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## Evaluation and comparison of antioxidant activity and biochemical compounds in some coloured potato cultivars

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**Abstract:** Potato is an important source of food, and in recent years, new genotypes have emerged on the European market, which particularly differentiate by the colour of tubers. The current study investigated and compared phytochemical properties and antioxidant activity of six potato cultivars: two of those with yellow-fleshed (Carpatin, Brasovean) and four with red and purple-fleshed (Cranberry Red, Mountain Rose, Purple Majesty, and Blue Congo), which were cultivated under the same climatic and soil conditions. The antioxidant activities were evaluated using two antioxidant systems 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS). The results show that yellow-fleshed cultivars had higher total soluble substance content; red and purple-fleshed cultivars had a higher content of antioxidant compounds. Cv. Blue Congo it was recorded the highest antioxidant capacity in terms of DPPH and ABTS, of 164.17  $\mu\text{mol}$  ascorbic acid (AsA)/100 g FW (fresh weight) and 114.96  $\mu\text{mol}$  AsA/100 g FW, respectively. The highest total phenolic content was registered at cv. Purple Majesty of 63.54 mg gallic acid equivalents/100 g FW. Regarding flavonoids, the highest content was 40.96 mg quercetin equivalents/100 g FW for cv. Blue Congo and anthocyanin at cv. Purple Majesty of 113.19 mg/100 g FW.

**Keywords:** *Solanum tuberosum* L.; cultivation; principal component analysis; nutritional value; biologically active compound; polyphenol

Potato (*Solanum tuberosum* L.) is a worldwide cultivated species due to its ecological plasticity and role in human nutrition. The potato crop has become increasingly important for food security due to its nutritional value and high production capacity. It is ranked among the top four major crops in the world after rice, wheat, and corn (Zhang et al. 2017).

Potato is an excellent source of vitamin C and other biologically active substances, such as polyphenols and flavonoids, which are commonly described as antioxidants (Ferdous et al. 2019). These compounds have effects against free radicals, reduce the risk of coronary heart disease by reducing cholesterol in blood serum, and increasing the resistance of vascular walls (Chellaram et al. 2014). Antioxidant-rich diets prevent certain types of cancer, as well as macular

retinal degeneration (Brown 2005). The cultivated species contain different levels of biologically active compounds. Potato is considered to be an important source of polyphenolic compounds, after apples and oranges, which are found mainly in its skins and intensely coloured cultivars (Ezekiel et al. 2013). Red and purple-fleshed potato cultivars are characterised by two or even three times higher antioxidant potential as compared to white-fleshed potatoes (Navarre et al. 2011). Biological properties of these coloured-fleshed potatoes and great concern regarding their toxicological safety indicate that they can have the potential for use in the nutraceutical industry and as sources of natural colourants with added value to the food industry (Bontempo et al. 2013). Their purple colour is a result of the anthocyanin, a strong

antioxidant that prevents the development of cancer cells. Recently, coloured-fleshed potatoes have attracted great interest for investigators and consumers due to their high antioxidant activities, taste, aspect, and their beneficial effect on the body (Jansen and Flamme 2006). The purpose of this study was to identify antioxidant activity level and biochemical compounds in six potato cultivars out of which two yellow-fleshed and four coloured-fleshed ones.

## MATERIAL AND METHODS

The pigmented potato cultivars were grown in South-Western Romania, (44°19'N, 23°48'E), on a psamosol, with a sandy texture, favourable for potato crop, in 2016. The experiment included a total of six potato cultivars (*Solanum tuberosum* L.) including two yellow-fleshed (ordinary) cultivars: Carpatin and Brasovean, obtained from National Institute of Research-Development for Potato and Sugar Beet Brasov (Romania) and four purple and red-fleshed cultivars: Cranberry Red, Mountain Rose, Purple Majesty, and Blue Congo, imported from abroad. Potatoes were harvested at maturity; the samples were organised in three replicates of 10 tubers, selected aleatory from each cultivar, and analysed in the laboratory of the chemistry of Faculty of Agriculture, University of Craiova (Romania).

**Analytical methods.** For the determination of investigated biochemical indices, samples were extracted with 80% aqueous methanol (1:20 *w:v*) by sonicating for 60 min in a bath sonicator Elmasonic S120 (Elma Schmidbauer GmbH, Singen, Germany) at 24 °C. The resulting slurries were centrifuged at 4 000 *g* for 5 min, and the supernatants were collected.

**Total soluble substance.** The total soluble substance (TSS) content was determined with refractometer DR 301-95 (A. Krüss Optronic, Hamburg, Germany) at 20 °C and results were expressed in °Brix.

**Total phenolic content.** The total phenolic content (TPC) was determined colorimetrically at 765 nm by the Folin-Ciocalteu reagent method, as described by Soare et al. (2015). Gallic acid was used to construct a standard curve, and the results were expressed as mg of gallic acid equivalents (GAE)/100 g FW (fresh weight).

**Total flavonoid content.** The total flavonoid content (TFC) was determined by the colorimetric method, with 10% Al(NO<sub>3</sub>)<sub>3</sub> and 5% sodium nitrite (NaNO<sub>2</sub>) in alkaline medium. The absorbance was read at 500 nm, and the results were calculated from

the quercetin calibration curve and expressed as mg quercetin equivalents (QE)/100 g FW (Soare et al. 2015).

**Total anthocyanin content.** The total anthocyanin content (TAC) was determined colorimetrically at 520 nm using the pH differential method, as described by Hamouz et al. (2011). The results were calculated with Eq. (1):

$$\text{TAC (mg cyaniding/L)} = (A_1 - A_2) \times f \quad (1)$$

where:  $A_1$  – absorbance in 2% HCl;  $A_2$  – absorbance in citric buffer at pH = 3.5 (prepared from 0.2 mol/L Na<sub>2</sub>HPO<sub>4</sub> and 0.1 mol/L citric acid);  $f$  = 396.598.

**Antioxidant activities.** Antioxidant activities were evaluated by two methods: DPPH (2,2-diphenyl-1-picrylhydrazyl) radical and ABTS (2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid) cation radical scavenging assay. DPPH radical scavenging assay was determined colorimetrically at 517 nm on a spectrophotometer Varian Cary 50 UV-Vis (Australia Pty Ltd., Mulgrave, Victoria). The discolouration degree of the purple colour from DPPH indicates the radical scavenging potential of the samples. Percentage of inhibition of the DPPH radical was calculated according to the following Eq. (2):

$$\% \text{ scavenging} = \frac{A_0 - (A_1 - A_2)}{A_0} \times 100 \quad (2)$$

where:  $A_0$  – absorbance of DPPH alone;  $A_1$  – absorbance of DPPH + extract;  $A_2$  – the absorbance of the extract only. The standard calibration curves using ascorbic acid (AsA) were plotted as a function of the percentage of DPPH radical scavenging activity. The results of antioxidant activity were expressed as micromole ascorbic acid equivalents/100 g fresh weight ( $\mu\text{mol AsA}/100 \text{ g FW}$ ).

ABTS radical cation scavenging activity was measured colorimetrically at 734 nm. Ascorbic acid was used as a standard. The standard calibration curves were plotted as a function of the percentage of ABTS radical cation scavenging activity calculated using Eq. 2. The results were expressed as micromole AsA equivalents/100 g fresh weight ( $\mu\text{mol AsA}/100 \text{ g FW}$ ). All determinations were performed in triplicate, and all results were calculated as mean.

**Statistical analysis.** For each analysis three measurements were performed, and the results were expressed as mean values and standard deviation and were calculated by one-way analysis of variance (ANOVA) using Statgraphics Centurion XVI Software (StatPoint Technologies, Warrenton, USA). Significant differences between samples were deter-

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Table 1. Content of total soluble substance (TSS) and antioxidant compounds of the potato cultivars evaluated

Cultivar	TSS (°Brix)	TPC (mg GAE/100 g FW)	TAC (mg/100 g FW)	TFC (mg QE 100/g FW)
Brasovean	4.7 ± 0.1 <sup>d</sup>	42.64 ± 0.94 <sup>c</sup>	10.3 ± 0.9 <sup>d</sup>	11.02 ± 1.03 <sup>e</sup>
Carpatin	7.9 ± 0.4 <sup>a</sup>	34.00 ± 1.1 <sup>d</sup>	11.5 ± 0.8 <sup>d</sup>	17.52 ± 0.5 <sup>d</sup>
Blue Congo	6.9 ± 0.1 <sup>b</sup>	54.67 ± 3.39 <sup>b</sup>	26.82 ± 0.38 <sup>c</sup>	40.96 ± 0.43 <sup>a</sup>
Purple Majesty	4.9 ± 0.1 <sup>cd</sup>	63.54 ± 2.17 <sup>a</sup>	113.19 ± 0.49 <sup>a</sup>	38.56 ± 0.55 <sup>a</sup>
Mountain Rose	3.4 ± 0.2 <sup>e</sup>	61.41 ± 1.87 <sup>a</sup>	105.34 ± 6.84 <sup>a</sup>	23.23 ± 2.06 <sup>c</sup>
Cranberry Red	5.4 ± 0.1 <sup>e</sup>	52.86 ± 2.86 <sup>b</sup>	43.68 ± 1.88 <sup>b</sup>	29.55 ± 1.31 <sup>b</sup>
<i>LSD</i> <sub>0.05</sub>	0.56	6.29	11.4	3.20

Mean values ± standard deviation; values with different letters (a–e) with a column. TPC – total phenolic content; GAE – gallic acid equivalents; TAC – total anthocyanin content; TFC – total flavonoid content; QE – quercetin equivalents; FW – fresh weight; *LSD* – least significant difference

mined by Duncan's multiple range tests at the level of significance  $P \leq 0.05$ . Also, there were calculated principal component analysis (PCA).

## RESULTS AND DISCUSSION

Average values for the analysed parameters showed significant differences between the potato cultivars under study (Table 1). Total soluble substance ranged from 3.4 °Brix for cv. Mountain Rose to 7.9 °Brix for cv. Carpatin. The values indicate that TSS content was higher in yellow-fleshed cultivars and lower in those with coloured flesh. These values obtained are much lower than those for sweet potatoes (Dinu and Soare 2015). TSS content may vary according to species, cultivar, and harvest time.

Total phenolic content for the cultivars under study ranged from 34.00 to 63.54 mg gallic acid equivalents (GAE)/100 g FW. The highest content was recorded in coloured-fleshed cultivars, in particular, cv. Purple Majesty, followed by cv. Mountain Rose with 61.41 mg GAE/100 g FW, cv. Blue Congo with 54.67 mg GAE/100 g FW, cv. Cranberry Red with 52.86 mg GAE/100 g FW. The lowest values were recorded for yellow-fleshed potato cultivars, cv. Carpatin with 34.00 mg GAE/100 g FW and cv. Brasovean with 42.64 mg GAE/100 g FW (Table 1). The results in the present study are similar to those recorded by Ru et al. (2019), who reported values in red or purple potatoes of 51.36–73.60 mg GAE/100 g while in yellow or white potatoes it was 8.77–19.91 mg GAE/100 g. Thus, it can be concluded that total polyphenols are influenced by the cultivar's genetics, crop area, and degree of pigmentation. TPC of the coloured potatoes was much higher than that of

ordinary potatoes. Many authors reported different results in TPC. According to Jarién et al. (2015), cv. Vitelotte, the dark purple-fleshed cultivar, had a significantly higher content of antioxidant compounds as compared to cv. Blue Congo (light purple) and cv. Red Emmalie (red-fleshed). Other authors stated that in potato, phenolic compounds and their stability are influenced by agrotechnical processes, climatic conditions, and ripeness during harvest and post-harvest manipulations (Ezekiel et al. 2013).

Total anthocyanin content recorded for coloured-fleshed cultivars ranged from 26.82 mg/100 g FW for cv. Blue Congo to 113.19 mg/100 g FW for cv. Purple Majesty. For the yellow-fleshed potato cultivars, TAC varied from 10.3 mg/100 g FW for cv. Brasovean to 11.5 mg/100 g FW for cv. Carpatin (Table 1). These

Table 2. Antioxidant activity of the potato cultivars evaluated

Cultivar	DPPH	ABTS
	(µmol AsA/100 g FW)	
Brasovean	64.78 ± 1.72 <sup>d</sup>	75.20 ± 3.83 <sup>c</sup>
Carpatin	49.15 ± 2.35 <sup>e</sup>	80.09 ± 1.11 <sup>c</sup>
Blue Congo	164.17 ± 3.82 <sup>a</sup>	114.96 ± 1.84 <sup>a</sup>
Purple Majesty	104.86 ± 5.14 <sup>c</sup>	93.22 ± 1.28 <sup>b</sup>
Mountain Rose	141.22 ± 1.78 <sup>b</sup>	107.35 ± 1.65 <sup>a</sup>
Cranberry Red	111.33 ± 7.33 <sup>c</sup>	71.77 ± 1.23 <sup>c</sup>
<i>LSD</i> <sub>0.05</sub>	7.53	10.75

Mean values ± standard deviation; values with different letters (a–e) with a column. DPPH – 2,2-diphenyl-1-picrylhydrazyl; ABTS – 2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid); AsA – ascorbic acid; FW – fresh weight; *LSD* – least significant difference

Table 3. Total variance explained-extraction method: principal component analysis

Component	Initial Eigen values			Extraction sums of squared loadings		
	total	% of variance	cumulative %	total	% of variance	cumulative %
1	2.94	58.83	58.839	2.94	58.84	58.839
2	1.28	25.66	84.499	1.28	25.660	84.499
3	0.55	11.11	95.609			
4	0.19	3.812	99.422			
5	0.03	0.578	100.000			

results are also similar to those by Lee et al. (2016), who reported values up to 89.95 mg/100 g dried samples for purple-fleshed and up to 1.56 mg/100 g for yellow-fleshed potato cultivar. In this regard, Jansen and Flamme (2006), in a study of twenty-seven potato cultivars and four clones, reported on average the highest amounts of anthocyanins of 0.65 g/kg FW in the skin, also for whole tubers of 0.31/kg FW and flesh of 0.22/kg FW. It can be concluded that TAC value highly depends on the cultivar, degree of flesh pigmentation, crop area, and studied sample (whole tuber, flesh, skin).

Total flavonoid content ranged from 11.02 to 40.96 mg quercetin equivalents (QE)/100 g FW. Regarding the coloured cultivars, cv. Blue Congo had the highest TFC, followed by cv. Purple Majesty of 38.56 mg QE/100 g FW, cv. Cranberry Red of 29.55 mg QE/100 g FW. Also, yellow-fleshed cultivars registered values from 11.02 mg QE/100 g FW at cv. Brasovean to 17.52 mg QE/100 g FW at cv. Carpatin. As in the case of TAC, too, also the highest values of TFC were recorded in coloured fleshed cultivars. According to some researchers, TFC is influenced by the potato cultivar and extraction method. Thus, Lee et al. (2016) reported values of TFC from 36.47 to 157.33 mg catechin equivalent (CE)/100 g dried samples of the purple-coloured potato cultivars and from 36.47 to 50.80 mg CE/100 g dried samples of the yellow cultivars and 75.35 mg CE/100 g dried samples white cultivars. Also, Damsa et al. (2015) determined the total flavonoid content using crude extracts from purple potato in different solvents (1% acidified methanol, 1% acidified ethanol and 1% acidified deionised water) and reported that for TFC the methanolic extract had the highest amount of 105.31 mg/100 g FW and the ethanolic extract had the lowest value of 25.37 mg/100 g FW.

Antioxidant activity values in terms of DPPH and ABTS for potato cultivars under study are provided in Table 2. DPPH for red and purple-fleshed potato cul-

tivars ranged from 111.33 to 164.17  $\mu\text{mol AsA}/100\text{ g FW}$ , and ABTS ranged from 71.77 to 114.96  $\mu\text{mol AsA}/100\text{ g FW}$ . For yellow-fleshed cultivars, DPPH was much lower, ranging from 49.15  $\mu\text{mol AsA}/100\text{ g FW}$  to 64.78  $\mu\text{mol AsA}/100\text{ g FW}$ , and ABTS varied between 75.20 and 80.09  $\mu\text{mol AsA}/100\text{ g FW}$ . High antioxidant activity for coloured fleshed tubers had also been reported by other authors (Hamouz et al. 2011, Lee et al. 2016). The values of antioxidant capacity in terms of DPPH for coloured fleshed cultivars are higher compared to those recorded by using the ABTS method. The results of the present study regarding antioxidant capacity at yellow-fleshed cultivars are similar to those reported by Lachman et al. (2009).

Variation in antioxidant activity can be a result of the method, solvent used, or cultivar.

Regardless of the antioxidant capacity evaluation method, it can be stated that the value difference between yellow-fleshed and red or purple-fleshed potato cultivars is the result of anthocyanins. Differences in TAC values were reported in previous researches, confirming the significant impact of genotype.

Regarding PCA analysis, the first two components account for 84.49% of the total variance, of which

Table 4. Character component score method: principal component analysis 2 components extracted

Character	Component	
	1	2
Phenolic compounds	0.810	0.418
Flavonoids	0.963	-0.157
Anthocyanins	-0.080	0.866
DPPH	0.307	0.820
ABTS	0.711	0.642

DPPH – 2,2-diphenyl-1-picrylhydrazyl; ABTS – 2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid)

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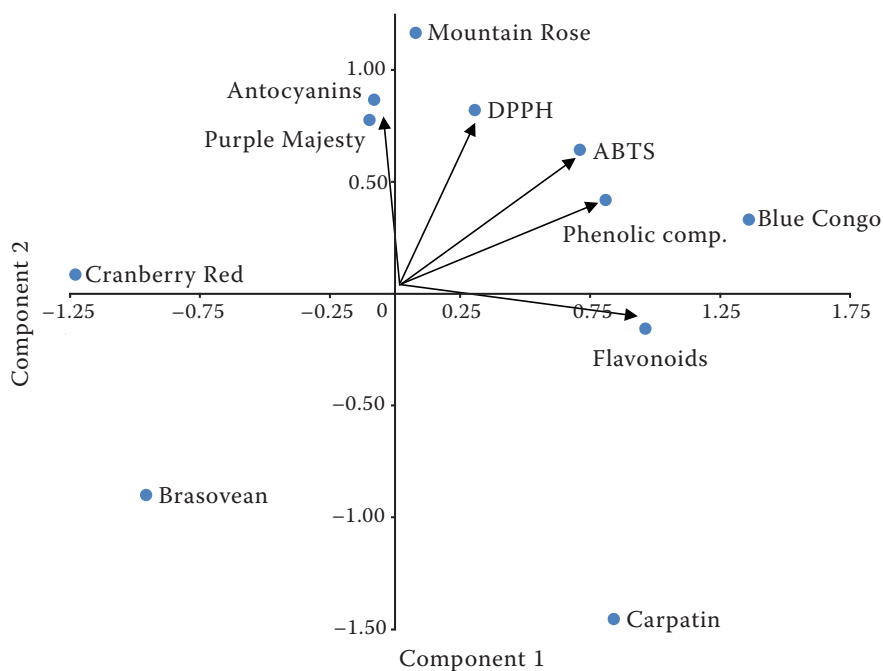


Figure 1. Distribution of the analysed variants by groups according to principal component analysis (PCA) analysis. DPPH – 2,2-diphenyl-1-picrylhydrazyl; ABTS – 2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid)

the first component registers 58.83 and the second component 25.66% (Table 3).

Concerning the analysis of the first component, the highest positive values are recorded for phenolic compounds and flavonoid content, so this component can be named high potential for these. For the second component, the highest positive values are recorded for anthocyanin and DPPH so that this component can be considered as a high potential for these (Table 4).

The first group consists of 2 variants with positive components, these variants being cv. Mountain Rose and cv. Blue Congo. This group is characterised by the fact that it has all the characters with maximum values except flavonoids content (Figure 1).

Carpatin is the only genotype that has the first component positive and the second one negative. This genotype has the highest flavonoid content and very high content of phenolic compounds, but poor content of anthocyanins, and low values for DPPH and ABTS. Brasovean is the only genotype that has both components negative. This genotype has the lowest values for almost all of the characters, except DPPH.

The fourth group consists of 2 genotypes, respective cvs. Cranberry Red and Purple Majesty, having the first component negative and the second component positive. This group has the highest value for anthocyanins and high value for phenolic compounds

and DPPH, but low values for flavonoids and ABTS. These potato cultivars can be a natural antioxidant in human nutrition sources. From a practical point of view, farmers can support market demands by focusing on the cultivation of coloured-fleshed potato cultivars.

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