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ORIGINAL ARTICLE

Morphological and Biochemical Diversity in Fruits of *Arbutus unedo* L. from East Aegean Region in Turkey

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Abstract

Proper characterization of genotypes and cultivars of different fruit species are of great importance for breeding point. Thus, both morphological and biochemical markers are routinely used to describe cultivars and genotypes. In this study, the morphological (fruit weight, fruit number per cluster, color), biochemical (total phenolics, total dietary fibre, total fat, vitamin C, sugars and organic acids) and antioxidant capacity existing in 15 promising strawberry tree (*Arbutus unedo*) genotypes selected from Mugla province in Turkey has been investigated. It turns out that a great difference in the values indicating morphological and biochemical characteristics exists among strawberry tree genotypes. Fruit weight comes out as between 4.67 and 7.88 g. The number of fruit per cluster is identified as between 3.77 and 8.60. Fructose is determined as the dominant sugar and malic acid as the major organic acid for all genotypes. Vitamin C and total dietary fibre content range from 46 to 62 mg/100 g and 9.74 to 13.28 g/100 g fresh fruits, respectively.

Keywords Strawberry tree · Vitamin C · Phenolics · Dietary Fibre Content · Diversity · Morphology

Morphologische und biochemische Vielfalt bei Früchten von *Arbutus unedo* L. aus dem ostägäischen Gebiet der Türkei

Schlüsselwörter Erdbeerbaum · Vitamin C · Phenolsäuren · Ballaststoffgehalt · Vielfalt · Morphologie

Introduction

Turkey is located in the eastern Mediterranean and is seen as a bridge between Europe and Asia. The landscape of the country possesses natural food resources including wild edible fruits due to its vast geographical diversity in terms of topography and climate. In particular, the country consists of three different bio-geographic regions, each with its own endemic wild edible fruit species and natural ecosystems (Ercisli et al. 2008a, 2008b; Sengul et al. 2011).

Among the wild edible fruits, the strawberry trees, due to their commercial and nutrient values, are of great significance for rural community. Strawberry tree called Arbutus species (*Arbutus unedo* and *Arbutus andrachne*) grows naturally in the forests consisting of red pine, oak, wild olive, myrtle trees and shrubs in the Mediterranean, Aegean, Marmara and Black Sea regions of Turkey (Serce et al. 2010).

Compared to *Arbutus andrachne, Arbutus unedo,* with its evergreen shrub structure bearing orange colored fruit in autumn, is more attractive and more promising due to its better fruit characteristics. Typically seen as a fruit species native to Mediterranean countries such as Algeria, Morocco, Tunisia, Turkey, Syria, Greece, Croatia, France, Portugal and Spain, *Arbutus unedo* is not only used for domestic consumption but also for medicinal purposes (Ruiz-Rodriguez et al. 2011).

Morphological and biochemical markers have been widely used in breeding studies and in the investigations into diversity of species and the relationship between genotypes, cultivars, cultivated species and their wild parents. Conventional plant breeding depends on morphological (phenotypic) selection in the first step (Ercisli et al. 2012). More recently, biochemical content, in particular, bioactive content (phytochemicals) of fruits has been widely searched in different laboratories in terms of their human health benefits. The breeders are now searching to find

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genotypes that have higher bioactive content in order to use them in cross breeding activities for the purpose of obtaining new cultivars that possess high nutrient value for health (Vidrih et al. 2013).

Therefore, understanding the chemical composition of foods by focusing particularly on the phytochemical fingerprinting has become central to research in order to address the increasing demand for nutraceuticals in foods. Directly involved in process of growth, maturation, and senescence, organic acids are of great significance in fruits as intermediates in the metabolic processes of the fruit. (Poyrazoglu et al. 2002). Sugars are very important parameters for market quality of fruits not only because consumers would like to buy more sweety fruits but also because sucrose and fructose have beneficial effects on gastrointestinal health (Canan et al. 2016).

In this study, some morphological and biochemical characteristics were identified for the 15 genotypes belonging to wild strawberry tree (*Arbutus unedo*).

Material and Methods

Plant Material

A total of 15 strawberry tree genotypes were used and fruits were harvested in June 2016 and 2017 from wild grown *Arbutus unedo* plants grown naturally in the forests of Mugla province in Aegean region of Turkey when they reached full maturity stage. The fruit samples were placed into sample containers and transported to laboratory for analysis. The fruit samples were collected randomly from all parts of the branches of the tree and they were stored at –20 C° until the analysis.

Pomological Characteristics

A total of 30 fruits were sampled for traits such as fruit weight (g) and color. The fruit color was measured using a portable Minolta Chroma Meter (Minolta, Model CR-400), which provided CIE L^*, a^* and b^* values (McGuire 1992).

Extraction and Identification of Organic Acids

For organic acid analysis, the method by Bevilacqua and Califano (1989) was used.

Identification of Total Antioxidant Activity

In order to determine antioxidant capacity, TEAC assay was used. ABTS was dissolved in acetate buffer and prepared with potassium persulfate, as described by Rice-Evans et al. (1995).

Extraction and Identification of Ascorbic Acid (Vitamin C)

Ascorbic acid content was determined following the modified HPLC (isocratic program) (Agilent 1100 series HPLC G 1322 A, Germany) analytical procedure outlined by Cemeroglu (2007).

Total Phenol Identification

The total phenolic content of strawberry tree fruits was determined spectrophotometrically at 765 nm following the Folin-Ciocalteu method as described by Singleton et al. (1999). A standard calibration curve was plotted using gallic acid (Merck, Germany) in the concentration range of 1–500 mg/L. The results were expressed as milligrams of gallic acid equivalents per 100 g of fruit.

Total Dietary Fibre Identification

Dietary fibres were determined according to the method of AOAC (1999).

Total Fat Identification

Total fat were determined according to the method of AOAC (1999).

Statistical Analysis

All data were analyzed using SPSS software and procedures. Analysis of variance tables were constructed using the Least Significant Difference (LSD) method at $p < 0.05$.

Results and Discussion

There were no statistical differences between years, so the data were pooled. Table 1 shows fruit weights, the number of fruit per cluster and color values of genotypes. There were statistically significant differences ($p < 0.05$) among genotypes for all pomological parameters (Table 1). Fruit weight came out as between 4.67 and 7.88 g and the number of fruits per cluster as between 3.77 and 8.60 (Table 1). *L, a* and *b* color indices ranged from 39.10 to 48.72, 31.02 to 45.22 and 19.81 to 30.68, respectively (Table 1). Islam and Pehlivan (2016) studied on 40 *Arbutus unedo* genotypes from Marmara region in Turkey and they reported average fruit weight, the number of fruit per cluster and *L, a* and *b* values of 40 genotypes as 5.00 g, 5.21, 47.26, 37.07 and

Table 1 Some pomological characteristics of *Arbutus unedo* genotypes (Average of 2016–2017 years)

Genotypes	Fruit weight (g)	The number of fruit per cluster	*L*	*a*	*b*
M-1	6.22bc	5.31de	45.27ab	35.98bc	24.40b
M-2	7.88a	3.77f	40.36ab	34.41 cd	22.67bc
M-3	5.27 cd	6.63c	47.41ab	37.64bc	22.11bc
M-4	7.05ab	4.44ef	39.80ab	34.17 cd	25.30ab
M-5	6.03bc	5.07de	42.64ab	36.04bc	19.81c
M-6	5.47 cd	6.07 cd	39.10b	36.67bc	20.07bc
M-7	5.61c	6.41 cd	47.30ab	31.02d	20.33bc
M-8	4.67d	8.60a	43.87ab	37.21bc	21.08bc
M-9	4.91 cd	7.85ab	43.40ab	40.14b	23.65bc
M-10	5.39 cd	6.26 cd	40.95ab	45.22a	25.45ab
M-11	6.47bc	5.01de	44.66ab	36.76bc	30.68a
M-12	5.72c	7.64b	48.02ab	35.05c	20.68bc
M-13	5.89c	7.24bc	48.72a	43.67ab	27.43ab
M-14	6.77b	5.70d	46.21ab	36.11bc	25.89ab
M-15	7.21ab	4.62e	46.81ab	42.94ab	28.62ab

NS Non significant
* There were significant ($P < 0.05$) differences among the different letters in the same lines

26.89, respectively. Karadeniz et al. (1996) reported fruit weight as between 3.38 and 9.74 g in *Arbutus unedo* genotypes grown in Black sea region. The differences could be due to genotypes and environmental factors.

Five organic acids were determined for all *Arbutus unedo* fruits and malic acid was dominant acid (0.94–2.76%) followed by citric acid (0.31–0.76%). The rate of Oxalic acid was identified as between 0.13 and 0.30%, Succinic acid as between 0.15 and 0.38% and Fumaric acid as between 0.11 and 0.34% (Table 2). There were statistically significant differences ($p < 0.05$) among organic acids except oxalic and succinic acid (Table 2). Malic and citric acid has been reported as the main organic acid in *Arbutus* (Vidrih et al. 2013) and this compound occurs naturally in all fruits and in many vegetables; it contributes to the pleasantly sour taste of fruits, and it is used as a food additive.

The genotypes significantly differed from each other in terms of fructose and glucose content but there was no difference in sucrose level ($p < 0.05$) (Table 3). Fructose turned out to be main sugar for all *Arbutus unedo* genotypes indicating the range of 7.21 g/100 g FW and 10.68 g/100 g FW and glucose level was determined as 4.07 g/100 g FW and 6.81 g/100 g FW and sucrose level as 0.41 g/100 g and 1.37 g/100 g (Table 3). Ruiz-Rodríguez et al. (2011)

Table 2 Organic acid content of *Arbutus unedo* genotypes (Average of 2016–2017 years) (g/100 g FW)

Genotypes	Malic acid	Citric acid	Oxalic acid	Succinic acid	Fumaric acid
M-1	2.07ab	0.48bc	0.25^{NS}	0.27^{NS}	0.30ab
M-2	2.76a	0.55b	0.30	0.38	0.24ab
M-3	1.11bc	0.31c	0.22	0.30	0.15ab
M-4	1.93ab	0.37bc	0.25	0.35	0.19ab
M-5	0.94c	0.40bc	0.24	0.19	0.20ab
M-6	2.14ab	0.66ab	0.15	0.33	0.11b
M-7	1.61bc	0.40bc	0.13	0.36	0.17ab
M-8	1.83b	0.55b	0.19	0.15	0.27ab
M-9	1.78bc	0.59ab	0.27	0.25	0.12b
M-10	1.45bc	0.60ab	0.25	0.22	0.19ab
M-11	2.23ab	0.64ab	0.24	0.20	0.33a
M-12	1.44bc	0.44bc	0.20	0.30	0.26ab
M-13	1.22bc	0.71ab	0.17	0.24	0.34a
M-14	0.97c	0.41bc	0.20	0.29	0.31ab
M-15	2.32ab	0.76a	0.19	0.27	0.25ab

NS Non significant, *FW* Fresh weight
* There were significant ($P < 0.05$) differences among the different letters in the same lines

Table 3 Sugar content of *Arbutus unedo* genotypes (Average of 2016–2017 years) (g/100 g FW)

Genotypes	Fructose	Glucose	Sucrose
M-1	7.67 cd	4.76ab	1.11^{NS}
M-2	9.51b	5.27ab	0.75
M-3	8.11 cd	4.55ab	1.18
M-4	10.07ab	6.44ab	1.37
M-5	9.07bc	5.54ab	0.70
M-6	7.21d	4.07b	0.86
M-7	8.03 cd	5.67ab	0.91
M-8	7.87 cd	5.11ab	0.56
M-9	8.44c	4.43ab	1.31
M-10	9.60ab	5.22ab	1.05
M-11	9.87ab	5.78ab	0.41
M-12	9.58ab	4.61ab	1.25
M-13	9.11bc	6.81a	0.67
M-14	10.68a	6.11ab	0.61
M-15	8.87bc	5.54ab	1.20

NS Non significant, *FW* Fresh weight
* There were significant ($P < 0.05$) differences among the different letters in the same lines

reported fructose level as 12.34 g/100 g, glucose level as 6.50 g/100 g and sucrose level as 0.34 g/100 g in *Arbutus unedo* fruits. Contents of fructose, glucose and sucrose in our study are in accordance with the results of Ruiz-Rodríguez et al. (2011).

There were statistically significant differences ($p < 0.05$) among the examined strawberry tree genotypes in terms of total phenolic content, total dietary fibre, vitamin C and total antioxidant capacities (Table 4). Total phenolic content, total dietary fibre, vitamin C and total antioxidant capacity were between 483 and 627 mg GAE/100 g FW, 9.74 and 13.28 g/100 g FW, 46 and 62 mg/100 g FW and 18.07 and 33.41 µmol TE/g FW, respectively. There were no statistical differences among genotypes for total fat content (Table 4). Vidrih et al. (2013) reported average 590 mg total phenols in 100 g strawberry tree fruits; however, Ruiz-Rodríguez et al. (2011) determined total phenol levels ranging from 951 to 1973 mg/100 g FW, which is more than those of our study. Vitamin C is quite variable in *Arbutus unedo* fruits. The average vitamin C levels in our results were higher than those of Spanish strawberry tree fruits given as 6.03 mg per 100 g (Pallauf et al. 2008), but lower than those of Turkish strawberry tree fruits, which ranged from 98.0 to 280.0 mg 100 g (Celikel et al. 2008). Ruiz-Rodríguez et al. (2011) and Pallauf et al. (2008) reported that *Arbutus unedo* fruits were rich in antioxidant capacity. Antioxidant capacity of strawberry trees ranged from 18.07 to 33.41 µmol TE/g FW indicating a great diversity which increases its vitality of antioxidant rich genotypes for future strawberry tree breeding.

Conclusion

The results point out that using wild grown strawberry trees for human nutrition as a good substitute for other edible fruit species may increase quality of human diet thereby improving natural vitamin intake without any side effect. Some genotypes investigated in this study displayed high antioxidant activity thanks to their total polyphenol con-

Table 4 Total phenolic, total dietary fibre, total fat, antioxidant capacity and vitamin C content of *Arbutus unedo* genotypes (Average of 2016–2017 years)

Genotypes	Total Phenolic Content (mg GAE per 100 g FW)	Total Dietary Fibre (g/100 g FW)	Total Fat (g/100 g FW)	Antioxidant Capacity (µmol TE/g FW)	Vitamin C (mg/100 g FW)
M-1	503bc	11.15c	0.57^{NS}	25.14c	46c
M-2	496bc	11.04 cd	0.51	23.07 cd	52bc
M-3	571ab	9.96de	0.35	20.60 cd	50bc
M-4	577ab	12.42ab	0.47	28.76bc	48bc
M-5	523bc	11.76bc	0.40	19.04 cd	46c
M-6	487bc	9.74e	0.38	19.74 cd	52bc
M-7	483c	10.94 cd	0.44	18.07d	60ab
M-8	541bc	10.21d	0.37	28.48bc	54b
M-9	611ab	10.66 cd	0.40	31.83ab	57ab
M-10	556b	12.30b	0.44	29.14b	52bc
M-11	588ab	11.89bc	0.55	30.89ab	48bc
M-12	627a	13.28a	0.45	33.41a	62a
M-13	614ab	10.49 cd	0.53	32.67ab	56ab
M-14	580ab	12.16bc	0.50	30.37ab	49bc
M-15	603ab	10.07de	0.44	31.40ab	58ab

NS Non significant, *FW* Fresh weight
* There were significant ($P < 0.05$) differences among the different letters in the same lines

tent. The values found in this study may be helpful for nutritionists as well as berry growers and breeders who can promote the cultivation of species and new cultivars with higher phenolic content and antioxidant activity.

Conflict of interest A.M. Colak declares that he/she has no competing interests.

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