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QUALITY ASSESSMENT OF JUICE PREPARED FROM DIFFERENT VARIETIES OF CURRANT (*Ribes* L.)

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ABSTRACT
In the Slovak Republic currants are traditionally grown species of small fruits mainly in house gardens. Although currently their area is very small compared to the other types of fruit. We can see the importance of growing this genus (*Ribes* L.) in its good adaptability to climate conditions, in small growing demands and in stable production of nutritionally highly valuable fruit. Currant berries as well as fresh currant juice are characterized by the presence of whole complex of antioxidant active substances. The aim of this study was to evaluate the nutritional quality of currant juice prepared from various species and varieties of genus *Ribes* (L.). based on the content of their total polyphenols, anthocyanin dyes and antioxidant activity. In work we used varieties Blanka, Primus, Viktória, Heinemannova neskorá, Red Lake, Treny, Jonkheer van Tets, Fertödi, Titania, Triton and Öjebyn. Contents of evaluated components were assessed spectrophotometrically. Total polyphenol content of monitored samples determined by the Folin-Ciocalteu method reached values from 1897.43 mg GAE.dm^{-3} DM to 3712.21 mg GAE.dm^{-3} DM. The highest one was in juice from variety Primus and the lowest from variety Blanka. In white varieties of currant, the presence of anthocyanin dyes was immeasurable. In varieties of red and black currant anthocyanin dye content achieved values from 1947.64 mg.dm^{-3} DM (Jonkheer van Tets) to 4161.07 mg.dm^{-3} DM (Heinemannova neskorá). The antioxidant activity determined by the FOMO method reached values from 4130.42 mg AA.dm^{-3} DM to 6571.69 mg AA.dm^{-3} DM. We recorded the highest antioxidant activity in juice of variety Fertödi and the lowest of variety Primus.

Keywords: currant; juice; anthocyanin; total polyphenols; antioxidant activity

INTRODUCTION
Members of the genus *Ribes* L. are mostly bushes naturally occurring in wild or cultivated in gardens and orchards in different mild climate areas of the world. Fruits are a rich source of vitamin C and other health promoting substances such as organic acids, pectin, micronutrients and trace elements **(Mattila et al., 2011)**. Berry fruit is an important source of various biologically active compounds with interesting physiological effects. **Puuppone et al., (2015)** state that small fruit is rich in fiber, vitamins, minerals, anthocyanins, and especially in various phenolic compounds. **Szajdek and Borowska (2008)** present in their work that main representatives of biologically active compounds of berry fruit are particularly vitamin C and polyphenols, such as anthocyanins, phenolic acids, flavanols, flavonols and tannins. **Battino et al., (2009)** state that berry fruit is characterized by a high content and wide variety of phenolic compounds, which differ in structure and molecular weight. The phenolic compounds present in currants are benzoic acid and cinnamic acid derivatives, tannins, stilbenes and flavonoids such as anthocyanins, flavonols and flavanols catechins. Their concentration is usually higher in the skin and just beneath it, than in the central part of the fruit. **Pinto et al., (2007)** found that most represented phenolic acids in berry fruit are cinnamic and benzoic acid derivatives, which predominantly occur in the form of esters and glycosides. To the benzoic acid derivatives present in currants belong p-hydroxybenzoic acid, salicylic acid, gallic acid and ellagic acid. From the cinnamic acid derivatives, the authors confirmed the presence of coumaric acid, caffeic acid and ferulic acid in currants. **Szajdek and Borowska (2008)** state that in the black currant a high p-coumaric and caffeic acid content was detected.

Goleniowski et al., (2013) report positive effect of phenolic compounds in the prevention of many civilization diseases such as coronary heart disease, stroke and cancer. Anthocyanins belong to the most important flavonoids occurring in black and red currant. Anthocyanins in currants are in the form of mono-, di- or triglycosides, wherein the glycoside residues are typically substituted at C3, or less frequently at C5 or C7 position. The most predominant sugars in anthocyanin molecule are glucose, galactose, rhamnose, arabinose and rutinose. Anthocyanin glycoside residues are often acylated by acids, mostly by p-coumaric, caffeic or ferulic acid, and less often by p-hydroxybenzoic, malonic or acetic acid **(Sójka, Król, 2009)**. Anthocyanins have many biologically significant features and the main attention is paid to their antioxidant activity. It is well known that they play an important role in the prevention of degenerative neuronal disorders, cardiovascular diseases, cancer and diabetes **(Lee et al., 2013)**.

From the stilbene group **Szajdek and Borowska (2008)** pointed to the presence of trans-resveratrol in red currant berries. Trans-resveratrol is a phenolic compound produced by plants in response to stress conditions, e.g. climate variability, exposure to ozone, sun radiation or heavy metals presence in soil. The pharmaceutical effects of trans-resveratrol include antioxidant and anti-inflammatory activity, as well as inhibition of LDL cholesterol oxidation, platelet aggregation and growth of various tumor cells **(Fei, 2015)**.

The chemical composition of berry fruit is highly variable depending on the variety, site of cultivation, on ripening, harvesting and storage conditions **(Talcott, 2007)**. **Battino et al., (2009)** state that the content of phenolic compounds in the berry fruits is determined by a number of factors such as species, cultivation method, region, weather conditions, maturity, harvesting, storage time and conditions. The authors further submit that fruits that grow in the cold northern climate with a short growing season, without fertilizers and pesticides, has higher polyphenol content than the same varieties grown in milder climate.

The aim of the work was to compare the quality of different types and varieties of currant processed to currant juice. We focused mainly on the determination of total polyphenols, antioxidant activity and anthocyanin dyes.

MATERIAL AND METHODOLOGY

In the work we evaluated 11 varieties of white, red and black currants. From the white group were varieties Blanka, Primus and Viktória, from the red group Heinemannova neskorá, Red Lake, Treny and Jonkheer van Tets and from the black group Fertödi, Titania, Triton and Öjebyn. The fruits were grown in Botanical garden of Slovak University of Agriculture in Nitra and collected at the stage of consumer maturity. Growing area, according to agro-climatic characteristics is included into very hot region and very dry sub-region with an average annual temperature of 9.5 °C and average annual rainfall of 584.5 mm. According to the soil characteristics, it is a heavy Gleyic Fluvisol formed on alluvial uncalcareous and calcareous sediments. In order to obtain the juice from currants, we used the screw press machine. There were used the whole currant bunches and during the pressing, peelings and seeds were removed.

Total polyphenol content was analyzed by the Folin-Ciocalteu method, whose principle is the reaction of Folin-Ciocalteu reagent with reducing substances to form a blue complex. The blue coloring intensity is proportional to the polyphenol content. We performed the evaluation with a spectrophotometer UV-VIS Jenway, at a wavelength of 700 nm and the content of total polyphenols is expressed as equivalent of gallic acid in mg GAE. dm^{-3} **(Singleton and Rossi, 1965)**.

Anthocyanin dye content was determined by spectrophotometry. The samples were extracted in ethanol with addition of 0.01% HCl. Repeated dye extraction until complete sample decolorization was carried out by heat. Anthocyanin dye content was investigated by measuring the absorbance on spectrophotometer UV-VIS Jenway at the wavelength selected by the dominant anthocyanin present in a given kind of fruit.

Antioxidant activity was determined by the FOMO method **(Prieto et al., 1999).** The principle of method is the reduction of Mo (VI) to Mo (V) by the action of reducing substances in the phosphorus presence. Coloring intensity of the resulting green phosphomolybdate complex is measured spectrophotometrically at a wavelength of 695 nm. Reducing ability of the compounds is expressed as the equivalent amount of ascorbic acid (AA), which is required to achieve the same reduction effect.

Results of analyzes were processed by statistical package Statistica 8.0 (StatSoft Inc., Tulsa, USA). Differences between the samples were monitored by Fisher's LSD test.

RESULTS AND DISCUSSION

High quality of black and red currant berries was for a long time evaluated only on the basis of the sugar, organic acids and vitamin C content. We know that the high nutritional quality of berries corresponds to the wide complex of compounds, often referred to as a phenol compounds, and these, together with vitamins, dyes and minerals, take part in forming the fruit antioxidant activity **(Nour et al., 2011)**.

In our work, we mainly focused on determination of total polyphenol content in samples of currant juices. We found out that the highest polyphenol content was in juice of red currant variety Titania with value 694.65 mg GAE.dm^{-3} and the lowest content in juice of white currant variety Blanka with value 178.17 mg GAE.dm^{-3}. Total polyphenol content in currant juice samples was decreasing in the order Titania >Triton >Fertödi >Öjebyn >Primus >Treny >RedLake >Viktória >Jonkheer van Tets >Heinemannova neskorá >Blanka. After the total polyphenol content conversion to dry matter, the highest content showed juice of variety Primus (3712.21 mg GAE.dm^{-3} DM) and the lowest of variety Blanka (1897.43 mg GAE.dm^{-3} DM) (Table 1).

Table 1 Varietal differences in the total polyphenol content of currant juices.

Variety	mg GAE.dm^{-3}	mg GAE.dm^{-3} DM
Blanka	178.17	1897.43^{a}
Heinemannova neskorá	189.03	1903.63^{a}
Viktória	225.360	1946.11^{b}
Jonkheer van Tets	220.12	2349.16^{c}
Red Lake	262.44	2688.92^{d}
Öjebyn	466.59	2903.29^{e}
Treny	282.66	3092.59^{f}
Triton	558.32	3184.93^{g}
Titania	694.65	3656.04^{h}
Fertödi	508.13	3658.25^{h}
Primus	390.15	3712.21^{i}

Note: $^{a-i}$ Means with the same letter are not significantly different from each other (Fisher's LSD test, $p > 0.05$); DM – dry matter.

By Fisher's LSD test we observed mutual differences between the currant juice samples in total polyphenol content. Statistically significant (p <0.01*)* highest polyphenol content was detected in the juice of white currant variety Primus, which was followed by the black currant juice varieties of Fertödi, Triton and Titania. There was not detected any statistically significant difference (p >0.05) between the variety of Fertödi and Triton. From juices made from red currant, the highest polyphenol content was found in the variety Treny. The lowest polyphenol content from the black currant group was found in the juice from variety Öjebyn. Middle polyphenol content was found in the juice sample from red currant varieties Red Lake and Jonkheer van Tets and in the juice from white currant variety Victoria. The lowest polyphenol content was in the juice samples from red variety Heinemannova neskorá and in the juice of white variety Blanka.

Total polyphenol content in selected varieties of raspberries, blackberries and currants grown in Hungary was observed by **Dénes et al., (2011)**. The highest content of polyphenols with an average value of 533 $mg.100g^{-1}$ recorded authors in the black currant and blackberries with value 379 $mg.100g^{-1}$. Average content of polyphenols detected in white currant varieties was 333 $mg.100g^{-1}$ and 192 $mg.100g^{-1}$ in red ones. Results of the above-mentioned authors also correspond with our findings. **Sójka a Król (2009)** used Folin-Ciocalteu method to determine total polyphenol content in the black currant marcs and reached values ranged from 2189.6 to 2285.6 $mg.100g^{-1}$. From that we can conclude that solid fruit components have higher content of polyphenolic substances than currant juice.

Nótin et al., (2011) investigated, what is the effect of drying temperature on the content of currant polyphenols. They used a black currant variety Titania. The samples were dried in a vacuum at 40, 50 and 60 °C, until moisture content below 10%. By exploring was found that the smallest changes in the polyphenol content were obtained by drying at 50 °C. Larger losses were observed when the black currants were dried at a temperature above 60 °C or below 40 °C, but for a longer time.

The aim of work of **Mitić et al., (2011)** was to assess the quality of dried red currants of Random variety grown in different regions of Serbia. The chemical composition can be highly variable depending on the growing region, what was also confirmed by this study. The authors found that the polyphenol content of red currants from the Beograd region with values from 3.96 to 12.68 mg $GAE.g^{-1}$ was higher than in the currants from the Niska Banja region with values from 3.47 to 7.46 mg $GAE.g^{-1}$.

Anthocyanin dyes are responsible for a wide range of red to violet fruits and vegetables coloration. The obtained results have confirmed this statement too. In the juices from white currant varieties Blanka, Primus and Viktória was found an undetectable presence of anthocyanin dyes (Table 2). On the basis of detected values we can state that the highest content of anthocyanin dyes was in juices from black currant varieties and specifically in juice of variety Titania with value 599.13 $mg.dm^{-3}$. The lowest levels of anthocyanin dyes were found in the juice of red currant variety Jonkheer van Tets with value 182.49 $mg.dm^{-3}$. Samples of currant juices can be ordered by the decreasing anthocyanin dye levels in fresh mass as follows Titania >Triton >Öjebyn >Fertödi >Heinemannova neskorá >Red Lake >Treny >Jonkheer van Tets. After the conversion of anthocyanin content to dry matter was their highest content detected in juice of variety Heinemannova neskorá (4161.07 $mg.dm^{-3}$ DM) and the lowest in juice of variety Jonkheer van Tets (1947.64 $mg.dm^{-3}$ DM) (Table 2).

Table 2 Varietal differences in the anthocyanin dye content of currant juices.

Variety	$mg.dm^{-3}$	$mg.dm^{-3}$ DM
Jonkheer van Tets	182.49	1947.64^{a}
Red Lake	244.47	2504.85^{a}
Öjebyn	444.18	2764.06^{bc}
Fertödi	423.52	3049.13^{cd}
Triton	537.15	3064.19^{cd}
Titania	599.13	3153.33^{d}
Treny	303.00	3315.20^{d}
Heinemannova neskorá	413.19	4161.07^{e}

Note: $^{a-e}$ Means with the same letter are not significantly different from each other (Fisher's LSD test, $p >0.05$); DM - dry matter.

Samples were mutually compared using Fisher's test. The highest content of dyes was found in juice of red variety Heinemannova neskorá, which statistically significantly differed (p <0.01) from the other currant juice samples. The second highest content was detected in juice of red currant variety Treny, which statistically significantly did not differ in anthocyanin content from juice sample prepared from black currant variety Titania. Black currant samples created 3 consecutive homogeneous groups from *d* to *bc*. The highest content was found in juice of black currant variety Titania, which statistically significantly did not differ from varieties Triton and Fertödi, but differed from Öjebyn sample, where we found the lowest content of anthocyanins. Juices from varieties Triton, Fertödi and Öjebyn statistically significantly did not differ in the anthocyanin content among themselves. We found the lowest dye content in juices of red currant varieties Jonkheer van Tets and Red Lake.

Koponen et al., (2008) investigated the content of anthocyanins in black currants and found out that their content in unprocessed currants is higher than the content after their processing. The total anthocyanin concentration in unprocessed currants was 3170 $mg.kg^{-1}$ and after processing into currant juice concentration decreased to 2790 $mg.kg^{-1}$. Enzymatic modification of currant juice led to an increase in total anthocyanin concentration to values from 2870 to 3330 $mg.kg^{-1}$, which are similar to those in unprocessed currants.

Dénes et al., (2011) monitored the concentration of anthocyanins in selected varieties of currant, blackberries and raspberries grown in Hungary. The highest anthocyanin values were found in black currants at the level of 3540 $mg.kg^{-1}$ DM, which is the value very similar to our results. Anthocyanin content at the level of 1450 $mg.kg^{-1}$ DM found authors in blackberries and at level 4190 $mg.kg^{-1}$ DM in a red currant variety, what is similar to our sample Heinemannova neskorá.

Mikkelsen and Poll (2002) state in their work that in the production process of black currant juice was maintained about 75% of anthocyanin content.

Rubinskien et al., (2005) were determining the anthocyanin content in the 9 varieties of black currant grown in Lithuania. The highest content of anthocyanins was recorded in juice produced from Kupoliniai variety with obtained value of 195.6 $mg.L^{-1}$ and the lowest content was in Ben Lomond variety with a value of 119.9 $mg.L^{-1}$.

Määttä et al., (2001) investigated the content of anthocyanins in black (Öjebyn), red (Red Dutch) and white (White Dutch) currant varieties. Black currant had very high anthocyanin content up to 3011 $mg.kg^{-1}$, while the red currant variety only 1770 $mg.kg^{-1}$. The presence of anthocyanins was not confirmed in white currants. As mentioned earlier, anthocyanins are responsible for the typical black and red pigments of relevant currants, whereas white currants lack their presence.

Koponen et al., (2008) observed the effect of pectolytic enzymes addition on the content of anthocyanins in juice from blueberries and black currants. The authors discovered that by the use of pectolytic preparations, the anthocyanin content increased up to 83% in blueberry juice and to 58% in black currant juice compared to the control containing no enzymatic preparation.

Currants belong to the fruits with highly positive health effects, also due to the whole complex of substances with antioxidant effects.

Based on the obtained results, we can say that the highest antioxidant activity from our samples reached the juice of black currant variety Titania (1167.61 mg $AA.dm^{-3}$) and on the contrary, the lowest reached white currant variety Blanka (417.10 mg $AA.dm^{-3}$). On the basis of a decreasing antioxidant activity, the monitored juices can be ranked as follows Titania >Fertödi >Öjebyn >Triton >Jonkheer van Tets >Heinemannova neskorá >Red Lake >Viktória >Treny >Primus >Blanka. By the antioxidant activity content conversion to dry matter was the highest antioxidant activity detected in juice of Fertödi variety (6571.69 mg $AA.dm^{-3}$ DM) and the lowest in juice of variety Primus (4130.42 mg $AA.dm^{-3}$ DM).

When evaluating differences in antioxidant activity between the juices by a Fisher´s LSD test, we found that in the monitored quality indicators are the smallest relative differences among samples right in the juice antioxidant activity. Whereas the juice samples were divided into 9 homogeneous groups when evaluating the polyphenols and to 6 homogeneous groups (without white currants evaluation) when evaluating anthocyanins, they were divided into 5 homogeneous groups when assessing the antioxidant activity (Table 3).

Juices from varieties Titania and Fertödi had the highest statistically significant antioxidant activity, in which they did not differ. They statistically significantly differed only from the juices of white varieties Primus, Victoria and Blanka. Juices from white varieties had the lowest antioxidant activity, but they statistically significantly differed just from juices of varieties Titania, Fertödi a Jonkheer van Tets. To the balanced group of juices with similar antioxidant activity belong juices of red varieties Heinemannova neskorá, Red Lake and Treny and juices of black varieties Öjebyn and Triton, among which we did not find statistically significant differences in antioxidant activity.

Using the FRAP method, **Borges et al., (2010)** investigated the antioxidant capacity in samples of black and red currants, blueberries, raspberries and cranberries. Authors observed the highest measured values of antioxidant capacity in black currants 51.6 μmol $Fe^{2+}.g^{-1}$, then in blueberries 30.0 μmol $Fe^{2+}.g^{-1}$ and raspberries 27.7 μmol $Fe^{2+}.g^{-1}$. Lower antioxidant activity was found in red currants 24.6 μmol $Fe^{2+}.g^{-1}$ and cranberries 18.6 μmol $Fe^{2+}.g^{-1}$.

Table 3 Varietal differences in the antioxidant activity of currant juices.

Variety	mg $AA.dm^{-3}$	mg $AA.dm^{-3}$ DM
Primus	434,11	4130,42^{a}
Viktória	502,98	4343,50^{a}
Blanka	417,10	4441,98^{ab}
Treny	458,00	5011,00^{abc}
Triton	879,48	5016,97^{abc}
Red Lake	517,33	5300,49^{abc}
Heinemannova neskorá	531,73	5354,83^{abc}
Öjebyn	891,34	5546,6^{abc}
Jonkheer van Tets	567,61	6057,74^{bc}
Titania	1167,61	6145,32^{c}
Fertödi	612,81	6571,69^{c}

Note: $^{a-c}$ Means with the same letter are not significantly different from each other (Fisher's LSD test, p >0.05); DM - dry matter.

Namiesnik et al., (2013) focused in their work on the determination of antioxidant capacity in selected types of berries, while they used gooseberries, cranberries and blueberries. The analysis was realized using the FRAP method. The highest values of total antioxidant capacity authors found in blueberries 94.10 μM $TE.g^{-1}$. The antioxidant capacity of cranberries and gooseberries was 26.97 μM $TE.g^{-1}$ and 6.51 μM $TE.g^{-1}$.

Kendir and Köroğlu (2015) observed antioxidant activity of several species of the genus *Ribes - Ribes alpinum, R. anatolica, R. biebersteinii, R. multiflorum, R. nigrum, R. orientale, R. rubrum and R. uva-crispa*a, growing wild in Turkey. The authors prepared water and methanol extracts of plant leaves and shoots and found that *Ribes orientale* reached the highest antioxidant activity among the assessed species.

Moyer et al., (2002) investigated correlation dependences between the antioxidant activity, the content of total polyphenols, and anthocyanin dyes in 107 genotypes of the genera *Vaccinium* L., *Rubus* L. a *Ribes* L., while found that the antioxidant activity correlates in the fruit more significantly with polyphenol content than with the anthocyanin dyes content.

CONCLUSION

Currant are an important raw material for the production of fruit juices, soft drinks and last but not least, of fruit wines. All these products are characterized by good organoleptic properties and beneficial effects on consumer health due to the presence of active antioxidant substances of different types. The aim of this work was to evaluate the content of total polyphenols, anthocyanin dyes and antioxidant activity in the juice from selected varieties of white, red and black currant. The value of total polyphenols in the currant juice ranged from 1897.43 mg. dm^{-3} DM (Blanka) to 3712.21 mg. dm^{-3} DM (Primus). In the white varieties of currant was immeasurable amount of anthocyanin dyes. In the assessed juices from red and black currants was their content from 1947.64 mg. dm^{-3} DM (Jonkheer van Tets) to 4161.07 mg. dm^{-3} DM (Heinemannova neskorá). Among the evaluated indicators were the smallest differences between the samples in the indicator of antioxidant activity. The highest antioxidant activity reached juice sample of Fertödi variety (6571.69 mg AA.dm^{-3} DM) and the lowest sample of variety Primus (4130.62 mg AA.dm^{-3} DM).

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