Acta Sci. Pol. Hortorum Cultus, 22(2) 2023, 85–97

https://czasopisma.up.lublin.pl/index.php/asphc ISSN 1644-0692 e-ISSN 2545-1405 https://doi.org/10.24326/asphc.2023.2214

ORIGINAL PAPER

Accepted: 30.09.2022
First published online: 26.04.2023
Issue published: 28.04.2023

BIOCHEMICAL COMPOSITION AND ANTIOXIDANT ACTIVITY OF MOROCCAN PLUM CULTIVARS

Youssef Ait Bella, Said Bouda ✉, Youssef Khachtib, Abdelmajid Haddioui

Laboratory of Agro-Industrial and Medical Biotechnology, Faculty of Sciences and Technics, Sultan Moulay Slimane University, B.P. 523, Béni Mellal, Morocco

ABSTRACT

Biochemical composition and antioxidant activity were analyzed for 15 plum cultivars grown in different climatic regions of Morocco where is considered as an important tree crops. Fruits were analyzed by determining 21 parameters. Total polyphenols, flavonoids, anthocyanin, antioxidant activity, total soluble solids, vitamin C, titratable acidity, ash, moisture, dry matter, juice pH, total sugars, crude fiber, crude proteins, respectively with an average of 6.8 mg GAE/g, 1.24 mg CE/g, 136.54 mg/100 g, 58.06%, 7.91%, 146.19 mg/kg, 1.37%, 1.93%, 83.33%, 16.66%, 2.97, 62.67 mg/g, 0,44% and 0.66% have varied between cultivars. For the mean values of chemical elements (mg/100 g) were 229.77 for potassium, 18.94 for magnesium, 1.31 for iron, 1.13 for zinc, 1.11 for copper, 1.09 for nickel and 0.50 for manganese. Besides, the results showed that plum cultivars are characterized by an important nutritional content. The cultivars Lmozari and Tabarkakacht exhibited respectively the highest total polyphenols (9.39 mg/g) and antioxidant activity (70.65%) comparing with others ones. In this study regarding the nutritional content of plum cultivars will help to improve plum knowledge and select the desired gene pool for multiplication, and which may provide towards enhancing health to the consumer.

Key words: plum, biochemical parameters, antioxidant activity, cultivar

INTRODUCTION

Plum has great economic importance due to the use of their fruits in the food industry. The plum tree is the most diverse of the stone fruits among a dozen different of *Prunus* species, which belonging the *Rosacea* family. The plum tree is adapted to various climatic conditions in all temperate fruit growing areas [Ertekin et al. 2006]. The most economically important plum species are generally classified into two groups: the European plum (*Prunus domestica* L.) and the Japanese plum (*Prunus salicina* Lindl.) [Hummer and Janick 2009]. In the world, plums are produced about 12.6 million tons in 2018 [FAO 2018]. Plum is an excellent source of nutriments and contributes extensively to human nutrition, and is also an important source of compounds influencing human health and preventing the occurrence of many diseases [Stacewicz-Sapuntzakis et al. 2001]. The fruit plum is made up of protein and some mineral element [Lombardi-Boccia et al. 2004, Ertekin et al. 2006]. Apart from these basic food contents, plum fruits are an affluent source of phenolic compounds, characterized by relatively high anthocyanin and antioxidant activity which is higher than

✉ saidbouda@yahoo.fr

apples and strawberries [Leong and Shui 2002, Kim et al. 2003a, Rop et al. 2009]. Many studies have reported on the biochemical characteristics of plum, among which Nergiz and Yildiz [1997], Gil et al. [2002], Lozano et al. [2009], Walkowiak-Tomczak et al. [2008] and Nisar et al. [2015]. Variation for phenolic compounds, total flavonoids, total anthocyanins and antioxidant capacity of plum was investigated by Kim et al. [2003b]. In addition, plum have been found pharmacologically active as antioxidant, anticancer, anxiolytic and mild laxative [Jabeen and Aslam 2011]. They are recognized by the USDA [2017] as the fruit with the highest ORAC content – radical oxygen absorption capacity (5770 and 949 ORAC units per 100 g for prunes and plums, respectively), followed raisins and blueberries. Moreover, plums can contain 2 to 15 times more phenolic compounds and up to 26 times the antioxidant activity of peaches or nectarines [Byrne et al. 2008].

In Morocco plums used fresh, dried or canned in the form of jam. The Moroccan plum cultivars are represented by international varieties of Japanese type, such as 'Golden Japan', 'Santa Rosa', 'Angeleno', and of European type such as 'Stanley', the most popular in the national market [Oukabli et al. 2005], and by local cultivars of unknown origin. However, there is little information on the biochemistry of plums cultivars. The aim of this study is to analyze biochemical content and antioxidant activity of plum fruit of 15 representing cultivars growing the main cropping area of the species, as well as to help broaden knowledge of the plum tree, and also for use in future plum selection programs.

MATERIAL AND METHODS

Plant material. The plant material used in this study included 15 Moroccan plum cultivars collected from different regions of prunus cropping area (Tab. 1, Fig. 1). Fresh ripe plums were collected at random from 3 trees per cultivar. Sampling was carried out taking into account the geographical distances and the altitude between the cultivars.

Chemical analyses. For dry matter (DM) 5 g of fruit fresh samples were dried in an oven at 105°C for 24 h and the moisture (M) was calculated on a dry weight and fresh weight basis [Mikdat 2010]. The total ash was placed in a crucible with known weight. The samples were ignited in a muffle furnace at 550°C for 4 hours, the results are expressed as a percentage (%) [Ough and Amerine 1988]. Crude fiber (fiber) was determined as described by Aryapak and Ziarati [2014], 5 g of the fresh plum were digested in 100 mL of 1.25% H_2SO_4. The solutions were boiled for 45 minutes and then were filtered and washed with hot distilled water. The filtrates were digested in 100 mL of 1.25% sodium hydroxide solutions. These solutions were heated for 60 minutes, filtered and washed with hot deionized water and over dried and measured. The final oven-dried residues were ignited in a furnace at 550°C and the results are expressed as a percentage. The pH of the juice samples was measured by using a digital pH meter type G. Boyer [Ruck 1963]. The titratable acidity (TA) was measured by titration plum juice; the result was expressed as percentage of malic acid equivalent [Ruck 1963]. The vitamin C (vit. C) (mg/kg) content in the fruit was determined by iodometry method [Peller 1998] with some modifications. A preliminary titration of iodine with sodium thiosulphate solution is necessary to determine the concentration of iodine (C2). In a beaker, 5 mL of a juice is introduced, then a few drops of starch indicator solution are added, and a 5 mL of iodine (C2). The solution is then black, because of the excess iodine. A graduated burette is filled with sodium thiosulfate solution at C1 = 5 × 10^{-3} mol/l and the remaining iodine solution is titrated until the complete disappearance of the black color, and then the volume of sodium thiosulfate poured in at equivalence (VEQ) is noted. The number of moles of vitamin C can be expressed as follows:

$$n(C_6H_8O_6)_{Total} = n(I_2)_{Total} - \frac{1}{2} \times C_1 \times V_{EQ}$$

The mass of vitamin C (m) that exists in a liter of juice can be established according to the following relationship:

$$m(vit.C) = n(C_6H_8O_6)_{Total} \times M(C_6H_8O_6) \times 1000/5$$

The mass (m) of vitamin C in milligram (mg) obtained per liter of plum juice is converted into milligram per kilogram (mg/kg) after multiplying the quotient of liter per kilogram (L/kg) of fresh matter (FM).

Table 1. Geographical origin of 15 plum cultivars ordered according to belonging species

Cultivar	Locality	Code	Latitude North	Longitude West	Species
Santa Rosa	Asguine (40 km S of Marrakech)	SAR	31°21'	7°45'	*Prunus salicina* Lindl.
Black Amber	Bouderbala (24 km E of Meknes)	BLA	33°49'	5°17'	*Prunus salicina* Lindl.
Fortune	Sidi Jaber (10 km W of Beni Mellal)	FOR	32°22'	6°26'	*Prunus salicina* Lindl.
Stanley	Aghbala (111 km E of Beni Mellal)	STA	32°28'	5°39'	*Prunus domestica* L.
Hamra	Anzo1 (19 km S of El Attaouia)	HAM	30°41'	7°16'	*Prunus domestica* L.
Dlahi	Bouadel (15 km E of Taounate)	DLH	34°34'	4°30'	*Prunus domestica* L.
Tabarkakacht	Ain Assardoun (2 km S of Beni Mellal)	TAB	32°19'	6°19'	*Prunus domestica* L.
Lbyade 1	Bouadel (15 km E of Taounate)	LBY1	34°34'	4°30'	*Prunus domestica* L.
Lbyade 2	Asguine (40 km S of Marrakech)	LBY2	31°21'	7°45'	*Prunus domestica* L.
Lbide	Magaste (46 km S of Marrakech)	LBI	31°14'	7°40'	*Prunus domestica* L.
Lbayda	Ain Assardoun (2 km S of Beni Mellal)	LBA	32°19'	6°19'	*Prunus domestica* L.
Safra	Ait Saleh (5 km N of Imouzzer Kandar)	SAF	33°46'	5°0'	*Prunus domestica* L.
Safra Rkika	Amane Syernine (30 km S of El-Hajab)	SARK	33°37'	5°25'	*Prunus domestica* L.
Lmozari	Ait Ouallal (40 km E of Meknes)	LMO	33°48'	5°11'	*Prunus domestica* L.
Frigo	Ait Saleh (5 km N of Imouzzer Kandar)	FRI	33°46'	5°0'	*Prunus domestica* L.

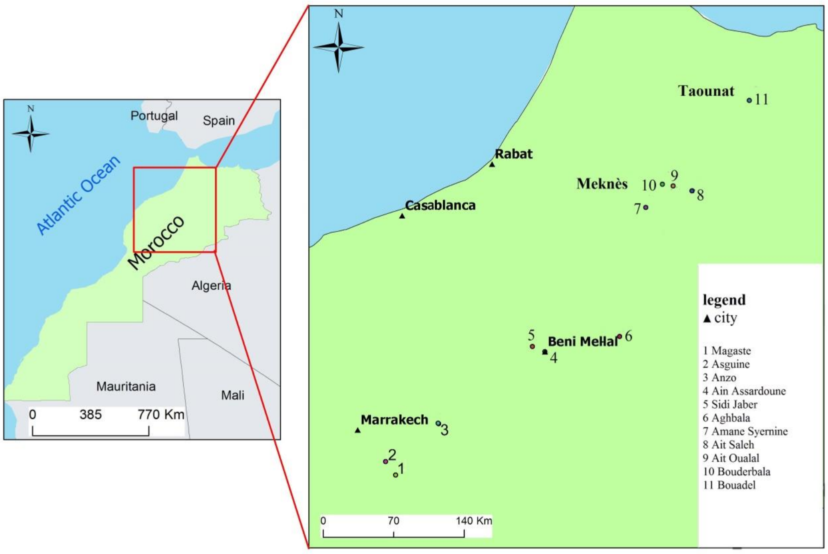

Fig. 1. Map of Morocco showing the locations of the plum cultivars analyzed

The total soluble solid (TSS) (%) was measured by using a hand refractometer (Brix hand refractometer, Dutscher), the result obtained in the degree Brix (°B) was described by Ruck [1963]. The crude protein (Prot) (%) was analyzed by Kjeldahl method [AOAC 1995]. The total anthocyanin (Ant) composition was measured by the pH differential method using two buffers: potassium chloride buffer (pH 1.0) and sodium acetate buffer (pH 4.5) [Wrolstad 1993]. The sample is mixed separately with each buffer and the absorbance of each dilution was measured at 510 nm and 700 nm. Results were expressed as milligrams of cyaniding-3-glucoside per 100 g of fresh weight.

Extract preparation: 5 g of the fresh plum was homogenized in 12.5 mL of methanol using a mixer (Waring). The homogenates were kept at 4°C for 12 h, then centrifuged at 9950 × g for 30 min. The supernatants were collected and the extraction of the residue was repeated under the same conditions. The two methanolic supernatants were combined (Xu and Chen 2011). The total sugars (TS) (mg/g) were measured as described by Dubois et al. [1956]. 500 µl of methanolic extract were added to 0.5 mL of phenol and 1.5 mL of sulfuric acid solution (H_2SO_4). The mixture was heated in a water bath at 100°C for 5 minutes. After cooling in crushed ice, the optical density of the mixture was measured at 485 nm (UV-Vis Spectrophotometer, JASCO V-630). The total flavonoid content (FLV) of the extracts was quantified using a method of Jia et al. [1999], a standard curve was produced with catechin (Sigma-Aldrich) under the same conditions as the sample. Briefly, 2 mL of the extracts were mixed with 3 mL of distilled water and 0.3 mL of sodium nitrite (0.72 mol/L). After 5 minutes, 0.6 mL of aluminum chloride (0.41 mol/L) was added and allowed to react further for 6 minutes before addition of 1 molar sodium hydroxide (2 mL). Finally, 2.1 mL of distilled water was added for all samples to make up to 10 mL. The absorbance of the mixture was immediately measured at 510 nm by the UV-Vis spectrophotometer (JASCO V-630). The result is expressed in milligram (mg) catechin equivalent per gram of fresh weight (mg CE/g). Phenolic content concentration (PC) in the obtained extracts was determined by a colorimetric assay based on procedures described by Singleton et al. [1999] with some modifications. The sample extract (0.5 mL) was mixed with 2.5 mL of 10% Folin-Ciocâlteu's reagent and 2 mL of 7.5% sodium carbonate solution. The reaction was kept in the dark for 40 minutes at 45°C and in the absorbance was read at 765 nm (UV-Vis Spectrophotometer, JASCO V-630). Gallic acid was used for constructing the standard curve. The results are expressed as mg of gallic acid equivalents per g of extract (mg GAE/g). The capacity to scavenge was monitored using the DPPH free radical according to a method reported by Hatano et al. [1988]. The sample extracts (0.3 mL) were mixed with 2.7 mL of methanolic solution containing DPPH radicals (6 × 10–5 mol/L). The mixture was shaken vigorously and left to stand in the dark until stable absorption values were obtained. The reduction of the DPPH radical was measured by monitoring continuously the decrease of absorption at 517 nm. The percentage of DPPH radical scavenging activity (RSA) was calculated using the equation:

$$RSA(\%) = \left[\frac{(A_0 - A_S)}{A_0}\right] \times 100$$

where A0 is the absorbance of control and AS is the absorbance of the sample.

The minerals composition was determined according to Ranganna [1995] method with some modifications. The mineral solution was used to estimate potassium (K), magnesium (Mg), copper (Cu), zinc (Zn), manganese (Mn), iron (Fe), nickel (Ni) concentrations by using atomic absorption Spectrophotometer ICP-AES (Inductively Coupled Plasma-Atomic Emission Spectrometry; Optima 8000 ICP-AES Spectrometer).

Statistical analyses. The data obtained were subjected to several statistical analyses including analysis of variance (ANOVA) and correlation analysis based on the Pearson correlation coefficient (α = 0.01) (SPSS, 2011). The principal components (PCA) and cluster analyses were also performed basing on the means of trait for each cultivar using respectively, the XLSTAT software (XLSTAT 2018) and Statistica StatSoft (1997).

RESULTS

The results of means values for all parameters are presented in Table 2. Except for protein and potassium, the analysis of variance exhibited significant differences between cultivars for the analyzed traits.

The values of dry matter content in the flesh plum studied changed between 10% for 'Safra' to 20.33% for 'Stanley', with a general average of 16.67%. Therefore, the moisture content value ranged between 79.67% for 'Stanley' and 90% for 'Safra' with an average of 83.33%. The total ash content was varied between values 0.93% for 'Dlahi' and 3.67% for 'Black Amber' with a medium value of 1.93%. Regarding the crude fiber varied from 0.29% for 'Lbide' to 0.71 for 'Stanley' with a mean of 0.45%. By averaging 2.98, the juice pH of plum spanned from 2.64 for 'Safra Rkika' to 3.33 for 'Stanley'. Accordingly, the titratable acidity varied between 0.78% ('Stanley') and 1.78% ('Safra Rkika') with an average of 1.37%. The highest vitamin C content was recorded for 'Lmozari' (249.33 mg/kg) and the lowest content was observed for 'Lbyade 1' (105.60 mg/kg) with a medium value of 146.19 mg/kg. The total soluble solid was between 5.72% for 'Frigo' and 10.14% for 'Safra Rkika' with a general mean of 7.91%. Furthermore, the total sugar content varied between 34.63 mg/g ('Frigo') and 93.04 mg/g ('Safra') with an average of 62.97 mg/g. In addition, the crude protein was between 0.51% for 'Safra' and 0.88% for 'Lmozari' with a mean value of 0.66%.

Average phenolic content (PC) was 6.8 mg GAE/g of FM with values ranging from 3.15 mg GAE/g FM for 'Lbyade 2' to 9.39 mg GAE/g FM for 'Lmozari'. The total flavonoid content changed from 0.21 mg CE/g FM for 'Safra Rkika' to 2.87 mg CE/g FM for 'Lmozari' with a mean of 1.24 mg CE/g FM. The scavenging activity on DPPH radical (RSA) was higher in Tabarkakacht cultivar (70.65%) and lower in 'Safra' (42.19%) with an average of 58.06%. Anthocyanin content (Ant) ranged from 97.26 mg/100 g FM for 'Safra Rkika' to 200.60 mg/100 g FM for 'Tabarkakacht' with an average of 136.54 mg/100 g.

Studied plum cultivars contain high level of K with values ranging from 178.36 mg/100 g for 'Fortune' to 283.58 mg/100 g for 'Safra Rkika' with a mean of 229.77 mg/100 g FM, and Mg with an average of 18.94 mg/100 g FM varied between 13.56 mg/100 g FM ('Dlahi') and 22.3 mg/100 g FM ('Black Amber'). The average of Mn content was determined as 0.507 mg/100 g and established between 0.181 mg/100 g ('Frigo') and 0.901 mg/100 g ('Safra Rkika'), and as for Cu amount was found between 1.07 mg/100 g ('Frigo', 'Safra' and 'Tabarkakacht') and 1.22 mg/100 g ('Lmozari') with a mean of 1.11 mg/100 g, which was 1.31 mg/100 g for Fe content with a variation from 1.12 mg/100 g in 5 cultivars ('Black Amber', 'Frigo', 'Safra', 'Stanley' and 'Tabarkakacht') to 1.78 mg/100 g in 'Lmozari'. Regarding the Zn content that spanned from 0.84 mg/100 g for 'Black Amber' to 2.02 mg/100 g for 'Lbayda', the recorded mean was 1.13 mg/100 g.

Table 2. Mean values and descriptive statistics for biochemical parameters considered in the studied plum cultivars

	BLA	DLH	FOR	FRI	HAM	LBA	LBI	LBY1	LBY2	LMO	SAF	SAR	SARK	STA	TAB	Mean	F
DM (%)	19.33	13.00	18.33	10.67	20.00	19.00	12.33	15.00	14.67	19.33	**10.00**	19.33	19.67	**20.33**	19.00	16.667	5.06***
M (%)	80.67	87.00	81.67	89.33	80.00	81.00	87.67	85.00	85.33	80.67	**90.00**	80.67	80.33	**79.67**	81.00	83.333	5.06***
Ash (%)	**3.67**	**0.93**	3.27	1.73	1.47	1.47	2.07	1.60	1.40	1.80	1.13	1.67	1.60	2.67	2.53	1.933	4.07***
Fiber (%)	0.53	0.49	0.48	0.53	0.51	0.41	**0.29**	0.38	0.47	0.49	0.31	0.37	0.37	**0.71**	0.38	0.448	2.14*
pH	3.05	3.25	3.11	2.90	2.72	2.86	2.98	3.05	3.01	3.31	2.78	2.87	**2.64**	**3.33**	2.80	2.977	25.78***
TA (%)	1.37	1.01	0.98	1.76	1.71	1.22	1.36	1.38	1.62	0.87	1.47	1.64	**1.78**	**0.78**	1.62	1.37	2.46*
Vit. C (mg/kg)	130.83	176.00	144.91	111.47	130.24	145.49	124.96	**105.60**	111.47	**249.33**	129.07	114.4	211.13	132.00	176.00	146.193	3.63***
TSS (%)	6.76	7.79	7.54	**5.72**	9.37	8.07	6.19	7.44	7.06	9.00	6.26	9.37	**10.14**	9.34	8.70	7.916	4.24***
TS (mg/g)	43.30	75.31	42.23	**34.63**	90.40	67.83	56.54	62.54	85.15	48.28	**93.04**	43.74	89.85	55.63	56.13	62.974	3.65***
PC (mg GAE/g)	7.02	8.61	8.81	7.28	7.70	5.75	4.10	6.02	**3.15**	**9.39**	4.81	7.06	5.05	9.32	7.93	6.799	6.73***
FLV (mg CE/g)	1.77	0.69	2.30	1.00	2.77	0.64	0.36	0.60	0.46	**2.87**	0.52	0.86	**0.21**	1.12	2.46	1.247	11.48***
Ant (mg/100 g)	180.56	100.29	100.98	200.42	200.24	100.26	100.34	100.06	100.32	100.27	100.17	166.13	**97.26**	200.13	**200.60**	136.54	2.38*
RSA (%)	65.48	56.86	65.08	66.58	65.69	64.95	52.66	52.15	51.14	63.56	**42.19**	45.47	52.26	56.11	**70.65**	58.055	12.66***
Prot (%)	0.58	0.58	0.66	0.66	0.80	0.73	0.58	0.58	0.66	**0.88**	**0.51**	0.62	0.73	0.66	0.66	0.659	0.27
K (mg/100 g)	225.23	204.20	**178.36**	187.00	213.39	218.86	249.92	214.38	258.37	239.35	218.46	280.86	**283.58**	274.08	200.57	229.77	0.42
Mg (mg/100 g)	**22.30**	**13.56**	17.55	21.70	15.45	17.17	21.22	17.32	17.44	18.85	22.04	19.12	18.21	21.35	20.77	18.941	2.44*
Mn (mg/100 g)	0.382	0.859	0.236	**0.181**	0.602	0.594	0.203	0.561	0.598	0.525	0.382	0.643	**0.901**	0.366	0.569	0.506	2.73**
Cu (mg/100 g)	1.08	1.12	1.11	**1.07**	1.12	1.12	1.11	1.10	1.15	**1.22**	**1.07**	1.10	1.15	1.08	**1.07**	1.116	11.28***
Fe (mg/100 g)	**1.12**	1.29	1.25	**1.12**	1.41	1.27	1.35	1.36	1.74	**1.78**	**1.12**	1.23	1.40	**1.12**	**1.12**	1.315	13.72***
Zn (mg/100 g)	**0.849**	1.38	0.966	0.850	1.478	**2.028**	1.20	1.12	1.15	1.33	0.85	0.96	1.17	0.85	0.85	1.137	5.27***
Ni (mg /100 g)	**1.092**	1.095	**1.092**	**1.092**	1.098	1.096	1.093	1.093	1.097	**1.102**	1.093	1.093	1.094	1.093	**1.092**	1.094	4.15***

Significance level, * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. Bold values are minimum and maximum

Table 3. Matrix of correlation between the biochemical parameters measured in plum cultivars

	DM	M	Ash	Fiber	pH	TA	Vit. C	TSS	TS	PC	FLV	Ant	RSA	Prot	K	Mg	Mn	Cu	Fe	Zn	Ni
DM		***	ns	ns	ns	ns	ns	***	ns	ns	*	ns	ns	*	ns	ns	ns	ns	ns	ns	ns
M	–1		ns	ns	ns	ns	ns	***	ns	ns	*	ns	ns	*	ns	ns	ns	ns	ns	ns	ns
Ash	0.44	–0.44		ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
Fiber	0.34	–0.34	0.36		*	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
pH	0 .03	–0.03	0.26	0.59		*	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
TA	–0.17	0.17	–0.27	–0.46	**–0.86**		ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Vit C	0.29	–0.29	0.01	0.08	0.12	–0.29		ns	ns	ns	ns	ns	ns	*	ns	ns	ns	*	ns	ns	*
TSS	**0.81**	**–0.81**	–0.05	0.18	–0.07	–0.07	0.39		ns	ns	ns	ns	ns	*	ns	ns	**	ns	ns	ns	ns
TS	–0.06	0.06	–0.57	–0.23	–0.47	0.32	0.19	0.25		ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
PC	0.43	–0.43	0.35	0.63	0.51	–0.56	0.33	0.38	–0.46		**	ns	*	ns	ns	ns	ns	ns	ns	ns	ns
FLV	0.50	–0.50	0.44	0.34	0.16	–0.21	0.38	0.28	–0.26	0.68		ns	**	*	ns	ns	ns	ns	ns	ns	ns
Ant	0.29	–0.29	0.37	0.50	–0.11	0.24	–0.19	0.15	–0.28	0.42	0.42		ns	ns	ns	ns	ns	*	ns	ns	ns
RSA	0.37	–0.37	0.46	0.40	0.09	–0.12	0.34	0.05	–0.35	0.53	**0.70**	0.43		ns	*	ns	ns	ns	ns	ns	ns
Prot	0.59	**–0.59**	–0.06	0.27	0.01	–0.09	0.58	0.59	0.10	0.34	0.56	0.07	0.49		ns	ns	ns	**	*	ns	***
K	0.32	–0.32	–0.12	–0.02	–0.02	0.07	0.04	0.48	0.25	–0.30	–0.40	–0.07	–0.58	0.10		ns	ns	ns	ns	ns	ns
Mg	–0.14	0.14	0.47	–0.01	–0.07	0.11	–0.11	–0.35	–0.39	–0.11	–0.03	0.37	–0.05	–0.31	0.14		**	ns	ns	**	ns
Mn	0.31	–0.31	–0.51	–0.15	–0.20	0.17	0.30	0.64	0.56	–0.05	–0.16	–0.23	–0.18	0.23	0.34	**–0.65**		ns	ns	ns	ns
Cu	0.25	–0.25	–0.30	–0.04	0.23	–0.22	0.57	0.37	0.21	–0.005	0.16	0.53	–0.01	**0.70**	0.31	–0.45	0.40		***	*	***
Fe	0.10	–0.10	–0.34	–0.06	0.19	–0.07	0.32	0.20	0.30	–0.20	0.10	–0.50	–0.09	0.57	0.29	–0.44	0.32	**0.92**		ns	***
Zn	0.18	–0.18	–0.46	–0.13	–0.07	–0.13	0.22	0.22	0.33	–0.11	–0.05	–0.40	0.17	0.48	–0.02	**–0.64**	0.41	0.50	0.41		*
Ni	0.25	–0.25	–0.38	0.15	0.19	–0.21	0.50	0.33	0.32	0.09	0.34	–0.25	0.15	**0.77**	0.15	–0.44	0.33	**0.85**	**0.82**	0.61	

Significance level, * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

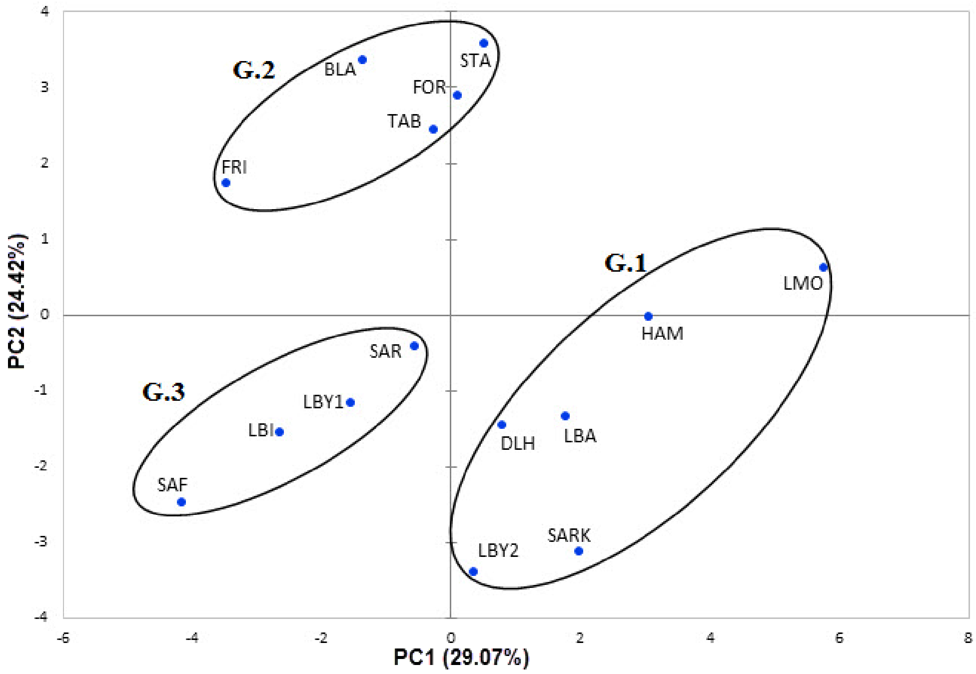

Fig. 2. Plot on the first two principal components of 15 plum cultivars: BLA – 'Black Amber', DLH – 'Dlahi', FOR – 'Fortune', FRI – 'Frigo', HAM – 'Hamra', LBA – 'Lbayda', LBI – 'Lbide', LBY1 – 'Lbyade 1', LBY2 – 'Lbyade 2', LMO – 'Lmozari', SAF – 'Safra', SAR – 'Santa Rosa', SARK – 'Safra Rkika', STA – 'Stanley', TAB – 'Tabarkakacht'

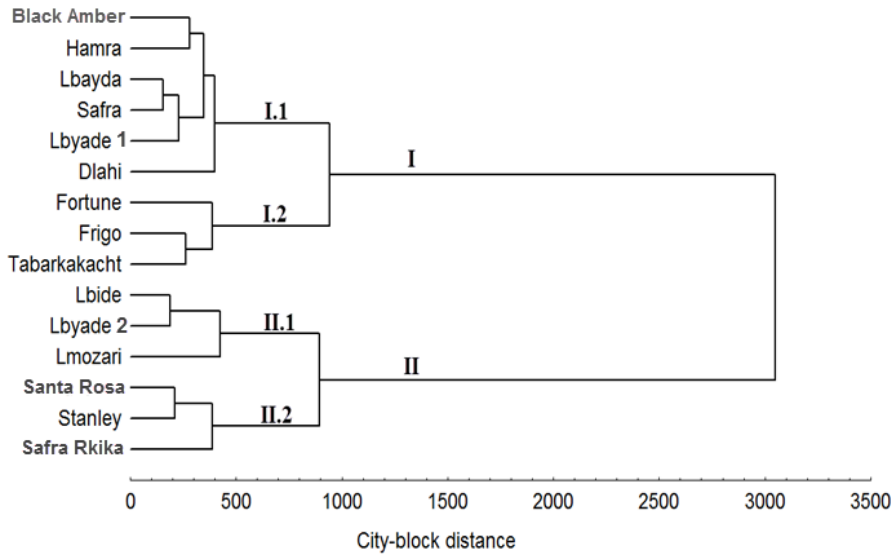

Fig. 3. Dendrogram of 15 plum cultivars based on biochemical parameters

The average amount of Ni was of 1.09 mg/100 g, value that is found in most cultivars.

Correlation among all parameters studied is summarized in Table 3. The significant and positive correlations were indicted by total soluble solids with dry matter content (r = 0.81***), the flavonoids content with radical scavenging activity (r = 0.70**) and polyphenols content (r = 0.68**), Fe element with Cu (r = 0.92***). In addition, the Ni element was positively and significantly correlated with Cu (r = 0.85***), Fe (r = 0.82***) and the crude protein (r = 0.77***).

On the other hand, the significant and negative correlations were recorded by the pH with the titratable acidity (r = –0.86***), the moisture content with total soluble solids (r = –0.81***) and crude protein (r = –0.59*), the radical scavenging activity with K element (r = –0.58*), and the Mg element with Mn (r = –0.65**).

The results obtained from the PCA showed that 53.49% of the total variation among cultivars was accounted by the two first components, with each component explaining respectively 29.07% and 24.42% (Fig. 2). The highest contributions to PC1 correspond positively to crude protein, Ni element, Cu element, total soluble solids and dry matter. The PC2 indicated that ash, polyphenols, radical scavenging activity, anthocyanin and flavonoids had the greatest positive contribution, while a total sugar had the highest negative contribution to this component. Figure 2 represent cultivars on the plot of the first two axis space. Three groups of cultivars were segregated. The first group (G.1) composed of 6 cultivars (‘Lmozari’, ‘Hamra’, ‘Lbayda’, ‘Dlahi’, ‘Safra Rkika’ and ‘Lbyade 2’), characterized by a high values of total soluble solids, titratable acidity, crude protein, Mn and Zn element. The second group (G.2) is formed by 5 cultivars (‘Stanley’, ‘Fortune’, ‘Black Amber’, ‘Tabarkakacht’ and ‘Frigo’). This group is distinguished with high values of ash, fiber, radical scavenging activity and anthocyanin. The third group (G.3) consisted of 4 cultivars (‘Santa Rosa’, ‘Lbyade 1’, ‘Lbide’ and ‘Safra’) characterized by a low amount of crude protein.

Further, the cluster analysis led to identify two major groups (Fig. 3). The first group bifurcates in two subgroups, one (I.1) contained cultivars Black Amber, Hamra, Lbayda, Safra, Lbyade 1 and Dlahi, and the other (I.2) consisted of Fortune, Frigo and Tabarkakacht cultivars. The second group was also subdivided in two subgroups. The first subgroup (II.1) is formed of cultivars Lbide, Lbayde 2, Lmozari, and the second subgroup (II.2) is composed of Santa Rosa, Stanley and Safra Rkika cultivars.

DISCUSSION

In this study, 21 biochemical parameters were considered to characterize Moroccan plum. The analysis of biochemical parameters showed significant differences between plum cultivars. These results are strengthened by previous studies on the same cultivars by using morphological and pomological traits [Ait Bella et al. 2018].

The Moroccan fresh plum had dry matter content (10% to 20.33%) similar to that found in Poland cultivars by Walkowiak-Tomczak et al. [2008] (12.70–19.90%), in Pakistan cultivars by Nisar et al. [2015] (10.83–29.60%), in Spanish by Lozano et al. [2009] (10.60–19.35%), in Turkish cultivar by Nergiz and Yildiz [1997] (10.15–25.48%) and in Romanian cultivars by Ionica et al. [2013] (15.71–25.20%). In addition, the dry matter was highly variable parameter, depending on variation in climatic condition and variable growing conditions [Walkowiak-Tomczak et al. 2008].

Regarding the ash content, the studied plum cultivars varied between 0.93% and 3.67%. This result is comparable with the one found in Pakistan plum (1.24–5.46%) by Nisar et al. [2015], and higher than the one found in Spanish plum (0.19–0.53%) by Lozano et al. [2009] and in Turkish plum (0.37–0.9%) by Nergiz and Yildiz [1997]. These differences could be attributed to the cultivar, harvesting year and accompanying conditions such as climate, geographical origin and the methods of cultivation. Indeed, different values of temperature, rainfall and light can influence the chemical composition of fruits [Walkowiak-Tomczak et al. 2008, Głowacka and Rozpara 2017].

The dietary fiber is essential for the proper functioning of intestinal transit and the overall health of humans, as it is metabolized by our gut microbiota into products that influence all of our metabolisms. In this work, the soluble fiber content (0.29–0.71%) is in agreement with that obtained by Lombardi-Boccia et al. [2004] (0.56%) for Italian cultivar.

The pH value of plum presented a high negative correlation with titratable acidity (r = 0.86***). The pH values ranging within 2.64% to 3.33%, which are similar to that found by Nisar et al. [2015] (2.27–3.20%) for 16 genotypes of plum (*Prunus domestica* L.) in Pakistan, Lozano et al. [2009] (3.14–3.42%) for 6 cultivars of Japanese plum (*Prunus salicina* Lindl.) in Spain, and lower than that reported by Gil et al. [2002] (3.84–4.35%), Nergiz and Yildiz [1997] (3.20–4.00%) and Bozhkova [2014] (3.15–3.73%), respectively in USA for cultivars of *Prunus salicina*, in Turkish for European plum varieties (*Prunus domestica* L.) and in Bulgaria for plum cultivars of *Prunus domestica*.

The titratable acidity values (0.78 to 1.78%) recorded in this study were similar to that reported by Lozano et al. [2009] (0.85–1.85%) in Spain, Bozhkova [2014] (0.55–1.28%) in Bulgaria, but they are higher than that found in American plum cultivars (0.31–0.48%) by Gil et al. [2002], in Romanian cultivars (0.34–0.77%) by Ionica et al. [2013], and lower than that obtained in Pakistan cultivars (1.49–2.34%) by Nisar et al. [2015], in Turkish cultivars (0.92–2.34%) by Nergiz and Yildiz [1997].

The vitamin C of plum showed a wide variation depending on cultivars ranging from 105.60 to 249.33 mg/kg, these values are within the range of consulted literature concerning Turkish cultivars (58.2–284.2 mg/kg) by Nergiz and Yildiz [1997], and higher than that obtained by Nisar et al. [2015] (52.51–137.6 mg/kg) in Pakistan, Gil et al. [2002] (20.5–102 mg/kg) in Spain and Bozhkova [2014] (33.6–119.2 mg/kg) in Bulgaria. Then plum is a good source of vitamin C, which plays multiple role, as antioxidant compound, and required for the creation of neurotransmitters and collagen, the main protein in our skin [Li and Schellhorn 2007]. The daily intake for adults of vitamin C is of about 75–90 mg, so consumption plum can fulfill this daily need.

The total soluble solids content recorded (5.72–10.14%) is low compared to that found in Pakistan cultivars (8.17–16.23%) by Nisar et al. [2015], in Bulgarian cultivars (15.6–22.19%) by Bozhkova [2014], in Romanian cultivars (12.40–20.43%) by Ionica et al. [2013] and in Poland cultivars (15.1–21,4%) by Głowacka and Rozpara [2017].

The fresh plum had low protein content (0.51–0.88%) which is similar to that obtained by Lozano et al. [2009] (0.38–0.96%) in Spain, Rop et al. [2009] (0.63–0.79%) in Czech Republic and Nergiz and Yildiz [1997] (0.59–1.09%) in Turkish, but is low to that presented by Ertekin et al. [2006] (2.81–3.88%) for 2 plum cultivars of *Prunus domestica* in Turkish.

The plum cultivars in this study were revealed very high in natural sugars varying from 34.63 to 93.04 mg/g, which are approximate to that found by Nisar et al. [2015] (67.17–105.07 mg/g), Bozhkova [2014] (69.6–123.1 mg/g), and low than that reported by Nergiz and Yildiz [1997] (64–147.4 mg/g). Therefore, dry matter was the predominant component in all plum cultivars, followed by total solid soluble, sugar, ash, protein and fiber and this decreasing order of proximate composition is in line with that released by USDA [2018] except for the ash which are classified after proteins.

The total polyphenols for Moroccan plum cultivars presented a strong association with antioxidant activity (r = 0.68**). This result is congruent with that found by Gil et al. [2002] (r = 0.94) in American plum. The phenolic content ranged between 3.15 and 9.39 mg GAE/g. These findings are similar to that found by Nisar et al. [2015] (2.63–9.92 mg/g) for Pakistan plum and Rop et al. [2009] (2.27–4.95 mg/g) for Czech Republic plum, but are higher than those found by Gil et al. [2002] (0.42–1.092 mg/g), Kim et al. [2003a, 2003b] (1.74–3.75 mg/g; 1.25–3.726 mg/g) for USA plum and Lozano et al. [2009] (0.945–2.024 mg/g) for Spanish plum. The different levels of phenolic content may be result from cultivars, geographic origin, growing seasons, other agricultural practices, and differences in analytical methods [Kim et al. 2003b]. One of the main potential health benefits of phenolic compounds in vegetables and fruits is their antioxidant activity, which protects low-density lipoproteins (LDL) from oxidation which is an important factor in the prevention of cardiovascular disease [Byrne et al. 2008].

The antioxidant activity of plum was assessed by scavenging activity on DPPH radicals which varied between 42.19% and 70.65%. The present result according with the one published by Nisar et al. [2015] (60–73%) for the plum cultivars from Pakistan. It is worth mentioning that the antioxidant activity of plum is higher than that of nectarine and peaches [Gil et al. 2002]. Antioxidants in fruits have the ability to produce resistance in the tissues against diseases and stress conditions [Nisar et al. 2015].

The flavonoids are generally responsible of the prevention of fat oxidation, and the protection of vitamins and enzymes, thereby contribute to the disease protection. The flavonoids have extensive biological properties that promote human health and reduce the risk of diseases [Tiwari and Husain 2017]. The flavonoids content in this work reached 0.21–2.78 mg CE/g, result that is similar to that obtained by Kim et al. [2003b, 2003a] (0.648–2.575 mg/g; 1.18–2.37 mg/g) for USA plum cultivars.

Anthocyanin plays a beneficial role in human health and has been found to be essential compounds endowing with antioxidants activity [Cevallos-Casals et al. 2006]. The anthocyanin range values (97.26–200.60 mg/100 g), were higher than these reported by Nisar et al. [2015] (14.23–212.38 mg/100 g) and by Cevallos-Casals et al. [2006] (33–173 mg/100 g), respectively in Pakistan for 16 cultivars of *Prunus domestica* and in USA for 14 red plum of *Prunus salicina*.

High level for the major minerals potassium and magnesium were found in Moroccan plum cultivars. The Moroccan plum was revealed very rich in potassium (178.36–283.58 mg/100 g) in comparison with several plum (Rop et al. [2009]; 159.63–397.63 mg/100 g in Czech Republic, Nergiz and Yildiz [1997]; 160.17–313.52 mg/100 g in Turkish, Lombardi-Boccia et al. [2004]; 174 mg/100 g in Italy). The high potassium content in plums was shown to have a positive effect on human health, mainly in the field of prevention of cardiovascular disease [Stacewicz-Sapuntzakis et al. 2001].

The magnesium helps to maintain normal nerve and muscle function, supports a healthy immune system, keeps the heartbeat steady, and helps bones remain strong. The magnesium values found (13.56–22.30 mg/100 g) in Moroccan plums are higher than those reported by Rop et al. [2009] (6.44–11.62 mg/100 g) for Czech Republic plum, Lombardi-Boccia et al. [2004] (4.9 mg/100 g) for Italian plum and USDA National Nutrient Database for Standard Reference (5–9 mg/100 g) in 2018, but lower to those reported by Ertekin et al. [2006] (23–26 mg/100 g) in Turkish plum.

The manganese element is one of the most microelement found (0.18–0.90 mg/100 g), with values according with those reported by Ertekin et al. [2006] (0.26–0.37 mg/100 g), and higher to that reported by USDA (0.018–0.094 mg/100 g). The manganese assists in carbohydrate, amino acid and cholesterol metabolism. The recommended daily allowance for adults of manganese spread from 1.8 mg to 2.3 mg, and the consumption of plum can fulfill these daily values. As regards the others micronutrient contents, the copper (1.07–1.22 mg/100 g) was higher than that established by USDA Food Composition Database [2018] (0.015–0.151 mg/100 g), and lower than that reported by Ertekin et al. [2006] (1.38–4.64 mg/100 g). The copper presented a high correlation with iron (r = 0.92***). It is required for connective tissue formation, as well as normal brain and nervous system function. The daily intake recommendation for a human adult is about 900 µg, and the consumption of plum covers this recommended daily.

The iron element needed for synthesis of hemoglobin, assists antioxidant enzymes and in the creation of certain hormones [Aggett 2012]. The iron values in Moroccan plum cultivars (1.12–1.78 mg/100 g) were generally higher to that reported by USDA (0.07–0.59 mg/100 g) and by Nergiz and Yildiz [1997] (0.115–0.943 mg/100 g), and lower to that obtained by Ertekin et al. [2006] (2–2.1 mg/100 g).

Zinc content (2.02–0.849 mg/100 g) was similar to that presented by Ertekin et al. [2006] (1.12–1.47 mg/100 g), and higher to that reported by USDA [2018] (0.04–0.3 mg/100 g). It is necessary for normal growth, immune function and wound healing.

Appreciable level of nickel was determined in studied cultivars with an average of 1.09 mg/100 g. In human body, nickel is used for increasing iron absorption, preventing anemia, and treating weak bones. This element showed a high association with copper (r = 0.85***) and iron (r = 0.82***). The descending order of mineral elements contents (mg/100 g) in Moroccan plum was K > Mg > Fe > Zn > Cu > Ni > Mn, while it was K > P > Mg > Ca > Fe > Zn > Cu > Mn released by USDA [2018], K > Mg > Fe > Cu > Zn > Mn for Turkish plum [Ertekin et al. 2006] and K > P > Mg > Ca > Na for Czech Republic plum [Rop et al. 2009].

The hierarchical cluster and PCA plot show that the plum cultivars were grouped independently of their geographical origin. This result is in accord once with that obtained by Ait Bella et al. [2018] by analyzing 30 plum cultivars using pomological and morphological parameters, and among them 15 have been concerned in this study

CONCLUSIONS

It may be concluded that Moroccan plum cultivars is rich by nutritional and chemical constituents. This results show the importance of choosing the best and the most useful cultivars for the consumption. Moreover, they can be considered as a good source of the naturals compounds with antioxidant activity. High variability was found between studied cultivars for the most biochemical and mineral traits. This variability could be attributed chiefly to genetic factors in conjunction with harvesting year, environmental conditions, soil elemental composition, maturity level and the method of cultivation. In addition, Lmozari cultivar has presented high values of vitamin C, protein, phenolic content, flavonoid, copper and iron. Then it should be considered as the best cultivars to be useful. The plum cultivars revealed a significant richness of mineral elements, essentially potassium, copper, manganese. The plum consumption can cover a part of recommended daily intake.

SOURCE OF FUNDING

This work was supported by the Moroccan Ministry of Higher Education through project's University of Sultan Moulay Sliman, Beni Mellal, Morocco.

REFERENCES

Aggett, P.J. (2012). Iron. In: Erdman, J.W., Macdonald, I.A., Zeisel, S.H. (eds). Present knowledge in nutrition. 10th ed. Washington, DC, Wiley-Blackwell, pp. 506–520.

Ait Bella, Y., Bouda, S., Haddioui, A. (2018). Phenotypic diversity analysis of plum (*Prunus domestica* L.) cultivars. Phytomorphology 68 (3–4), 93–101.

AOAC (1995). Official methods of analysis. 16th ed. Association of Official Analytical Chemists, Washington, DC, USA.

Aryapak, S., Ziarati, P. (2014). Nutritive value of Persian walnut (*Juglans regia* L.) orchards. Am.-Eur. J. Agric. Environ. Sci., 14(11), 1228–1235. https://doi.org/10.5829/idosi.aejaes.2014.14.11.12438

Bozhkova, V. (2014). Chemical composition and sensory evaluation of plum fruits. Trakya Univ. J. Natural Sci., 15(1), 31–35.

Byrne, D., Cisneros-Zevallos, L., Ramming, D. (2008). Cardiovascular health benefits of peaches and plums. California Tree Fruit Agreement, 65–85.

Cevallos-Casals, B.A., Byrne, D.H., Okie, W.R., Cisneros--Zevallos, L. (2006). Selecting new peach and plum genotypes rich in phenolic compounds and enhanced functional properties. Food Chem., 96(2), 273–280. https://doi.org/10.1016/j.foodchem.2005.02.032

Dubois, F., Gilles, X.A., Hamilton, J.K., Rebecs, P.A, Smith, F. (1956). Colorimetric method for determination of sugars and related substances. Analyt. Chem., 28, 350–356.

Ertekin, C., Gozlekci, S., Kabas, O., Sonmez, S., Akinci, I. (2006). Some physical, pomological and nutritional properties of two plum (*Prunus domestica* L.) cultivars. J. Food Engin., 75(4), 508–514. https://doi.org/10.1016/j.jfoodeng.2005.04.034

FAO, 2018. FAOSTAT Crops. http://faostat.fao.org/beta/en/#data/QC [date of access: May 2020].

Gil, M.I., Tomás-Barberán, F.A., Hess-Pierce, B., Kader, A.A. (2002). Antioxidant capacities, phenolic compounds, carotenoids, and vitamin C contents of nectarine, peach, and plum cultivars from California. J. Agricult. Food Chem., 50(17), 4976–4982. https://doi.org/10.1021/jf020136b

Głowacka, A., Rozpara, E. (2017). Evaluation of several dessert cultivars of plum, new under climatic conditions of Poland. Hort. Sci. (Prague), 44(3), 126–132. https://doi.org/10.17221/38/2016-HORTSCI

Hatano, T., Kagawa, H., Yasuhara, T., Okuda, T. (1988). Two new flavonoids and other constituents in licorice root: their relative astringency and radical scavenging effects. Chem. Pharm. Bull., 36(6), 2090–2097. https://doi.org/10.1248/cpb.36.2090

Hummer, K.E., Janick, J. (2009). Rosaceae: taxonomy, economic importance, genomics. In: Kevin, M.F., Susan, E.G. (eds). Genetics and genomics of Rosaceae. Springer, New York, pp. 1–19.

Ionica, M.E., Nour, V., Trandafir, I., Cosmulescu, S., Botu, M. (2013). Physical and chemical properties of some European plum cultivars (*Prunus domestica* L.). Notulae Bot. Horti Agrobot. Cluj-Napoca, 41(2), 499–503. https://doi.org/10.15835/nbha4129354

Jabeen, Q., Aslam, N. (2011). The pharmacological activities of prunes: The dried plums. J. Med. Plants Res., 5(9), 1508–1511.

Jia, ZS., Tang, M.C., Wu, J.M. (1999). The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chem., 64(4), 555–559. https://doi.org/10.1016/S0308-8146(98)00102-2

Kim, D.-O., Jeong, S.W., Lee, C.Y. (2003a). Antioxidant capacity of phenolic phytochemicals from various cultivars of plums. Food Chem., 81(3), 321–326.

Kim, D.-O., Chun, O.K., Kim, Y.J., Moon, H.Y., Lee, C.Y. (2003b). Quantification of polyphenolics and their antioxidant capacity in fresh plums. J. Agricult. Food Chem., 51(22), 6509–6515. https://doi.org/10.1021/jf0343074

Leong, L.P., Shui, G. (2002). An investigation of antioxidant capacity of fruits in Singapore markets. Food

Chem., 76(1), 69–75. https://doi.org/10.1016/S0308-8146(01)00251-5

Li, Y., Schellhorn, H.E. (2007). New developments and novel therapeutic perspectives for vitamin C. J. Nutr., 137(10), 2171–2184. https://doi.org/10.1093/jn/137.10.2171

Lombardi-Boccia, G., Lucarini, M. Lanzi, S., Aguzzi, A., Cappelloni, M. (2004). Nutrients and antioxidant molecules in yellow plums (*Prunus domestica* L.) from conventional and organic productions: a comparative study. J. Agric. Food Chem., 52(1), 90−94. https://doi.org/10.1021/jf0344690

Lozano, M., Vidal-Aragón, M.C., Hernández, M.T., Ayuso, M.C., Bernalte, M.J., García-Parra, J., Belén, V. (2009). Physicochemical and nutritional properties and volatile constituents of six Japanese plum (Lindl.) cultivars. Europ. Food Res. Technol., 228(3), 403–410. https://doi.org/10.1007/s00217-08-0946-3

Mikdat, S. (2010). Determination of walnut genotypes with high fruit bearing and quality in Dicle, Hani, Egil and Kocaköy townships. J. Agric. Fac. Gaziosmanpasa Univ., 27(1), 85–93.

Nergiz, C., Yildiz, H. (1997). Research on chemical composition of some varieties of European plums (*Prunus domestica*) adapted to the Aegean district of Turkey. J. Agricult. Food Chem., 45(8), 2820–2823. https://doi.org/10.1021/jf970032e

Nisar, H., Ahmed, M., Akbar Anjum, M., Hussain, S. (2015). Genetic diversity in fruit nutritional composition, anthocyanins, phenolics and antioxidant capacity of plum (*Prunus domestica*) genotypes. Acta Sci. Pol. Hortorum Cultus, 14(1), 45–61.

Ough, C.S., Amerine, M.A. (1988). Methods analysis of musts and wines. 2nd ed. John Wiley, New York, USA.

Oukabli, A., Mamouni, A. (2005). Le prunier. Variétés à pruneaux et de table [The plum tree. Prune and table varieties]. Transf. Technol. Agric. Bulletin mensuel d'information et de liaison du PNTTA, 126.

Peller, J.R. (1998). Exploring chemistry. Laboratory experiments in general, organic and biological chemistry. Prentice Hall, New Jersey, pp. 163–173.

Ranganna, S. (1955). Handbook of analysis and quality control for fruit and vegetable products. 2nd ed. Tata McGraw-Hills Publishing Company Limited, New Delhi.

Rop, O., Jurikova, T., MLcek, J., Kramarova, D., Sengee, Z. (2009). Antioxidant activity and selected nutritional values of plums (*Prunus domestica* L.) typical of the White Carpathian Mountains. Scientia Hortic. 122(4), 545–549. https://doi.org/10.1016/j.scienta.2009.06.036

Ruck, J.A. (1963). Chemical methods for analysis of fruit and vegetable products. Research Branch, Canada Department of Agriculture, Ottawa.

Singleton, V.L., Orthofer, R., Lamuela-Raventós, R.M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocâlteu reagent. Meth. Enzy- mol., 299, 152–178. https://doi.org/10.1016/S0076-6879%2899%2999017-1

Stacewicz-Sapuntzakis, M., Bowen, P.E., Hussain, E.A., Damayanti-Wood, B.I., Farnsworth, N.R. (2001). Chemical composition and potential health effects of prunes: a functional food. Crit. Rev. Food Sci. Nutr., 41(4), 251–286. https://doi.org/10.1080/20014091091814

Tiwari, S.C., Husain, N. (2017). Biological activities and role of flavonoids in human health, a review. Indian J. Sci. Res., 12(2), 193–196.

USDA [United States Department of Agriculture] (2018). Plums, food data central search results. Available: https://fdc.nal.usda.gov/fdc-app.htmL#/food-details/169949/nutrients [date of access: May 2020].

USDA, Agricultural Research Service 2017. High ORAC foods may stall aging. Available: https://www.ars.usda.gov/news-events/news/research-news/1999/high-orac-foods-may-slow-aging/ [date of access: 2020].

Walkowiak-Tomczak, D., Reguła, J., Łysiak, G. (2008). Physico-chemical properties and antioxidant activity of selected plum cultivars fruit. Acta Sci. Pol., Technol. Aliment., 7(4), 15–22.

Wrolstad, R.E. (1993). Color and pigment analyses in fruit products. Agric. Exp. Stat. Oregon State Univ., Station Bull., 624, pp. 4–11.

Xu, H.-X., Chen, J.-W. (2011). Commercial quality, major bioactive compound content and antioxidant capacity of 12 cultivars of loquat (Eriobotrya japonica Lindl.) fruits. J. Sci. Food. Agric., 91, 1057–1063.