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Biochemistry

UPLC PDA, MS Analysis of Main Biologically Active Compounds of Fruits *Prunus cerasifera* Ehrh Grown in Western Georgia

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(Presented by Academy Member Giorgi Kvesitadze)

The goal of the research was to study the main bioactive compounds of wild-growing forms and fruits of some varieties of tkemali (Lat. *Prunus cerasifera* Ehrh) grown in Georgia, using the UPLC PDA, MS methods. In all the samples studied by us, the total amount of organic acids is quite high and ranges from 3.2% to 5.5%. In all cases, the dominant acid is malic acid (1.89% to 2.59%). More than 1/5 part of the content of citric acids falls on quinic acid (from 0.8% to 1.06%). Citric acid is the smallest in quantity in the fruit of tkemali (from 0.01% to 0.06%). As a rule, the predominant carbohydrate in tkemali fruits is up to 6.7%, its content is almost two times higher than fructose (up to 2.5%) and the indicator of sucrose is different for different varieties and forms. A high content of sucrose (more than 6.0%) is characteristic of red-leaved red-fruited varieties, regardless of the place of sampling. There have been identified 6 anthocyanin glycosides. Using the UPLC-PDA-MS method, the dominant compounds in all cases are cyanidin derivatives (cyanidin-3-0-rutinoside), and their content in the pulp, juice and skin is 12.48–9.6–25.6 mg 100 g^{-1}, respectively. Anthocyanins in the wild forms of tkemali are much higher (20.07±0.602 mg100 g^{-1} fw), especially in the skin (112.89±3.612 mg 100 g^{-1} fw), than in cultivated varieties (4.57±0.137 mg 100 g^{-1} fw). The high antioxidant activity of tkemali fruit has been established by DPPH method. *© 2023 Bull. Georg. Natl. Acad. Sci.*

tkemali (*Prunus cerasifera* Ehrh), compounds, quality, UPLC PDA, MS analysis

The interest in raw materials from the Prunus family rich in biologically active compounds, as well as products obtained from it, is quite high all over the world. Biologically active compounds of fruits, bones and leaves have been studied [1-3]. Variety of tkemali has been of the greatest research interest recently. Many biologically active compounds have been identified in its fruits and the chemical composition of new selective forms of myrobela (*Prunus cerasifera* L.) and their effect on the taste characteristics of fruits has been studied [4]. There has also been studied the quantitative

content of phenolic compounds, organic acids, the chemical composition of hybrid varieties], the content of fat and fatty acids of prunus skin, as well as the possibility of obtaining biodiesel [5]. In several varieties (Turkey), there has been examined the content of carbohydrates, organic acids and other compounds during fruit ripening[6]. Using the HPLC-DAD/ESI-MS method, the anthocyanins content in the leaves of *Prunus cerasifera* was studied[7]; the resulting preparations were used to obtain a nanopreparation [8]. A study of *Prunus cerasifera* tree gum showed that the dominant substances are arabinose and galactose [9].

Prunus cerasifera is a widespread plant in Georgia. There can be found both wild and cultivated species of this plant. In different corners of Georgia, people prepare various products from the fruits of tkemali according to different recipes: sauce, tklapi, korao, jam and others. Nevertheless, in the numerous literature sources reviewed by us, only works published in 1981 deal with studies of tkemali fruits growing in Georgia [10], as well as their morphological diversity [11].

The present study deals with the qualitative and quantitative content of biologically active compounds in the fruits of wild and cultivated forms of tkemali grown in Georgia.

Materials and Methods

Chemicals and reagents. All solvents used for study were HPLC-MS pure (Methanol, Acetonitrile (CAN), Formic acid (F.A), ethylene acetate – Merk, Germany). Aluminum chloride (Merk, Germany), 2,2-diphenyl-1-picrylhydrazyl (DPPH), vanillin, Folin Ciocaulteu reagent, rutin, gallic acid, citric acid, malic acid and chlorogenic acid (Sigma-Aldrich).

Plant materials. We harvested fruits in 2016-2021 in different months of the period of consumer ripeness. The object of the study is the fruits of wild forms and cultivars of tkemali (Lat. *Prunus cerasifera* Ehrh). Tkemali is a perennial fruit-bearing plant of the genus stone fruit of the Rosaceae family, sometimes it is a tree-like shrub, highly branched, prickly or thornless plant. Tkemali fruits were harvested in different regions of Georgia at the stage of maturity: Gazafkhulis merckhali (Gonio) harvested -29.06; Mirabela (Gonio 31.07); Citeli drosha (Gonio 05.08); Adjaruli vardisferi (Khulo 03.08); Citeli drosha (Khulo 03.08); Akhalcikhura 13.08; Ajanis Ungrula Batumi 16.08); Wild red tkemali (Khulo Danisparauli 07.08); Wild red tkemali (Khulo 24.09); Wild dark red tkemali (Khulo 24.09); Wild dark red tkemali (Khulo Gorjomi 27.09)

Physicochemical properties. The total soluble solids (TSS) (0Brix) of tkemali was determined with digital refractometer (Atago), fruit mass was determined by analytical balance (GAS, South Korea), total titration activity (TA) was determined using buffer 0.1 mol NaOH and by indicator pH meter (pH 7.1) (Mettler Toledo-Switzerland), Spectral analysis by spectrophotometer UV 5 (Mettler Toledo-Switzerland).

Preparation of extracts of tkemali fruit. Tkemali fruit extracts have been prepared according to the scheme. We divided the fruit into skin, pulp and pits, as well as juice. Ethanol (1:1) was added to the juice to precipitate pectin and other polymers and centrifuged for 5 min at 12,000 rpm at 50°C. 5 g of pulp and 1 g of skin (separately) were added to 100 ml of ethanol (1% HCl) and placed under the influence of an ultrasonic processor (Hielscher UP400 St ultrasonic processor) until cavitation was achieved (about 1.5 min). It was centrifuged (under previously described conditions) and concentrated to an aqueous residue (5ml).

Prior to chromatographic separation, we prepared the sample (2ml of concentrate) for chromatography using the Solid Phase Extraction (Waters) method, which involves loading the sample onto a column (SPE-C18) and activating the column with methanol before loading the samples. Then the

activated sorbent was balanced with distilled water. Only after that we got the sample on the cartridge through vacuum. At the next stage, we obtained water-eluting compounds from the sorbent and, if necessary, concentrated them (fraction 1). Non-anthocyanin phenolic compounds were eluted with ethyl acetate (fraction 2) (subsequently concentrated to dryness in vacuum), and anthocyanins were eluted with methanol acidified with 0.5% formic acid (fraction 3). After concentrating the resulting eluant, the sample was filtered through Waters Acrodisc LC PVDF 13 mm 0.45 μm filter.

Determination of total phenols occurred by Folin-Ciocalteu method (calculated on gallic acid) [12], determination of AA – using the stable radical of 2,2-diphenyl-1-picrylhidrazyl (DPPH) methods, quantitative determination of total flavonoids by spectral methods (AlCl3 – reactive calculated by rutin) [13].

UPLC PDA, MS analysis. Individual compounds were determined by Ultra Performance Liquid Chromatography photodiode array and mass (UPLC-PDA, MS) detectors (Waters (USA): Acquity H class Quaternary Solvent Manager, Sample manager-FTN, PDA Detector, mass QDa Detector) method. Organic acid and carbohydrate analysis by column (Phenyl 3.5 μm, 4.6x150 mm), solvent 1 deionized water and solvent 2 ACN (gradient). Analysis of phenolic compounds by column BEN C18, 1.7 μm, Solvent 1 – 0.2% F.A, solvent 2 – ACN, (gradient), Flow 0.3 mL min^{-1}, column tem. 40°C, MS scan 100-1200 da, Probe 600°C, Positive (ESI-MS)+ or negative (ESI-MS)-, Spray voltage at 0.8 kV, capillary 1.5 kV, CV 5-40; PDA UV-Vis spectra were scanned 215-500 nm [14].

Statistical analysis. Data were subjected to ANOVA and the means were compared with the Least Significant Difference test (LSD) at a 5% level of probability. Difference among means were compared using Duncan's Multiple Range test at significant level 95% ($p \leq 0.05$). All statistical analysis was performed using Excel software package.

Results and Discussion

Physicochemical properties – the fruits of tkemali vary significantly in size depending on their origin. Wild forms produce small fruits, measuring approximately 20 mm in cross-section and 25 mm in longitudinal section. Conversely, cultivars produce larger fruits, measuring 27-30 mm and 35-37 mm in the green-leaved, red-fruited and red-leaved, red-fruited forms, respectively. As a result, the fruits also differ in weight and volume, with wild-growing forms weighing 6-8 g and cultivated varieties weighing 18-25 g.

The taste of fruits is associated with the content of organic acids and carbohydrates. Sweet and sour taste is determined by their ratio along with the quality content. Fraction 1 was obtained by solid-phase extraction, in which organic acids and carbohydrates were extracted, 3 organic acids (Fig. 1) and 3 hydrocarbons (Fig. 2) can be considered as the dominant compounds in the chromatographic study.

Substance (s)1 – [M-H-] – m/z 132.93 dominant compounds, fragmentation m/z 114.99, retention time 6.322 min, maximum absorbance UV – 215.5 nm. According to the standard (malic acids (Sigma-Aldrich) composition and weight of METLIN compounds, (s)1 corresponds to malic acids ($C_4H_6O_5$); (s)2 – [M-H-] – m/z 190.97, fragmentation result – m/z 111 peaks; retention time – 7.584 min, maximum absorbance – UV-210.7 nm, corresponds to citric acids ($C_6H_8O_7$); (s)3 – [M-H-] – m/z 190.98; retention time – 5.748 min, maximum absorbance – UV-213.1 nm, corresponds to quinic acids ($C_7H_{12}O_6$) (Fig. 1); (s)4 – [M-H-] – m/z 179.06, but the addition of formic acid leads to the formation of a pseudomolecule m/z+F.A 224.98. The retention time of the chromatogram is 5.146 min, the absorption maximum is not visible in the UV spectrum, corresponds to glucose; (s)5 – [M-H-] – m/z 178.92, but the addition of formic acid leads to the

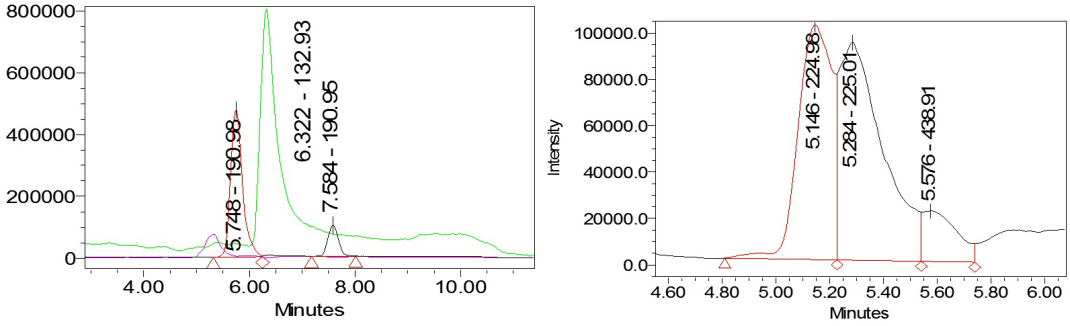

Fig. 1. *Prunus cerasifera* fruit organic acid and carbohydrate UPLC-PDA-MS chromatogram SIR M/Z (M-H).

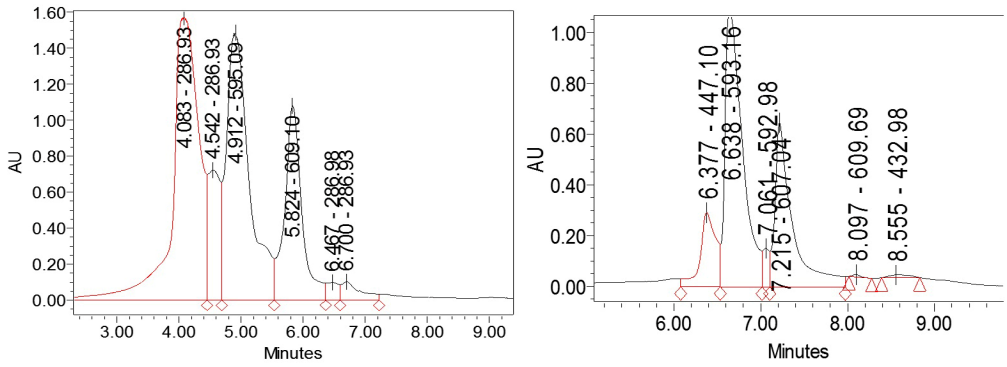

Fig. 2. Substance 7 and 8 UPLC-PDA- MS chromatogram M/Z (M+H) and M/Z (M-H).

formation of a pseudomolecule m/z+F.A. 225.01, and the addition of chloride ions leads to the formation of m/z 214.87. Retention time 5.284min, maximum absorbance not visible in UV spectrum, corresponds to fructose; (s)6 – [M-H-] – m/z 341.10, but the addition of formic acid leads to the formation of a pseudomolecule m/z+F.A. 387.04 and the addition of chlorine ion gives m/z+CI= 377.04. Retention time – 5.600min, maximum absorption is not visible in the UV spectrum, corresponds to sucrose (Fig.1).

In all the samples studied by us, the total amount of organic acids is quite high and ranges from 3.2% to 5.5%. In all cases, the dominant acid is malic acid (1.89% to 2.59%). More than 1/5 part of the content of citric acids falls on quinic acid (from 0.8% to 1.06%). Citric acid is the smallest in quantity in the fruit of tkemali (from 0.01% to 0.06%) (Table). We compared the obtained organic acid quantification data with results obtained in other geographic settings. Our data on the dominance of malic acid were confirmed. The content of malic acid is 0.896±0.008 g 100 g^{-1}, which is 2 times or more less than in the fruits collected under our conditions (2.18±0.065%). There is a small amount of citric acid (13.898±0.07mg 100g^{-1}), which practically corresponds to our conditions (0.09±0.003%). Among other acids, succinic and fumaric acids were recorded in Turkey, which are not recorded in our country. The content of quinic acid in Georgian realities is quite high, from 0.42±0.015% to 1.04±0.037%. The total acidity is also different, on the example of Turkey – 0.355±0.006 mmol TE kg^{-1} fw, in our conditions it is much higher up to 3.5±0.126% [3].

As a rule, the predominant carbohydrate in tkemali fruits is glucose (up to 6.7%); its content is almost two times higher than fructose (up to 2.5%), and the indicator of sucrose is different for different varieties and forms. A high content of sucrose (more than 60%) was characteristic of red-leaved red-fruited varieties (Citeli drosha – Khulo), regardless of the place of sampling. Under Romanian conditions, the dry matter content is much higher

Table. The content of organic acid and carbohydrate in the fruit and juice in different varieties of tkemali

	Sample name	Tsiteli drosha (Gonio)	Gazaphkhulis mertskhali	Adjaruli vardispheri	Wild red tkemali
1	Quinic acid, %	0.42±0.015	1.04±0.037	0.64±0.020	0.53±0.021
2	Citric acid, %	0.06±0.0002	0.02±0.0007	0.03±0.0009	0.03±0.001
3	Malic acid, %	2.52±0.085	2.10±0.079	2.21±0.070	2.32±0.092
4	Total acid, %	3.4±0.115	3.5±0.126	3.2±0.102	3.2±0.112
5	Fructose g/L	0,4815±0.017	1,4805±0.044	1,5345±0.052	2,493±±0.079
6	Glucose g/L	4,707±0.188	6,1155±0.207	7,182±0.272	5,497±0.208
7	Sucrose g/L	7,4115±0.281	0,018±0.0007	1,282±0.044	1,7325±0.065
8	Total sugar g/L	12,6±0.453	7,614±0.274	9,9985±0.319	9,7225±0.330

and exceeds 20% [38], while in Serbia this figure is more than 15% [39], which significantly exceeds the figures obtained in the course of our study. An exception is the late-ripening variety Adjaris Ungrula, in which, by the end of August, the solids content in the juice reaches a maximum of 15% Brix.

(s)7,8 [M+H] – m/z 449.08 (447.10) has been fixed on the chromatogram (2 compounds), The retention time is 4.156 and 4.664 min, the absorption maximum in the ultraviolet beam is fixed at 279.8 nm and 518 nm, molecular weight of the fragment m/z 286.92 (cyanidin). According to the mass base of METLIN compounds (https://metlin.scripps.edu), (s)7 corresponds to cyanidin-3-O-galactoside, the empirical formula of which is MW: 449.4 g mol^{-1}, $C_{21}H_{21}O_{11}$+ and (s) 8 corresponds to cyanidin-3-O-glucoside MW: 449.4 g mol^{-1}, $C_{21}H_{21}O_{11}$+ cyanidin 3-O-glucoside; (s) 9; 10 [M+H] – m/z 595.04 (593.16) has been fixed on the chromatogram with the retention time 6.320 and 6.894 min, the absorption maximum in the UV 279.8 nm and 518 nm, result of fragmentation m/z 286.89 (cyanidin). (s)9 cyanidin-3-O-rutinoside, MW: 595.5 m mol^{-1}, $C_{27}H_{31}O_{15}$+; (s)10 cyanidin-3-(6-trans-pcoumaroyl) glucoside MW: 595.5 m mol^{-1}, $C_{30}H_{27}O_{13}$+; (s)11 [M+H] – m/z 609.15 (607.04) has been fixed on the chromatogram with the retention time 7.103 min, the absorption maximum in the UV 279.8 nm and 518 nm, result of fragmentation m/z 300.91 (peonidine). (s)11 peonidin 3-rutinoside MW: 609.6 g/mol, $C_{28}H_{33}O_{15}$+; (s)12 [M+H] – m/z 637.00 has been fixed on the chromatogram with the retention time 8.391 min, the absorption maximum in the UV 279.8 nm and 518 nm, result of fragmentation m/z 331.09 (malvidin). Substance 12 malvidin-3-O-(6-p-coumaroyl)glucoside MW: 639.6 g/mol, $C_{32}H_{31}O_{14}$+; using the UPLC-MS method, there have been identified 6 anthocyanin glycosides.

After the identification of the compounds, their quantitative analysis has been carried out. Anthocyanins are unevenly distributed in the fruit. Anthocyanins are accumulated in the skin, regardless of the variety and species, their content is 3-4 times higher than the amount of anthocyanins in the whole fruit, pulp or juice (112 mg 100 g^{-1} of raw mass in the skin of wild tkemali). In addition, in the skin there are mainly delphinidin derivatives (40.1 mg 100 g^{-1} up to 40% of the total content) and in the juice, mainly cyanidin derivatives are transferred (12.2 mg 100 g^{-1}, up to 45% of the total content). Anthocyanins are more abundant in wild forms (mg 100 g^{-1}) and relatively less in cultivated varieties, and they vary in different varieties. In this regard, a high rate is recorded in Adjaris Ungrula and Tsiteli Drosha (14.71 and 18.86 mg 100 g^{-1}, respectively). The data obtained by us are similar to the myrobalan (*Prunus cerasifera* L.) variety "Alimena" in Italy, where 20.24-55.33 cyanidine-3-O-glucoside 100 g^{-1} FW was recorded [5]. One and the same variety contains anthocyanins in different amounts in various geographical conditions. In Tsiteli Drosha, gathered at 700 m above sea level (Khulo), their content is almost 3 times more than those collected in Gonio (10 m above sea level).

The chemical composition of the fruit parts was found to be proportionally related to their antioxidant activity. The skin with 4.71 mg sample 50% inactivate 0.1 mM DPPH showed the highest rate. Relatively less amount has the juice – 8.22 mg and the whole fruit – 9.56 mg. Anthocyanins are distributed accordingly in these parts (56.41 ± 1.895 mg $100\,g^{-1}$, 2.04 ± 0.081 mg $100\,g^{-1}$ and 14.72 ± 0.441 mg $100\,g^{-1}$ respectively). The obtained data are in agreement with other studies carried out abroad [5], where the high antioxidant activity of the fruit has been recorded.

Conclusions

Three organic acids and three carbohydrates have been identified in the fruit of tkemali for the first time under the conditions of Georgia. Anthocyanin glycosides- cyanidin-3-0-galactoside, cyanidin-3-0-glucoside, cyanidin-3-0-rutinoside, cyanidin-3-(6-trans-pcoumaroyl) glucoside, peonidin-3-0-rutinoside, malvidin- 3-0-para-coumaroyl glucoside. Their quantitative content in several cultivars and wild forms of tkemali fruits has been studied. It has been determined that the anthocyanin content of the fruit, juice and its residue and, accordingly, the antioxidant activity are different.

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ბიოქიმია

დასავლეთ საქართველოში მოყვანილი ტყემლის ***Prunus cerasifera*** **Ehrh** ნაყოფის მაჟორული ბიოაქტიური კომპონენტების **UPLC PDA, MS** ანალიზი

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ნაშრომის მიზანია საქართველოში მოზარდი ტყემლის ველური ფორმების და ზოგიერთი ჯიშის ნაყოფის მაჟორული ბიოაქტიური ნაერთების კვლევა UPLC PDA, MS მეთოდების გამოყენებით. ჩვენ მიერ შესწავლილ ყველა ნიმუშში ორგანულ მჟავათა საერთო რაოდენობა საკმაოდ მაღალია და მერყეობს 3,2-დან 5,5%-მდე. ყველა შემთხვევაში, დომინანტური მჟავა არის ვაშლის მჟავა (1,89-2,59% ნედლი მასის). მჟავათა შემცველობის 1/5-ზე მეტი მოდის

ქინის მჟავაზე (0,8-დან 1,06%-მდე). ლიმონის მჟავა რაოდენობით ყველაზე მცირეა ტყემლის ნაყოფში (0,01-დან 0,06%-მდე). ტყემლის ნაყოფებში უპირატესი ნახშირწყლებია გლუკოზა (6,7%-მდე), და ფრუქტოზა (2,5%-მდე), ხოლო საქაროზას მაღალი შემცველობა (6,0%-ზე მეტი) დამახასიათებელი იყო წითელფოთლიანი წითელნაყოფიანი ჯიშებისთვის, სინჯის აღების ადგილის მიუხედავად. UPLC-PDA-MS მეთოდის გამოყენებით იდენტიფიცირებულია 6 ანტოციანური გლიკოზიდი. ანტოციანებიდან დომინანტი ციანიდინი და მისი წარმოებულებია. ტყემლის ველურ ფორმებში ანტოციანები გაცილებით მეტია (20,07±0,602მგ100გ$^{-1}$, ნედლ მასაზე გადაანგარიშებით (ნ.მ.გ.)), განსაკუთრებით კანში (112,89±3,612მგ100გ$^{-1}$ (ნმგ)), ვიდრე ეს კულტურულ ჯიშებშია (4,57±0,137მგ100გ$^{-1}$, (ნმგ)). დადგენილია ტყემლის ნაყოფის მაღალი ანტიოქსიდანტური აქტივობა DPPH მეთოდით.

REFERENCES

1. Jawad M., Ali M., Qasim S., Akbar A., Khan N. A., Sadiq M. B. (2022) Determination of phenolic compounds and bioactive potential of plum (Prunus Salicina) peel extract obtained by ultrasound-assisted extraction. *BioMed Res. Int. 2022*, 7787958. https://doi.org/10.1155/2022/7787958.
2. Wang Y., Chen X., Zhang Y., Chen X. (2012) Antioxidant activities and major anthocyanins of myrobalan plum (*Prunus cerasifera* Ehrh.). *J. Food Sci.* 77 (4), C388–C393. https://doi.org/10.1111/j.1750-3841.2012.02624.x.
3. Celik F., Gundogdu M., Alp S., Muradoglu F., Ercişli S., Gecer M. K., Canan I. (2017) Determination of phenolic compounds, antioxidant capacity and organic acids contents of *Prunus domestica* L., *Prunus cerasifera* Ehrh. and *Prunus spinosa* L. Fruits by HPLC. *Acta Chromatogr.* 29 (4), 507–510. https://doi.org/10.1556/1326.2017.00327.
4. Sottile F., Napolitano A., Badalamenti N., Bruno M., Tundis R., Loizzo M. R., Piacente S. (2023) New bloody pulp selection of myrobalan (*Prunus cerasifera* L.): pomological traits, chemical composition, and nutraceutical properties. *Foods*, 12 (5), 1107. https://doi.org/10.3390/foods12051107.
5. Savic Gajic I., Savic I., Cekić N., Đorđević D., Bogićević M. (2022) The valorization of plum seed oil for the development of topical formulation. *Adv. Technol.*, 11: 22–31. https://doi.org/10.5937/savteh2201022S.
6. Gündüz K., Saraçoğlu O. (2012) Variation in total phenolic content and antioxidant activity of *Prunus cerasifera* Ehrh. Selections from Mediterranean Region of Turkey. *Sci. Hortic.* 134, 88.
7. Liu, W., Nisar, M. F., Wan, C. *J. Chem.* (2020) Characterization of phenolic constituents from *Prunus cerasifera* Ldb leaves. *J. Chem.*, e5976090. https://doi.org/10.1155/2020/5976090.
8. Jaffri S. B., Ahmad K. S. *Open Chem.* (2018) *Prunus cerasifera* Ehrh. Fabricated ZnO nano falcates and its photocatalytic and Dose Dependent in Vitro Bio-Activity: photodegradation and antimicrobial potential of biogenic ZnO Nano Falcates. *Open Chem.*, **16** (1), 141–154. https://doi.org/10.1515/chem-2018-0022.
9. Shi Z., Jia C., Wang D., Deng J., Xu G., Wu C., Dong M., Guo Z. (2019) Synthesis and Characterization of Porous Tree Gum Grafted Copolymer Derived from Prunus Cerasifera Gum Polysaccharide. *Int. J. Biol. Macromol.*, 133, 964–970. https://doi.org/10.1016/j.ijbiomac.2019.04.128.
10. Chemical composition of the fruit of Georgian myrobalan plum from the Krasnodar territory varieties of *Prunus Cerasifera* Ssp. Georgica.1. *Tr. Po Prikl. Bot. Genet. Sel.* 1981, 3: 66–67, 90–93.
11. Baiashvili E. (2007) Morphological Diversity of Georgian Forms of *Prunus cerasifera* Ehrh. *Bull. Georg. Natl. Acad. Sci.*, 175, #2: 98-100.
12. Gabour Sad, T., Djafaridze I., Kalandia A., Vanidze M., Smilkov K., Jacob C. (2021) Antioxidant Properties of the Native Khechechuri Pear from Western Georgia. *Sci.*, 3 (1). https://doi.org/10.3390/sci3010010.
13. Kharadze M., Abashidze N., Djaparidze I., Vanidze M., Kalandia A. (2018) Antioxidant Activity of Chestnut Honey Produced in Western Georgia. *Bull. Georg. Natl. Acad. Sci.*, **12** (2): 145–151.
14. Kharadze M., Djaparidze I., Shalashvili A., Vanidze M., Kalandia A. (2018) Phenolic compounds and antioxidant properties of some white varieties of grape wines spread in Western Georgia. 12(3).

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