Potato Research
https://doi.org/10.1007/s11540-022-09542-3

Antioxidant Capacity and Phenolic Content of New Turkish Cultivars of Potato

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Received: 14 May 2020 / Accepted: 5 January 2022/Published online: 04 February 2022
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Abstract

Potatoes are a good source of starch, vitamin C, potassium and protein with a high biological value. In addition, potatoes have antioxidant activity because they contain phenolics such as chlorogenic acid. Studies that determine the amount and capacity of antioxidant substances that are beneficial to health are valuable. This study determined the phenolic and antioxidant capacity of the new potato cultivars (Çağlı, Fatih, Leventbey, Muratbey, Nahita, Nam, Onaran, Ünlenen) registered in Turkey. Cultivars were assessed by dividing medium- and large-sized cultivars according to their weight into two groups. Three different methods of antioxidative capacity (ABTS, DPPH, FRAP) were used in this study. HPLC-PDA was used for analyzing phenolic acids (caffeic acid, chlorogenic acid, and chlorogenic acid isomer). Nahita had the highest levels of chlorogenic, total phenolic, and total phenolic content among the large-sized cultivars. For antioxidant ability, Fatih had the highest values among large-sized cultivars. Onaran showed the highest values for chlorogenic acid, total phenolic acid, ABTS, and DPPH among the medium-sized cultivars while Nam showed the highest values in terms of FRAP and total phenol content. Strong positive correlations were found between the scavenging capacity of radicals and chlorogenic acid contents in potatoes.

Keywords Antioxidant capacity · Chlorogenic acid · HPLC-PDA · Phenolic acid · Turkish potato cultivar

Introduction

The incidence of some cancer types and cardiovascular diseases decreases with the increase in fruit and vegetable consumption (Heidemann et al. 2008). Protective effects are likely due to numerous phytochemicals such as phenolic compounds found in plant

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foods (Valcarcel et al. 2015). Phenolics have demonstrated antioxidant effects by inhibiting the development of free radicals in the human body (Kampa et al. 2004).

Potatoes are a good source of high biological protein, starch, vitamin C, potassium, and antioxidants such as carotenoids, phenolics, and flavonoids (Reddivari et al. 2007). Potatoes provide a better source of phenolic materials than popular vegetables like carrots, lettuce, and tomatoes (Chun et al. 2005). Most of the phenolics in the potato are chlorogenic acids. Chlorogenic acid acts as an antioxidant (Brown 2005). The chemical structures of caffeic acid, chlorogenic acid, and chlorogenic acid isomer, which are an important part of the phenolic acids of potatoes, are illustrated in Figure 1.

Potato is one of the most consumed foods in Turkey. Furthermore, because of the growing demand for fresh, natural, and healthy products, it is important to determine the functional characteristics of new potato cultivars. The study aims to determine the antioxidant activity and phenolic acid (caffeic acid, chlorogenic acid, and chlorogenic acid isomer) levels of eight new potato cultivars registered in Turkey. The functional properties of the new cultivars have not been documented in a comprehensive study.

Materials and Methods

Plant Material

Eight cultivars of Turkish potatoes were used in this research; they were cultivated under the same conditions in the fields of the Potato Research Institute in Niğde province. Standard practices including fertilization, irrigation, disease, and pest control were followed in all potato cultivars. All tubers were harvested in October 2017 from the research field at the Potato Research Institute in Niğde, Turkey. After the potatoes arrived at the laboratory, the tests were carried out without delay. The tubers were washed under running tap water and allowed to dry at ambient temperature (approx. 25 °C). After drying, the extracts were taken from the potato samples immediately and stored at −20 ° C for almost a week.

Potato samples were divided into two groups (medium and large) according to their weight and the results of the analysis were evaluated according to this grouping. There was no statistically significant difference among the weight of the cultivars in each group (p>0.05). Two samples were taken from two different tubers for analyses. Two

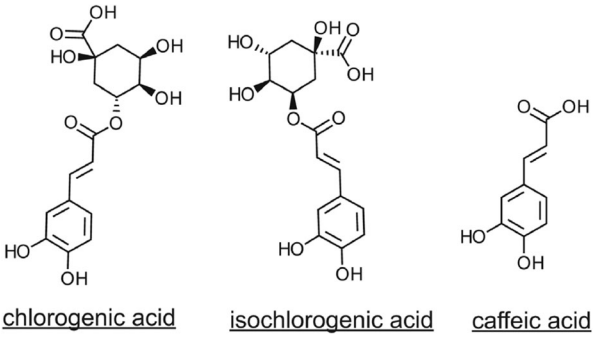

Fig. 1 Chemical structures of caffeic acid, chlorogenic acid, and chlorogenic acid isomer (Friedman et al., 2017)

replicate runs were performed for each sample. The names, average weights, and colour parameters of the cultivars are given in Table 1.

Colour Measurement

The potato was peeled and cut into ellipse shapes. The colour was measured using a colour spectrophotometer (X-rite Ci64 /USA). The colour was expressed in L^*, a^*, b^*, C^*, and h, where the L^* represents lightness ($L^* = 0$ yields black and $L^* = 100$ denotes white), a^* expresses red (+) or green (−), and the b^* indicates yellow (+) or blue (−). C^* value represents chroma, and h is the hue angle. Chroma and hue are calculated from the a^* and b^* coordinates in $L^*a^*b^*$.

Extraction of Phenolic Compounds

Potato samples were grated. The fresh sample (1 g) was homogenized in methanol (10 ml, 70% aqueous). The homogenate was centrifuged at 4000 rpm for 15 min. The supernatant was transferred to a rotary evaporator balloon and evaporated at 45 ° C. Then 25 ml of methanol (100%) was added to the balloon and mixed. The methanolic extract was then filtered (Whatman no:1). All analyses based on extraction were made on fresh weight (Karadeniz et al. 2005).

DPPH Radical Scavenging Activity Assay

The antioxidant activity of the samples was determined by using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging method (Brand-Williams et al. 1995). DPPH solution (4.1075 M) was prepared with 100% methanol. DPPH solution (200 μL) and the sample (800 μL) were mixed and allowed to stand in the dark for 30 min. All samples were read at a spectrophotometer (Optizen pop, Korea) at 517 nm against the blank prepared with 0.8 ml methanol. The results were expressed as mg of Trolox per 100 g fresh weight potato sample using a standard calibration curve of Trolox.

Table 1 Average weight (N=2) and colour values (N=4) of potato cultivars

Tuber size	Cultivars	Average weight (g)	L^*	a^*	b^*	C^*	h
Medium	Nam	94.87±2.87	64.75±4.09	−0.97±0.27	28.63±4.24^{b}	30.89±1.62^{b}	91.83±0.34^{a}
	Onaran	90.25±3.61	69.05±1.32	−1.50±0.06	20.46±2.31^{a}	20.52±2.30^{a}	94.23±0.44^{b}
	Leventbey	110.15±7.00	68.67±2.61	−1.17±0.36	29.81±2.56^{b}	29.83±2.57 ^{b}	92.23±0.58^{a}
	Muratbey	99.48±4.70	67.72±0.84	−1.16±0.17	32.01±0.59^{b}	32.02±0.59 ^{b}	92.07±0.29^{a}
Large	Çağlı	125.21±6.15	66.97±2.22^{ab}	−0.99±0.38^{b}	19.09±1.57^{a}	17.65±0.64^{a}	92.88±0.90
	Fatih	143.91±7.31	67.71±0.89^{ab}	−2.11±0.16^{a}	35.54±3.31^{c}	35.60±3.29^{d}	93.42±0.56
	Nahita	130.57±6.55	65.65±2.76^{a}	−2.13±0.29^{a}	28.50±0.64^{b}	28.57±0.65^{b}	94.26±0.52
	Ünlenen	124.93±4.20	69.82±0.74^{b}	−2.01±0.09^{a}	31.09±0.61^{b}	31.40±0.74^{c}	93.62±0.32

All values are presented as the mean ± standard deviation (SD) of samples. Dissimilar letters show the differences between the values ($\alpha = 0.05$) according to the Duncan multiple comparison test ($p<0.05$)

Ferric Reducing/Antioxidant Power (FRAP) Assay

The FRAP reagent was freshly prepared by mixing acetate buffer (500 mL, 300 mM, pH 3.6), TPTZ solution (50 mL 10 mM TPTZ in 40 mM/HCl), and $FeCl_36H_2O$ (50 mL, 20 nM) in a ratio of 10:1:1. FRAP reagent (2.7 ml), purified water (270 μl), and the sample (90 μl) were mixed with the vortex. The mixture was left in a 37°C water bath for 4 min. The mixture was read at 593 nm on the spectrophotometer. The values of FRAP were determined as $FeSO_47H_2O$ equivalence (Choi et al. 2016).

ABTS Radical Cation Decolourization Assay

ABTS radical cation decolourization analysis was carried out by making some modifications according to Re et al. (1999). Potassium persulfate (0.63 mM) and ABTS solution (1.8 mM) were mixed in a ratio of 1: 1, and the mixture was left in the dark for 24 h. The solution was mixed with methanol until the absorbance 0.700 ± 0.030 at 734 nm was obtained. ABTS solution (990 μl) was mixed with 10 μl of the sample and read on the spectrophotometer at 732 nm and the concentration was determined against the Trolox curve.

Total Phenolic Content (TPC)

Total phenolic content was determined according to Karadeniz et al. (2005). Extraction solution (0.25 ml), Folin-Ciocalteu reagent (0.25 ml), and deionized water (3.5 ml) were mixed. After 3 min, 1 ml of 20% Na_2CO_3 was added and mixed again. The mixture was left in the water bath at 25 **°C** for 1 h. Absorbance was measured at 720 nm using a UV–visible spectrophotometer (Optizen pop, Korea). The results were expressed as mg catechin/100 g fresh weight.

Analysis of Phenolic Acid Compounds

Phenolic compounds of samples were analyzed according to the method of Friedman et al. (2017). HPLC analysis was performed using a Thermo Scientific HPLC Dionex Ultimate 3000 system equipped with an automatic injector WPS-3000SL, TCC-3000SD column oven, and an MWD-3000 Multiple Wavelength photodiode array detector. A C18 (250 * 4.6 mm ID, 5 μm particle size) column was used. The mobile phase was acetonitrile (A) vs 1% formic acid in purified water (B) and the following gradient program was performed: (A) =5% (0–5 min), 18% (5.1–30 min), 53% (30.1–70 min), 90% (70.1–80 min), and 5% (80.1–100 min). Methanolic extract filtered through a 0.45 μm nylon filter and 20 μl of this solution was injected into the column. Flow rate was 1 ml/min at 35 °C and peaks were read at 320 nm.

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) with SPSS 23. The Duncan multiple comparisons test at $\alpha = 0.05$ was used to compare means among cultivars in the group. Pearson's correlation test was used for the detection of relationships between analysis results. Differences at $p<0.05$ were considered statistically significant.

Results and Discussion

Colour

Colour is one of the important factors that influence the quality of foods (Nemś and Pęksa 2018). The colour parameters of the potato cultivars are shown in Table 1. There was no significant difference found in L^* and a^* values of medium-sized potato cultivars ($p>0.05$). There were highly significant differences found in b^* and C^* and h values between the medium-sized potato cultivars ($p<0.001$). Nam cultivar had the lowest L^* and h value and the highest a* value among the medium-sized cultivars. The brightest cultivar was cv. Muratbey and the lightest cultivar was cv. Onaran. Muratbey cultivar showed the most intense yellow colour in medium-size cultivars. The greenest in this group was the cv. Onaran.

There was no significant difference found in the h values of the cultivars in the large potato group ($p>0.05$). There was a significant difference found in the L^* values of this group ($p<0.05$). Highly significant differences were more pronounced in a^*, b^*, and C^* values of large size cultivars ($p<0.001$). The yellowest and brightest cultivar was cv. Fatih, while the lightest cultivar was the cv. Ünlenen. Muñoz et al. (2017) reported that the highest yellowness and brightness values in Agria, Agata, and Carrera potato cultivars were seen in cv. Agria. A study by Andersen et al. (2002) found L^* value between 38.8 and 49.1, C^* value between 22.3 and 29.2, and h value between 9.9 and 21.7 in four different fresh red potatoes.

Antioxidant Activity

Potatoes have an antioxidant capacity due to the phytochemicals they contain (Ezekiel et al. 2013). The antioxidant capacity results of eight new potato cultivars are given in Table 2. There were highly significant differences found in antioxidant capacity (ABTS, DPPH, FRAP, TPC) between medium-sized cultivars ($p<0.001$). The highest capacity to scavenge the ABTS and DPPH radicals was found in Onaran among the medium-sized cultivars. The second highest value in terms of ABTS and DPPH capacities was found in cv. Nam, and there was no statistical difference found between the antioxidant capacities of cv. Onaran and cv. Nam. The highest iron (III) ion reduction capacity was found in Muratbey samples when compared to other medium-sized cultivars. Leventbey cultivar showed the lowest FRAP value and this value was found significantly different from other medium-sized cultivars ($p<0.05$). TPC of Nam cultivar was higher and was found significantly different from other medium-sized cultivars ($p<0.05$).

According to Table 2, there were significant differences found in antioxidant capacity values (ABTS, DPPH, FRAP) between large-sized cultivars ($p<0.05$). There were highly significant differences found in TPC values between large-sized cultivars ($p<0.01$). ABTS, DPPH, and FRAP analyses showed that the Fatih cultivar had the highest antioxidant activity. ABTS and DPPH values of Fatih cultivar showed significant differences compared to other large-sized cultivars ($p<0.05$). The highest value in TPC was seen in the Nahita cultivar and this TPC value showed significant differences compared to other large-sized cultivars ($p<0.05$). The DPPH value of the Çağlı cultivar was the lowest and this value was found significantly different from other large-sized

Table 2 Effects of cultivar on antioxidant activities of potato tubers (N=4)

Tuber size	Cultivars	ABTS (mg/100g Trolox eq.)	DPPH (mg/100g Trolox eq.)	FRAP (mg/100g Fe^{2+} eq.)	TPC (mg/100g catechin eq.)
Medium	Nam	82.89±10.59^{b}	18.27±5.30^{b}	26.76±1.97^{b}	105.30±1.80^{c}
	Onaran	85.50±7.54^{b}	21.73±1.92^{b}	23.04±2.92^{b}	90.87±10.46^{bc}
	Leventbey	45.92±3.13^{a}	7.05±1.29^{a}	11.46±2.02^{a}	52.65±6.01^{a}
	Muratbey	48.68±5.85^{a}	6.19±0.41^{a}	36.29±7.12^{c}	80.90±22.08^{b}
Large	Çağlı	71.13±5.90^{a}	13.52±2.82^{a}	44.32±13.68^{b}	56.39±1.88^{a}
	Fatih	137.69±58.96^{b}	22.90±6.58^{b}	51.12±26.11^{b}	72.64±24.30^{a}
	Nahita	81.16±18.44^{a}	18.90±3.59^{ab}	30.36±9.88^{ab}	92.43±6.08^{b}
	Ünlenen	65.08±5.97^{a}	16.69±2.34^{ab}	14.16±0.84^{a}	59.87±4.34^{a}

All values are presented as the mean ± standard deviation (SD) of samples. Dissimilar letters show the differences between the values (α = 0.05) according to the Duncan multiple comparison test (p<0.05)

cultivars (p<0.05). The iron (III) ion reduction capacity of the Ünlenen cultivar was very low and statistically different from large-sized cultivars (p<0.05).

Reddivari et al. (2007) reported that total antioxidant capacity in selected special potato tubers ranged from 157 μg Trolox equivalents/g FW to 832 μg Trolox equivalents /g fresh weight. Valcarcel et al. (2015) reported that antioxidant activity levels of 60 cultivars of potato ranged from 8 to 440 and 30 to 1884 mg of Trolox per 100 g of the dry weight of sample in the flesh and skin, respectively. Choi et al. (2016) reported that the TPC of the 16 samples ranged (in μg/mg DW) from 69.8 (Atlantic Whole) to 113 (Superior Cortex-A).

Phenolic Compounds

The concentration of phenolic compounds of the potato cultivars is shown in Table 3. There were highly significant differences found in chlorogenic acid and total phenolic acid values among medium-sized cultivars (p<0.01), while there was no difference in the values of caffeic acid and chlorogenic acid isomers (p>0.05). The highest amounts of chlorogenic acid and total phenolic acid were observed in the Onaran cultivar among the medium-sized cultivars. There was a significant difference found between cv. Onaran and other medium-sized cultivars (p<0.05). The highest amount of caffeic acid was observed in Nam and Leventbey cultivars, respectively.

Table 3 showed that there were significant differences found in the values of chlorogenic acid (p<0.01), chlorogenic acid isomer (p<0.05), caffeic acid (p<0.001), and total phenolic acid (p<0.01) between large-sized cultivars. The highest amounts of chlorogenic acid and total phenolic acid were observed in the Nahita cultivar among the large-sized cultivars. Nahita cultivar was followed by Fatih cultivar in this category and there was no statistical difference found between Nahita and Fatih. The amount of chlorogenic acid isomer was highest in the Fatih cultivar and this value was found significantly different from other large-sized cultivars (p<0.05). The amount of caffeic acid was found highest in Çağlı cultivar and this value was statistically different from other large-sized cultivars (p<0.05).

Table 3 Phenolic acid profile of new cultivars (N=4)

Tuber size	Cultivars	Chlorogenic acid isomer (mg/kg)	Chlorogenic acid (mg/kg)	Caffeic acid (mg/kg)	Total phenolic acid (mg/kg)
Medium	Nam	0.39±0.20	2.58±1.37^{b}	0.27±0.28	3.23±1.82^{a}
	Onaran	1.11±0.98	5.30±1.55^{c}	0.07±0.06	6.47±2.51^{b}
	Leventbey	0.31±0.14	2.26±0.81^{ab}	0.26±0.36	2.82±1.06^{a}
	Muratbey	0.05±0.01	0.66±0.05^{a}	0.03±0.01	0.74±0.05^{a}
Large	Çağlı	0.22±0.11^{a}	3.84±0.47^{a}	0.38±0.11^{b}	4.44±0.53^{a}
	Fatih	1.50±0.69^{b}	13.33±7.13^{b}	0.04±0.02^{a}	14.86±6.77^{b}
	Nahita	1.05±0.76^{ab}	15.22±4.99^{b}	0.10±0.15^{a}	16.38±5.63^{b}
	Ünlenen	0.41±0.19^{a}	1.89±0.38^{a}	0.02±0.01^{a}	2.32±0.55^{a}

All values are presented as the mean ± standard deviation (SD) of samples. Dissimilar letters show the differences between the values (α = 0.05) according to the Duncan multiple comparison test (p<0.05)

Navarre et al. (2011) reported that chlorogenic acid is the major phenolic compound in potatoes and the amount of phenolic acid in potato cultivars was between 22 and 473 mg/100 g dry weight. Im et al. (2008) reported that the amount of chlorogenic acid ranged from 0.35 to 12 mg/100 g, the amount of chlorogenic acid isomer ranged from 0.06 to 4.39 mg/100g, and the amount of caffeic acid ranged from 0.01 to 0.11 mg/100 g in five different Korean potato cultivars. Reddivari et al. (2007) reported that the amount of chlorogenic acid ranged from 138 to 548 μg/g FW, the amount of caffeic acid ranged from 33 to 42 μg/g FW, the amount of gallic acid ranged from 15 to 87 μg/gFW, and the amount of catechin ranged from 84 to 91 μg/g FW in 25 different potatoes. Blessington et al. (2010) reported that the amount of chlorogenic acid ranged from 7.9 to 13 μg/g FW in 8 different potato genotypes.

Correlation

Scatter graphs of some important correlations are shown in Figure 2. There was a high, positive correlation found between ABTS and DPPH (p<0.001). This correlation showed that the ABTS variable could be explained as a ratio of 64.9% with the DPPH variable. There was a high, positive correlation found between ABTS and chlorogenic acid (p<0.001); ABTS-chlorogenic acid correlation explained that potato antioxidant's ability to scavenge the ABTS radical is due to 57% chlorogenic acid (Fig 2). Similarly, there was a high, positive correlation found between DPPH and total phenolic acid (p<0.001). This correlation showed that the capacity of potato antioxidants to scavenge the DPPH radical through redox reaction was due to 44% total phenolic acids. DPPH showed a moderate negative correlation with a^* value (p<0.01) but a moderate positive correlation with h value (p<0.01). DPPH variable indicated a moderate positive correlation with the TPC variable (p<0.01). Also, the FRAP variable indicated a positive correlation with the ABTS variable (p<0.05). Chlorogenic acid showed a high negative correlation with a^* value (p<0.001), but a moderate positive correlation with h value (p<0.01). This means that the green colour of the potato increases when the chlorogenic acid content increases in the tuber.

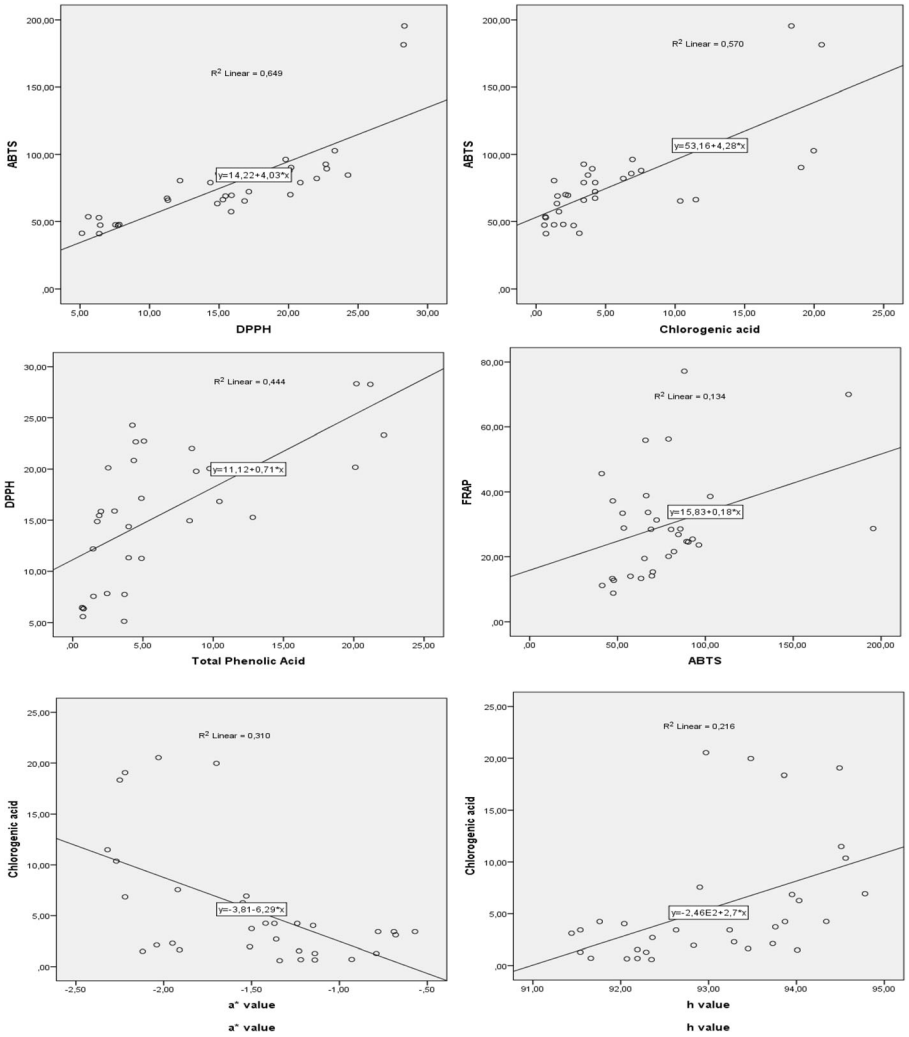

Fig. 2 Scattering graphs of correlations between ABTS-DPPH and ABTS-chlorogenic acid (top), DPPH-total phenolic acid and FRAP-ABTS (middle), and chlorogenic acid-*a** value and chlorogenic acid-*h* value (bottom). Pearson's correlation coefficients are respectively 0.806***, 0.755***, 0.667***, 0.366*, −0.557***, 0.465**. * $p<0.05$ ** $p<0.01$ *** $p<0.001$

Riciputi et al. (2018) found a very strong positive correlation between chlorogenic acid with ABTS ($r=0.888$; $p<0.001$) and DPPH ($r=0.847$; $p<0.001$). Reddivari et al. (2007) reported that total phenolics and DPPH were strongly correlated ($p<0.001$) and total phenolics and ABTS were high correlated ($p<0.001$). Navarre et al. (2011) reported that total phenolics and antioxidant capacity (ORAC) were strongly correlated ($p<0.001$). Calliope et al. (2018) reported a strong correlation between total polyphenols and total monomeric anthocyanin ($r=0.715$; $p<0.001$). Reyes et al. (2005) reported a high, positive correlation between antioxidant capacity and total phenolic content of purple and red flesh potatoes. Also, they have reported a strong correlation between the total amount of anthocyanin and total phenolics.

Conclusion

Consumers, who want to eat healthy food, are increasingly interested in functional foods. Therefore, the results of the present study are of primary interest and might help select potato cultivars that have functional and industrial effects owing to the presence of phenolic compounds. The obtained data provided new information to the literature regarding the functionality of new potato varieties. The results showed that the antioxidant capacity of the new cultivars was moderate. Probably, the peeling of potatoes reduced the phenolic acid content of the cultivars because peels have high phytochemical content. The large-sized potato cultivars with the highest total phenolic acid content were Nahita and Fatih. There was no statistical difference found between Nahita and Fatih cultivar in this category. The highest chlorogenic acid and total phenolic acid content between medium-sized cultivars were seen in the Onaran cultivar. There was a significant difference found between Onaran and other medium-sized cultivars. The highest antioxidant capacity was found in the Fatih cultivar while the highest TPC value was in the Nahita cultivar among the large potato cultivars. There was a high, positive correlation found between chlorogenic acid with DPPH and ABTS. More comprehensive studies on nutrient composition and glycoalkaloid content of new Turkish potato cultivars should be made.

Declarations

Conflict of Interest The authors declare no competing interests.

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