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Original scientific paper

SOME PHYSICOCHEMICAL CHARACTERISTICS OF BLACK AND WHITE MULBERRY GENOTYPES FROM BOSNIA AND HERZEGOVINA

Azra SKENDER[1], Mirsad KURTOVIĆ[2], Sezai ERCISLI[3], Dinko BEĆIRSPAHIĆ[1]

[1]Biotechnical Faculty of University Bihać, Bihać, Bosnia and Herzegovina
[2] Faculty of Agricultural and Food Sciences of University Sarajevo, Sarajevo, Bosnia and Herzegovina
[3]Department of Horticulture, Faculty of Agriculture, Ataturk University, Erzurum, Turkey

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Recently, interest in fruit consumption and the practice of healthy eating is growing. Therefore, the focus of this research is to determine some physicochemical properties of mulberry fruits from the area of northwest Bosnia, where significant amount genetic resources of mulberries are available. In total, six genotypes of black and eight genotypes of white mulberries were analyzed. From physical properties, the fruit mass, fruit height, fruit width and length were determined. Black mulberries are found richer than white mulberries for most of the searched parameters. The average water, soluble solids, total acidity, total sugar, ash, vitamin C, total phenol and total anthocyanin of black mulberry genotypes were 86.46%, 14.88%, 0.08%, 7.30%, 0.68%, 45.84 mg/100 g FW (fresh weight), 50.67 mg GAE/100 g FW and 562.42 cyanidin-3-glucoside mg/g. These values were 82.49%, 17.51%, 0.09%, 7.34%, 0.78%, 43.79 mg/100 g FW and 29.49 mg GAE/100 g FW for white mulberries. The obtained results can serve for future steps in the breeding of these species, and because of the high quality fruit characteristics, they

Corresponding author: Azra Skender, PhD. Biotecnical faculty, University of Bihać, Luke Marjanovića bb, 77 000 Bihać, Bosna i Hercegovina. Telephone number: ++ 387 37 228 059; Fax number: ++ 387 37 228 059; e-mail: skender.azra71@gmail.com

can affect the conservation of these species due to the increasing genetic erosion of this species.

Keywords: *Morus nigra*, *Morus alba*, physical and chemical characteristics, mulberry

INTRODUCTION

Horticultural plants are very diverse group and they are nutritious, tasty, and healthy for humans (OZTURK *et al*., 2009; HALASZ *et al*., 2010; ALIBABIĆ *et al*., 2018; GULIYEV *et al*., 2018; GUNDUZ and OZBAY, 2018). Among the horticultural fruits, consumers prefer berries, like strawberry, raspberry, mulberry etc. for their delicious taste and higher nutritional content.

The mulberry (*Morus* sp.) is a deciduous tree of the *Moraceae* family. There are 24 species of *Morus* and one subspecies, with least 100 known varieties. It originates from Asia and through the centuries, numerous species have been created, and many species and subspecies of the genus *Morus* are available on the market today.

Mulberry is a multipurpose tree, which can be utilized for catering diversified needs suc h as food, fodder, fuel and fibre. The mulberry is a tree that is grown mainly in Asian countries due to a leaf that feeds the silkworm (*Bombyx mori*). The mulberry leaf is the only natural food for the silkworm, and it is also one of the main components of the silk industry. China and India, as the largest silk producers, have developed various types of mulberries that are adaptable to different agro-climatic conditions (DATTA 2000; PAN 2000, 2003). Most of them are belongs to *M. alba, M. atropurpurea, M. bombycis, M. indica, M. latifolia* and *M. multicalius*. SSR markers are important for distinguishing different genetic lineages and characterize an extensive and largely gene pool available to mulberry cultivars. Molecular results also evidenced the dissemination of the cultivated mulberry species from China around the world, the introduction in South Korea and Japan in the first dissemination step and the later wide dissemination of modern mulberry to the Mediterranean area and later to South America and the Caribe area (GARCIA-GOMEZ *et al*., 2019).

The coloured mulberry fruit is a good source of phenolic compounds, including anthocyanins, flavonoids and carotenoids (GERASOPOULOS and STAVROULAKIS, 1997; ERCISLI and ORHAN, 2007; OZGEN *et. al*., 2009; MIKULIC-PETKOVSEK *et al*., 2012; SKENDER *et al*., 2015; OKATAN, 2018). Mulberry fruits are rich in phenols and have a unique sour and refreshing taste (IMRAN *et al*., 2010; KUTLU *et al*., 2011; GECER *et al*., 2016). As well as being edible fresh, the mulberry is suitable for making juices and syrups, jams, marmalades and jellies, but also brandy. The fruits of the mulberry can also be dried. The medicinal parts of the mulberry are the fruit and leaf containing C vitamins (2-3 milligrams per gram), carotene, vitamin B1, vitamin D, numerous minerals, tannins and proteins. Black mulberry in nature is very valuable for medicine and chemistry, gaining importance in the prevention and treatment of diseases (OKATAN, 2018).

In Bosnia and Herzegovina there is no progress in the cultivation of this fruiting species, although its existence is evident in the region of continental (Bosnia) as well as warmer, Mediterranean and sub Mediterranean climate (Herzegovina). In this area there are various genotypes of black and white mulberries. More recently more attention has been paid to healthy eating habits, and interest in consuming of this fruit is growing because of its high nutritional value. However, in spite of the high-value nutritive components in the fruit, this species is still an insufficiently explored resource in our area. Furthermore, to promote the value addition of mulberry, it is imperative to characterize the fruit traits from a biochemical point of view as well so as to enable them to fit into current processing industry requirements i.e. superior qualitative and sensorial properties combined with higher contents of health-promoting bioactive compounds

Therefore, the aim of this study is to examine the physicochemical properties of mulberry fruits from the northwestern Bosnia region.

MATERIALS AND METHODS

Plant material

As a material, 14 genotypes of mulberries which sprouted by themselves (6 black and 8 white) were used in the area of the municipality of Bužim (Table 1). These genotypes 15 – 33 years old originated from seeds. The municipality of Bužim is located in the northwestern part of Bosnia. The practical part of the field investigation and sample collection was realized in two-vegetation season (2014 and 2015), and the results were presented as the average of two years. In 2014, the annual rainfall in the investigated area was high and amounted to 1934.3 mm, while for 2015 the amount of rainfall was 1377.7 mm. The average annual temperature of air in the investigated area for 2014 was 12.27 °C, while for 2015 the temperature was somewhat lower and amounted to 12.2 °C. The analyzed white mulberry genotypes are labeled as "Ma1", "Ma2", "Ma3", "Ma4", "Ma5", "Ma6", "Ma7" and "Ma8". Black mulberry genotypes are labeled as "Mn1", "Mn2", "Mn3", "Mn4", "Mn5", and "Mn6". The fruits of the mulberries were harvested at a full maturity stage, then delivered to the laboratory of the Biotechnical Faculty in Bihać, where the analyzes were performed. Of each genotype examined, a sample of 30 fruits was analyzed. Care was taken to avoid unripe, damaged, or over-ripe fruits.

Table 1. Genotypes of black and white mulberry, age, coordinates and elevations

Species	Genotypes	Age (years)	East coordinates	North coordinates	Altitude
Morus nigra	"Mn1"	25	16 01 09	45 03 23	325
	"Mn2"	30	16 02 41	45 04 11	256
	„Mn3"	20	16 00 51	45 05 32	228
	„Mn4"	26	16 01 33	45 03 43	239
	"Mn5"	28	16 01 06	45 05 24	209
	"Mn6"	30	16 02 26	45 02 26	318
Morus alba	„Ma1"	33	16 01 14	45 03 27	310
	"Ma2"	25	16 02 23	45 04 07	221
	„Ma3"	20	16 02 37	45 04 10	252
	„Ma4"	20	16 01 31	45 05 26	207
	„Ma5"	15	16 02 58	45 02 36	298
	„Ma6"	17	16 03 17	45 02 37	350
	„Ma7"	22	16 03 32	45 01 54	269
	"Ma8"	25	16 03 43	45 01 47	260

Pomological evaluation

The morphological characteristics of the fruit were mass, width, height and length of the stalk that were determined according to the methodology described by MILIVOJEVIĆ *et al.* (2009) and KUCELOVA *et al.* (2016). The following properties were measured by morphological analysis: a) fruit mass in g, n = 30, was detected with analytical scales (Kern ADB-A01S05, Germany); b) fruit width in mm, n= 30, measurement was done in the middle part of the fruits and was measured with digital caliper with sensitivity of 0.05 mm (HOEGERT, Germany); c) fruit height in mm, n = 30 measurement was performed from the base to the apical part of the fruits and was measured with digital caliper with sensitivity of 0.05 mm (HOEGERT, Germany); d) length of the stalk in mm, n = 30, measured with digital caliper with sensitivity of 0.05 mm (HOEGERT, Germany).

Biochemical evaluation

The water content was analyzed by drying with the addition of quartz sand. By this method, water is determined indirectly by measuring the residue that is lagging behind after drying. The addition of sand increases the surface of the sample and accelerates evaporation. It dries at 105 ° C, to constant mass and measure. Determination of the dry matter (solubile solid) content was done using a refractometer (Carl Zeiss refractometer, Model II). Titratable total acidity was measured potentiometrically by titrating the sample with 0.1 NaOH until the pH reached 8.01, and was expressed as % citric acid equivalent.

Total sugar determined using the standard procedures according to Luff-Schoorl described by VRAČAR (2001). Using a pipette, take 25 ml of Luff-Schoorl reagent and transfer to a 300 ml Erlenmeyer flask; add exactly 25 ml of the clarified sugar solution. Add 2 granules of pumice stone, heat, stirring by hand, over a free flame of medium height and bring the liquid to the boil in approximately two minutes. Place the Erlenmeyer immediately on an asbestos-coated wire gauze with a hole approximately 6 cm in diameter under which a flame has been lit. The flame shall be regulated in such a way that only the base of the Erlenmeyer is heated. Fit a reflux condenser to the Erlenmeyer flask, boil for exactly ten minutes. Cool immediately in cold water and after approximately five minutes titrate as follows: Add 10 ml of potassium iodide solution and immediately afterwards, add 25 ml of sulphuric acid 6 N. Titrate with sodium thiosulphate solution 0·1 N until a dull yellow color appears, add the starch indicator and complete titration. Carry out the same titration on an accurately measured mixture of 25 ml of Luff-Schoorl reagent and 25 ml of water, after adding 10 ml of potassium iodide solution and 25 ml of sulphuric acid 6 N without boiling. The result was expressed as a percentage of the sample. For chemical parameters, three repetitions were performed.

The ash content was determined by incineration at 600 ºC until white powder was obtained (Analog Selector). Five g of dried fruit was measured, lighted directly and burned at 600 °C until white ash is obtained.

Vitamin C was determined by iodometric method described by HELMENSTINE (2007). In a volumetric flask, over 5 g of mulberry puree was added solution of hydrochloric acid 2% up to a final volume of 100 mL. After 15 minutes of extraction, the mixture was filtered and 5 mL filtrate was put in an Erlenmeyer flask of 100 mL, followed by adding 5 mL of distilled water, 3 mL solution of potassium iodide 1% and 2 mL of starch 1%. The obtained sample was titrated with a solution of potassium iodate 0.0017 M, freshly prepared. The content of vitamin C, expressed in mg 100 g-1 FW, was determined based on the volume of potassium iodate used for the titration, according to the mass of tomato from each sample.

The total phenolic contents of mulberry species were determined using the Folin-Ciocalteu reagent method adapted according to DEWANTO *et al*. (2002). The reaction mixture contained 200 µL of sample extracts, 800 µL of freshly prepared diluted Folin-Ciocalteu reagent and 2 mL of 7.5% sodium carbonate. The final mixture was makeup to 7 mL with deionized water. Mixtures were kept in dark at ambient temperature for 2 h to complete the reaction. The absorbance at 765 nm was measured on a Perkin Elmer lambda 35, UV/VIS Spectrophotometer, with 1 cm cell. Gallic acid was used as a standard, the amount of phenolic compounds was calculated from a calibration graph y = 0.0035 ppm + 0.0248 (R2 =0.996) and the results were expressed as gallic acid equivalents (GAE) in mg per 100 g fresh weight (mg GAE/100 g FW). The reaction was conducted in triplicate and results were averaged.

The total anthocyanin content was determined according to the pH-differential method as described GIUSTI and WROLSTAD (2001). Total anthocyanin of extract was expressed as milligrams of cyanidin-3-glucoside (C3G) equivalent per 100 g of sample. Samples of each extraction were analyzed in triplicate.

Statistical analysis

Finally, a statistical analysis of all results was conducted. Analysis of the examined properties for each group was done separately by analysis of variance (ANOVA). The significance of the difference between the treatments was determined by the Tukey-test at the significance level of 0.05. The analysis of the main components (PCA) (HOTELLING, 1936) was carried out on the basis of a correlation matrix in which the physical-chemical properties of all investigated dental genotypes were included. In the graphic presentation of the analysis of the main components, the dispersion of combinations of the modalities of the experimental factors based on the first two main components is shown. The obtained data were processed using the computer statistical program Past (HAMMER *et al*., 2001).

RESULTS AND DISCUSSION

Pomological evaluation of black and white mulberry genotypes

The analyzed pomological characteristics of the fruits of the tested genotypes of the mulberries, which sprouted on their own are shown in Table 2. The analysis of variance determined the significant influence of genotype as a factor of variability on all investigated physical properties of black and white mulberries. From the results (Table 2), it is visible that the highest mass of the black mulberry fruits had obtained from “Mn5” genotype (2.51 g) and the smallest was obtained from “Mn1” genotype (1.09 g). The results of the fruit mass can be compared with the results of previous studies. From the literature references, it can be seen that the mass of the black mulberry is in the range of 0.62 g to 6.78 g (ERCISLI *et al.*, 2007; ERCISLI and ORHAN, 2008; HOLECYOVA *et al.*, 2009; SINGHAL *et al.*, 2010; YILMAZ *et al*., 2012; PREDOJEVIĆ *et al.*, 2012; GECER *et al.*, 2016; ALJANE and SDIRI, 2016). From previous studies, the mass of white mulberry fruits ranges from 0.66 g to 3.49 g (ERCISLI *et al.*, 2007; YILMAZ *et al*., 2012; PREDOJEVIĆ *et al.*, 2012; GECER *et al.*, 2016; ALJANE and SDIRI, 2016). The dimensions of the fruit (length and width) of the white mulberry genotype Ma1, and in the black mulberry, the genotype “Mn5” stands out in all morphological parameters. Generally, the black mulberry genotypes in this study have higher values of morphometric fruit properties compared to the genotypes of the white mulberry. The length of the fruit stalk varied from 0.18 cm in the black mulberry to 0.37 cm in the white mulberry.

Biochemical evaluation of black and white mulberry genotypes

The analyzed biochemical characteristics of the fruits of the examined genotypes are shown in Table 3. The results of the variance analysis for black mulberry (Table 3) showed that the genotype as a factor of variability had a statistically significant effect on the dry matter, acids, sugars, vitamins C, total phenol and content of anthocyanin, while a statistically significant influence was not determined for water and ash content. Similar results were obtained in white mulberry analysis where the genotype factor had a statistically significant influence on the content of water, dry matter, acids, sugar, vitamin C and total phenol content, while there was no significant effect on ash content in the examined fruits.

Table 2. Pomological characteristics of black and white mulberry genotypes

Species	Genotypes	Fruit length (cm)	Fruit width (cm)	Stem length (cm)	Fruit weight (g)
Morus nigra	"Mn1"	$1{,}20 \pm 0{,}30^{a}$	$0{,}49 \pm 0{,}09^{a}$	$0{,}21 \pm 0{,}13^{a}$	$1{,}09 \pm 0{,}35^{a}$
	"Mn2"	$1{,}58 \pm 0{,}18^{c}$	$0{,}69 \pm 0{,}09^{b}$	$0{,}18 \pm 0{,}10^{a}$	$2{,}23 \pm 0{,}53^{d}$
	„Mn3"	$1{,}32 \pm 0{,}15^{ab}$	$0{,}67 \pm 0{,}08^{b}$	$0{,}25 \pm 0{,}09^{ab}$	$1{,}80 \pm 0{,}54^{bc}$
	„Mn4"	$1{,}32 \pm 0{,}21^{ab}$	$0{,}68 \pm 0{,}11^{b}$	$0{,}26 \pm 0{,}10^{ab}$	$1{,}61 \pm 0{,}69^{b}$
	"Mn5"	$1{,}93 \pm 0{,}27^{d}$	$0{,}80 \pm 0{,}12^{c}$	$0{,}33 \pm 0{,}15^{b}$	$2{,}51 \pm 0{,}54^{d}$
	"Mn6"	$1{,}43 \pm 0{,}16^{bc}$	$0{,}74 \pm 0{,}10^{bc}$	$0{,}30 \pm 0{,}08^{b}$	$2{,}14 \pm 0{,}55^{cd}$
Average		1,46	0,68	0,26	1,90
Morus alba	„Ma1"	$1{,}52 \pm 0{,}21^{c}$	$0{,}71 \pm 0{,}09^{c}$	$0{,}20 \pm 0{,}13^{a}$	$1{,}72 \pm 0{,}61^{b}$
	"Ma2"	$1{,}25 \pm 0{,}23^{a}$	$0{,}55 \pm 0{,}07^{a}$	$0{,}24 \pm 0{,}10^{ab}$	$1{,}29 \pm 0{,}49^{a}$
	„Ma3"	$1{,}51 \pm 0{,}34^{c}$	$0{,}65 \pm 0{,}08^{bc}$	$0{,}37 \pm 0{,}15^{c}$	$1{,}72 \pm 0{,}44^{b}$
	„Ma4"	$1{,}48 \pm 0{,}15^{bc}$	$0{,}60 \pm 0{,}07^{ab}$	$0{,}33 \pm 0{,}15^{bc}$	$2{,}24 \pm 0{,}42^{c}$
	„Ma5"	$1{,}38 \pm 0{,}27^{abc}$	$0{,}61 \pm 0{,}12^{ab}$	$0{,}32 \pm 0{,}14^{bc}$	$1{,}35 \pm 0{,}52^{ab}$
	„Ma6"	$1{,}32 \pm 0{,}17^{ab}$	$0{,}58 \pm 0{,}09^{ab}$	$0{,}30 \pm 0{,}13^{abc}$	$1{,}25 \pm 0{,}43^{a}$
	„Ma7"	$1{,}44 \pm 0{,}14^{bc}$	$0{,}59 \pm 0{,}08^{ab}$	$0{,}23 \pm 0{,}11^{ab}$	$1{,}54 \pm 0{,}43^{ab}$
	"Ma8"	$1{,}26 \pm 0{,}10^{a}$	$0{,}57 \pm 0{,}08^{a}$	$0{,}30 \pm 0{,}09^{abc}$	$1{,}27 \pm 0{,}46^{a}$
Average		1,40	0,61	0,29	1,55

Different letters in rows from for each parameter indicate significantly different values among genotype at $P \leq 0.05$

The water content of the black mulberry ranged from 85.50% ("Mn3") to 87.88% ("Mn6") with an average value of 86.46%. A higher average value of water content (87.20%) in the black mulberry was published by KAMILOGLU *et al*., (2013), whilst in research conducted by SKENDER *et al*. (2017), the water content was lower in relation to this study and ranged from 82.87 to 85.85%. In the white mulberry, the water content ranged from 77.84% ("Ma2") to 86.46% (Ma4) with an average of 82.49%. A slightly higher value of water content for *Morus alba* was published by SKENDER *et al*. (2017) and ranged from 86.25 to 87.01%.

The highest content of soluble solids (19.17%) was observed in the genotype "Mn2", while the lowest content was recorded in the genotype "Mn3" (12.11%). The average soluble solids content of black mulberries was 14.88%. The average content of the soluble solids in the white mulberry ranged from 13.53% ("Ma4") to 22.15% ("Ma2") with an average value of 17.51%. Generally, the average content of the soluble solids was higher in white mulberries, and the content of the water in the fruits of the black mulberry. Previous studies show similar values of the soluble solids content. For black mulberries, the soluble solids content ranged from 11.73

to 22.10% (ERCISLI *et al*., 2008; ERCISLI *et al*., 2010; OKATAN *et al*., 2016) while the measured values of the soluble solids content for the white mulberries ranged from 14.00 to 26.50% (ERCISLI *et al*., 2010).

The highest total acid content in the black mulberry was found in the genotype “Mn3” (0.21%), and the lowest in the genotype “Mn6” (0.01%). The total acid content of white mulberry genotypes ranged from 0.01 (“Ma6”) to 0.19% (“Ma1”), while the total sugar content ranged from 3.71 (“Ma5”) to 11.69% (“Ma6”). The total sugar content of the black mulberries was in the range of 4.09 (“Mn6”) up to 9.96% (“Mn1”). In this research, the white mulberry genotypes had a higher average content of acids and total sugars compared to the black mulberry. The acidity is an important index for assessing the quality of fresh fruit (JIANG and NIE, 2015) as the ratio of total acid content to the amount of sugar in the fruit has an impact on the taste because of reducing the effect of acidity on sweetness and enhancing effect on the sourness (GUNDOGDU *et al*., 2011). Sugar content in mulberry fruit was previously investigated by many scientists: PREDOJEVIĆ *et al*. (2012), MAHMOOD *et al*. (2012), EYDURAN *et al*. (2015), GECER *et al*. (2016) and SKENDER *et al*. (2017). They found from 5.90 to 17.65% of total sugars in fruits of the black mulberry, and 4.40-17.11% in the white mulberry. From previous studies, it can be concluded that the total acid content varied from 0.07% to 1.98% for the black mulberry (ERCISLI *et al*., 2010, OKATAN *et al*., 2016 and SKENDER *et al*., 2017), i.e. from 0.44% to 1.10% for the white mulberry (ERCISLI *et al*., 2010 and SKENDER *et al*., 2017).

Table 3. Biochemical characteristics of black and white mulberry genotypes

Species	Genotypes	Moisture (%)	Total soluble solids (%)	Total acids (%)	Total sugars (%)	Ash (%)
	„Mn1“	86,15 ± 1,08[a]	13,85 ± 1,08[a]	0,03 ± 0,00[ab]	9,96 ± 0,69[b]	0,77 ± 0,11[a]
	„Mn2“	87,49 ± 9,41[a]	19,17 ± 3,73[b]	0,14 ± 0,00[c]	7,12 ± 3,18[ab]	0,64 ± 0,04[a]
Morus	„Mn3“	85,50 ± 0,22[a]	12,11 ± 1,59[a]	0,21 ± 0,00[d]	6,96 ± 1,00[ab]	0,49 ± 0,12[a]
nigra	„Mn4“	85,87 ± 0,35[a]	14,19 ± 0,22[a]	0,03 ± 0,00[ab]	7,89 ± 1,80[ab]	0,74 ± 0,13[a]
	„Mn5“	85,87 ± 0,35[a]	14,13 ± 0,35[a]	0,08 ± 0,05[b]	7,76 ± 0,72[ab]	0,65 ± 0,13[a]
	„Mn6“	87,88 ± 1,59[a]	15,83 ± 0,59[ab]	0,01 ± 0,00[a]	4,09 ± 0,29[a]	0,79 ± 0,09[a]
Average		86,46	14,88	0,08	7,30	0,68
	„Ma1“	82,43 ± 3,44[ab]	17,56 ± 3,44[ab]	0,19 ± 0,01[c]	10,16 ± 2,16[bc]	0,78 ± 0,05[a]
	„Ma2“	77,84 ± 2,10[a]	22,15 ± 2,10[b]	0,15 ± 0,00[bc]	6,44 ± 1,59[ab]	0,96 ± 0,15[a]
	„Ma3“	81,44 ± 4,31[ab]	18,55 ± 4,31[ab]	0,15 ± 0,00[b]	4,31 ± 0,28[a]	0,75 ± 0,09[a]
Morus	„Ma4“	86,46 ± 1,62[b]	13,53 ± 1,62[a]	0,14 ± 0,04[b]	4,48 ± 1,09[a]	0,80 ± 0,05[a]
alba	„Ma5“	85,11 ± 1,70[b]	14,89 ± 1,70[a]	0,02 ± 0,00[a]	3,71 ± 0,67[a]	0,80 ± 0,15[a]
	„Ma6“	81,58 ± 0,70[ab]	18,42 ± 0,70[ab]	0,01 ± 0,00[a]	11,69 ± 3,40[c]	0,71 ± 0,06[a]
	„Ma7“	81,13 ± 0,33[ab]	18,86 ± 0,33[ab]	0,02 ± 0,00[a]	7,49 ± 0,90[abc]	0,70 ± 0,16[a]
	„Ma8“	83,92 ± 2,32[ab]	16,08 ± 2,30[ab]	0,05 ± 0,00[a]	10,40 ± 1,85[bc]	0,74 ± 0,08[a]
Average		82,49	17,51	0,09	7,34	0,78

Species	C vitamin (mg/100g FW)	Total phenols (GAE/100g FW)	Anthocyanins (Cy 3-glu mg/g)
rus nigra	82,86 ± 0,05^{c}	53,50 ± 7,85^{b}	116,15 ± 0,48^{a}
	39,64 ± 8,21^{b}	16,06 ± 2,09^{a}	703,16 ± 0,30^{d}
	45,14 ± 0,02^{b}	92,66 ± 6,42^{c}	920,68 ± 0,43^{e}
	19,79 ± 0,01^{a}	101,33 ± 10,06^{c}	959,56 ± 0,32^{f}
	43,81 ± 0,17^{b}	20,06 ± 1,88^{a}	545,76 ± 0,76^{c}
	43,81 ± 0,17^{b}	20,40 ± 1,15^{a}	129,23 ± 0,40^{b}
Average	45,84	50,67	562,42
Morus alba	36,86 ± 1,00^{a}	38,33 ± 5,13^{d}	
	54,04 ± 6,15^{c}	6,26 ± 1,98^{a}	
	46,51 ± 1,37^{b}	19,10 ± 1,15^{bc}	
	50,44 ± 3,52^{bc}	39,13 ± 2,01^{d}	
	49,06 ± 0,37^{bc}	44,56 ± 5,05^{de}	
	30,35 ± 0,40^{a}	50,00 ± 3,00^{e}	
	37,48 ± 0,16^{a}	12,06 ± 0,40^{ab}	
	45,56 ± 0,35^{b}	26,50 ± 0,70^{c}	
Average	43,79	29,49	

Species	C vitamin (mg/100g FW)	Total phenols (GAE/100g FW)	Anthocyanins (Cy 3-glu mg/g)
Morus nigra	82,86 ± 0,05^{c}	53,50 ± 7,85^{b}	116,15 ± 0,48^{a}
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	45,14 ± 0,02^{b}	92,66 ± 6,42^{c}	920,68 ± 0,43^{e}
	19,79 ± 0,01^{a}	101,33 ± 10,06^{c}	959,56 ± 0,32^{f}
	43,81 ± 0,17^{b}	20,06 ± 1,88^{a}	545,76 ± 0,76^{c}
	43,81 ± 0,17^{b}	20,40 ± 1,15^{a}	129,23 ± 0,40^{b}
Average	45,84	50,67	562,42
Morus alba	36,86 ± 1,00^{a}	38,33 ± 5,13^{d}	
	54,04 ± 6,15^{c}	6,26 ± 1,98^{a}	
	46,51 ± 1,37^{b}	19,10 ± 1,15^{bc}	
	50,44 ± 3,52^{bc}	39,13 ± 2,01^{d}	
	49,06 ± 0,37^{bc}	44,56 ± 5,05^{de}	
	30,35 ± 0,40^{a}	50,00 ± 3,00^{e}	
	37,48 ± 0,16^{a}	12,06 ± 0,40^{ab}	
	45,56 ± 0,35^{b}	26,50 ± 0,70^{c}	
Average	43,79	29,49	

Minerals are important in human nutrition, some play essential roles in bone making and others are important in body maintenance or for metabolic purposes. Some of the minerals are part of the enzyme molecules (FAZLI and FAZLI, 2014). The average content of ash measured in white mulberry genotypes was higher (0.78%) compared to the genotypes of the black mulberry (0.68%).

Previously, researchers have concluded that deep-coloured mulberry fruits are a good source of flavonoids, phenolics and anthocyanin (SÁNCHEZ-SALCEDO et al., 2015; JIANG and NIE, 2015), which could explain why the lowest levels of flavonoids, phenolics and anthocyanins were noted in the fruits of white mulberry genotypes (KRISHNA et al., 2018). According to EYDURAN et al. (2015), fruit species can be classified into three groups (low, moderate and high) according to the content of vitamin C and mulberries are generally placed in the moderate vitamin C content group. Based on Table 3, it can be said that the highest content of vitamin C in the black mulberries was found in fruits of genotype "Mn1" (82.86 mg/100 g FW), whilst the lowest content was observed in the genotype "Mn4" (19.79 mg/100 g FW). The average content of vitamin C in the black mulberry was 45.84%. The content of vitamin C in white mulberries ranged from 30.35 mg/100 g FW ("Ma6") to 54.04 mg/100 g FW ("Ma2") with an average of 43.79 mg/100 g FW. A significantly lower value of vitamin C content was reported by GECER et al. (2016), EYDURAN et al. (2015) and OKATAN et al. (2016) for black mulberries, or by GECER et al. (2016) and EYDURAN et al. (2015) for the white mulberries. In black mulberry genotypes, the total phenol content ranged from 16.06 mg GAE/100 g FW ("Mn2") to 101.33 mg GAE/100 g FW ("Mn4") while the white mulberry genotypes had 6.26 mg to 50.00 mg GAE/100 g FW phenol content. The obtained values of the phenol content are in accordance with the merits obtained by OKATAN et al. (2016); ALJANE and SDIRI (2016); ERCISLI et al. (2010) and ERCISLI and ORHAN (2008) for the black mulberry and ALJANE and SDIRI (2016) and ERCISLI et al. (2010) for the white mulberries.

The content of the anthocyanin in the genotypes of the black mulberry ranged from 116.15 Cy 3-glu mg/g ("Mn1") to 959.56 Cy 3-glu mg/g ("Mn4") with an average value of 562.42 Cy 3-glu mg/g. From previous studies, the content of anthocyanin ranges from 643 Cy 3-glu mg/g to 1000 Cy 3-glu mg/g (ERCISLI *et al*., 2010; OKATAN *et al*., 2016 and ALJANE and SDIRI, 2016). Previously, researchers have concluded that a deep-colored mulberry fruit is a good source of flavonoids, phenolics and anthocyanin (SÁNCHEZ-SALCEDO *et al*., 2015; JIANG and NIE, 2015). In the JIANG and NIE (2015); SÁNCHEZ-SALCEDO *et al*. (2015) and KRISHNA *et al*. (2018), the absence of an anthocyanin in white mulberries is noted, while in our research this component has not been analyzed for the white mulberry.

The mean value of all tested properties of black and white mulberries was subject to PCA analysis. The results showed that the first two components explained a total of 52.82% of the variations, i.e. the first component explained 30.67%, and the other 22.15%. In the first five PCA components, 95.73% of the variability was explained. Significantly higher values were obtained in the SKENDER *et al*. (2017) in which the pomological and chemical characteristics of the mulberries from the northwestern part of Bosnia were investigated (the first two main components contained 83.81% of the total variance of the experiment). Variables with the largest characteristic vectors in each of the first five main components are: PC1 - fruit weight and fruit width; PC2 - fruit length and total phenols; PC3 - moisture, dry matter, anthocyanin and C vitamin; PC4 - stem length, acidity and ash; PC5 - total sugars.

By using the main components (PC1 and PC2) as spatial dimensions (axes x and y), a set of two-dimensional graphs was constructed, showing the interrelations of the examined physical and chemical characteristics of the fruits of black and white mulberries, as well as the spatial distribution of all the analyzed genotypes (Figure 1).

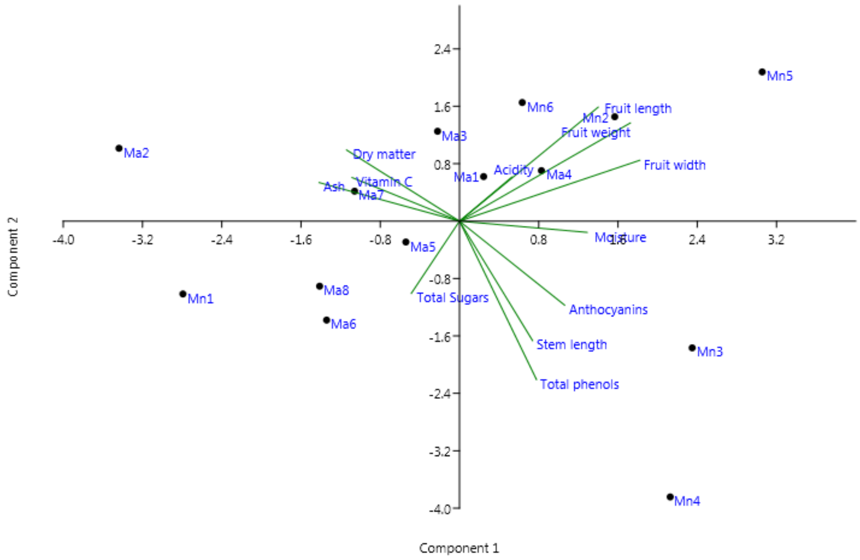

Figure. 1. Distribution of genotypes of black and white mulberry genotypes using the analysis of the main components (PCA) and the interrelationship of pomological and biochemical characteristics

On the basis of Figure 1, separation of genotypes is visible on all four sides of the chart. Of all the genotypes, the greatest differentiation is present in the genotypes “Mn1”, “Ma2”, “Mn5”, and “Mn3” and “Mn4”. The genotype of the black mulberry “Mn1” was separated with the lowest physical characteristics of the fruit (fruit length, fruit width, mass of the fruit), the smallest content of anthocyanin, and the highest content of vitamin C. The white mulberry genotype “Ma2” was separated by the smallest content of water and total phenols in the fruit and the largest content ash. Extraction of the black mulberry genotype “Mn5” is a consequence of high values of the physical properties of the fruit (fruit length, fruit width and fruit mass). Two genotypes “Mn3” and “Mn4” stood out on the basis of high values in the content of anthocyanin, and in addition to the indicated fruits of the genotype “Mn3”, they had the smallest content of water, solids, ash content, and the highest acid content. The fruits of the genotype “Mn4”, in addition to the high content of anthocyanin, also had a high content of phenols and the smallest content of vitamin C.

CONCLUSION

In this study, the pomological and biochemical properties of fruits of the genotypes of black and white mulberries from the area of northwestern Bosnia were analyzed. On average, genotypes of black mulberries had higher physical properties of the fruit. Also, genotypes of black mulberry were distinguished by the high values of the content of phenol and anthocyanin, and can be a great potential for use for health purposes. The obtained results can serve for future steps in the breeding of these species, and because of the high quality fruit characteristics can affect the conservation of these species due to the increasing genetic erosion of the mulberries.

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NEKA FIZIČKOHEMIJSKA SVOJSTVA GENOTIPOVA CRNOG I BELOG DUDA IZ BOSNE I HERCEGOVINE

Azra SKENDER[1], Mirsad KURTOVIĆ [2], Sezai ERCISLI [3], Dinko BEĆIRSPAHIĆ [1]

[1]Biotehnički Fakultet Univerzitet Bihać, Bihać, Bosna i Herzegovina
[2] Fakultet za poljoprivredu i nauku o hrani Univerzitet Sarajevo, Sarajevo, Bosna i Herzegovina
[3]Departmant za Hortikulturu, Poljoprivredni fakultet, Ataturk Univerzitet, Erzurum, Turska

Izvod

Nedavno, interesovanje za upotrebu voća i praktikovanje zdrave ishrane je u porastu. Zato, fokus ovog istraživanja je da se odrede neka fizičkohemijska svojstva duda iz oblasti severozapadne Bosne, gde značajne količine genetičkih resursa duda su dostupne. Ukupno šest genotipova crnog i osam genotipova belog duda su ispitani. Od fizičkih karakteristika, masa ploda, visina ploda, širina i dužina ploda su merene. Crni dud je bogatiji nego beli za većinu ispitanih parametara. Prosečno voda, ukupna kiselost, ukupni šećeri, pepeo, viramin C, ukupni fenoli i antocijanini crnog duda su 86.46%, 14.88%, 0.08%, 7.30%, 0.68%, 45.84 mg/100 g FW, 50.67 mg GAE/100 g FW i 562.42 cyanidin-3-glucoside mg/g. Ove vrednosti su 82.49%, 17.51%, 0.09%, 7.34%, 0.78%, 43.79 mg/100 g FW i 29.49 mg GAE/100 g FW za beli dud. Dobijeni rezultati mogu da služe za sledeće korake u oplemenjivanju ovih vrsta, i zbog visokog kvaliteta ploda, oni mogu uticati na upotrebu ovih vrsta usled povećane genetičke erozije.

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