

Study of total antioxidant capacity of red raspberry (*Rubus idaeus* L.) shoots

Estudio de la capacidad antioxidante total de brotes de frambuesa roja (*Rubus idaeus* L.)

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Abstract

Background: Today, cardiovascular, oncological, and neurodegenerative diseases are the main causes of death in the world, according to official World Health Organization (WHO) statistics. Antioxidants are used to treat and prevent these diseases. In order to develop optimal technology for obtaining drugs based on plant extracts with antioxidant action, it is necessary to determine the total antioxidant capacity of raspberry shoots. **Objectives:** The study aimed to determine the total antioxidant capacity of red raspberry shoots, study the content of biologically active substances (BAS), and the antioxidant activity of red raspberry shoot extracts obtained during subsequent exhaustive extraction.

Methods: The number of phenolic compounds, catechins, flavonoids, and hydroxycinnamic acids was determined by a spectrophotometric analysis method, whereas organic acids were determined by the alkalimetric method in red raspberry shoot extracts; the antioxidant activity of obtained extracts was evaluated by potentiometric method.

Results: The total antioxidant capacity of red raspberry shoots was 164.12 mmol-equiv./m_{dry weight}, the sum of the total content of phenolic compounds was 24.40 mg gallic acid (GA)/mL, catechins – 21.36 mg epigallocatechin-3-O-gallate (EGCG)/mL, flavonoids – 0.77 mg rutin (R)/mL, hydroxycinnamic acids derivatives – 2.56 mg chlorogenic acid (ChA)/mL and organic acids – 1.88 mg citric acid (CA)/mL in red raspberry shoot extracts obtained during subsequent exhaustive extraction. The analysis showed that there is a very high positive correlation between antioxidant activity and total phenolic compounds, catechin, flavonoid, hydroxycinnamic acids derivatives, and organic acids content in red raspberry shoot extracts.

Conclusions: Total red raspberry shoots' antioxidant capacity has been determined. The study results can be used to develop optimal technology for obtaining drugs based on the extract of red raspberry shoots, which has an antioxidant effect.

Key words: *Rubus idaeus L.*, Total Antioxidant capacity, Total Phenolic content, Total Organic acids content, Correlation, Sequential Exhaustive extraction

Resumen

Contexto: Hoy en día, las enfermedades cardiovasculares, oncológicas y neurodegenerativas son las principales causas de muerte en el mundo según estadísticas oficiales de la Organización Mundial de la Salud OMS. Los antioxidantes se utilizan para tratar y prevenir estas enfermedades. Para desarrollar una tecnología óptima para la obtención de fármacos a base de extractos de plantas con acción antioxidante, es necesario determinar la capacidad antioxidante total de los brotes de frambuesa.

Objetivos: El estudio tuvo como objetivo determinar la capacidad antioxidante total de los brotes de frambuesa roja, estudiar el contenido de sustancias biológicamente activas (SBA) y la actividad antioxidante de los extractos de brotes de frambuesa roja obtenidos mediante extracción exhaustiva.

Métodos: La cantidad de compuestos fenólicos, catequinas, flavonoides y ácidos hidroxicinámicos se determinó por método de análisis espectrofotométrico, mientras que los ácidos orgánicos por método alcalimétrico en extractos de brotes de frambuesa roja; La actividad antioxidante de los extractos obtenidos se evaluó por método potenciométrico.

Resultados: La capacidad antioxidante total de los brotes de frambuesa roja fue de 164.12 mmol-equiv./m_{de peso seco}, la suma del contenido total de compuestos fenólicos fue de 24.40 mg gálico ácido (GA)/mL, catequinas – 21.36 mg epigallocatequina-3-O-galato (EGCG)/mL, flavonoides – 0.77 mg rutina (R)/mL, derivados de ácidos hidroxicinámicos – 2.56 mg clorogénico ácido (ChA)/mL y ácidos orgánicos – 1.88 mg cítrico ácido (CA)/mL en extractos de brotes de frambuesa roja obtenidos durante extracción exhaustiva. La correlación analizada mostró que existe una correlación positiva entre la actividad antioxidante y el contenido de compuestos fenólicos totales, catequinas, flavonoides, derivados de ácidos hidroxicinámicos y ácidos orgánicos en extractos de brotes de frambuesa roja.

Conclusiones: Gracias a nuestros resultados se ha determinado la capacidad antioxidante total de los brotes de frambuesa roja. Los resultados del estudio se pueden utilizar para

desarrollar una tecnología óptima para la obtención de fármacos basados en el extracto de brotes de frambuesa roja, que tiene un efecto antioxidante.

Palabras clave: *Rubus idaeus L.*, Capacidad antioxidante total, Contenido de fenoles totales, Contenido de ácidos orgánicos totales, Correlación, Extracción exhaustiva secuencial

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1. Introduction

Nowadays we observe a great interest in antioxidants, especially nature origin, due to the increasing level of cancer, cardiovascular and metabolic diseases (1). Those diseases are associated with the growing impact on humans of adverse environmental factors, such as ultraviolet and electromagnetic radiation, man-made pollution of the atmosphere with radioactive and toxic compounds, the use of food products with a high content of artificial chemical agents (preservatives, thickeners, dyes, flavors, etc.), leading to the formation of an excess amount of free radicals in the body and oxidative damage to organic macromolecules (2).

Oxidative stress causes an imbalance of the natural antioxidant system, significantly increases the risk of developing diabetes mellitus, atherosclerosis, cancer, heart ischemia, and Alzheimer's disease. Therefore, it is recommended to regularly consume certain foods and drinks, drugs, dietary supplements with antioxidant activity to neutralize the harmful effects of free radicals (3).

Raspberry (*Rubus idaeus L.*) is a shrub that belongs to the *Rosaceae* family and widely grows in Ukraine, Europe, Asian and America (4). Raspberry fruit, leaves, and shoots have been used for medicinal purposes for centuries (5,6). The leaves and fruits were traditionally used to treat gastrointestinal, respiratory disorder and heart problems. Raspberry shoots were used directly to treat sore throat, flu, fever, and diabetes (7).

Red raspberry shoots contain catechins, ellagitannins, flavanol derivatives, ellagic acid, phenolic, and organic acids (8). Ellagitannins are a group of hydrolyzable tannins characteristic of the *Rosaceae* family. Sanguine H-6 is the main ellagitannin found in raspberry shoots (9). Raspberry leaves have also been found to contain ellagitannins, some catechins and flavanols, and organic acids (10,11). In contrast to the shoots and leaves of red raspberries, eleven anthocyanins were found in the fruits (12,13).

The antioxidant activity of raspberry fruit and leaves have been established (5,14). However, much less information is available on the antioxidant activity and chemical composition of raspberry shoots extracts. There is no reviews about the determination total antioxidant capacity of raspberry shoots. The total antioxidant capacity of raw materials needs to be studied and further apply total antioxidant in developing drugs, dietary supplements and cosmetologically products.

This study aimed to determine the total antioxidant capacity and biologically active substances content of red raspberry shoots extracts obtained by subsequent exhaustive extraction.

2. Materials and methods

2.1 Plant material

The leafless second-year red raspberry shoots were collected after the fruiting period near village of Ternova, Kharkiv region, Ukraine in 2021.

2.2 Equipment and reagents

The pH meter HANNA 2550 (Germany) with a combined platinum electrode EZDO 50 PO (Taiwan) was used for potentiometric measurements. Quantitative analysis of biologically active compounds was carried out on UV-spectrophotometer UV – 1000 (China) with matched 1 cm quartz cells. The weighing was performed using digital analytical balance AN100 (AXIS, Poland) with $d = 0.0001$ g. All solvents and other chemicals used in the study were of analytical grade.

2.3 Extraction procedure

A 10.0 g of red raspberry shoots were ground to 1-2 mm in size. The extraction was carried out one by one using distilled water, 20% ethanol, 40% ethanol, 60% ethanol, and 96% ethanol at the ratio raw material/solvent 1/20 (m/v) in a water bath at 80° C with reflux for 1 hour. After cooling, the solutions were filtrated and concentrated to 20 mL by a rotary evaporator at 40 ° C under a vacuum.

2.4 Quantitative analysis

2.0 mL of the extract was placed in a weighing bottle, brought to a constant mass, evaporated in a water bath, and dried from 100 to 105 ° C for 3 hours. The weighing bottle was cooled in a desiccator at room temperature for 30 min and weighed ⁽¹⁶⁾. The dry residue w , (%) in extract samples was calculated according to equation 1:

$$w(\%) = \frac{m_{dry} \cdot 100}{V_a} \text{ (Eq.1)}$$

where, m_{dry} – mass of the dry residue after drying an aliquot of the extract sample, g; V_a – volume of extract sample aliquot, mL.

The total content of phenolic compounds was measured by the Folin-Ciocaltau assay, the absorbance was measured at 760 nm ⁽¹⁵⁾. The phosphomolybdotungstic reagent was used as standard. The calibration curve ($Y = 0.1055X + 0.1745$ ($R^2=0.9951$)) was plotted with

interval concentrations 1.0 – 5.0 µg/mL, the calibration equation. The total phenolic compounds content in extracts (X), expressed as GA was calculated according to equation 2:

$$X(\text{mg} / \text{mL}) = \frac{C_x \times K_{\text{dil}} \times 1000}{V} \text{ (Eq.2)}$$

where, C_x – concentration of gallic acid according to the calibration curve, $C \times 10^{-6}$, g/mL; V – extract volume, mL; K_{dil} – coefficient of dilution, mL.

The vanillin reagent assay was applied to determine the total catechins (18); the absorbance was measured at 505 nm. The calibration curve ($Y = 0.0025X - 0.0851$ ($R^2 = 0.9951$)) was plotted with 100 – 400 µg/mL interval concentrations of epigallocatechin-3-O-gallate (EGCG). The total catechins content in extracts (X), expressed as EGCG was calculated according to equation 3:

$$X(\text{mg} / \text{mL}) = \frac{C_x \times K_{\text{dil}} \times 1000}{V} \text{ (Eq.3)}$$

where, C_x – concentration of epigallocatechin-3-O-gallate according to calibration curve, $C \times 10^{-6}$ g/mL; V – volume of extract, mL; K_{dil} – coefficient of dilution, mL.

The total flavonoids were determined using the complex formation assay with AlCl_3 ; the absorbance was measured at 417 nm (19). The concentration of standard solution of rutin was 0.02 mg/mL. The total flavonoids content in extracts (X), expressed as R, was calculated according to equation 4:

$$X(\text{mg} / \text{mL}) = \frac{A \times K_{\text{dil}} \times m_{\text{st}} \times 1000}{A_{\text{st}} \times V} \text{ (Eq.4)}$$

where, A – absorbance of analyzed solution; A_{st} – absorbance of standard solution of rutin; V – volume of extract, mL; K_{dil} – coefficient of dilution, mL, m_{st} – mass of rutin, g.

The total hydroxycinnamic acids derivatives content was measured by assay of complex formation with NaNO_2 - Na_2MoO_4 , the absorbance was measured at 525 nm (20). The total content of hydroxycinnamic acids derivatives in extracts (X), expressed as chlorogenic acid (ChA) was calculated according to equation 5:

$$X(\text{mg} / \text{mL}) = \frac{A \times K_{\text{dil}} \times 1000}{188 \times V} \text{ (Eq.5)}$$

where, A – absorbance of analyzed solution; 188 – specific adsorption coefficient of chlorogenic acid; V – volume of extract, mL; K_{dil} – coefficient of dilution, mL.

The total organic acids content was determined by acid-base titration with the fixation endpoint by potentiometric method (21). The total content of organic acids in extracts, expressed as citric acid (CA) was calculated according to equation 6:

$$X(\text{mg} / \text{mL}) = \frac{(V_{\text{equiv}} - V_x) \times 0.0032 \times K_{\text{dil}} \times K \times 1000}{V} \quad (\text{Eq.6})$$

where, 0.0032 – the amount of citric acid, equivalent to 1 mL of sodium hydroxide solution (0.05 mol/L), g; V_{equiv} is the volume (mL) of sodium hydroxide solution (0.05 mol/L), which was used for titration; V_x – the volume (mL) of sodium hydroxide solution (0.05 mol/L), which was spent for titration in a blank experiment; V – volume of extract, mL; K_{dil} – coefficient of dilution, mL.; K is the correction coefficient for 0.05 mol/L sodium hydroxide solution.

2.5 Antioxidant activity assay

Antioxidant activity (AOA) of extracts was evaluated by potentiometric method (22). Antioxidant activity was calculated according to equation 7 and expressed as mmol-equiv./m_{dry res.}:

$$AOA = \frac{C_{\text{ox}} - \alpha \times C_{\text{red}}}{1 + \alpha} \times K_{\text{dil}} \times 10^3 \times \frac{m_1}{m_2} \quad (\text{Eq.7})$$

where, $\alpha = C_{\text{ox}}/C_{\text{red}} \times 10^{(\Delta E - E_{\text{ethanol}})nF/2.3RT}$; C_{ox} – concentration of $\text{K}_3[\text{Fe}(\text{CN})_6]$, mol/L; C_{red} – concentration of $\text{K}_4[\text{Fe}(\text{CN})_6]$, mol/L; $E_{\text{ethanol}} = 0.0546 \cdot C_{\%} - 0.0091$; $C_{\%}$ – concentration of ethanol; ΔE – change of potential; $F = 96485.33$ C/mol – Faraday constant; $n = 1$ – number of electrons in electrode reaction; $R = 8.314$ J/molK – universal gas constant; $T = 298$ K; K_{dil} – coefficient of dilution, mL.; m_1 – mass of dry residue; m_2 – mass of dry residue in 1.0 mL of extract.

2.6 Correlation analysis

Pearson's (r) correlation coefficient was used to analyze the correlation between antioxidant activity (AOA) and the amount of phenolic, catechin, flavonoid, hydroxycinnamic acids derivatives and organic acids. The correlation coefficient takes a value in the range of -1 to +1. Correlation is very high if it is within the range from 0.90 to 1.00; from 0.70 to 0.90 is a high correlation; from 0.50 to 0.70 is a moderate correlation; from 0.30 to 0.50 is a low correlation; from 0.00 to 0.30 negligible correlation (23).

2.7 Statistical analysis

Six samples were analyzed for all the experiments, and all the assays were performed 5 times. The results were expressed as mean values with confidence intervals. MS EXCEL 7.0 and STATISTIKA 6.0 were used to execute the statistical analysis.

3. Results

3.1 Determination the total content of phenolic compounds

The aqueous extract had the most significant content of phenolic compounds (13.90 ± 0.29 mg/mL), while other raspberry shoots extracts demonstrated a much lower content of phenolic constituent (Table 1). The sum of the total phenolic compound content of red raspberry shoots extracts was 24.40 mg/mL.

3.2 Determination the total content of catechins

The sum of total catechins content was 21.36 mg/mL. The highest amount of catechins was observed in the aqueous extract (12.50 ± 0.25 mg/mL), followed by the other ethanol extracts. According to the results, the amount of catechins (87.54 %) was higher among all phenolic compounds (3.16 % flavonoids, and 1.49 % hydroxycinnamic acids derivatives) (Table 1).

3.3 Determination the total content of flavonoids

The sum of total flavonoid content was 0.77 mg/mL. The highest amount of flavonoids was observed in the aqueous extract (0.40 ± 0.01 mg/mL), followed by the other ethanol extracts (Table 1).

3.4 Determination the total content of hydroxycinnamic acids derivatives

The sum of total hydroxycinnamic acids derivatives content was 2.56 mg/mL. The highest amount of hydroxycinnamic acids derivatives was observed in the aqueous extract (1.50 ± 0.03 mg/mL), followed by the other ethanol extracts (Table 1).

3.5 Determination the total content of organic acids

The aqueous extract had the greatest content of organic acids (1.10 ± 0.03 mg/mL), while other raspberry shoot extracts demonstrated a much lower content of organic acids. The sum of total organic acids content was 1.88 mg/mL (Table 1).

3.6. Determination the total antioxidant activity

The total antioxidant capacity of raspberry shoots was 164.12 mmol-equiv./m_{dry weight}. The antioxidant activity increases in the following extracts order: 96 and 80 % < 60 % extract < 40 % extract < 20 % extract < aqueous (Table 1).

Table 1. The quantitative content of catechins, flavonoids, hydroxycinnamic acids derivatives, organic acids, and antioxidant activity, calculated from the extraction of red raspberry shoots (1:20 ratio raw material/solvent)

Extractant	Total phenolic content, mg/mL	Total catechin content, mg/mL	Total flavonoid content, mg/mL	Total hydroxycinnamic acids derivatives content, mg/mL	Total organic acids, mg/mL	Antioxidant activity, mmol-equiv./m _{dry weight}
distilled water	13.9±0.29	12.5±0.25	0.40±0.01	1.50±0.03	1.10±0.03	85.00±1.70
20% ethanol	5.8±0.12	5.0±0.10	0.20±0.01	0.60±0.01	0.40±0.01	37.60±0.75
40% ethanol	4.1±0.10	3.4±0.07	0.14±0.01	0.40±0.01	0.30±0.01	37.26±0.75
60% ethanol	0.4±0.01	0.3±0.01	0.02±0.003	0.04±0.003	0.03±0.003	3.11±0.06
80% ethanol	0.1±0.001	0.08±0.003	0.005±0.001	0.01±0.001	0.01±0.001	0.62±0.01
96% ethanol	0.1±0.001	0.08±0.001	0.005±0.001	0.01±0.001	0.01±0.001	0.62±0.01
The total content	24.40	21.36	0.77	2.56	1.88	164.12

3.6 Correlation analysis

Pearson's (r) coefficients between antioxidant activity and phenolic compounds, catechins, flavonoids, hydroxycinnamic acids derivatives, and organic acids were 0.9898, 0.9860, 0.9723, 0.9851 and 0.9697, respectively (Table 2).

Table 2. Pearson's (r) correlation coefficient between antioxidant activity and biologically active compounds content in extracts of red raspberry shoots

	Total phenolic content	Total catechin content	Total flavonoid content	Total hydroxycinnamic acids derivatives content	Total organic acids content
Antioxidant activity	0.9898	0.9860	0.9723	0.9851	0.9697

4. Discussions

4.1 Description of sequential exhaustive extraction

In our previous research (23), we created and described the approach of exhaustive sequential extraction. This type of extraction is based on the extraction of the same raw material with extractants of different polarity for example, distilled water as a more polar extractant and ethanol solutions of different concentrations as a less polar extractant. Consistent, exhaustive extraction allows you to extract hydrophilic and lipophilic BAS completely. In this case, the raw material was not dried after extraction; therefore, the volume of the extractant absorbed by the raw material was considered.

4.2 Determination the total content of phenolic compounds

Raspberry shoots are a rich source of phenolic compounds such as ellagitannins, catechins, flavonols and phenolic acids derivatives. Ellagitannins are a group of complex phenolic compounds found in high concentrations in raspberry shoots. They are represented by the derivatives of sanguin and lambertianin. Ellagitannins are metabolized in the gut to form ellagic acid, which has been shown to have anti-inflammatory and anticancer properties (8). The Folin-Ciocalteu method was applied to evaluate the total amount of phenolic compounds. The total phenolic compounds were expressed as gallic acid. A recent study of Bobinatie R. *et al.* (25), they have investigated 41 red raspberry leaves cultivars. They found that the phenolic compounds content varied in different samples from 1.0 to 6.0 mg/mL in ethanolic extract. Compared to our results, in our study, the total amount of phenolic compounds is higher from 4 to 24 times. In another study, Pavlovic *et al.* reported 144.20 mg/mL in the 60% methanolic extract of red raspberry leaves (26). Buricova *et al.* evaluated a total content of phenolic compounds of 2.76 mg/mL aqueous extract of red raspberry leaves (27). In our opinion, the difference in the content of phenolic compounds, is associated with different brewing times, leaves/extractant ratios used, species, climate, and geographical position.

4.3 Determination the total content of catechins

The raspberry shoots presented a variety of catechins, such as epigallocatechin-3-O-gallate, epicatechin, catechin, and epigallocatechin. The catechin is the main compound among catechins in the raspberry shoots (28). The vanillin reagent assay determined the total catechins expressed in epigallocatechin-3-O-gallate equivalent. In recent research by Durgo K. *et al.* (9), the total catechins found were 0.17 mg/mL in the aqueous extract of red raspberry leaves in our research, we are reporting 21.36 mg/mL, 120 times higher

than obtained by the authors. Luo *et al.* reported a total catechin content of 0.10 mg/mL in 60% methanolic extract red raspberry leaves (29), and we obtained 0.3 mg/mL in ethanol extract. The large values difference may be because that raspberry shoots contain more catechins than flavonol derivatives. Catechins in the biometabolism of plant shoots are responsible for the intensity of cell division and protection. In contrast, flavonol derivatives have a signal function and remarkable antioxidant effect against reactive oxygen species.

4.4Determination the total content of flavonoids

Flavonoids are a phytochemical widely distributed in raspberries with various health benefits. Several flavonols have been detected in the raspberry shoot: rutin, quercetin-3-O-glucuronide, hyperoside, myricetin and kaempferol (8). The total flavonoids were determined using complex formation with $AlCl_3$ assay. The total flavonoid content was expressed in rutin equivalent. Costa T. *et al.* (30), reported 12.92 mg/mL of flavonoids in 20% ethanolic extract of red raspberry leaves. In contrast, we obtained a value of 94 % lower (0.20 mg/mL). Pavlovic *et al.* reported a total flavonoids content of 10.64 mg/mL in 60% methanolic extract red raspberry leaves extract (26). Comparing the content of flavonoids in extracts obtained from the leaves and shoots of red raspberry, we can conclude that flavonol derivatives dominate in the leaves, then in the shoots. Therefore, our theory mentioned above is approved.

4.5Determination the total content of hydroxycinnamic acids derivatives

Raspberries are a rich source of hydroxycinnamic acids. The most abundant hydroxycinnamic acid in raspberries is chlorogenic acid, a powerful antioxidant associated with various health benefits. Other hydroxycinnamic acids in raspberries include: caffeic acid, p-coumaric acid, ferulic acid and sinapic acid (9). The total hydroxycinnamic acids derivatives content was measured by assay of complex formation with $NaNO_2$ - Na_2MoO_4 and expressed in chlorogenic acid equivalent. Costa T. *et al.* (30) reported 9.28 mg/mL hydroxycinnamic acids derivatives in 20% ethanolic extract of red raspberry leaves. in our case, the total amount of hydroxycinnamic acids derivatives was 72.11% lower. Yang *et al.* reported a total hydroxycinnamic acids content of 8.24 mg/mL in distilled water red raspberry leaves extract (31), meanwhile, we obtained the total hydroxycinnamic acids – 2.56 mg/mL. We have observed that the concentration of hydroxycinnamic acids in raspberry leaf extract is higher than in the shoot extract. We believe that this is related to the biometabolism of flavonoids. According to the shikimate pathway, derivatives of hydroxycinnamic acids serve as precursors to flavonoids. As we have also demonstrated that the concentration of flavonoids is higher in the leaf extract than the shoot extract, it follows that the content of hydroxycinnamic acids in the leaf extract should also be higher.

4.6 Determination the total content of organic acids

Some of the main organic acids in raspberry shoots include malic acid, citric acid, quinic acid, and oxalic acid and citric acid is considerably abundant in raspberry shoots (32). The total organic acids content was determined by acid-base titration with the fixation endpoint by potentiometric method. The total organic acids were expressed in citric acid. Mikulic-Petkovsek M. *et al.* (33) investigated amount of organic acids in the aqueous extract of red raspberry fruits by high-performance liquid chromatography. This study revealed that the total organic acids were 2.2 mg/ml In our research, the sum of total organic acids was 14.54 % lower than in the reported study.

4.7 Determination the antioxidant activity

The antioxidant activity values of investigated extracts were estimated with the potentiometric method. This method was chosen due to its high sensitivity, rapid analysis procedure, and relatively low cost of equipment and reagents (34). However, certain acceptance criteria are required to justify the choice of extraction conditions,. According to the available literature, the main acceptance criterion is obtaining the maximum content of phenolic and extractive compounds. We propose to use the total antioxidant capacity of raw materials as an acceptance criterion for choosing the optimal extraction conditions, for several of reasons, firstly, the antioxidant activity and the content of phenolic compounds have a high positive correlation, secondly, the determination of antioxidant activity requires less time than the determination of the content BAS and extractive compounds. The term "total antioxidant capacity of raw materials" means the sum of the antioxidant activity of all hydrophilic and lipophilic BAS contained in the studied raw materials.

4.8 Correlation analysis

Luo *et al.* (29) reported a good correlation between the antioxidant activity of red raspberry extract and the amount of phenolic compounds. They found correlation coefficients of 0.915 and 0.830 when evaluating antioxidant activity by ABTS and DPPH assays, respectively. In our study, the highest correlation coefficient value was between antioxidant activity and the total content of phenolic compounds ($r = 0.9898$). Therefore, phenolic compounds influenced the antioxidant activity of red raspberry leaf extract.

5. Conclusions

The total red raspberry shoots antioxidant activity was determined. The BAS and antioxidant activity analysis of red raspberry shoot extracts revealed that the aqueous extract had a remarkable content of phenolic compounds, catechins, flavonoids,

hydroxycinnamic acids, organic acids and antioxidant activity. Moreover, the quantitative analysis showed that catechins were the main compounds among phenolic ones. Furthermore, correlation analysis revealed a strong positive linear relationship between antioxidant activity and phenolic compounds. The study results can be used to develop optimal technologies for obtaining drugs based on the extract of red raspberry shoots, which has an antioxidant effect.

Conflict of interests

The authors have no conflicts of interests to declare.

Authors' contributions

Mykola Golik, Sergii Kolisnyk, Sergii Baiurka and Svetlana Karpushina participated in the structuring of the study, discussion of the results, and final writing of the manuscript. Alexander Altukhov carried out the experimental part and participated in the discussion. Olexander Maslov, Mykola Komisarenko, Oksana Tkachenko, and Iuliia Kolisnyk participated in the conception of the study, experimental phase, discussion of the results, and final writing of the manuscript.

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