčinová Sedláčková et al., 2019)**, *Ziziphus jujuba* **(Ivanišová et al., 2017)**, *Corylus avellana* **(Nikolaieva et al., 2019)**, *Solidago canadensis* **(Shelepova et al., 2019)**, *Hippophae rhamnoides* **(Ivanišová et al., 2020)**.

CONCLUSION

The chemical composition, antioxidant activity, total polyphenol, flavonoid, and phenolic acid content of peel, pulp, and seeds extracts from *Pseudocydonia sinensis* were studied. The content of micro and macronutrients was found in the seeds much higher than in the pulp and peel. It should also be noted that all *Pseudocydonia sinensis* samples are a very valuable source of potassium, which is necessary for the water and electrolyte balance. Total fatty acids predominate in the pulp than in the peel and seeds. Total amino acids predominate in the seeds than in the peel and pulp. The results revealed the highest content of bioactive compounds (total polyphenols, flavonoid, and phenolic acid) and antioxidant activity in peel compared with pulp and seeds. This study demonstrates the potential application of *P. sinensis* as a valuable source of natural phenolic antioxidants and can be used as raw material to elaborate diverse food products, providing important functional properties. When introduced in Ukraine and Slovakia, the amount of beneficial substances in fruits and seeds is not reduced, which makes it possible to recommend this species for wide cultivation.

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The authors declare no conflict of interest.

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This article does not contain any studies that would require an ethical statement.

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