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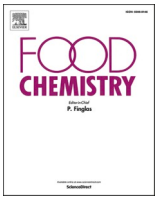

Valorization of grape pomace extracts against cranberry, elderberry, rose hip berry, goji berry and raisin extracts: Phytochemical profile and *in vitro* biological activity

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ABSTRACT

The circular economy is gaining attention around the world as a sustainable approach to tackling environmental problems, promoting more responsible management of resources. The aim of this work is the valorization of grape pomace as a waste product of agrifood chain. We prepared decoction (DC), ultrasound-assisted and microwave-assisted extracts (UAE and MAE respectively) of grape pomace, determining their phytochemical profile (using HPLC-ESI-Q-TOF-MS), antioxidant activity and enzyme inhibitory effects. Then, the results were compared with those of raisins and several edible berries already present in the market. Grape pomace extracts presented the highest total phenolic content (62–68 mg gallic acid equivalents/g; mg GAE/g), whereas the concentrations in the other berries were 4–43 mg GAE/g. These results were in agreement with the higher antioxidant activity and tyrosinase inhibition observed in grape pomace compared with the other berries, except for the metal chelating activity. The main compounds in grape pomace extracts were flavonoids (particularly quercetin glycosides), followed by organic acids (citric, isocitric and gallic acids). These results open new perspectives in the development of food supplements and nutraceuticals based on grape pomace extracts.

1. Introduction

Antioxidant compounds are extremely important for human health, being responsible of several protecting cellular mechanisms; they can be found in a plethora of natural sources, including berries (Olas, 2018). Diverse new extraction methods can be applied to the preparation of berries extracts, such as pressurized-liquid extraction (PLE), ultrasound-assisted extraction (UAE), microwave-assisted extraction (MAE), enzyme-assisted extraction (EAE) also in combination with conventional methods, rendering the procedures more efficient and environmentally friendly (Feng, Zhang, Sun, Mujumdar, & Yu, 2023). Thanks to these methodologies, diverse bioactive compounds have been identified and quantified. For example, blueberries and chokeberries are rich of flavon-3-ols, while red raspberries and cloudberries show high levels of tannins and ellagitannins. In general, berries are rich sources of ellagic acid, chlorogenic acid and gallic acid: blueberry contains up to 2 g/kg of

Abbreviations: ABTS, 2,2′-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid); ACAE, acarbose equivalent; AChE, acetylcholinesterase; BChE, butyrylcholinesterase; CUPRAC, CUPric Reducing Antioxidant Capacity; DC, decoction; DE, dried extract; DPPH, 2,2-diphenyl-1-picrylhydrazyl; EDTAE, disodium edetate equivalent; EtOH, ethanol; FRAP, Ferric Reducing Antioxidant Power; GAE, gallic acid equivalent; GALAE, galanthamine equivalent; HPLC-ESI-Q-TOF-MS, High Performance Liquid Chromatography – Electrospray Ionization- Quadrupole- Time Of Flight – Mass Spectrometry; HPLC-UV, High-Performance Liquid Chromatography-Ultraviolet; KAE, kojic acid equivalent; MAE, microwave-assisted extraction; MCA, metal chelating activity; MeOH, methanol; PBD, phosphomolybdenum; RE, rutin equivalent; SD, standard deviation; TE, Trolox equivalents; TFC, Total Flavonoid Content; TIPC, Total Individual Phenolic Content; TPC, Total Phenolic Content; UAE, ultrasound-assisted extraction.

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chlorogenic acid (Romani, Vignolini, Ieri, & Heimler, 2016). Ellagic acid accounts for about 50 % of the total phenolic compounds in cranberries and raspberries (Nile & Park, 2014; Skrovankova, Sumczynski, Mlcek, Jurikova, & Sochor, 2015). Grapes and red currants present high concentrations of resveratrol, belonging to the family of stilbenes.

Studies carried out on humans have demonstrated significant improvements in antioxidant capacity, lipid and carbohydrate metabolism following the intake of fresh berries. The benefits were observed both in healthy subjects and in those with pre-existing cardiovascular and metabolic risk factors (Basu, Rhone, & Lyons, 2010). The modulation of various antioxidant and pro-oxidant markers in healthy subjects demonstrates the potential prophylactic actions of fresh berries and their products and highlights their importance as an integral part of an optimal diet (Olas, 2018; Sesso, Gaziano, Jenkins, & Buring, 2007). Since hypertension, oxidation of lipids and LDL lipoproteins, high plasma levels of cholesterol and glucose are considered important risk factors, these findings suggest the protective role of berries as real "superfoods".

However, despite their documented beneficial effects on human health and the abundance of functional foods and supplements based on berries, they do not appear to be among the most commonly consumed fruits by the population, hence not meeting their basic needs (Baker, Lu, Parrella, & Leggette, 2022).

To reach the economic growth and sustainable way of life, it is of primary importance to change the management of our shared natural resources, waste and pollutants. With the aim to achieve these goals, one useful approach could be to prompt industries and consumers to recycle and reduce food waste, supporting sustainable patterns of consumption by 2030 (Kirchherr, Yang, Schulze-Spüntrup, Heerink, & Hartley, 2023).

The development of wine industry has increased constantly during the last years resulting in the production of huge amounts of waste. Given the importance of environmental sustainability, different researches have focused on the management of by-products derived from wine production (Ferrer-Gallego & Silva, 2022). Waste-water along with solid wastes represent the main refuse of the wine sector; thus, wine industries started investing in waste-water treatment, water saving and valorization of by-products and sludge (Ruggieri et al., 2009). Every year 9 million tons of grape pomace is generated which accounts for approximately 20 % of the grape processed in terms of weight (Schieber, Stintzing, & Carle, 2001). Grape pomace derives from grape press procedure containing peels and seeds (Ruggieri et al., 2009). Its high content of phenolic acids and flavonoids is well described in literature justifying the possible use of grape pomace for the development of nutraceuticals and cosmetic products. In fact, phenolic compounds may exhibit antioxidant effects acting as free radical scavengers or hydrogen donors or showing a metal chelating or singlet oxygen quenching effects (Luchian et al., 2019; Nemzer, Al-Taher, Yashin, Revelsky, & Yashin, 2022), opening the possibility to design different fortified products starting from food waste (Liu et al., 2022; Olmo-Cunillera et al., 2019).

Considering that berries and grapes are extremely rich in phenolic acids and flavonoids, the aim of this study is to investigate the potential nutraceutical use of grape pomace as by-product, comparing its extracts with those of commercially available berries and fruits in terms of their phytochemical profile and antioxidant activity. In this way, grape pomace-derived products could be used as an alternative to commercial berries, hence contributing to the circular economy by the valorization of by-wastes products in wine industry. Actually the global market is full of food supplements based on berries while the use of grape pomace is still rare in this context. Taking into account the increasing relevance of green approaches in food chemistry, three sustainable extraction techniques have been applied to the preparation of the extracts, *e.g.* decoction (DC), ultrasound-assisted extraction (UAE) and microwave-assisted extraction (MAE). For each extract the total phenolic and flavonoid content was determined by colorimetric assays, together with the phytochemical profile by HPLC-ESI-Q-TOF-MS. Their antioxidant activity was investigated through 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS), cupric ion reducing antioxidant capacity (CUPRAC), ferric ion reducing antioxidant potential (FRAP), metal chelating and phosphomolybdenum assays along with the inhibitory effects against cholinesterase, amylase, glucosidase and tyrosinase through *in vitro* assays.

2. Materials and methods

2.1. Plant materials and sample preparation

Local Montepulciano grape pomace (1 Kg) collected in Collecorvino (Tenuta del Priore, Collecorvino, Pescara, Italy) in 2019, was used for the extraction procedures. Dried goji berries (*Lycium barbarum*) (1 g) and raisins (*Vitis vinifera* L.) (1 g) were purchased from a local market in Italy. Dried cranberry berries (*Vaccinium Vitis Idaea* L.*)* (1 g), dried elderberry berries (*Sambucus Nigra*) (1 g) and dried rose hip berries (*Rosa Canina*) (1 g) were purchased from a local vendor in Bulgaria. The plant materials have been all lyophilized and ground in a blender. The samples were conserved at −20 °C until the extraction.

2.2. Reagents

Ethanol puriss., methanol (gradient grade, ≥99.9 %), acetonitrile (gradient grade, ≥99.9 %), formic acid reagent grade ≥95 %, were purchased from Sigma Aldrich (Sigma Aldrich, St. Louis, Missouri, USA). Gallic acid monohydrate, benzoic acid, quercetin anhydrous, chlorogenic acid, rutin trihydrate, *p*-coumaric acid, catechin hydrate, myricetin, isorhamnetin, *trans*-ferulic acid, ellagic acid and citric acid were all analytical standards (≥99 % HPLC) purchased by Sigma Aldrich (Sigma Aldrich, St. Louis, Missouri, USA). Kojic acid (≥98.5 % (HPLC)) was purchased by Sigma Aldrich (Sigma Aldrich, St. Louis, Missouri, USA), phosphomolybdenum, disodium edentate and trolox were all of analytical grade from Sinopharm Chemical Reagent Co. (Sinopharm Chemical Reagent Co., Ltd. Shanghai, China).

2.3. Extraction procedures

For decoction, 20 mL of EtOH/H_2O (7:3; v:v) was added to approximately 1 g of the powder. The mixture was heated at reflux under agitation and kept boiling for 10 min. After centrifugation (4400 rpm, 3 min.) and filtration on a mesh filter, the solvent was removed by rotary evaporation obtaining the dried extract. For the UAE approximately 1 g of sample was weighted and 20 mL of EtOH/H_2O (7:3; v:v) added. The mixture was pre-heated at 36 °C in ultrasonic bath (Bandelin, Berlino, Germany) and sonicated for 30 min. at 36 °C. After centrifugation (4400 rpm, 15 min.) and filtration on a mesh filter, the solvent was removed by rotary evaporation to obtain the dried extract. For the MAE about 1 g of sample was dissolved in 20 mL of EtOH/H_2O (7:3; v:v) in a glass, sealed vial using an automatic Biotage Initiator™ 2.0 (Biotage Sweden AB, Uppsala, Sweden), with 2.45 GHz high-frequency microwaves and power range: 0–300 W, following these parameters: temperature thermostatically kept at 60 °C; 10 W, 10 min. Centrifugation (4400 rpm, 20 min) and filtration on a mesh filter were performed. To obtain the dried extract, the solvent was removed by rotary evaporation. The extracts obtained by DC, UEA and MAE have been prepared following the protocols previously established by us and described in recent literature (Mollica et al., 2021; Stefanucci et al., 2020). The extraction yields have been calculated following the formula below:

$$\%yield = [(weight\ of\ dried\ extract)/(weight\ of\ dried\ plant\ sample)]\ x\ 100$$

2.4. Determination of Total phenolic and flavonoid content

The quantification of total phenolic content (TPC) and total flavonoid content (TFC) was conducted in accordance with the procedures outlined in a previous paper by Zengin & Aktumsek (Zengin &

Aktumsek, 2014). The total phenolic and flavonoid contents were detected by Folin-Ciocalteu and $AlCl_3$ methods, respectively. The results were explained as the equivalents of gallic acid (mg GAE/g dry extract (DE)) and rutin (mg RE/g DE), respectively. The experimental details are given in the supplemental materials.

2.5. Determination of the phytochemical profile by HPLC-ESI-Q-TOF-MS

Approximately 5–10 mg of dried extracts were re-dissolved in 1 mL of MeOH:H_2O (7:3, v:v). The samples were sonicated to promote the complete solubilization of the extracts. After filtration by 0.45 μm filters, the analyses were performed using an Agilent 1200 equipped with an Agilent 6530B Q-TOF MS (see Supporting Information for more details about instrument and method, adapted from Stefanucci et al. (2024). The identification of the compounds was performed using accurate mass data, ion source fragmentation, MS/MS fragmentation pattern, comparison with analytical standards and bibliographic research. The characterization of the compounds in DC, UAE and MAE extracts was conducted in negative ion mode to determine mainly phenolic acids and flavonoids, whereas the positive ion mode was used for anthocyanins. A brief description of the main phytochemicals identified or tentatively characterized in DC, UAE and MAE extracts is reported below, while the assigned identification of each compound in the extracts along with the HPLC-MS parameters (observed mass, molecular formula, error (ppm) and fragment ions) are provided in the Supporting Information. The main phytochemicals in each extract were quantified through the HPLC-UV signals. We used as analytical standards: catechin (280 nm), ellagic acid (250 nm), *trans*-ferulic acid (320 nm), benzoic acid (250 nm), gallic acid (280 nm), *p*-coumaric acid (320 nm), chlorogenic acid (320 nm), rutin (350 nm), myricetin (350 nm), isorhamnetin (350 nm), and quercetin (350 nm). Plotting the area of the peak *vs.* concentration, we prepared the calibration curves ($R^2 \geq 0.999$) using a linear dynamic range of 0.5 to 100 mg L^{-1} for all the standards except for *p*-coumaric acid (5 to 100 mg L^{-1}) and ellagic acid (2 to 20 mg L^{-1}). Only for citric acid and its isomer, we performed the quantification in MS/MS mode considering the transition 191 → 111 and a linear dynamic range of 1–25 mg L^{-1} ($R^2 = 0.98$). The limits of detection were 0.15 mg L^{-1} for all compounds except (iso)citric acid (0.3 mg L^{-1}), ellagic acid (0.6 mg L^{-1}) and *p*-coumaric acid (1.5 mg L^{-1}). The limits of quantification were the lowest value of the linear dynamic ranges previously indicated.

2.6. Antioxidant assays

In vitro antioxidant assays, based on previously reported techniques (Zengin et al., 2014), were carried out. The results obtained from the 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical scavenging, cupric reducing antioxidant capacity (CUPRAC), and ferric reducing antioxidant power (FRAP) tests were conveyed as mg of Trolox equivalents (TE) per gram of DE. The antioxidant potential assessed by the phosphomolybdenum (PBD) assay was measured as mmol of Trolox equivalents (TE) per gram of DE, and metal chelating activity (MCA) was reported as mg of disodium edetate equivalents (EDTAE) per gram of DE. The experimental details are given in the supplemental materials.

2.7. Enzyme inhibitory tests

In accordance with established protocols, enzyme inhibition experiments were performed on the samples (Zengin, 2016). The quantification of amylase and glucosidase activity inhibition was expressed as mmol of acarbose equivalents (ACAE) per gram of DE, whereas acetylcholinesterase (AChE) and butyrylcholinesterase (BChE) activity inhibition was denoted as mg of galanthamine equivalents (GALAE) per gram of DE. Tyrosinase inhibition was measured as mg of kojic acid equivalents (KAE) per gram of DE. The experimental details are given in the supplemental materials.

2.8. Statistical analysis

The experiments were executed in triplicate. First, tests were performed to assess data normality using the Shapiro-Wilk test. A descriptor with a *p*-value greater than 0.05 was normally distributed. The the differences among the extracts were assessed using an Analysis of Variance (ANOVA) and Tukey's test. The statistical analysis was conducted using Graph Pad Prism (version 9.2).

3. Results and discussion

3.1. Extraction yields

Extraction yields have been calculated for each DE following the formula reported in paragraph 2.3. Data show a specific trend for Goji berries (82 % decoction DE, 81 % DE for UAE and 47 % DE for MAE), raisins (80 % decoction DE, 55 % DE for UAE and 66 % DE for MAE), rose hip (55 % decoction DE, 15 % DE for UAE and 33 % DE for MAE) and elderberries (47 % decoction DE, 30 % DE for UAE, 46 % DE for MAE) for which decoction represents the best extraction procedure. Conversely grape pomace and cranberries MAE present extraction yields higher than those calculated for UAE and decoction (36 % grape pomace DE against 32 % and 26 % DE of decoction and UAE respectively; 63 % cranberries DE against 55 % and 43 % DE of decoction and UAE respectively). We can suppose that the positive effect of temperature during decoction could be explained by the higher solubility of polyphenols in the solvent mixture, the higher diffusivities of the extracted molecules, and the improved mass transfer at higher temperatures. However, it is well-known that high temperatures (70 °C) together with the presence of molecular oxygen could decrease the anthocyanins yield due to their thermal degradation. Both grape pomace and cranberries are rich in anthocyanins and pro-anthocyanins content. This could be the reason why we observed extraction yield values for MAE of grape pomace and cranberries higher than those of DC and UAE preparations.

3.2. Total phenolic and flavonoid content

Phenolic compounds are secondary metabolites present in plants showing a wide range of biological effects, such as anti-cancer, antioxidant, and anti-inflammatory activities, which make them extremely important in the plant kingdom (Sun & Shahrajabian, 2023). Measuring the TPC in plant extracts could offer an initial understanding of their potential in the pharmaceutical field. The Folin-Ciocalteu method was utilized to determine the TPC in the tested extracts in the present study. The highest level was determined in the decoction of grape pomace with 67.42 mg GAE/g DE, followed by the UAE of cranberry (43.31 mg GAE/g DE) and the decoction of rose hip (38.50 mg GAE/g DE) (Table 1).

In the literature, several researchers reported different values (1.10–72.87 mg GAE/g extract; 115–311 μg/L and 1002.53–1238.59 mg GAE/g dry sample) of the total phenolic content of the tested samples (Kasapoğlu et al., 2023; Korz et al., 2023; Turan et al., 2023). Regarding the TFC, it was the highest in grape pomace extracts when compared to the extracts or raisins and the other berries, indicating its suitability as an alternative to the latter. Furthermore, the elderberry extracts contained significant amounts of flavonoid (3.80–4.97 mg RE/g DE). The raisin extracts showed the lowest TFC and TPC among the tested samples, with no significant differences among the extraction techniques used. For all the other samples, the performed extraction methods have a considerable influence on the total flavonoid content of the grape or tested berries. For example, the highest total content of phenols and flavonoids was determined in the UAE for cranberries and elderberries, while it was found in the DC for rose hips. From this point on, the selection of extraction methods also depends on the structure of the plant materials. For example, cranberry and elderberry are softer materials than rose hips and therefore ultrasonic waves can penetrate more easily (Shen et al., 2023). However, decoction is more suitable for hard plant

Table 1
Total phenolic (TPC) and flavonoid (TFC) content of the tested extracts*.

Samples	Extraction methods	TPC (mg GAE/g)	TFC (mg RE/g)
Grape pomace	Decoction	67.42 ± 0.19^{a}	5.10 ± 0.09^{c}
	UAE	62.62 ± 1.25^{b}	6.85 ± 0.30^{a}
	MAE	62.83 ± 1.18^{b}	6.37 ± 0.22^{b}
Cranberry	Decoction	14.18 ± 0.85^{j}	1.82 ± 0.09^{ef}
	UAE	43.31 ± 0.33^{c}	1.93 ± 0.02^{ef}
	MAE	14.79 ± 0.33^{ij}	1.66 ± 0.03^{fg}
Elderberry	Decoction	17.20 ± 0.70^{gh}	3.80 ± 0.23^{d}
	UAE	34.73 ± 1.07^{e}	4.97 ± 0.16^{c}
	MAE	32.26 ± 0.37^{f}	4.78 ± 0.17^{c}
Rose hip	Decoction	38.50 ± 1.41^{d}	2.11 ± 0.12^{e}
	UAE	16.46 ± 0.22^{hi}	1.64 ± 0.05^{fg}
	MAE	19.21 ± 0.47^{g}	1.39 ± 0.02^{g}
Goji berries	Decoction	9.25 ± 0.20^{k}	0.55 ± 0.03^{h}
	UAE	9.60 ± 0.11^{k}	0.55 ± 0.02^{h}
	MAE	10.88 ± 0.16^{k}	0.53 ± 0.03^{h}
Raisins	Decoction	4.01 ± 0.18^{l}	0.22 ± 0.06^{h}
	UAE	4.11 ± 0.07^{l}	0.29 ± 0.06^{h}
	MAE	3.98 ± 0.05^{l}	0.30 ± 0.02^{h}

* Values are reported as mean ± SD of three parallel measurements. GAE: Gallic acid equivalent; RE: Rutin equivalent. Different letters indicate significant differences between the tested extracts ($p < 0.05$).

materials and therefore this technique was more effective in rose hip sample preparation (Petkova et al., 2020). Klavins, Kviesis, and Klavins (2017) investigated the effects of different extraction methods (Soxhlet, ultrasound-assisted and shaking) on the chemical composition of cranberry showing that UAE (1.68 g/100 g powder berry) is particularly useful to extract phenolics from the cranberry samples. In another study by Gudžinskaitė et al. (2020), the total phenolic content of the UAE of American cranberry varieties varied between 10.61 mg GAE/g dry sample and 18.06 mg GAE/g dry sample. In a recent study on elderberry by Domínguez et al. (2020), the UAE prepared with different solvents show total phenolic content ranging from 2524 to 3157 mg GAE/100 g dry sample. Petkova, Ognyanov, Kirchev, and Stancheva (2021) reported that the total phenolic content in the decoction of rosehip (96.7 mg GAE/250 mL) was higher than that of infusion (68.2 mg GAE/250 mL). Da Rocha & Noreña (da Rocha & Noreña, 2020) described the effects of ultrasound and microwave extractions on the total phenolic content of grape pomace, demonstrating that the strong microwave or ultrasonic waves increased the level of the total phenolic content. Similarly, the effects of solvent and ultrasonic waves on the chemical profiles of grape pomace were described by González-Centeno, Comas-Serra, Femenia, Rosselló, and Simal (2015). Drosou, Kyriakopoulou, Bimpilas, Tsimogiannis, and Krokida (2015) also recorded a high level of the total phenolic content (167661–4,389,984 ppm GAE in dry extract for ultrasound assisted extraction; 200,025–231,619 ppm GAE in dry extract for microwave assisted extraction) of grape pomace samples after UAE with hydro alcoholic ($EtOH/H_2O$) solvent compared to single ethanol and water. However, some concerns have been raised regarding the results of the spectrophotometric tests. In particular, the Folin-Ciocalteu reagent can be reduced not only by phenols but also by non-phenols (peptides, polysaccharides, *etc.*), which led to falsely high results (Sánchez-Rangel, Benavides, Heredia, Cisneros-Zevallos, & Jacobo-Velázquez, 2013).

3.3. Determination of the phytochemical profile

To validate the results obtained by TPC and TFC, HPLC-MS-MS was used to characterize all the extracts; a list of the compounds is given in Table 2.

Grape pomace extracts presented the highest number of compounds when compared to the other extracts, in grape pomace DC, UAE and MAE, 67 compounds were identified or tentatively characterized. The characterization of all compounds is shown in Supplementary Material (Table S1). Base peak chromatograms of grape pomace DC (a), UAE (b) and MAE (c) (HPLC-ESI-Q-TOF-MS in negative ion mode) are reported in Fig. S1. The relative contributions (%) of each compound to the total extract are shown in Supplementary Material (Figs. S2, S3). The most abundant compounds were organic acids, mainly tartaric and malic acids, which represented approximately 40–45 % of the total extracts. The extracts were also rich in flavonoids; the most abundant compounds were catechin, quercetin and kaempferol glycosides. Several anthocyanins were also detected, among them malvidin glycosides (malvidin-3-*O*-acetylhexoside and malvidin-3-(6-*O*-coumaroyl) hexoside) were predominant, representing approximately 50 % of all the anthocyanidins (Supplementary Material, Fig. S3). Unfortunately we were not able to detect them in the other berries and fruits extracts. This could be due to a well-known degradation process which can occur on anthocyanins following these conditions: thermal processing over 50 °C; pH, storage temperature, chemical structure and concentration of such compounds, presence of enzymes, proteins and metallic ions (Moldovan, David, Chișbora, & Cimpoiu, 2012; Patras, Brunton, O'Donnell, & Tiwari, 2010; Spigno, Tramelli, & De Faveri, 2007).

The quantification of the main compounds, mostly flavonoids, is reported in Table 3. In general, MAE is suitable for the extraction of flavonoids, in particular catechin (0.89–0.97 mg g^{-1}), (*epi*)catechin (1.00 mg g^{-1}) and quercetin glycosides. Gallic acid was the most abundant phenolic acid, with a concentration of 0.22 mg g^{-1}.

44 compounds were identified or tentatively characterized in cranberry berries decoction, UAE and MAE (Fig. S4). The characterization, relative contribution of each compound and quantification of the main compounds are provided in Supplementary Material (Tables S2 and S3, Fig. S5). All the extracts contained a high percentage of isocitric and citric acids (more than 30 % of the total extract) and benzoic derivatives (another 30 % approximately). Regarding flavonoids, the most abundant were quercetin derivatives. A large number of studies have been conducted to determine the phenolic profile of cranberry berries. A previous study on cranberry secondary metabolites reported as main compounds benzoic acid derivatives, hydroxybenzoic and hydroxycinnamic acid derivatives, flavonol glycosides, anthocyanins and proanthocyanidins (Wang, Vorsa, Harrington, & Chen, 2018). Another research underline the presence of flavonol glycosides, in particular myricetin and quercetin glycosides (Diaconeasa, Florica, Rugină, Lucian, & Socaciu, 2014). Furthermore, different studies have been conducted to determine the phenolic profile of cranberry berries in phenolic acids and flavonoids (Abeywickrama, Debnath, Ambigaipalan, & Shahidi, 2016; Gudžinskaitė et al., 2020), and some of them also investigated the anthocyanins profile (Borges, Degeneve, Mullen, & Crozier, 2010; Seeram et al., 2006). In our research, in agreement with Wang, Vorsa, Harrington, and Chen. (2018), we determined a large amount of benzoic acid derivatives. We also determined a profile of phenolic acids similar to Abeywickrama et al. (2016), *e.g.* the presence of gallic, protocatechuic, caffeic, *p*-coumaric, ferulic and chlorogenic acids. The main phenolic compounds and benzoic acid derivatives were quantified in cranberries using the UV signal, whereas citric and isocitric acids were quantified by MS. The difference in using UV or MS was due to the presence or absence of the exact analytical standards (for instance, quercetin was used for all its derivatives). According to Table S3, it can be seen that there were not significant differences among the concentrations of the minor compounds. However, regarding the total concentration of phytochemicals, MAE presented the lowest concentration, whereas UAE provided the highest recovery yield. Benzoic acid derivatives were the main compounds in all the extracts, showing the following results: decoction (10.5 mg g^{-1} DE), UAE (11.6 mg g^{-1} DE), MAE (10.1 mg g^{-1} DE). Among the phenolic acids, only protocatechuic acid was quantified (about 0.4 mg g^{-1} DE in all the type of extracts).

28 compounds have been identified or tentatively characterized in decoction, UAE and MAE of elderberries (Fig. S6, Table S4). Isocitric and citric acids, malic acid, phenylalanine hexoside, protocatechuic acid and rutin are abundant in all the extracts, in agreement with other studies (Mikulic-Petkovsek et al., 2023; Veberic, Jakopic, Stampar, &

Table 2
HPLC-MS-MS characterization of the compounds found in the different analyzed extracts. Among fragment ions, the base peak is in bold. The compounds found in positive ion mode are marked with (+). The last column shows in which sample the compounds were present (Grape = grape pomace, Cran = cranberries, Eld = elderberries, Rose = rose berries, Goji = goji berries, Rai = raisins).

t_R (min)	Observed [M-H]$^-$	Molecular formula	Error (ppm)	Fragment ions (*m/z*)	Assigned identification	Extract
1.699	377.0857	$C_{12}H_{22}O_{11}$	−0.97	341.1084, 221.0679, **179.0550**, 161.0440, 143.0354, 131.0367, 119.0371, 113.0240	Disaccharide (HCl adduct)	Cran, Goji,
1.800	149.0098	$C_4H_6O_6$	−4.05	**87.0088**	Tartaric acid	Grape, Rai
1.916	191.0200	$C_6H_8O_7$	−1.71	173.0094, 129.0187, **111.0084**, 87.0090, 85.0294	Isocitric acid	Grape, Cran, Eld, Rose, Goji, Rai
1.978	133.0144	$C_4H_6O_5$	−0.82	**115.0032**, 71.0141	Malic acid	Grape, Cran, Eld, Rose, Goji, Rai
2.532	191.0200	$C_6H_8O_7$	−1.26	173.0138, 129.0198, **111.0090**, 87.0090, 85.0299	Citric acid	All
2.558	117.0193	$C_4H_6O_4$	0.28	99.0086, **73.0296**	Succinic acid	Eld, Rose,
2.956	205.0354	$C_7H_{10}O_7$	−0.2	**111.0085**, 99.0472, 87.0087, 67.0189, 57.0365	Methylcitric acid	Cran, Rose,
2.969	326.1245	$C_{15}H_{21}NO_7$	0.06	**164.0711**, 101.0242	Phenylalanine hexoside	Eld,
3.202	315.0723	$C_{13}H_{16}O_9$	−0.78	**153.0194**, 109.0296	Protocatechuic acid-*O*-hexoside	Cran, Rai
3.210	169.0143	$C_7H_6O_5$	−0.38	**125.0243**	Gallic acid	Grape, Cran, Rose,
3.278	164.0715	$C_9H_{11}NO_2$	1.23	**147.0446**, 103.0550, 91.0550, 72.0092	Phenylalanine	Eld,
3.703	331.0673	$C_{13}H_{16}O_{10}$	−0.65	**169.0140**, 125.0247	Galloyl hexoside	Grape,
3.888	315.1085	$C_{14}H_{20}O_8$	0.07	**153.0554**, 123.0446	Hydroxytyrosol hexoside	Grape, Eld,
4.017	329.0880	$C_{14}H_{18}O_9$	−0.15	**167.0345**, 152.0110, 123.0454, 108.0202	Vanillic acid hexoside	Eld,
4.311	219.0509	$C_8H_{12}O_7$	0.64	173.0080, 129.0185, **111.0085**, 87.0079, 67.0193, 57.0349	Dimethylcitric acid	Grape, Cran, Rose, Rai
4.557	299.0773	$C_{13}H_{16}O_8$	−0.16	239.0587, 209.0440, 179.0339, 151.0383, **137.0238**, 119.0343, 113.0197	Monohydroxybenzoyl hexose	Cran,
4.639	153.0556	$C_8H_{10}O_3$	−0.64	**123.0445**	Hydroxytyrosol	Grape,
4.709	219.0514	$C_8H_{12}O_7$	−0.28	**111.0091**, 87.0087, 67.0188, 57.0361	Dimethylcitric acid	Cran, Eld, Rose,
4.991	359.0982	$C_{15}H_{20}O_{10}$	0.17	**197.0444**, 153.0570, 135.0431	Syringic acid hexoside	Grape, Rose,
5.521	153.0194	$C_7H_6O_4$	−0.97	**109.0293**	Protocatechuic acid	Grape, Cran, Eld, Rose,
5.434	353.0876	$C_{16}H_{18}O_9$	0.88	**191.0564**, 179.0349, 173.0428, 135.0447	Neochlorogenic acid	Eld,
5.788	345.0826	$C_{14}H_{18}O_{10}$	0.39	**183.0294**, 168.0056, 124.0157	Methylgallate-hexoside	Rose,
5.926	203.0826	$C_{11}H_{12}N_2O_2$	−0.08	186.0527, 159.0918, 142.0665, **116.0497**, 74.0243	L-Triptophan	Eld,
6.317	311.0408	$C_{13}H_{12}O_9$	0.29	**179.0344**, 149.0088, 135.0440	Caftaric acid	Grape, Rai
6.330	175.0613	$C_7H_{12}O_5$	−0.34	157.0501, 131.0711, 129.0574, **115.0397**, 113.0603, 85.0657	Isopropyl-malic acid	Grape,
6.339	371.0980	$C_{16}H_{20}O_{10}$	1.07	325.0879, **163.0392**, 119.0482	Coumaric acid-*O*-hexoside (formate adduct)	Cran, Eld, Goji,
6.378	183.0299	$C_8H_8O_5$	−0.39	**168.0061**, 124.0157	Methyl gallate	Grape,
6.584	327.1094	$C_{15}H_{20}O_8$	−1.57	165.0525, **147.0458**	Phenyllactic acid 2-*O*-hexoside	Rose,
6.955	339.0726	$C_{15}H_{16}O_9$	−3.31	**177.0194**, 149.0232, 133.0289	Esculetin hexoside	Cran,
7.014	341.0875	$C_{15}H_{18}O_9$	0.71	**281.0664**, 251.0555, 221.0456, 179.0342, 135.0441	Caffeic acid-*C*-hexoside	Grape,
7.132	487.1455	$C_{21}H_{28}O_{13}$	0.06	323.0974, **163.0400**, 145.0291, 119.0457	Coumaric acid-*O*-dihexoside	Rose, Goji,
7.137	577.1351	$C_{30}H_{26}O_{12}$	0.51	451.1001, **425.0879**, 407.0771, 289.0704, 287.0557, 125.0237	(Epi)catechin-(epi)catechin (B-type)	Grape, Rose,
7.429	515.1400	$C_{22}H_{28}O_{14}$	0.71	353.0903, 341.0861, **323.0765**, 191.0549, 179.0355	Caffeoylglucosyl quinic acid	Goji,
7.841	447.1501	$C_{19}H_{28}O_{12}$	1.51	**401.1451**, 269.1024, 161.0463, 131.0357	Benzyl alcohol hexose pentose (formate adduct)	Grape, Eld, Rai
7.865	337.0929	$C_{16}H_{18}O_8$	−0.05	**163.0394**, 119.0503	3-*p*-Coumaroylquinic acid	Rose,
7.917	315.1086	$C_{14}H_{20}O_8$	−0.18	**269.1029**, 161.0435, 153.0204	Benzyl glucopyranoside (formate adduct)	Cran,
7.964	325.0930	$C_{15}H_{18}O_8$	0.64	**163.0399**, 119.0503	Coumaric acid-*O*-hexoside	Grape, Cran, Goji,
8.114	577.1347	$C_{30}H_{26}O_{12}$	1.26	451.1025, **425.0859**, 407.0748, 289.0700, 287.0558, 125.0246	(Epi)catechin-(epi)catechin (B-type)	Grape, Rose,
8.272	341.0872	$C_{15}H_{18}O_9$	1.63	**281.0653**, 251.0558, 221.0449, 179.0333, 135.0447	Caffeic acid-*C*-hexoside	Grape,
8.888	447.1496	$C_{19}H_{28}O_{12}$	1.97	**401.1453**, 293.0799, 269.0978, 233.0577, 161.0399	Benzyl alcohol hexose pentose (formate adduct)	Grape,
8.950	289.0718	$C_{15}H_{14}O_6$	−0.27	**245.0815**, 205.0506, 203.0715, 179.0338, 125.0237	Catechin	Grape, Rose,
8.961	465.1033 (+)	$C_{21}H_{20}O_{12}$	−0.91	**303.0497**, 257.0479, 229.0479	Delphinidin-3-*O*-hexoside	Grape,
9.144	329.0880	$C_{14}H_{18}O_9$	−0.54	283.0822, **121.0292**, 77.0400	Benzoic acid-*O*-hexoside (formate adduct)	Cran,
9.454	353.0879	$C_{16}H_{18}O_9$	−0.21	**191.0555**, 179.0343, 161.0227, 135.0457 111.0085	Chlorogenic acid	Cran, Eld, Goji,
9.699	461.1300	$C_{19}H_{26}O_{13}$	0.45	**415.1246**, 293.0882, 121.0293, 77.0407	Benzoic acid-*O*-pentosylhexoside (formate adduct)	Cran,
9.750	431.1917	$C_{20}H_{32}O_{10}$	0.03	**385.1862**, 223.1308, 153.0927	Roseoside (formate adduct)	Grape, Cran, Rose,
10.490	577.1345	$C_{30}H_{26}O_{12}$	1.41	451.1000, **425.0866**, 407.0745, 289.0684, 287.0554, 125.0262	(Epi)catechin-(epi)catechin (B-type)	Grape,
10.581	433.2077	$C_{20}H_{34}O_{10}$	0.18	**387.2010**, 225.1589, 179.0573, 161.0426, 113.0223	Dihydro-roseoside (formate adduct)	Rose,

(*continued on next page*)

Table 2 (*continued*)

t_R (min)	Observed [M-H]$^-$	Molecular formula	Error (ppm)	Fragment ions (m/z)	Assigned identification	Extract
10.613	491.1194	$C_{23}H_{24}O_{12}$	2.31	**329.0653**, 315.0495, 300.0280, 299.0202, 271.0634	Tricin-*O*-hexoside	Grape,
10.643	177.0187	$C_9H_6O_4$	2	**133.0293**	Esculetin	Cran,
10.848	449.1085 (+)	$C_{21}H_{20}O_{11}$	−1.24	**287.0544**	Cyanidin-3-*O*-hexoside	Grape,
10.868	771.1982	$C_{33}H_{40}O_{21}$	0.72	**609.1467**, 462.0797, 301.0339, 178.9973, 151.0014	Quercetin-*O*-hexoside-*O*-rutinoside	Goji,
11.016	577.1344	$C_{30}H_{26}O_{12}$	1.54	451.1053, **425.0849**, 407.0772, 289.0721, 287.0540, 125.0242	(Epi)catechin-(epi)catechin (B-type)	Grape,
11.461	179.0350	$C_9H_8O_4$	0.35	**135.0451**	Caffeic acid	Cran,
11.629	517.1561	$C_{22}H_{30}O_{14}$	1.1	384.9326, 355.1009, 337.0938, 248.9599, **193.0502**, 175.0389, 149.0610, 134.0336	Ferulic acid-*O*-di-hexoside	Goji,
11.783	479.1191 (+)	$C_{22}H_{22}O_{12}$	−1.32	**317.0658**	Petunidin-*O*-hexoside	Grape,
12.338	289.0718	$C_{15}H_{14}O_6$	0.1	**245.0822**, 205.0502, 203.0713, 179.0343, 125.0243	(Epi)catechin	Grape,
12.393	449.1083	$C_{21}H_{22}O_{11}$	2.04	**287.0563**, 269.0436, 259.0579	Dihydrokaempferol-*O*-hexoside	Rose,
13.787	325.0933	$C_{15}H_{18}O_8$	−1.94	163.0410, **119.0506**	Coumaric acid-*O*-hexoside	Rose,
13.989	367.1027	$C_{17}H_{20}O_9$	1.13	193.0541, **173.0437**, 111.0419	4-Feruloylquinic acid	Eld,
14.060	463.1236 (+)	$C_{22}H_{22}O_{11}$	−0.56	**301.0704**, 286.0453	Peonidin-3-*O*-hexoside	Grape,
14.186	197.0455	$C_9H_{10}O_5$	0.34	169.0152, **124.0160**	Ethyl gallate	Grape,
14.494	491.1189	$C_{23}H_{24}O_{12}$	0.95	**329.0657**, 314.0408, 313.0328, 299.0184	Tricin-*O*-hexoside	Grape,
16.546	355.1032	$C_{16}H_{20}O_9$	0.65	**193.0504**, 134.0373	Ferulic acid-*O*-hexoside	Cran,
16.736	163.0400	$C_9H_8O_3$	0.47	**119.0498**	*p*-Coumaric acid	Cran, Eld, Rose, Goji,
16.869	625.1412	$C_{27}H_{30}O_{17}$	−0.51	**463.0885**, 301.0368	Quercetin-*O*-dihexoside	Grape,
16.917	435.0927	$C_{20}H_{20}O_{11}$	1.36	303.0522, 285.0409, 177.0188, **151.0034**, 125.0232	Taxifolin-*O*-pentoside	Rose,
17.025	755.2041	$C_{33}H_{40}O_{20}$	0.01	591.1320, 489.1022, 301.0320, **300.0270**, 271.0254, 255.0285, 178.9984, 151.0062	Quercetin derivative	Eld,
17.612	509.1299	$C_{23}H_{26}O_{13}$	0.25	355.0663, **347.0759**, 329.0664, 193.0108, 149.0236	Unknown	Grape,
17.911	191.0353	$C_{10}H_8O_4$	−1.99	**176.0104**, 148.0142	Scopoletin	Goji,
17.982	493.0623	$C_{21}H_{18}O_{14}$	0.2	**317.0308**, 178.9971, 151.0322	Myricetin-*O*-glucuronide	Grape,
18.105	641.1357	$C_{27}H_{30}O_{18}$	0.89	**479.0828**, 317.0294	Myricetin-*O*-dihexoside	Grape,
18.137	355.1032	$C_{16}H_{20}O_9$	0.91	**193.0503**, 134.0363	Ferulic acid-*O*-hexoside	Cran,
18.167	479.0827	$C_{21}H_{20}O_{13}$	0.83	317.0278, **316.0223**, 287.0183, 271.0249, 178.9981, 151.0009	Myricetin-*O*-hexoside	Grape,
18.858	449.2033	$C_{20}H_{34}O_{11}$	−0.39	**269.1387**, 225.1536	Apigenin derivative	Rose,
19.221	449.1091	$C_{21}H_{22}O_{11}$	−0.49	**287.0551**, 151.0041, 135.0465	Eriodictyol-*O*-hexoside	Rose,
19.925	441.0822	$C_{22}H_{18}O_{10}$	1.03	331.0419, 289.0702, 271.0577, 245.0943, **169.0137**, 125.0254	(Epi)catechin-*O*-gallate	Grape,
20.046	303.0509	$C_{15}H_{12}O_7$	−0.41	**285.0388**, 177.0180, 125.0246	Taxifolin	Cran,
20.429	519.1132	$C_{24}H_{24}O_{13}$	1.82	**315.0481**, 300.0287, 299.0170	Isorhamnetin-*O*-acetylhexoside	Grape,
20.726	609.1463	$C_{27}H_{30}O_{16}$	0.66	301.0334, **300.0265**, 178.9964, 151.0037	Rutin	Grape, Eld, Goji, Rai
21.381	463.0878	$C_{21}H_{20}O_{12}$	0.91	301.0339, **300.0274**, 271.0232, 255.0299, 178.9972, 151.0026	Quercetin-*O*-hexoside	All
21.599	300.9992	$C_{14}H_6O_8$	−1.05	257.0091, **229.0137**	Ellagic acid	Rose,
21.689	477.0672	$C_{21}H_{18}O_{13}$	0.73	**301.0348**, 178.9984, 151.0028	Quercetin-*O*-glucuronide	Grape, Rose, Rai
21.812	463.0878	$C_{21}H_{20}O_{12}$	0.82	301.0335, **300.0269**, 271.0247, 255.0277, 178.9968, 151.0033	Quercetin-*O*-hexoside	Grape, Cran, Rai
21.997	493.0987	$C_{22}H_{22}O_{13}$	0.41	**331.0445**, 330.0377, 316.0233, 315.0179	Mearnsetin-*O*-hexoside	Grape,
22.120	435.0930	$C_{20}H_{20}O_{11}$	0.60	**303.0509**, 285.0398, 177.0183, 151.0037, 125.0250	Taxifolin-*O*-pentoside	Rose,
22.564	579.2071	$C_{28}H_{36}O_{13}$	2.56	**417.1550**, 402.1324, 181.0477, 166.0344, 151.0153	Syringaresinol-*O*-hexoside	Eld,
22.598	505.1346 (+)	$C_{24}H_{24}O_{12}$	−0.78	**301.0702**, 286.0471	Peonidin-3-*O*-acetylhexoside	Grape,
22.820	535.1455 (+)	$C_{25}H_{26}O_{13}$	−1.66	**331.0813**, 315.0501, 299.0546, 287.0542, 270.0519, 242.0579, 179.0330	Malvidin-3-*O*-acetylhexoside	Grape,
23.840	593.1512	$C_{27}H_{30}O_{15}$	0.26	**285.0396**, 255.0283, 229.0507, 151.0035	Kaempferol-*O*-rutinoside	Eld, Goji,
23.907	447.0927	$C_{21}H_{20}O_{11}$	1.25	285.0383, **284.0327**, 255.0292, 227.0333, 151.0046	Kaempferol-*O*-hexoside	Grape, Rai
24.055	641.1504 (+)	$C_{31}H_{28}O_{15}$	−0.89	**317.0655**, 302.0412	Petunidin-(6-*O*-caffeoyl)hexoside	Grape,
24.598	193.0506	$C_{10}H_{10}O_4$	0.4	178.0247, 149.0604, **134.0366**	Ferulic acid	Cran,
24.653	623.1606	$C_{28}H_{32}O_{16}$	1.93	**315.0495**, 300.0266, 271.0224	Isorhamnetin-*O*-rutinoside	Eld, Goji,
24.656	433.0763	$C_{20}H_{18}O_{11}$	3.97	**301.0349**, 178.9935, 151.0009	Quercetin-*O*-pentoside	Grape, Cran, Rose,
24.993	611.1400 (+)	$C_{30}H_{26}O_{14}$	−0.52	**303.0503**, 257.0428, 229.0570	Delphinidin-3-(6-*O*-coumaroyl)hexoside	Grape,
25.087	447.0930	$C_{21}H_{20}O_{11}$	0.71	**285.0386**, 284.0322, 255.0309, 227.0349, 151.0053	Kaempferol-*O*-hexoside	Grape,
25.272	461.0725	$C_{21}H_{18}O_{12}$	−1.03	**285.0406**, 175.0238, 113.0233	Scutellarin	Grape,
25.334	447.0932	$C_{21}H_{20}O_{11}$	−0.77	**301.0343**, 271.0241, 255.0270, 178.9975, 151.0028	Quercetin-*O*-deoxyhexoside	Grape, Cran, Rose,
25.586	477.1030	$C_{22}H_{22}O_{12}$	2.08	315.0539, **314.0416**, 150.9988	Isorhamnetin-*O*-hexoside	Grape, Eld,
26.101	625.1559 (+)	$C_{31}H_{28}O_{14}$	−0.87	**301.0709**, 286.0458, 258.0535	Peonidin-(6-*O*-caffeoyl)hexoside	Grape,

(*continued on next page*)

Table 2 (*continued*)

t_R (min)	Observed [M-H]$^-$	Molecular formula	Error (ppm)	Fragment ions (*m/z*)	Assigned identification	Extract
26.243	655.1666 (+)	$C_{32}H_{30}O_{15}$	−1.6	**331.0811**, 316.0574, 299.0539, 287.0545, 270.0515, 242.0571, 179.0314	Malvidin-(6-*O*-caffeoyl)hexoside	Grape,
26.386	435.1291	$C_{21}H_{24}O_{10}$	0.68	**273.0753**, 167.0352	Phloretin-*O*-hexoside	Cran, Rose,
27.009	595.1448 (+)	$C_{30}H_{26}O_{13}$	−0.06	**287.0546**	Cyanidin-(6-*O*-coumaryoyl)hexoside	Grape,
27.216	655.1666	$C_{32}H_{32}O_{15}$	0.55	501.1029, 475.1221, 347.0760, **329.0659**, 303.0880, 193.0137, 149.0248	Unknown	Grape,
27.278	317.0302	$C_{15}H_{10}O_8$	−0.01	**178.9959**, 151.0022	Myricetin	Grape,
27.530	625.1558 (+)	$C_{31}H_{28}O_{14}$	−0.85	**317.0653**, 302.0423, 274.0446	Petunidin-(6-*O*-coumaroyl)hexoside	Grape,
29.291	431.0974	$C_{21}H_{20}O_{10}$	2.27	286.0470, **285.0385**, 284.0310, 255.0299, 229.0465, 227.0313	Kaempferol-*O*-deoxyhexoside	Grape, Cran,
29.551	639.1715 (+)	$C_{32}H_{30}O_{14}$	−1.27	**331.0813**, 315.0499, 299.0549, 287.0553, 270.0533, 242.0565, 179.0327	Malvidin-3-(6-*O*-coumaroyl) hexoside	Grape,
29.653	609.1609 (+)	$C_{31}H_{28}O_{13}$	−0.82	**301.0707**, 286.0465, 258.0515, 230.0617	Peonidin-3-(6-*O*-coumaroyl)hexoside	Grape,
31.112	591.1352	$C_{27}H_{28}O_{15}$	0.82	529.1330, **489.1027**, 447.0940, 301.0351, 300.0269, 178.9945	Quercetin-3-*O*-(4''-hydroxylmethylglutaryl)-*α*-rhamnoside	Cran,
31.179	312.1239	$C_{18}H_{19}NO_4$	1.79	297.1011, **178.0499**, 148.0535, 135.0443	Feruloyltyramine	Goji,
35.767	301.0355	$C_{15}H_{10}O_7$	−0.63	178.9990, **151.0035**	Quercetin	Grape, Cran, Eld, Rose,
36.716	567.1136	$C_{28}H_{24}O_{13}$	1.65	301.0349, **300.0277**, 271.0269, 255.0383, 178.9984, 151.0021	Quercetin derivative	Cran,
37.403	593.1300	$C_{30}H_{26}O_{13}$	0.08	447.0908, **285.0395**, 284.0324, 257.0451	Kaempferol-*O*-(coumaroyl)-hexoside	Rose,
38.605	327.2169	$C_{18}H_{32}O_5$	2.22	229.1436, 211.1329, 183.1418, **171.1017**	Oxo-dihydroxy-octadecenoic acid	Grape, Eld, Rai
38.871	271.0616	$C_{15}H_{12}O_5$	−1.3	177.0192, **151.0024**, 119.0525, 107.0134	Naringenin	Cran,
40.117	345.0610	$C_{17}H_{14}O_8$	1.22	**330.0372**, 315.0123	Syringetin	Grape,
40.172	329.2333	$C_{18}H_{34}O_5$	−0.29	**229.1467**, 211.1354, 171.1049	Trihydroxy-octadecenoic acid	Grape, Eld, Goji, Rai
40.442	315.0506	$C_{16}H_{12}O_7$	0.25	**300.0264**	Isorhamnetin	Grape,

Schmitzer, 2009). Senica, Stampar, Veberic, and Mikulic-Petkovsek (2017) mentioned quercetin glycosides as the major flavonols in elderberry berries followed by kaempferol and isorhamnetin derivatives. In our work, we determined a high level of quercetin glycosides; on the contrary, kaempferol and isorhamnetin glycosides were present but not abundant when compared with the other compounds. To the best of our knowledge, phenylalanine derivatives have not been previously mentioned as one of the main compounds in elderberry extracts (Fig. S7). The UAE showed the highest concentration in both phenolic acids (1.56 mg g^{-1} DE) and flavonoids (5.4 mg g^{-1} DE). Among the phenolic compounds, rutin was the most abundant: 3.7 mg g^{-1} DE in decoction, 4.6 mg g^{-1} DE in the ultrasound-assisted extract and 4.0 mg g^{-1} DE in the microwave-assisted extract (Table S5). We quantified also isocitric and citric acids because of the high percentage they showed in all the extracts, being isocitric acid the most abundant.

38 compounds have been found in rose berries decoction, UAE and MAE (Fig. S8, Table S6). In a previous work conducted by Hvattum (2002), 21 phenolic compounds were detected in rose hip showing the presence of numerous quercetin, taxifolin and eriodictyol glycosides. Several glycosides of quercetin and taxifolin have been found in our extracts. Isocitric and citric acid, malic acid, methylgallate hexoside and kaempferol-*O*-(coumaroyl)-hexoside were the main compounds in all the type of extracts, followed by protocatechuic acid, catechin and quercetin-*O*-deoxyhexoside (Fig. S9). Citric and malic acids have been previously detected in *R. canina* along with phenolic compounds (Demir, Yildiz, Alpaslan, & Hayaloglu, 2014). Among the quantified compounds, isocitric acid presented the highest concentration, between 9.8 and 12.5 mg g^{-1} depending on the sample treatment, followed by citric acid (4.4–5.7 mg g^{-1}). Demir et al. (2014) determined a concentration of citric acid of 9.12 g/ 100 g in dried extract. Hrnčič, Cör, Kotnik, and Knez (2019) calculated the content of different phenolic compounds in rose hip fruits extracted using different techniques, among them catechin (0.012–0.164 μg/mg) and ellagic acid (0.145–0.650 μg/mg). Compared with our results (Table S7), we obtained a high quantity of catechin, while ellagic acid was in the similar range previously reported.

A limited number of compounds (20) have been identified in goji berries decoction, ultrasound-assisted extract and microwave-assisted extracts (Table S8). The most abundant compounds were a disaccharide in Goji berries DC and MAE, and organic acids (isocitric, citric and malic acids) in all of them. The main phenolic compounds were the phenolic acid *p*-coumaric acid and the flavonoid rutin (Fig. S10). We quantified the main compounds present in the extracts that could have a biological effect (Table S9). Phenolic acids, *p*-coumaric acid and its derivative have been quantified showing a total of 1.10 mg g^{-1} for DC, 1.09 mg g^{-1} for UAE and 1.34 mg g^{-1} for MAE. The content of *p*-coumaric acid was previously estimated in extracts of L. *barbarum* fruits; it resulted in 64.0 μg/g in the study conducted by Inbaraj, Lu, Kao, and Chen (2010) and 2.32 μg/g in the research of Magiera and Zaręba (2015), while we found a quantity of 0.37–0.46 mg g^{-1} of dried extract depending on the method of extraction. Rutin was more abundant in the microwave-assisted extract (0.32 mg g^{-1} of dried extract). In a previous work, the content of rutin in L. *barbarum* fruits was estimated as 11.4 μg/g, much lower than our results (Magiera et al., 2015). Finally, isocitric and citric acids were quantified showing a major abundance of isocitric acid in all the extracts.

Only 16 compounds have been identified or tentatively characterized in raisins extracts (Table S10, Fig. S11). The main compounds were organic acids, *e.g.*, tartaric acid, malic acid, citric and isocitric acids. Caftaric acid and quercetin derivatives were the main polyphenols, but their concentration was low. The quantification of isocitric and citric acids, caftaric acid and quercetin derivatives is shown in Table S11.

3.4. Antioxidant activity

Antioxidant compounds play a central role in the defense mechanism against attacks by free radicals. This is an essential mechanism for treating some degenerative and chronic diseases such as cancer, diabetes, and cardiovascular problems (Haque, Khaliduzzaman, Asaduzzaman, Pattadar, & Hasan, 2023). DPPH and ABTS radicals are the most common in antioxidant studies and are used to evaluate the radical quench ability of antioxidant compounds. In general the antiradical properties of the tested extracts depend on the extraction methods used (Table 4).

In both radical scavenging assays, the best activity was measured for grape pomace extracts (DPPH: 45.05–45.23 mg TE/g DE; ABTS: 61.53–61.70 mg TE/g DE), followed by rose hip (DPPH: 22.02–43.95 mg

Table 3
Quantification of compounds in decoction (DC), ultrasound-assisted extract (UAE) and microwave-assisted extract (MAE) of grape pomace.

N°	Assigned identification	DC (mg g^{-1} DE)	UAE (mg g^{-1} DE)	MAE (mg g^{-1} DE)
Flavonoids				
22	catechin	0.91 ± 0.06^{a}	0.97 ± 0.07^{a}	0.89 ± 0.06^{a}
30	(*epi*)catechin	1.00 ± 0.07^{a}	1.00 ± 0.07^{a}	1.01 ± 0.07^{a}
37 + 38	myricetin-*O*-dihexoside + myricetin-*O*-hexoside	0.33 ± 0.02^{a}	0.38 ± 0.0 3^{ab}	0.42 ± 0.03^{b}
40	isorhamnetin-*O*-acetylhexoside	0.25 ± 0.02^{a}	0.24 ± 0.02^{a}	0.30 ± 0.02^{b}
42	quercetin-*O*-hexoside	0.24 ± 0.02^{a}	0.29 ± 0.02^{b}	0.31 ± 0.02^{b}
43 + 44 + 45	quercetin-*O*-glucuronide + quercetin-*O*-hexoside + mearnsetin-*O*-hexoside	1.5 ± 0.1^{a}	1.8 ± 0.1^{b}	1.8 ± 0.1^{b}
48	kaempferol-*O*-hexoside	0.20 ± 0.01^{a}	0.23 ± 0.02^{ab}	0.26 ± 0.02^{b}
52 + 54	kaempferol-*O*-hexoside + quercetin-*O*-deoxyhexoside	0.74 ± 0.04^{a}	0.89 ± 0.04^{b}	0.94 ± 0.04^{b}
65	quercetin	0.15 ± 0.01^{a}	0.16 ± 0.01^{a}	0.20 ± 0.01^{b}
Total		**5.3 ± 0.2^{a}**	**6.0 ± 0.2^{b}**	**6.1 ± 0.2^{b}**
Phenolic acids				
5	gallic acid	0.22 ± 0.02^{a}	0.21 ± 0.01^{a}	0.22 ± 0.02^{a}
Others				
2	isocitric acid	1.5 ± 0.1^{a}	1.5 ± 0.1^{a}	1.8 ± 0.1^{b}
4	citric acid	0.76 ± 0.05^{a}	0.84 ± 0.06^{ab}	0.95 ± 0.07^{b}
Total		**2.3 ± 0.1^{a}**	**2.3 ± 0.1^{a}**	**2.8 ± 0.1^{b}**
TIPC		**7.8 ± 0.2^{a}**	**8.6 ± 0.2^{b}**	**9.2 ± 0.2^{c}**

Values (mg g^{-1} dried extract) are the mean ± SD of three parallel measurements. TIPC = total individual phenolic content (the sum of all phytochemicals).

TE/g DE; ABTS: 43.35–61.70 mg TE/g DE) and elderberry extracts (DPPH: 16.78–39.29 mg TE/g DE; ABTS: 36.21–58.96 mg TE/g DE). Similar to the total phenolic content, the weakest radical scavenging ability was observed for the raisin extracts (DPPH: 0.91–2.50 mg TE/g DE; ABTS: 14.93–15.59 mg TE/g DE). Electron donation is essential in the antioxidant mechanism, thus CUPRAC and FRAP assays were performed to prove this concept. The tests are based on electron transfer from antioxidants to metal ions, and the changes are measured calorimetrically. In these tests, the highest effect was found for grape pomace extracts (CUPRAC: 172.26–178.47 mg TE/g DE; FRAP: 115.58–121.04 mg TE/g DE). In general these parameters are deeply influenced by the extraction method applied on the raw matrix; for example, the best effect was found for rose hips decoction, while the highest potency for cranberries UAE extract. However, we observed antioxidant values for grape pomace extracts very close each other. This could be due to an extremely high variability in grape pomace's bioactive compounds, ranging from plant-derived polyphenols to polyunsaturated fatty acids (PUFAs), all characterized by a number of hydroxyl groups responsible of this ability, such can be strengthened by steric hindrance. We can suppose that a poor specificity in the extraction ability by each technique is responsible of a low variability in antioxidant results for such grape pomace extracts.

The best radical scavenging and reducing power for grape pomace extracts can be explained by the presence of some compounds. As shown in Table 3, the grape pomace extracts contain significant amounts of quercetin derivatives and catechin, considered effective antioxidants (Grzesik, Naparło, Bartosz, & Sadowska-Bartosz, 2018; Qi, Qi, Xiong, & Long, 2022). In addition, Pearson correlation analysis revealed a strong correlation between the total phenolic content and antioxidant properties (Fig. 1).

Overall phenolic compounds are the leading players in the antioxidant activity of the tested extracts. Transition metals are vital catalysts in the Fenton reaction, responsible for the generation of hydroxyl radicals. Consequently, chelating these metals can induce a decrease in hydroxyl radical production. Goji and elderberry extracts showed greater metal chelating abilities than other extracts. The most active samples were the decoction of goji berries (18.40 mg EDTAE/g DE) and microwave extract of elderberry (17.01 mg EDTAE/g DE). There is no relationship between the observed metal chelation ability and the total phenolic content, but this ability can be attributed to non-phenolic chelators such as peptides, polysaccharides, or sulfides (Chanthasri et al., 2018; Taherkhani, 2017). The phosphomolybdenum (PBD) assay is one of the total antioxidant assays, involving the conversion of Mo(VI) to Mo(V) by antioxidants in the acidic state. Phenolic and non-phenolic antioxidants can play a role in this conversion. Looking at the free radical scavenging and reducing power tests, the most potent abilities were found in grape pomace extracts (1.89–1.97 mmol TE/g DE), followed by elderberry and rose hip extracts. In addition, grape pomace

Table 4
Antioxidant properties of the tested extracts.*

Samples	Extraction methods	DPPH (mg TE/g)	ABTS (mg TE/g)	CUPRAC (mg TE/g)	FRAP (mg TE/g)	MCA (mg EDTAE/g)	PBD (mmol TE/g)
Grape pomace	Decoction	45.05 ± 0.22^{a}	61.70 ± 0.01^{a}	172.26 ± 7.25^{a}	121.04 ± 0.12^{a}	9.24 ± 0.29^{ef}	1.89 ± 0.09^{a}
	UAE	45.23 ± 0.13^{a}	61.54 ± 0.04^{a}	178.47 ± 0.98^{a}	115.58 ± 1.60^{b}	8.30 ± 0.36^{efg}	1.97 ± 0.06^{a}
	MAE	45.07 ± 0.16^{a}	61.53 ± 0.02^{a}	177.68 ± 3.78^{a}	116.49 ± 4.02^{b}	8.32 ± 0.30^{efg}	1.86 ± 0.05^{a}
Cranberry	Decoction	15.62 ± 0.72^{f}	36.19 ± 0.46^{e}	41.78 ± 1.69^{h}	24.62 ± 0.96^{i}	7.42 ± 0.53^{fg}	0.82 ± 0.01^{h}
	UAE	44.13 ± 0.51^{a}	61.57 ± 0.06^{a}	136.25 ± 3.61^{b}	87.04 ± 0.77^{c}	12.81 ± 0.66^{bc}	1.32 ± 0.01^{d}
	MAE	17.07 ± 0.98^{f}	37.88 ± 1.05^{e}	44.11 ± 0.47^{h}	26.38 ± 0.30^{i}	8.36 ± 0.18^{efg}	0.90 ± 0.05^{gh}
Elderberry	Decoction	16.78 ± 0.86^{f}	36.21 ± 0.33^{e}	42.09 ± 0.43^{h}	24.26 ± 1.63^{i}	14.42 ± 0.44^{b}	0.82 ± 0.03^{h}
	UAE	39.29 ± 0.50^{b}	58.96 ± 0.22^{b}	86.31 ± 1.27^{d}	55.39 ± 1.42^{e}	14.00 ± 0.15^{b}	1.29 ± 0.07^{d}
	MAE	36.89 ± 0.63^{c}	57.26 ± 0.83^{b}	71.02 ± 4.13^{e}	45.24 ± 0.63^{f}	17.01 ± 1.33^{a}	1.71 ± 0.02^{b}
Rose hip	Decoction	43.95 ± 0.30^{a}	61.70 ± 0.03^{a}	121.20 ± 2.41^{c}	75.54 ± 0.60^{d}	13.15 ± 0.45^{bc}	1.46 ± 0.05^{c}
	UAE	22.02 ± 0.42^{e}	43.35 ± 0.93^{d}	52.68 ± 1.19^{g}	30.84 ± 0.88^{h}	10.09 ± 0.85^{de}	0.88 ± 0.04^{gh}
	MAE	28.80 ± 0.74^{d}	49.70 ± 0.20^{c}	60.29 ± 0.09^{f}	40.24 ± 0.86^{g}	11.58 ± 1.44^{cd}	0.90 ± 0.02^{gh}
Goji berries	Decoction	4.70 ± 0.47^{h}	26.09 ± 0.74^{g}	13.48 ± 0.35^{i}	9.18 ± 0.16^{j}	18.40 ± 0.36^{a}	1.20 ± 0.04^{de}
	UAE	6.16 ± 0.16^{gh}	26.29 ± 1.48^{g}	13.39 ± 0.03^{i}	9.05 ± 0.13^{j}	13.23 ± 0.48^{bc}	1.26 ± 0.05^{d}
	MAE	6.60 ± 0.47^{g}	28.72 ± 0.14^{f}	15.10 ± 0.29^{i}	10.83 ± 0.32^{j}	16.56 ± 0.57^{a}	1.31 ± 0.04^{d}
Raisins	Decoction	0.91 ± 0.06^{j}	15.20 ± 0.58^{h}	9.43 ± 0.13^{i}	7.37 ± 0.52^{j}	7.64 ± 0.52^{fg}	0.93 ± 0.05^{ef}
	UAE	1.50 ± 0.23^{ij}	14.93 ± 0.27^{h}	9.54 ± 0.05^{i}	10.52 ± 1.56^{j}	6.65 ± 0.29^{g}	1.07 ± 0.04^{gh}
	MAE	2.50 ± 0.12^{i}	15.59 ± 0.51^{h}	9.04 ± 0.16^{i}	7.73 ± 0.66^{j}	7.43 ± 0.76^{fg}	0.98 ± 0.03^{fg}

* Values are reported as mean ± SD of three parallel measurements. TE: Trolox equivalent; EDTAE: EDTA equivalent. Different letters indicate significant differences between the tested extracts ($p < 0.05$).

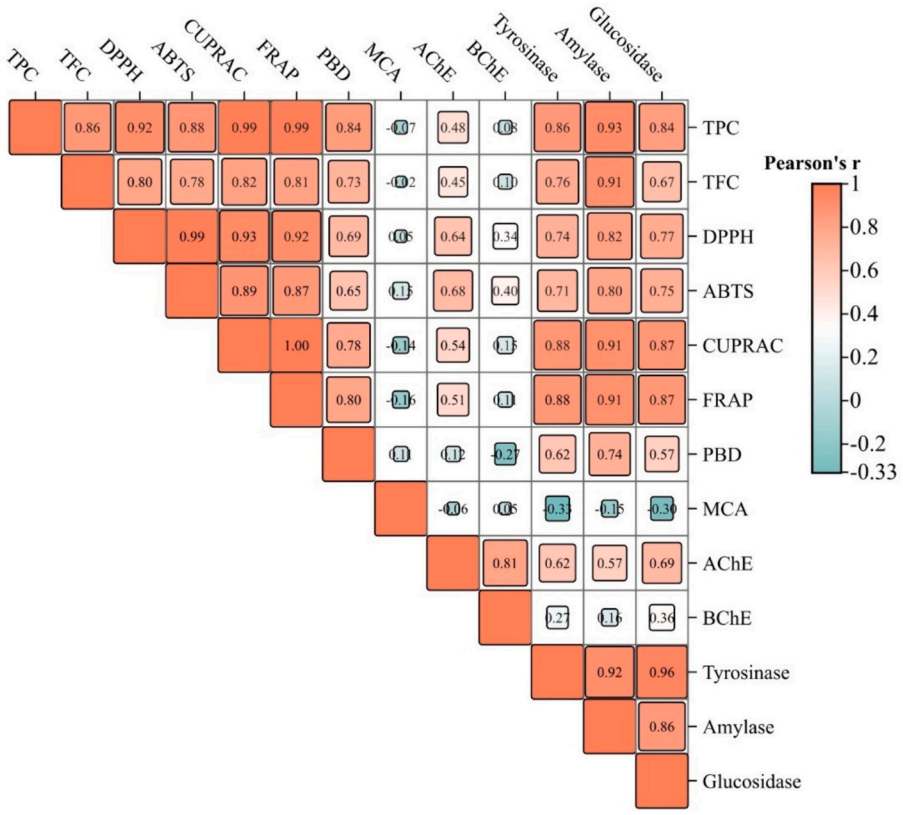

Fig. 1. Pearson correlation between total bioactive components and biological activities. ABTS, 2,2′-azino-bis(3-ethylbenzothiazoline) 6-sulfonic acid; AChE, acetylcholinesterase; BChE, butyrylcholinesterase; CUPRAC, cupric ion reducing antioxidant capacity; DPPH, 1,1-diphenyl-2-picrylhydrazyl; FRAP, ferric ion reducing antioxidant power; MCA, metal chelating activity; PBD, phosphomolybdenum activity; TPC, total phenolic acid content; TFC, total flavonoid content.

shows the best antioxidant activity correlated to the presence of high level of total phenolic compounds. Overall, the extraction methods exert different effects on the antioxidant activity of the berries, while they do not have a great impact on the antioxidant properties of the grape pomace, since these values are very close each other's. However, the choice of extraction methods had a major impact on cranberry, elderberry and rosehip. For example, the DPPH radical scavenging activity of the cranberry decoction was 15.62 mg, but it was 44.13 mg TE/g (almost three times higher) in the UAE extract. In addition, similar results were also recorded for reducing power tests. From this point, the best ability of UAE can be explained by the fact that ultrasonic waves can effectively destroy the cell wall and the phenolics can be easily released. The approach was also supported by several researchers (Chemat et al., 2017; Shen et al., 2023). Regarding rosehip, decoction was found to be the best extraction technique. The observation can be explained by the fact that the decoction process can improve the solubility of bioactive compounds and thus more compounds can be released (Zhang, Lin, & Ye, 2018) from the matrix.

3.5. Enzyme inhibition activity

Enzymes serve as essential components for the development of novel pharmaceutical applications. In addition to the catalytic effects, their inhibition can alleviate the symptoms of some diseases, such as diabetes, obesity, and Alzheimer's. Amylase and glucosidase are the primary targets for controlling blood sugar levels in people with diabetes (Anshika et al., 2022). In addition, the inhibition of cholinesterase is known as the cholinergic hypothesis, which explains the increase in acetylcholine levels and, therefore, the improvement in cognitive functions in Alzheimer's disease (Zhang et al., 2022). Some compounds have already been used as enzyme inhibitors in pharmaceutical applications, however they show unpleasant side effects in long term treatment, thus new, natural and safe enzyme inhibitors are hardly due. We investigated the inhibitory effects of the tested extracts on cholinesterase, amylase, glucosidase, and tyrosinase (Table 5). For both AChE and BChE inhibition, the rose hip and cranberry extracts showed a stronger effect than others. The extraction methods influenced the cholinesterase inhibition of the tested samples. In particular, the change in the levels of chemical compounds can lead to a variation in the observed enzyme inhibitory results. For example, the best AChE and BChE inhibitory ability was found in grape pomace decoction extract, which was characterized by a high content of malvidine derivatives. Thus, the observed ability can be attributed to the presence of malvidin and its derivatives (Strugała-Danak, Spiegel, & Gabrielska, 2023). The goji berry and raisin extracts did not affect tyrosinase. Our observations for tyrosinase may be associated with the presence of some compounds. For example, quercetin and catechin are effective tyrosinase inhibitors and can be attributed to grape pomace's observed tyrosinase inhibitory effect (Jakimiuk et al., 2022; Kim et al., 2023). In addition, the best tyrosinase ability was found in the MAE of cranberry with 23.55 mg KAE/g. As shown in Fig. S5, the extract obtained by MAE contained higher amounts of benzoic acid derivatives and the observed tyrosinase ability can be attributed to the presence of these compounds (Khan et al., 2010). Regarding antidiabetic enzymes, the highest amylase inhibition was recorded in grape pomace extracts, followed by elderberry and cranberry extracts. Similarly, the best glucosidase inhibition was achieved by grape pomace extracts followed by rose hip and cranberry extracts. The observed amylase and glucosidase inhibition had a strong correlation with the total phenolic content. In agreement with our results, some authors reported that phenolic compounds were effective glucosidase inhibitors in *in vitro* and *silico* assays, confirming the presence of gallic acid in grape pomace extracts, protocatechuic acid in cranberry extracts, chlorogenic acid in elderberry extracts and coumarinic acid in goji extracts (Guan, Long, Ren, Li, & Zhang, 2022;

Table 5
Enzyme inhibitory effects of the tested extracts*.

Samples	Extraction methods	AChE (mg GALAE/g)	BChE (mg GALAE/g)	Tyrosinase (mg KAE/g)	Amylase (mmol ACAE/g)	Glucosidase (mmol ACAE/g)
Grape pomace	Decoction	1.88 ± 0.03^{cd}	2.83 ± 0.11^{c}	53.40 ± 0.31^{a}	0.77 ± 0.01^{a}	1.69 ± 0.01^{a}
	UAE	1.79 ± 0.01^{de}	2.33 ± 0.04^{de}	54.35 ± 0.63^{a}	0.78 ± 0.04^{a}	1.68 ± 0.01^{a}
	MAE	1.71 ± 0.04^{e}	2.66 ± 0.14^{cd}	54.50 ± 0.45^{a}	0.78 ± 0.02^{a}	1.64 ± 0.01^{a}
Cranberry	Decoction	2.05 ± 0.03^{a}	4.33 ± 0.07^{ab}	20.52 ± 0.90^{cd}	0.48 ± 0.04^{bcd}	1.19 ± 0.07^{bc}
	UAE	1.88 ± 0.01^{bcd}	4.07 ± 0.25^{b}	20.87 ± 1.05^{cd}	0.53 ± 0.01^{bc}	1.28 ± 0.03^{b}
	MAE	2.10 ± 0.04^{a}	4.62 ± 0.05^{a}	23.55 ± 0.58^{bc}	0.55 ± 0.07^{b}	1.05 ± 0.03^{cd}
Elderberry	Decoction	1.84 ± 0.02^{de}	4.65 ± 0.07^{a}	21.62 ± 1.65^{cd}	0.52 ± 0.01^{bc}	0.90 ± 0.03^{d}
	UAE	1.30 ± 0.02^{f}	2.09 ± 0.16^{efg}	na	0.55 ± 0.02^{b}	0.61 ± 0.07^{ef}
	MAE	1.77 ± 0.03^{d}	4.42 ± 0.05^{ab}	13.18 ± 0.96^{e}	0.56 ± 0.01^{b}	0.93 ± 0.06^{d}
Rosehip	Decoction	2.04 ± 0.09^{ab}	4.44 ± 0.16^{ab}	25.35 ± 2.61^{b}	0.50 ± 0.04^{bcd}	1.17 ± 0.04^{bc}
	UAE	2.04 ± 0.05^{ab}	4.31 ± 0.02^{ab}	20.34 ± 2.19^{d}	0.50 ± 0.04^{bcd}	1.20 ± 0.08^{bc}
	MAE	2.03 ± 0.11^{abc}	4.45 ± 0.07^{ab}	16.01 ± 1.14^{e}	0.49 ± 0.02^{bcd}	1.18 ± 0.11^{bc}
Goji berries	Decoction	0.94 ± 0.09^{gh}	2.14 ± 0.04^{efg}	na	0.44 ± 0.02^{cde}	0.64 ± 0.05^{ef}
	UAE	0.86 ± 0.04^{h}	1.88 ± 0.01^{fg}	na	0.37 ± 0.02^{ef}	0.66 ± 0.04^{ef}
	MAE	0.93 ± 0.01^{h}	1.81 ± 0.05^{g}	na	0.40 ± 0.03^{def}	0.74 ± 0.04^{e}
Raisins	Decoction	1.09 ± 0.06^{g}	2.31 ± 0.36^{efg}	na	0.32 ± 0.04^{f}	0.66 ± 0.03^{f}
	UAE	1.10 ± 0.08^{g}	2.11 ± 0.23^{def}	na	0.42 ± 0.05^{def}	0.57 ± 0.04^{ef}
	MAE	0.01 ± 0.01^{i}	1.89 ± 0.07^{fg}	na	0.35 ± 0.01^{ef}	0.60 ± 0.04^{ef}

* Values are reported as mean ± SD of three parallel measurements. GALAE: Galantamine equivalent; KAE: Kojic acid equivalent; ACAE: Acarbose equivalent. Different letters indicate significant differences between the tested extracts ($p < 0.05$).

Mahdi, Azzi, & Lahfa, 2020; Nisar, Shah, Akram, Ayaz, & Rashid, 2022). Fernandes, Martins, Moreira, and Macedo (2020) evaluated the amylase inhibitory effect of grape pomace extracts obtained by ultrasound assisted method and reported almost 94 % of inhibition; catechin and procyanidin B2 might be responsible for the observed inhibitory effect. Ruffo et al. (2017) reported that the cholinesterase inhibition (IC_{50} value) potential of Calabrian and Chinese goji berries was 10.2 mg/mL and 14.8 mg/mL, respectively. In addition, Sicari et al. (2023) found that the addition of goji berries in the preparation of functional bread improved the inhibition of amylase activity. Overall these data are affected by the extraction methods, since a different composition in bioactive components can be detected for each sample. However, the complex nature of the phytochemicals, the presence of non-phenolic compounds (peptides, sugars, *etc.*) and their different interactions at the active or allosteric site of the enzyme can affect such capacity.

4. Conclusions

In this work we developed an efficient procedure to characterize compounds in grape pomace and berries extracts, also applying the correlation analysis between founded compounds and their biological activities, which represent an innovative aspect in food waste valorization. Three extraction techniques have been applied to the preparation of grape pomace and berries extracts, consequently diverse total phenolic and flavonoid contents have been measured for each of them. Grape pomace extracts show the best TPC and TFC among them and the values are very close each other; for other matrices a specific trend can be observed. Overall the MAE procedure presents the best extraction yields for grape pomace and cranberries. Grape pomace extracts exert the best antioxidant activity and enzyme inhibitory effect on tyrosinase enzyme. Such bioactivity is a direct effect of their phenolic composition, hence, the HPLC-MS represents an important tool to obtain the phytochemical profile of the plant and to quantify the main compounds, which are responsible for the observed biological effects *in vitro*. These results confirm the use of such extracts as rich sources of biologically active compounds, both enzyme inhibitors and antioxidants for the development of nutraceutical and cosmeceutical products. This work corroborates the potential of grape pomace as a by-product in the wine industry, prompting its further valorization and involvement in circular economy and recycle of industrial waste.

CRediT authorship contribution statement

Lorenza Marinaccio: Writing – original draft, Methodology, Investigation. **Giulia Gentile:** Investigation. **Eulogio J. Llorent-Martínez:** Software, Resources, Investigation. **Gokhan Zengin:** Investigation. **Domiziana Masci:** Conceptualization. **Federica Flamminii:** Resources. **Azzurra Stefanucci:** Writing – review & editing, Writing – original draft, Project administration. **Adriano Mollica:** Funding acquisition.

Declaration of competing interest

The authors declare no competing financial interests.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

The Supporting Information contains details about the HPLC-ESI-Q-TOF-MS method and the complete phytochemical composition for each extract, antioxidant and enzyme inhibitory assays procedures. Supplementary data to this article can be found online at [https://doi.org/10.1016/j.foodchem.2024.141323].

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