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ABSTRACT

The bulb onion (*Allium cepa* L.) has been cultivated for thousands of years and used as an important component of human diet. Recent studies suggest that onions can be used to cure, reduce, or prevent some of the health problems such as cancer, cardiovascular diseases, antidiabetic, asthma, antibiosis, and prebiotic effects due to its high antioxidant effect. In this study, we determined the antioxidant capacities of a wide range of onion cultivars; nine commercial cultivars and five advance selections differing in color. The variables tested include bulb size, scale color, total phenolic (TP), total antioxidant activity determined by both "Ferric reducing ability of plasma" (FRAP) and "Trolox equivalent antioxidant capacity" (TEAC). We found that yellow onion had the greatest TP content (3.7 mg GAE/g dw); and, the red group had higher TP mean than the white group (2.2 mg GAE/g dw vs. 1.1 mg GAE/g dw). For the antioxidant capacity measurements, the red group had the greatest means by both methods (15.4 μmol TE/g dw and 9.3 μmol TE/g dw for TEAC and FRAP). Yellow onions had higher TEAC (14.7 μmol TE/g dw vs. 8.7 μmol TE/g dw) and FRAP values (9.8 μmol TE/g dw vs. 5.6 μmol TE/g dw) than white onions. Among the cultivars tested great differences of TP, TEAC and FRAP was observed. The TP content of Me-Tan 88 (8.3 mg GAE/g dw) was two times higher than the yellow group. Yellow color Dayton had the greatest TEAC (20.5 μmol TE/g dw) and FRAP (12.3 μmol TE/g dw) means followed by yellow color Me-Tan 88 (19.4 and 11.4 μmol TE/g dw). The two antioxidant measurements were found to be highly correlated (0.99) where absolute values of FRAP were about 40% less than those of TEAC. The values of TEAC and FRAP were significantly correlated by TP with similar *r*s (0.74 and 0.73, respectively). TP, TEAC and FRAP were significantly and positively correlated to soluble solids (0.41, 0.43, and 0.40, respectively). Our results suggested that the red onions had higher antioxidant activities than yellow and white onions although yellow onions had the richest phenolic contents.

1. Introduction

The bulb onion (*Allium cepa* L.) has been cultivated for thousands of years and is believed to have been first domesticated in the mountainous areas of Afghanistan, Pakistan, Tajikistan, or northern Iran (Brewster, 1994). The genus *Allium* is broadly dispersed over the warm-temperate and temperate zones of the northern hemisphere where its greatest diversity exists in Turkey, Iran, Iraq, Afghanistan, Kazakhstan, and western Pakistan (Hanelt, 1990). Naturally grown *Allium* species can be found in open, sunny, dry sites in fairly arid climates, dry mountain slopes of these countries (Hanelt, 1990). The Alliums are not only one of the earliest cultivated crops, but also one of the earliest classified plants. Morphological characteristics such as bulb size, shape, color, and pungency are the first known classification criteria.

The edible Alliums are grown worldwide and have been historically maintained as open pollinated populations and are grown, traded, and consumed in most countries (Havey, 1995). The bulb onion is grown as fresh shoots for green salad onions and as bulbs for consuming uncooked, cooked, and pickled or production of seed and sets. Bulbs can differ in size, shape, color, pungency, single center, firmness, and tightness of outer dry skins and neck. Cultivated onions are of two major types, known as short-day and long-day onions. However, a third group can be expressed as an intermediate day length type that forms bulbs between the two major groups. Onions that require 14 h or more to bulb are classified as long day, whereas those that bulb as day length exceeds 11–12 h are considered short-day onions (Pike, 1986). Bulbs of various colors are preferred by consumers in different parts of the world. The average world production of the bulb onion in the last 3 years was approximately 63 million tons (FAO, 2007). Leading five countries in 2005, 2006, and 2007 average production were China 19.7 million tons, India 7.8 million tons, USA 3.4 million tons, Pakistan 2.0 million tons, and Turkey 1.9 million tons.

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Turkey is one of the countries where onion has been cultivated for thousands of years (Baytop and Mathew, 1984). Onion is a one of the earliest produced and consumed crop in Turkey and is used daily in cooking by all Turkish families year-round. It is one of the most important vegetable crops in Turkey, and is grown for green stage consumption, mature bulb used as a main vegetable dish or as a flavorful ingredient of the main meat dishes. In addition, onion and its relatives are still used in remote villages of Turkey for asthma, bolting, fertility, infections, high blood pressure, high fever, kidney stone, parasite, and hemorrhoid to cure or enhance these health problems.

Better quality, high yield, uniformity, and resistance to diseases are major breeding achievements in onion. Important bulb quality traits are bulb size, shape, color, pungency, firmness, dormancy, and amount of soluble solids. Bulb shape, size, and soluble solids show continuous phenotypic variation that suggests quantitative inheritance (McCollum, 1971). In addition, McCollum (1966, 1968, 1971) reported significant environmental effects and low heritability of bulb diameter and weight, high heritability of soluble solids (62–82%), and a negative genetic correlation between bulb size and soluble solids. Galmarini et al. (2001) identified a QTL associating with traits soluble solids, pungency, and antiplatelet activity in onion. Havey et al. (2004) evaluated a segregating family from a cross of high and low solids onion parent and reported phenotypic correlations among soluble carbohydrates, pungency and antiplatelet activity. He also emphasized health-enhancing attributes of onion. Desjardins (2008) reported that there are numerous scientific reports suggesting onions and or its relatives can be used to cure, reduce, or prevent some of the health problems such as cancer, cardiovascular diseases, antidiabetic, asthma, antibiosis, and prebiotic effects. Onions and its relatives possess sulfur containing compounds (Kubec et al., 2000), phenolic (Fossen et al., 1998), minerals with antioxidant capacity (Terry et al., 2000), and polysaccharides with significant prebiotic properties (Biedrzycka and Bielecka, 2004). Recent trends encourage breeders to use health benefits and antioxidant characteristics as a quality parameter of fruits and vegetables in plant breeding programs. Researchers were evaluated the chemical and antioxidant properties of different types of onions and found that they have high concentration of quercetin, kaempherol and luteolin (Desjardins, 2008; Lanzotti, 2006). Tepe et al. (2005) investigated methanol extracts of five different *Allium* species other than *A. cepa*. Prakash et al. (2007) compared phenolic content and antioxidant capacity of four onion scale color; green, white, red and violet, with no variety was specified. They suggested that red onions have the highest quercetin and kaempherol contents among the other onion types. Santas et al. (2008) compared the polyphenol content and antioxidant capacities of white and Calçot onions.

In our study, the objectives were similar, but our focus of sampling area, extraction method and methodology differ from previous studies. Samples in our study were collected from different scale color of new cultivars. Acetone extracted onion samples were used in this study compare to methanol (Tepe et al., 2005) and ethyl acetate extractions in the literature (Shon et al., 2004). TEAC assay used along with FRAP as suggested by Ozgen et al. (2006), compare to the scavenging activity of DPPH radical, β-carotene–linoleate system (Shon et al., 2004) and free radical scavenging activities (FRSA) (Prakash et al., 2007).

The goals of our study were to (1) quantify and report total phenolics, anthocyanins and two measures of antioxidant capacity; FRAP and TEAC in new onion selections and cultivars (2) investigate the effect of scale color on the antioxidant capacity of onions and (3) determine the magnitude of variation between selections and cultivars.

2. Materials and methods

2.1. Plant material and measurement of horticultural attributes

Nine commercial cultivars (Bereket, Dayton, Hazar, Kapıdağmoru, Karbeyazı, Me-Tan 88, Seç, Seyhan, and Victoria) and five advance selections (Tan-25-88, Delta Tan, Selection 6, 26, 33) were used as bulb materials. Advance selections and cultivars were produced in the production field of commercial seed company located in Cepni village, Bandirma, Balikesir, Turkey on similar conditions. Bulbs were harvested and cured under ambient conditions for 5 days. Bulbs from each cultivar were randomly sampled and used for the analysis. These cultivars were consisted

Table 1
Scale color, cultivars, their types, day length sensitivities and their horticultural attributes used in the study.

Scale color	Cultivar	Day length sensitivity	Bulb width (mm)	Bulb length (mm)	Total soluble solids (%)	L^*	a^*	b^*
Yellow	Bereket[c]	Long day	70.0 ± 4.8[a]	62.0 ± 6.3 cd	7.3 ± 0.8 def	66.7 ± 6.8 abc	−2.3 ± 0.4 cd	6.6 ± 1.0 bc
Yellow	Delta Tan[s]	Long day	75.8 ± 4.9	71.0 ± 5.4 ab	7.8 ± 0.9 cde	70.8 ± 3.3 ab	−2.2 ± 1.1 cd	6.1 ± 2.4 cd
Yellow	Me-Tan 88[c]	Long day	72.8 ± 5.1	62.4 ± 6.4 cd	11.4 ± 1.0 a	65.2 ± 5.8 c	−2.9 ± 0.6 d	9.7 ± 1.2 a
Yellow	Dayton[c]	Intermediate	74.4 ± 6.6	61.6 ± 10.2 cd	10.0 ± 1.1 b	66.8 ± 4.0 c	−2.4 ± 0.4 cd	7.2 ± 0.9 bc
Yellow	Seç[c]	Intermediate	73.2 ± 9.5	63.5 ± 5.7 cd	7.2 ± 1.3 ef	69.5 ± 2.1 bc	−2.3 ± 0.5 cd	6.2 ± 1.0 cd
Yellow	Selection 6[s]	Intermediate	68.1 ± 3.5	76.2 ± 5.1 a	5.8 ± 1.0 g	74.0 ± 2.7 a	−3.1 ± 0.4 d	9.0 ± 0.7 bc
Yellow	Hazar[c]	Short day	74.8 ± 6.4	64.2 ± 4.7 bc	8.3 ± 1.5 cd	69.7 ± 2.7 abc	−2.9 ± 0.7 d	7.9 ± 1.9 bc
Yellow	Seyhan[c]	Short day	69.9 ± 6.3	55.9 ± 7.4 d	6.7 ± 0.9 f	71.6 ± 3.9 ab	−3.0 ± 1.0 cd	7.8 ± 2.9 ab
Yellow	Tan-25-88[s]	Long day	65.4 ± 4.5	63.1 ± 7.0 cd	7.4 ± 0.8 def	66.9 ± 3.2 bc	−2.4 ± 0.6 cd	6.4 ± 1.4 cd
Yellow	Victoria[c]	Long day	78.4 ± 9.5	66.5 ± 6.2 bc	8.5 ± 0.6 c	69.3 ± 4.6 abc	−2.7 ± 0.9 cd	7.7 ± 1.5 bc
White	Karbeyazı[c]	Long day	72.5 ± 6.7	61.2 ± 5.0 cd	7.8 ± 0.4 cdef	69.1 ± 3.7 abc	−1.8 ± 0.3 cd	5.0 ± 0.8 de
White	Selection 33[s]	Intermediate	86.4 ± 5.0	75.7 ± 6.5 a	8.4 ± 1.1 cd	65.4 ± 7.1 bc	−1.1 ± 0.1 c	3.8 ± 0.7 e
Red	Kapıdağmoru[c]	Intermediate	78.6 ± 7.7	61.7 ± 11.3 cd	8.0 ± 0.3 cde	28.8 ± 4.5 e	35.6 ± 3.5 a	0.6 ± 3.7 f
Red	Selection 26[s]	Intermediate	79.7 ± 7.5	60.8 ± 4.1 cd	8.3 ± 0.8 cde	41.8 ± 5.7 d	31.4 ± 2.9 b	−5.9 ± 0.5 g
Scale color								
Yellow			72.3 ± 7.1 b	64.6 ± 8.2 ab	8.1 ± 1.8 a	69.0 ± 4.7 a	−2.6 ± 0.7 c	7.5 ± 1.9 a
White			79.5 ± 9.2 a	68.4 ± 9.3 a	8.1 ± 0.9 a	67.2 ± 5.8 a	−1.4 ± 0.4 b	4.4 ± 1.0 b
Red			79.2 ± 7.4 a	61.3 ± 8.2 b	8.2 ± 0.6 a	35.3 ± 8.3 b	33.5 ± 3.8 a	−2.7 ± 4.2 c
Mean			74.3 ± 8.0	64.7 ± 8.5	8.1 ± 1.6	64.0 ± 13.0	2.7 ± 12.7	5.6 ± 4.2

[*] Chromameter describes color in three coordinates: L, lightness, from 0 (black) to 100 (white); a, from −60 (green) to 60 (red); and b, from −60 (blue) to 60 (yellow).
[a] Means were separated by Duncan's Multiple Range test at 5%. Cultivar and scale color groups should be compared separately where entities not having common letters are significantly different.
[c] Commercial cultivar.
[s] Advance selection.

of three different scale colors; two white, two red-purple and ten yellow cultivars (Table 1). The onions were carried out the laboratory and measurements of horticultural attributes were completed within 48 h. Onion width and length was measured using digital caliper. Total soluble solids content (TSS) was determined with a refractometery (Atago, Model ATC-1E). Onion external color was measured using a Minolta portable chromameter (Minolta, Model CR-400) which provided CIE L^*, a^* and b^* values. Chromameter describes color in three coordinates: L^*, lightness, from 0 (black) to 100 (white); a^*, from −60 (green) to 60 (red); and b^*, from −60 (blue) to 60 (yellow). Three subsamples of 10 onions were used for measurements of horticultural attributes.

2.2. Analytical procedures and sample preparation

For each cultivar, three replicates of four bulbs were skinned, chopped and homogenized with water (1:1, w/v) in a standard food blender. The slurry was used in chemical analysis.

2.2.1. Determination of total phenolic (TP)

TP content was measured according to Singleton and Rossi (1965) procedure. Briefly, onion slurries were extracted with buffer containing acetone, water, and acetic acid (70:29.5:0.5, v/v/v) for 3 h in darkness. Samples were replicated three times. Then, extract, Folin-Ciocalteu's phenol reagent and water incubated for 8 min followed by adding 7% sodium carbonate. After 2 h, the absorbance was measured by an automated UV–vis spectrophotometer (Model T60U, PG Instruments) at 750 nm. Gallic acid was used as standard. The results were expressed as μg of gallic acid in g dry weight (GAE/g dw) basis.

2.2.2. The total antioxidant activity (TAC)

TAC was estimated by using two standard procedures FRAP and TEAC assays as suggested by Ozgen et al. (2006). Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) was used as a standard for both assays. The results were expressed as μmol trolox equivalent g dry weight (TE/g dw) basis.

2.2.2.1. The ferric reducing ability of plasma (FRAP). FRAP was determined according to the method of Benzie and Strain (1996). Assay was conducted using three aqueous stock solutions containing 0.1 mol/L acetate buffer (pH 3.6), 10 mmol/L TPTZ [2,4,6-tris(2-pyridyl)-1,3,5-triazine] acidified with concentrated hydrochloric acid, and 20 mmol/L ferric chloride. These solutions were prepared and stored in the dark under refrigeration. Stock solutions were combined (10:1:1, v/v/v) to form the FRAP reagent just prior to analysis. For each assay laboratory duplicate from each replicate, 2.90 mL of FRAP reagent and 100 μL of sample extract were mixed. After 30 min, the absorbance of the reaction mixture was determined at 593 nm in a spectrophotometer.

2.2.2.2. Trolox equivalent antioxidant capacity (TEAC). For the standard TEAC assay, ABTS (2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid) was dissolved in acetate buffer and prepared with potassium persulfate as described in Ozgen et al. (2006). The mixture was diluted in acidic medium of 20 mM sodium acetate buffer (pH 4.5) to an absorbance of 0.700 ± 0.01 at 734 nm for longer stability (Ozgen et al., 2006). For the spectrophotometric assay, 2.90 mL of the $ABTS^{\bullet+}$ solution and 100 μL of bulb extract were mixed and incubated in 10 min and the absorbance was determined at 734 nm.

2.3. Statistical analysis

Data were analyzed using SAS software and procedures (SAS, 2005). Means and standard deviations were calculated using TABULATE procedure. To construct analysis of variance (ANOVA) tables GLM procedure was used. Two sets of ANOVAs were constructed. First, one-way ANOVAs were constructed where the means of cultivars were separated by Duncan's Multiple Range Test at 5%. In the second sets the cultivars were considered as nested in scale color so that the means of these factors could be separated by Duncan's Multiple Range Test at 5%. The relationships among to bulb width, bulb length, soluble solids and scale color measurements (L^*, a^*, b^*) were investigated using correlation analysis. CORR procedure was used to conduct the analysis. Correlation coefficients, r, were considered as statistically significant when their relevant P values were below 5%.

3. Results and discussion

Horticultural attributes of bulb size, TSS, color measurements of red, white and yellow onion cultivars were presented in Table 1. Although bulb widths of the cultivars did not statistically differ, the means of bulb length were significantly different in 5% level (Table 1). The longest bulbs were measured from Selection 6, Selection 33 and Delta Tan averaging more than 70 mm. Bulb width and length significantly differed among the scale color group. Red onions had broader bulbs than yellow ones, while white onions had longer bulbs than red onions. The cultivars significantly differed for TSS content; the highest TSS was recovered from Me-Tan 88, a long day commercial cultivar. The scale color groups did not significantly differed for TSS.

As expected, the color groups were statistically significant for color measurements (L^*, a^*, b^*) for scale color groups (Table 1). For L^*, the greatest means were from yellow group (69.0) followed by white (67.2) and red (35.3) onions tested. Similar pattern was observed for b^*. The red group had the greatest means for a^* (33.5), followed by white (−1.4) and yellow (−2.6) onions. The variations among the cultivars were also found to be significant (Table 1). The L^* means varied from 28.8 (Selection 6) to 74.0 (Kapıdağmoru). The same cultivars also had the greatest (35.6 Kapıdağmoru) and the lowest (−3.1, Selection 6) a^* values. b^* ranged from −5.9 (Selection 26) to 9.7 (Me-Tan 88) among the selected cultivars.

Both the cultivars and scale color had significantly different means for TP and TAC measurements (Table 2). As a group, yellow onions had the greatest TP content (3.7 mg GAE/g dw). The red group had higher TP content than the white group (2.2 mg GAE/g dw vs. 1.1 mg GAE/g dw). For the antioxidant capacity measurements, the red group had the highest TEAC and FRAP (15.4 and 9.3 μmol TE/g dw) values. Yellow onions had greater TEAC (14.7 μmol TE/g dw vs. 8.7 μmol TE/g dw) and FRAP means than white onions (9.8 μmol TE/g dw vs. 5.6 μmol TE/g dw).

Great differences of TP, TEAC and FRAP were determined among the cultivars tested (Table 2). White scale color Selection 33 had the lowest values for TP (0.9 mg GAE/g dw), TEAC (8.8 μmol TE/g dw) and FRAP (5.3 μmol TE/g dw). The TP content of yellow color Me-Tan 88 (8.3 mg GAE/g dw) was more than 2-fold higher than the average of yellow group. Hazar and Dayton were cultivars with high TP content among the yellow onions. Although the red group had the greatest group mean for antioxidant capacity, the cultivars with the greatest TEAC and FRAP means were from yellow group. Dayton had the greatest TEAC (20.5 μmol TE/g dw) and FRAP (12.3 μmol TE/g dw) values followed by Me-Tan 88 (19.4 and 11.4 μmol TE/g dw, respectively).

Most onion cultivars are rich in vitamins, minerals, fibers, sulfur and phenolic compounds. The antioxidant effects of onions are associated with phenolic compounds. The red onions are rich in anthocyanins, while the yellow onions have high concentration of flavonols, quercetin and kaempherol (Desjardins, 2008). Nemeth and Piskula (2007) compared quercetin contents of many food and beverages and found that red onions have higher quercetin content than yellow onions. Prakash et al. (2007) compared outer, middle

Table 2
Mean and standard deviations for total phenolic content (TP) and antioxidant capacity (TEAC and FRAP) of red, white and yellow onion cultivars.

Scale color	Cultivar	TP[a] (mg GAE/g dw)	TEAC[b] (μmol TE/g dw)	FRAP[c] (μmol TE/g dw)
Yellow	Bereket[cm]	3.9 ± 0.2[d] cd	15.7 ± 0.8 b	9.1 ± 0.5 c
Yellow	Delta Tan[s]	1.5 ± 0.2 fg	13.2 ± 0.7 d	8.0 ± 0.3 d
Yellow	Me-Tan 88[cm]	8.3 ± 1.0 a	19.4 ± 0.5 a	11.4 ± 0.3 b
Yellow	Dayton[cm]	4.8 ± 0.8 b	20.5 ± 1.3 a	12.3 ± 0.4 a
Yellow	Seç[cm]	2.7 ± 0.5 e	11.6 ± 0.6 e	6.8 ± 0.4 e
Yellow	Selection 6[s]	3.3 ± 0.7 de	13.2 ± 0.9 d	8.2 ± 0.4 d
Yellow	Hazar[cm]	5.0 ± 0.6 bc	15.7 ± 0.6 b	9.1 ± 0.4 c
Yellow	Seyhan[cm]	2.3 ± 0.4 ef	14.2 ± 0.7 cd	8.2 ± 0.3 d
Yellow	Tan-25-88[s]	2.2 ± 0.6 ef	10.4 ± 0.9 e	6.1 ± 0.6 ef
Yellow	Victoria[cm]	3.2 ± 0.8 de	13.4 ± 0.7 d	7.6 ± 0.7 d
White	Karbeyazı[cm]	1.3 ± 0.3 fg	10.7 ± 0.6 e	5.9 ± 0.3 fg
White	Selection 33[s]	0.9 ± 0.4 g	8.8 ± 0.6 f	5.3 ± 0.3 g
Red	Kapıdağmoru[cm]	2.4 ± 0.5 ef	15.9 ± 0.8 b	9.5 ± 0.6 c
Red	Selection 26[s]	2.1 ± 1.0 ef	14.9 ± 0.7 bc	9.2 ± 0.2 c
Scale color				
Yellow		3.7 ± 2.0 a	14.7 ± 3.2 a	8.7 ± 1.9 b
White		1.1 ± 0.4 c	9.8 ± 1.2 b	5.6 ± 0.5 c
Red		2.2 ± 0.7 b	15.4 ± 0.9 a	9.3 ± 0.5 a
Mean		3.1 ± 1.9	14.1 ± 3.2	8.3 ± 2.0

[a] TP contents were estimated by the Folin-Ciocalteu assay of Singleton and Rossi, 1965.
[b] TEAC values were determined by the method of Ozgen et al., 2006.
[c] FRAP values were determined by the method of Benzie and Strain, 1996
[d] Means were separated by Duncan's Multiple Range test at 5%. Cultivar and scale color groups should be compared separately where entities not having common letters are significantly different.
[cm] Commercial cultivar.
[s] Advance selection.

Table 3
Correlation coefficients (*r*) for bulb size, soluble solids, color measurements and total phenolic content (TP) antioxidant capacity (TEAC and FRAP) of onion cultivars.

Variable	BL	SS	*L*[**]	*a*[**]	*b*[**]	TP[a]	TEAC[b]	FRAP[c]
Bulb width	0.37*	0.17	−0.26	0.26*	−0.32	−0.18	−0.06	−0.08
Bulb length (BL)		−0.09	0.17	−0.15	0.09	−0.29	−0.31*	−0.27
Soluble solids (SS)			−0.1	0.02	0.03	0.41*	0.43*	0.40*
L				−0.91*	0.66*	−0.02	−0.30	−0.35*
a					−0.81*	−0.20	0.15	0.19
b						0.42*	0.14	0.09
TP							0.74*	0.73*
TEAC								0.99*

* Represent significance at 5%.
[**] Chromameter describes color in three coordinates: L, lightness, from 0 (black) to 100 (white); a, from −60 (green) to 60 (red); and b, from −60 (blue) to 60 (yellow).
[a] TP contents were estimated by the Folin-Ciocalteu assay of Singleton and Rossi, 1965.
[b] TEAC values were determined by the method of Ozgen et al., 2006.
[c] FRAP values were determined by the method of Benzie and Strain, 1996.

and inner layers of red, violet, white and green onions for their specific phenolic contents. Regardless of the layers, he found that red onions had the highest quercetin and kaempherol contents. Santas et al. (2008) compared the polyphenol content and antioxidant capacities (by TEAC and FRAP) of white and Calçot onions using water and methanol, ethanol and acetone (50, 75 and 100%) extractions. Regardless of the extraction type and concentrations white onion had higher TEAC and FRAP means corresponding to higher polyphenol contents. Our results support the findings indicating favoring red onions as we also recovered the highest antioxidant activities from red scale color onion group. In most other red fruits, especially in berries anthocyanins are known to have the most potent antioxidants (Zafra-Stone et al., 2007). In the case of onions, however, it is possible to recover high antioxidant activities from cultivars of yellow or white onion groups probably due to mainly high quercetin and kaempherol contents (Desjardins, 2008; Lanzotti, 2006).

The relationships among the variable studied were investigated by correlation (Pearson) analysis at 5% and the relevant results were presented in Table 3. The color measurements were significantly correlated with each other (r = 0.66–0.91). However, color measurements were not highly correlated to TP, FRAP and TEAC. As observed in most red fruits and vegetables the intensity of color-red color is a good indication of high antioxidant capacity due to the high concentration of anthocyanins (Celik et al., 2008; Ozgen et al., 2009). In the case of onion; only scale color groups indicated the antioxidant trend. The *L*, *a*, *b* values, in other words the intensity of scale color was not directly related to antioxidant capacity within the each scale color onions. The two antioxidant measurements were found to be highly correlated (r = 0.99) where absolute values of FRAP were about 40% less than those of TEAC. The values of TEAC and FRAP were significantly correlated by TP with similar *r*s (0.74 and 0.73, respectively). All of these measurements, TP, TEAC and FRAP were significantly and positively correlated to TSS (r = 0.41, 0.43, and 0.40, respectively).

Significant correlations among the TP, TEAC and FRAP were reported for both cultivated and wild onions. For example, Santas et al. (2008) recovered r = 0.88 and r = 0.78 correlations between TEAC and FRAP to polyphenol content, respectively with two cultivated onions. Similarly, Nencini et al. (2007) reported 0.46 r between FRAP and polyphenol content determined from the evaluations of several *Allium* species (*A. neapolitanum* Cyr., *A. roseum* L., *A. subhirsutum* L., *A. sativum* L.). Therefore, our correlation values were within the ranges reported in the relevant literature.

4. Conclusion

In this study, we compared and characterized the TP content and antioxidant capacity of the onion cultivars differing in scale color and determined the strength of relationships among commonly measured variables. Our results confirmed that the red onions in general, have higher antioxidant activities than yellow and white onions although some specific yellow onions might have high antioxidant activities caused by their high total penolic contents. Therefore, our results also suggest that with rigorous selection studies it would be possible to breed onion cultivars with high antioxidant capacities in all scale color groups.

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References

Baytop, T., Mathew, B., 1984. The Bulbous Plants of Turkey. BT Batsford Ltd., London.
Benzie, I.F.F., Strain, J.J., 1996. The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. Annals of Biochemistry 239, 70–76.
Biedrzycka, E., Bielecka, M., 2004. Prebiotic effectiveness of fructans of different degrees of polymerization. Trends in Food Science and Technology 15, 170–175.
Brewster, J.L., 1994. Onions and Other Vegetable Allies. CAB International, Wallingford, UK.
Celik, H., Özgen, M., Serçe, S., Kaya, C., 2008. Phytochemical accumulation and antioxidant capacity at four maturity stages of cranberry fruit. Scientia Horticulturae 117, 345–348.
Desjardins, Y., 2008. Onion as a nutraceutical and functional food. Cronica Horticulturae 48, 8–14.
FAO, 2007. http://faostat.fao.org/site/567/default.aspx#ancor.
Fossen, T.A., Pedersen, A.T., Andersen, O.M., 1998. Flavonoids from red onion (*Allium cepa*). Phytochemistry 47, 281–285.
Galmarini, C.R., Goldman, I.L., Havey, M.J., 2001. Genetic analyses of correlated solids, flavor, and health-enhancing traits in onion (*Allium cepa* L.). Molecular Genetics and Genomics 265, 543–551.
Hanelt, P., 1990. Taxonomy, evolution, and history. In: Rabinowitch, H., Brewster, J.L. (Eds.), Onion and Allied Crops. CRC Press, Boca Raton, FL, pp. 1–26.
Havey, M.J., 1995. Onion and other cultivated alliums Allium spp. (Liliaceae). In: Smartt, J., Simmonds, N.W. (Eds.), Evolution of Crop Plants. 2nd ed. Longman Scientific and Technical, pp. 344–350.
Havey, M.J., Galmarini, G.R., Gökçe, A.F., Henson, C., 2004. QTL affecting soluble carbohydrate concentrations in stored onion bulbs and their association with flavor and health-enhancing attributes. Genome 47, 463–468.
Kubec, R., Svobodova, M., Velisek, J., 2000. Distribution of S-alk(en)lycysteine sulfoxides in some Allium species. Identification of new flavor precursor: S-ethylcyteine sulfoxide (Ethiin). Journal of Agriculture and Food Chemistry 48, 428–433.
Lanzotti, V., 2006. The analysis of onion and garlic. Journal of Chromatography A 1112 (1–2), 3–22.
McCollum, G.D., 1966. Heritability and genetic correlation of some onion bulb traits. Journal of Heredity 57, 105–110.
McCollum, G.D., 1968. Heritability and genetic correlation of soluble solids, bulb size and shape in white sweet Spanish onion. Canadian Journal of Genetics and Cytology 10, 508–514.
McCollum, G.D., 1971. Heritability of onion bulb shape and size, estimates from half-sib families. Journal of Heredity 62, 101–104.
Nemeth, K., Piskula, M.K., 2007. Food content, processing, absorption and metabolism of onion flavonoids. Critical Review in Food Science and Nutrition 47, 397–409.
Nencini, C., Cavallo, F., Capasso, A., Franchi, G.G., Giorgio, G., Micheli, L., 2007. Evalution of antioxidative properties of *Allium* species growing wild in Italy. Phytotherapy Research 21, 874–878.
Ozgen, M., Reese, R.N., Tulio, A.Z., Miller, A.R., Scheerens, J.C., 2006. Modified 2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) method to measure antioxidant capacity of selected small fruits and comparison to ferric reducing antioxidant power (FRAP) and 2,2′-diphenyl-1-picrylhydrazyl (DPPH) methods. Journal of Agriculture and Food Chemistry 54, 1151–1157.
Ozgen, M., Serce, S., Kaya, C., 2009. Phytochemical and antioxidant properties of anthocyanin-rich *Morus nigra* and *M. rubra* fruits. Scientia Horticulturae 119, 275–279.
Pike, L.M., 1986. Onion breeding. In: Bassett, M.J. (Ed.), Breeding Vegetable Crops. AVI Publishing Company, Inc., Westport, CT, pp. 357–394.
Prakash, D., Singh, B.N., Upadhyay, G., 2007. Antioxidant and free radical scavenging activities of phenols from onion (*Allium cepa*). Food Chemistry 102, 1389–1393.
Santas, J., Carbo, R., Gordon, M.H., Almajano, M.P., 2008. Comparison of the antioxidant activity of two Spanish onion varieties. Food Chemistry 107, 1210–1216.
SAS Institute, 2005. SAS Online Doc. Version 8. SAS Inst., Cary, NC.
Shon, M.Y., Choi, S.D., Kahng, G.G., Nam, S.H., Sung, N.J., 2004. Antimutagenic, antioxidant and free radical scavenging activity of ethyl acetate extracts from white, yellow and red onions. Food and Chemical Toxicology 42 (4), 659–666.
Singleton, V.L., Rossi, J.L., 1965. Colorimetry of total phenolics with phosphomolybdic–phosphotungstic acid reagents. American Journal of Enology and Viticulture 16, 144–158.
Tepe, B., Sokmen, M., Akpulat, H.A., Sokmen, A., 2005. In vitro antioxidant activities of the methanol extracts of five Allium species from Turkey. Food Chemistry 92 (1), 89–92.
Terry, N., Zayed, A.M., de Souza, M.P., Tarun, A.S., 2000. Selenium in higher plants. Annual Review of Plant Physiology and Plant Molecular Biology 51, 401–432.
Zafra-Stone, S., Yasmin, T., Bagchi, M., Chatterjee, A., Vinson, J.A., Bagchi, D., 2007. Berry anthocyanins as novel antioxidants in human health and disease prevention. Molecular Nutrition & Food Research 51, 675–683.