Ascorbic acid, anthocyanins, organic acids and mineral content of some black and red currant cultivars

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Abstract — **Introduction**. Red and black currants are a valuable component of a healthy diet because they are an excellent source of ascorbic acid, anthocyanins and minerals. **Materials and methods**. Three red currant cultivars and eight black currant cultivars were evaluated in terms of fruit quality. Some selected physicochemical characteristics such as berry weight, dry matter, soluble solids, total sugars, titratable acidity and total anthocyanins were investigated. Total anthocyanin content was measured with the pH differential absorbance method while citric, malic, tartaric and ascorbic acid were quantified by a reversed-phase HPLC method. Sodium, calcium, magnesium, iron, manganese, chromium and zinc were determined by ICP-MS following a microwave digestion, while potassium content was determined by FAAS. **Results**. Significant differences in the physicochemical and mineral content were detected among the cultivars. The range of total anthocyanins of the tested samples was 12.14–22.06 mg·100 g^{-1} (red currants) and 116.17–287.78 mg·100 g^{-1} (black currants). Ascorbic acid content varied between 23.23–44.62 mg·100 g^{-1} (red currants) and 161.58–284.46 mg·100 g^{-1} (black currants). Citric acid was predominant in all studied black and red currant cultivars, followed by malic and tartaric acids. Black and red currants have rich mineral composition, especially potassium, calcium and magnesium. Black currant fruits were superior to red currants with regard to calcium and magnesium content.

Romania / Ribes rubrum / Ribes nigrum / soft fruits / red currants / black currants / proximate composition / anthocyanins / organic acids / mineral content

Acide ascorbique, anthocyanines, acides organiques et teneur en minéraux de quelques cultivars de groseilles et de cassis.

Résumé — **Introduction**. Les groseilles et les cassis sont un élément précieux pour une alimentation saine car ils sont une excellente source d'acide ascorbique, d'anthocyanines et de minéraux. **Matériel et méthodes**. Trois cultivars de groseille et huit cultivars de cassis ont été évalués quant à la qualité de leurs fruits. Certaines caractéristiques physico-chimiques telles que le poids, la matière sèche, les solides solubles, les sucres totaux, l'acidité titrable et les anthocyanines totales des baies ont été étudiées. La teneur totale en anthocyanines a été mesurée par la méthode d'absorbance différentielle du pH tandis que les acides citrique, malique, tartrique et ascorbique ont été mesurés par la méthode de chromatographie liquide sous haute pression en phase inverse. Les éléments sodium, calcium, magnésium, fer, manganèse, chrome et zinc ont été déterminés par ICP-MS après une digestion au micro-onde tandis que la teneur en potassium a été déterminée par FAAS. **Résultats**. Des différences significatives de teneurs en éléments physico-chimiques et minéraux ont été détectées parmi les cultivars. La gamme des anthocyanines totales des échantillons examinés a été de 12.14–22.06 mg·100 g^{-1} (groseilles rouges) et 116.17–287.78 mg·100 g^{-1} (cassis). La teneur en acide ascorbique a varié entre 23.23–44.62 mg·100 g^{-1} (groseilles rouges) et 161.58–284.46 mg·100 g^{-1} (cassis). L'acide citrique a été l'acide prédominant dans tous les cultivars étudiés de groseille et de cassis ; il a été suivi des acides maliques et tartriques. Les groseilles et les cassis ont une riche composition minérale, particulièrement en ce qui concerne le potassium, le calcium et le magnésium. Les teneurs en calcium et magnésium des cassis ont été supérieures à celles des groseilles rouges.

Roumanie / Ribes rubrum / Ribes nigrum / petits fruits / groseille rouge / cassis / composition globale / anthocyane / acide organique / teneur en éléments minéraux

1. Introduction

As with other fruits and vegetables, berries are important dietary sources of fibre, vitamins and minerals. In particular, many types of berries contain a high level of ascorbic acid, so much so that often only a handful of the fruit can provide the recommended daily allowance (RDA) [1]. They also contain a vast number of other phytochemicals for which there are no known deficiency conditions but which may have marked bioactivities in mammalian cells of potential health benefit [2]. The beneficial biological effects of these food bioactives may be driven by two of their characteristic properties: their affinity for proteins and their antioxidant activity. Over the last 15 years, numerous publications have demonstrated that, besides their in vitro antioxidant capacity, certain phenolic compounds, such as anthocyanins, catechins, proanthocyanidins, and other non-coloured flavonoids, may regulate different signalling pathways involved in cell survival, growth and differentiation [3]. These effects include antioxidant, anti-allergic, anti-inflammatory, anti-viral, anti-proliferative, anti-mutagenic, anti-microbial, anti-carcinogenic, protection from cardiovascular damage and allergy, microcirculation improvement, peripheral capillary fragility prevention, diabetes prevention, and vision improvement [4–6]. Compared with most fruit, berries are unusual in that they are rich in anthocyanins, which are glycosidic-linked flavonoids responsible for their red, violet, purple and blue colours.

Some of the most valuable species among berries, consumed both in the raw and processed state, are black and red currants [7]. Black currants (Ribes nigrum L.) and red currants (Ribes rubrum L.) contain a diverse range of phenolics and possess a high antioxidant activity, which makes them an interesting target for the functional food industry [8–10]. Black currants are widely used to make juices, wines, soft drinks and various preserved products [11]. Black currant nectar and jam contain a lot of ascorbic acid and anthocyanins [12, 13].

In black currant breeding, attention is paid not only to the processing of berries, but to their potential in the fresh market as well [14]. Berries for consumption are expected to be of large size and good-looking, with good taste and aroma. Also, particular attention is paid to the improvement of the quality of processed berries, notably juice colour, ascorbic acid content, dry matter and soluble solids [15, 16].

The high fruit quality of black and red currants is based on the contents of sugars, organic acids, polyphenols and vitamin C [17]. As is known, these fruits have a high content of organic acids, represented mainly by citric acid, malic acid and tartaric acid, which makes them extremely appreciated among the other fruits, due to their slightly-sour taste and special flavour. The rich content of citric acid transforms them into a real nutraceutical for stomach and liver afflictions.

The dark red coloration of the black currant berries and of the products derived from them is a result of a very high level of anthocyanins [7, 18, 19]. Anthocyanins are of interest to the food industry because of their antioxidant power, attractive colour and stability in high-acid foods [4, 20]. In general, the anthocyanin profile of a tissue is characteristic, and it has been used in taxonomy, and for the detection of adulteration of juices and wines [1]. Black currants are characterised by the presence of the rutinosides and glucosides of delphinidin and cyanidin [21, 22], with the rutinosides being the most abundant. Other anthocyanins and flavonol conjugates have been noted, but at much lower concentrations [23, 24]. Whilst red currants (R. rubrum) are very closely related to black currants (R. nigrum), they contain mainly cyanidin diglycosides with cyanidin monoglucosides present only as minor components [25]. According to Bermudez-Soto and Tomas-Barberan, the most abundant in the black currant flavonol composition were myricetin glycosides, followed by quercetin glycosides [26].

Not only the bioactive compounds are responsible for the antioxidant capacity, but mineral elements also have some modifying effect. Black and red currants contain minerals and trace elements which are essential to human health. Plessi et al. reported high amounts of potassium, calcium and magnesium but small quantities of sodium [27]. The large amount of potassium in comparison with sodium could be beneficial for hypertensive patients.

Accumulating evidence exists suggesting that genotype may have a profound influence on the content of bioactive compounds in berries [9, 28–31]. Therefore, in our study, black currant cultivars and red currant cultivars grown at the same location were compared in terms of fruit weight, dry matter, soluble solids, titratable acidity, total anthocyanins, ascorbic, citric, malic and tartaric acids, and mineral element content.

2. Materials and methods

2.1. Plant material

Fruits of eight black currant cultivars (Abanos, Blackdown, Bogatar, Deea, Record, Ronix, Tenah and Tinker) and three red currant cultivars (Abundent, Houghton Castle and Rosu Timpuriu) were randomly harvested from the Banu Maracine Didactical Station of the University of Craiova (44°20'0'' N, 23°49'0'' E) in the Oltenia region of Romania. The berries (approximately 2.5 kg of fruits from each cultivar) were picked at the optimum ripe stage. The berries were not selected for size, but reflected the typical size for the cultivar.

2.2. Analytical methods

Average fruit weight was determined from the weight of 100 fruits from each plot. There were five plots per cultivar.

The percent of total dry matter was determined by drying the sample in an oven at 105 °C. Soluble solids were measured in the juice pressed from the whole fruit. Soluble solids concentration was measured using a digital refractometer and the results were expressed as percentages. The total sugar content was determined by the Schoorl method and the results were expressed as $g \cdot 100\ g^{-1}$ fresh matter; the titratable acidity was determined by titration of a known amount of water extract of fruits with 0.1 N NaOH using phenolphthalein as an indicator; it was expressed as g citric acid$\cdot 100\ g^{-1}$ fresh matter.

2.3. Determination of total anthocyanins

Total anthocyanin content was measured with the pH differential absorbance method, as described by Cheng and Breen [32]. Briefly, absorbance of the extract was measured at (510 and 700) nm in buffers at pH 1.0 (hydrochloric acid-potassium chloride, 0.2 M) and pH 4.5 (acetate acid-sodium acetate, 1 M). Anthocyanin content was calculated using a molar extinction coefficient of 29,600 (cyanidin-3-glucoside) and absorbance of $A = [(A_{510} - A_{700})_{pH\ 1.0} - (A_{510} - A_{700})_{pH\ 4.5}]$. Results were expressed as mg cyanidin-3-glucoside equivalents per 100 g fresh weight.

2.4. Determination of malic, citric, tartaric and ascorbic acids

Five g of whole fruits were homogenised to puree in a porcelain mortar and diluted to 100 mL with 0.1 N HCl. After 30 min, the extraction solution was centrifuged at 4200 rpm for 10 min. The supernatant was filtered through a 0.2-µm-pore-size filter.

Organic acid contents were determined by reversed-phase HPLC on a Surveyor Thermo Electron system equipped with a Diode Array Detector (DAD) using a Hypersil Gold aQ column (25 cm × 4.6 mm) with a particle size of 5 µm. A 50-mM water solution of KH_2PO_4 buffer at pH 2.8 was used as the mobile phase. The column temperature was kept at 10 °C and the flow rate at $0.7\ mL \cdot min^{-1}$. Detection of organic acids was carried out by absorbance at 214 nm, while detection of ascorbic acid was at 254 nm. All the results were expressed in mg per 100 g fresh weight.

2.5. Determination of mineral content

Sodium (Na), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), chromium (Cr) and zinc (Zn) were determined after mineralisation in a microwave oven by

Table I.
Specific heating programme used for microwave digestion in determination of sodium, calcium, magnesium, iron, manganese, chromium and zinc of red and black currant berries by ICP-MS.

Step	Temperature (°C)	Power (W)	Run time (min)
1	80	200	5
2	80	200	2
3	120	400	15
4	120	400	2
5	200	600	10
6	Cooling	0	20

using the inductively coupled plasma-mass spectrometry (ICP-MS) method, while potassium (K) content was determined by flame atomic absorption spectrometry (FAAS).

For the microwave digestion, a Milestone digestion microwave system was used. Quantities of approximately 2.5-g samples were introduced into tetrafluoro-metoxil (TFM) reaction vessels, and after that 5 mL nitric acid 65% and 2 mL hydrogen peroxide 30% were added. A specific heating programme was used (table I). Reagent blanks were included in each series of digestions. After cooling them down, the vessel contents were transferred to 50-mL volumetric flasks and made up to the mark with ultrapure water.

A commercial ICP-MS system (Perkin-Elmer ELAN 9000) and an atomic absorption spectrometer in flame mode (Avanta PM) were used (table II). Etalon standards were obtained from multi-element stock solutions, ICP-MS calibration STD 3 and mono-element 1000 mg $K \cdot L^{-1}$.

All analyses were performed in triplicate, with a maximum error of less than 5%. All results were expressed in mg per 100 g fresh weight.

Intergenotype significance of differences was calculated according to the LSD test. Data were reported as means ± standard error of the mean. Differences at $P \leq 0.05$ were considered to be statistically significant.

3. Results and discussion

3.1. Physical and chemical characteristics of currant fruits

Berry quality (firmness, weight) determines the storage potential, transportability and trade appearance [30].

In the case of the red currant cultivars, the weight of 100 berries was the highest for the cultivar Abundent (75.0 g for 100 berries), significantly higher than the values observed for Houghton Castle (57.4 g for 100 berries) and Rosu Timpuriu (56.0 g for 100 berries), between which no significant difference was registered (table III).

The black currant cultivars Abanos (118.2 g for 100 berries) and Bogatar (110.5 g for 100 berries) produced the biggest berries (table III). For the Bogatar cultivar, Laugale found an average weight of 86 g for 100 berries [33], while Libek and Kikas found 100 g for 100 berries for the same cultivar [34]. In our study, fruits of the Blackdown cultivar registered an average weight of 107.3 g for 100 berries while Kampuss and Strautina reported an average weight of 74 g for 100 berries for the same cultivar [35].

Among the investigated red currant cultivars, the highest dry matter was found in fruit of the cultivars Houghton Castle (17.54%) and Abundent (16.96%), while the fruit dry matter of the cultivar Rosu Timpuriu was significantly lower (15.12%) (table III).

Table II.
ICP-MS and the atomic absorption spectrometer in flame operating conditions used for determination of sodium, calcium, magnesium, iron, manganese, chromium and zinc in red and black currant berries.

ICP-MS, model ELAN 9000					Spray chamber			Atomic absorption spectrometer in flame Model Avanta PM	
Rf power (W)	ICP torch	Torch injector	Nebuliser	Nebuliser gas flow ($L \cdot min^{-1}$)	Sweeps / reading	Reading / replicate	Number of replicates	Optics	Flame
1000	Fassel-type	Ceramic alumina	Cross-flow	0.93	20	2	5	Double fascicle	Air – acetylene

Table III.
Physical and chemical characteristics determined for three red and eight black currant fruits (Romania).

Cultivar	Fruit weight (g per 100 berries)	Total dry matter (%)	Soluble solids (%)	Total sugars (%)	Titratable acidity as citric acid (%)	Anthocyanins ($mg \cdot 100\ g^{-1}$ fresh weight)
Red currants						
Abundent	75.0 ± 0.57	16.96 ± 0.48	10.10 ± 0.61	8.23 ± 0.65	1.54 ± 0.032	12.14 ± 0.87
Houghton Castle	57.4 ± 4.24	17.54 ± 0.44	10.40 ± 0.50	8.55 ± 0.53	1.33 ± 0.018	22.06 ± 0.56
Rosu Timpuriu	56.0 ± 0.28	15.12 ± 0.81	11.40 ± 2.17	9.61 ± 2.30	1.48 ± 0.018	18.86 ± 0.78
$LSD_{0.05}$	7.875	1.200	0.661	0.827	0.048	0.436
Black currants						
Abanos	110.5 ± 2.69	21.72 ± 0.73	14.70 ± 0.53	13.12 ± 0.44	1.35 ± 0.018	146.80 ± 0.20
Blackdown	107.3 ± 3.25	21.96 ± 0.62	14.73 ± 0.42	13.15 ± 0.65	1.19 ± 0.018	212.81 ± 0.48
Bogatar	118.2 ± 5.09	21.23 ± 0.58	15.57 ± 0.12	14.04 ± 0.69	1.39 ± 0.018	179.33 ± 0.48
Deea	104.0 ± 2.83	17.94 ± 1.25	14.30 ± 0.20	12.69 ± 0.41	1.58 ± 0.018	134.29 ± 0.14
Record	77.1 ± 2.12	21.65 ± 0.60	15.20 ± 0.53	13.65 ± 0.56	1.51 ± 0.018	287.78 ± 0.08
Ronix	108.8 ± 5.66	20.17 ± 0.67	14.37 ± 0.65	12.76 ± 0.56	1.65 ± 0.018	116.17 ± 0.29
Tenah	78.8 ± 0.65	23.17 ± 0.53	14.63 ± 0.49	13.05 ± 0.52	1.58 ± 0.018	224.79 ± 0.10
Tinker	99.9 ± 2.69	21.92 ± 0.61	14.00 ± 0.10	12.38 ± 0.78	1.62 ± 0.018	171.74 ± 0.22
$LSD_{0.05}$	7.978	1.263	0.740	0.786	0.032	2.503

Black currant berries are mainly used for processing, so particular attention is paid to the improvement of the quality of processed berries, notably juice colour, ascorbic acid and anthocyanin content, dry matter, and soluble solids [16]. Berries of the cultivar Tenah were notable for having the largest amount of dry matter (23.17%). Berries of the other cultivars also accumulated large amounts [between (20.17 and 21.96)%], while the lowest amount was found in the berries of the Deea cultivar (17.94%) (table III).

The largest amount of dry soluble solids was established in berries of the Bogatar (15.57%) and Record (15.20%) cultivars, while the lowest amount was in berries of the Tinker cultivar (14.0%) (table III). Kampuss and Strautina reported a soluble solids content of 14.5% for berries of the Blackdown cultivar [35] against 14.73%

Table IV.
The content of individual organic acids in fruits (mg·100 g^{-1} fresh weight) of three red and eight black currant cultivars (Romania).

Cultivar	Tartaric acid	Malic acid	Citric acid	Ascorbic acid
Red currants				
Abundent	40.22 ± 6.43	34.21 ± 1.09	2517.04 ± 7.62	23.23 ± 0.56
Houghton Castle	29.03 ± 4.49	48.87 ± 2.56	3083.88 ± 7.94	44.62 ± 0.14
Rosu Timpuriu	24.72 ± 2.43	40.61 ± 0.71	3032.80 ± 1.73	31.11 ± 0.22
$LSD_{0.05}$	15.070	5.273	20.448	0.551
Black currants				
Abanos	112.94 ± 1.06	131.40 ± 7.92	3308.47 ± 94.27	284.46 ± 1.47
Blackdown	49.75 ± 3.82	235.24 ± 12.75	3553,31 ± 6.89	276.27 ± 2.33
Bogatar	41.59 ± 5.21	207.34 ± 4.56	2548.17 ± 23.31	219.16 ± 2.78
Deea	52.17 ± 4.45	134.07 ± 6.69	3336.95 ± 42.12	207.26 ± 2.01
Record	31.31 ± 3.77	303.94 ± 5.57	2473.43 ± 16.67	161.58 ± 3.26
Ronix	39.64 ± 2.08	95.10 ± 3.08	3253.21 ± 37.86	195.33 ± 1.53
Tenah	45.66 ± 6.82	246.96 ± 8.89	3021.54 ± 16.68	258.99 ± 3.01
Tinker	72.95 ± 13.31	243.05 ± 4.68	3482.50 ± 4.22	272.67 ± 2.22
$LSD_{0.05}$	11.519	13.123	167.743	2.139

found in our study (table III). In accordance with dry soluble solids content, the highest average value of total sugar content was recorded with fruit of the Bogatar (14.04%) and Record (13.65%) cultivars.

The titratable acidity of the red and black currants was expressed as citric acid equivalents. There were significant differences due to cultivars. The titratable acidity of the red currants investigated in our study varied from 1.33% for Houghton Castle to 1.54% for Abundent. Black currants exhibited significant differences in titratable acidity, which varied between 1.65% (Ronix) and 1.19% (Blackdown) (table III).

The berries of black currants are rich in polyphenolic compounds and especially in anthocyanins, demonstrating antioxidant activity. Anthocyanin pigments are responsible for the characteristic dark-purple colour of black currants. A large variability was observed in anthocyanin content and significant differences were observed. The richest berries were those of the cultivar Record (287.78 mg·100 g^{-1}), while Ronix berries had the lowest content of anthocyanins (116.17 mg·100 g^{-1}). In our studies, Blackdown registered an amount of 212.81 mg·100 g^{-1}, which is in accordance with the results of Kampuss and Strautina, who recorded 214.1 mg·100 g^{-1} [35], and with those of Moyer et al., who recorded 216 mg·100 g^{-1} anthocyanins in the fruits of the same cultivar [2]. The berries of red currant cultivars accumulated from (12.14 to 22.06) mg anthocyanins·100 g^{-1} (table III).

An interesting finding was that small fruit size was highly correlated with anthocyanin content because of the higher proportion of skin where these compounds are concentrated. For black currants, fruit weight was inversely correlated (r = 0.73) with total anthocyanins.

3.2. Organic acid contents of currant fruits

Our results showed that the black currant cultivars contain significantly more ascorbic acid than the red currant cultivars (table IV).

The content of ascorbic acid in currants was largely influenced by cultivar. The cultivars Abanos, Blackdown, Tenah and Tinker had the highest ascorbic acid content (above 250 mg·100 g^{-1}), while lower ascorbic acid contents were found in the cultivars Ronix (195.33 mg·100 g^{-1}) and Record (161.58 mg·100 g^{-1}). For the Blackdown cultivar, Kampuss and Strautina reported an ascorbic acid content of 225.7 mg·100 g^{-1} [35], lower than our results (258.99 mg·100 g^{-1}) for the same cultivar. For the Bogatar cultivar, Libek and Kikas found an ascorbic acid content of 153 mg·100 g^{-1} [34], lower than our results (219.16 mg·100 g^{-1}) for the same cultivar.

The Ronix and Tinker cultivars had exceptionally high levels of ascorbic acid but very low anthocyanin content, while the Record cultivar had the highest anthocyanin content but the lowest ascorbic acid content. However, there was no inverse correlation between ascorbic acid content and anthocyanin content for any of the black currant cultivars studied.

Among the organic acid levels (citric, malic, tartaric) measured in the fruits of red and black currant cultivars, citric acid was predominant, ranging from 2517.04 mg·100 g^{-1} (Abundent) to 3083.88 mg·100 g^{-1} (Houghton Castle) for red currants, and from 2473.43 mg·100 g^{-1} (Record) to 3336.95 mg·100 g^{-1} (Deea) for black currants. Differences in citric acid content were statistically significant among the studied red currant cultivars. For black currant cultivars, most cultivars had citric acid content above 3000 mg·100 g^{-1} (Abanos, Blackdown, Deea, Ronix, Tenah and Tinker,) among which no significant difference was registered, whereas the other investigated cultivars showed significantly lower contents (table IV).

Considering the malic acid content, the highest level was registered with the cultivar Record (303.94 mg·100 g^{-1}), followed by Tenah (246.96 mg·100 g^{-1}), Tinker (243.05 mg·100 g^{-1}) and Blackdown (235.24 mg·100 g^{-1}). Lower and approximate values were recorded with the cultivars Deea (134.07 mg·100 g^{-1}) and Abanos (131.40 mg·100 g^{-1}), while the lowest malic acid content was found in the cultivar Ronix (95.10 mg·100 g^{-1}) (table IV).

The results of tartaric acid detected in the fruits of the studied black currant cultivars indicated that the cultivar Abanos showed the highest average content (112.94 mg·100 g^{-1}), followed by Tinker (72.95 mg·100 g^{-1}), which were significantly higher in comparison with the values observed for the cultivars Blackdown, Bogatar, Ronix and Tenah, among which no significant difference was registered. The lowest average content of tartaric acid was recorded with the cultivar Record (31.31 mg·100 g^{-1}) (table IV).

3.3. Mineral composition of currant fruits

For the mineral composition of the studied black and red currants, the results showed that these berries have rich mineral composition, especially calcium, magnesium, potassium and iron. Black currant fruits were superior to red currants with regard to calcium and magnesium content (table V).

Among red currant cultivars, the berries of the Abundent cultivar were distinguished for having significantly larger contents of calcium (33.99 mg·100 g^{-1}) and magnesium (38.17 mg·100 g^{-1}) than the two other cultivars studied. No significant differences appeared among the red currant cultivars concerning the other minerals' contents.

Analysing the results for black currant cultivars, significant differences were found for calcium, magnesium, potassium and zinc contents.

Considering the results of calcium content in the fruits of black currant cultivars, it can be noticed that the highest content of calcium was obtained with the cultivar Tenah (64.20 mg·100 g^{-1}), whereas the other investigated cultivars showed lower contents [between (31.27 and 53.27) mg·100 g^{-1}]. Considering the magnesium content, the highest level was also registered with the cultivar Tenah (65.93 mg·100 g^{-1}), while the other cultivars recorded values between (45.74 and 57.35) mg·100 g^{-1} (table V).

The average values of potassium content ranged from 251.13 mg·100 g^{-1} (Abanos) to 305.05 mg·100 g^{-1} (Tenah), with significant differences between these two limits.

Table V.
Mineral composition of three red and eight black currant fruits (mg·100 g^{-1} fresh weight) (Romania).

Cultivar	Ca	Mg	K	Na	Fe	Mn	Zn	Cr
Red currants								
Abundent	33.99 ± 1.33	38.17 ± 1.12	249.55 ± 14.66	1.31 ± 0.12	1.38 ± 0.22	0.14 ± 0.02	0.34 ± 0.02	0.09 ± 0.01
Houghton Castle	23.22 ± 1.43	31.55 ± 0.98	255.66 ± 14.33	1.28 ± 0.18	1.27 ± 0.18	0.15 ± 0.02	0.30 ± 0.02	0.08 ± 0.01
Rosu Timpuriu	18.17 ± 0.46	27.37 ± 0.87	240.39 ± 12.51	1.10 ± 0.22	1.15 ± 0.12	0.10 ± 0.03	0.25 ± 0.03	0.08 ± 0.01
$LSD_{0.05}$	5.209	4.475	62.356	0.801	0.615	0.107	0.107	0.044
Black currants								
Abanos	50.86 ± 2.43	57.35 ± 1.56	251.13 ± 11.56	0.98 ± 0.09	1.31 ± 0.16	0.14 ± 0.01	0.28 ± 0.02	0.07 ± 0.01
Blackdown	53.27 ± 1.23	56.71 ± 1.89	268.04 ± 9.88	0.99 ± 0.09	1.38 ± 0.13	0.15 ± 0.02	0.32 ± 0.02	0.09 ± 0.01
Bogatar	31.27 ± 0.98	45.74 ± 0.99	302.15 ± 16.63	1.22 ± 0.14	1.13 ± 0.09	0.14 ± 0.02	0.16 ± 0.02	0.05 ± 0.01
Deea	42.73 ± 1.55	57.01 ± 1.48	263.84 ± 6.55	1.07 ± 0.11	1.51 ± 0.18	0.15 ± 0.02	0.18 ± 0.02	0.11 ± 0.02
Record	40.77 ± 1.22	51.31 ± 1.66	285.66 ± 12.95	1.28 ± 0.16	1.48 ± 0.21	0.15 ± 0.02	0.22 ± 0.01	0.13 ± 0.03
Ronix	43.50 ± 1.19	57.30 ± 2.06	286.51 ± 18.32	1.24 ± 0.23	1.53 ± 0.26	0.18 ± 0.03	0.17 ± 0.01	0.10 ± 0.02
Tenah	64.20 ± 2.34	65.93 ± 1.96	305.05 ± 15.44	1.19 ± 0.14	1.72 ± 0.26	0.18 ± 0.04	0.21 ± 0.01	0.07 ± 0.01
Tinker	41.89 ± 1.30	55.76 ± 0.78	262.73 ± 8.88	1.09 ± 0.16	1.61 ± 0.18	0.19 ± 0.04	0.36 ± 0.03	0.06 ± 0.01
$LSD_{0.05}$	5.274	5.245	42.771	0.478	0.627	0.087	0.061	0.054

The cultivars Tinker and Blackdown contained significantly more zinc than the other investigated cultivars (table V).

4. Conclusions

Considering our results, it appears that red and black currants are an extremely rich source of ascorbic acid and anthocyanins. The anthocyanin content and composition of red and black currants were consistent with published values.

Houghton Castle was the best-graded red currant cultivar based on the high contents of dry matter, ascorbic acid and anthocyanins.

Based on dry matter content, as well as on total anthocyanins and ascorbic acid contents, it can be concluded that the black currant cultivars Blackdown, Tenah and Tinker can be considered as the richest ones.

Our results reflect the genetic differences of the red and black currant cultivars. Therefore, these quality attributes are important to breeders for developing advanced selections ensuring the attractive technological features and flavour of the product.

The variation in organic acid content may have implications for both sensory properties and the glycaemic index.

Also, our results showed that black and red currants have rich mineral composition. Tenah is the cultivar with the highest content of calcium, magnesium, potassium and iron, while Blackdown and Tinker registered higher contents of zinc.

The observed differences in composition are of such magnitude that they may affect both nutritional and sensory properties. Due to their high contents of antioxidants and minerals, red and black currants are good candidates for use in nutritional supplement formulations.

The data developed should be useful with other databases in describing authentic red and black currant cultivars to target specific consumer requirements.

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Ácido ascórbico, antocianinas, ácidos orgánicos y contenido en minerales de algunos cultivares de grosella y de grosella negra.

Resumen — **Introducción**. Las grosellas y las grosellas negras son un elemento preciado para una alimentación sana, dado que son una excelente fuente de ácido ascórbico, de antocianinas y de minerales. **Material y métodos**. Se evaluaron tres cultivares de grosella y ocho cultivares de grosella negra, en cuanto a la calidad de sus frutos. Se estudiaron ciertas características físico-químicas, tales como el peso de las bayas, la materia seca, los sólidos solubles, los azúcares totales, la acidez valorable y las antocianinas totales. Se midió el contenido total de antocianinas, mediante el método de absorbancia diferencial del pH, mientras que los ácidos cítrico, málico, tartárico y ascórbico se midieron mediante el método de cromatografía de líquidos de alta resolución en fase inversa. Los elementos sodio, calcio, magnesio, hierro, manganeso, cromo y cinc se determinaron mediante ICP-MS, tras una digestión en el microondas, mientras que el contenido de potasio se determinó mediante FAAS. **Resultados**. Entre los cultivares, se detectaron diferencias significativas de contenidos de elementos físico-químicos y minerales. La gama de las antocianinas totales de las muestras examinadas fue de 12,14–22,06 mg·100 g^{-1} (grosellas rojas) y 116,17–287,78 mg·100 g^{-1} (grosellas negras). El contenido en ácido ascórbico varió entre 23,23–44,62 mg·100 g^{-1} (grosellas rojas) y 161,58–284,46 mg·100 g^{-1} (grosellas negras). El ácido cítrico fue el ácido predominante en la totalidad de los cultivares estudiados de grosella y de grosella negra; le siguieron los ácidos málicos y los tartáricos. Las grosellas y las grosellas negras tienen una composición mineral rica, particularmente en lo que se refiere al potasio, al calcio y al magnesio. Los contenidos de calcio y de magnesio de las grosellas negras fueron superiores que los de las grosellas rojas.

Rumania / Ribes rubrum / Ribes nigrum / bayas / grosella roja / grosella negra / composición aproximada / antocianinas / ácidos orgánicos / contenido mineral