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Physical and Chemical Properties of Some European Plum Cultivars (*Prunus domestica* L.)

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Abstract

Fruits from twelve plum cultivars (*Prunus domestica* L.), were analyzed in terms of physical and chemical characteristics. The fruits trees were grown in a trial at University of Craiova - Fruit Growing Research Station (SCDP) Valcea, which is located in Bujoreni, an important Romanian plum production area. Fruits were picked at harvest maturity. Several analyzes were performed, such as fruit linear dimensions, size index, fruit weight, dry matter, soluble solids content, titratable acidity, total anthocyanins, malic, tartaric and citric acids content. The best features in terms of physical and chemical properties proved to be found in 'Alina', 'Alutus', 'Tuleu Timpuriu', 'Oltenal' and 'Renclod Althan'.

Keywords: chemical properties, cultivars, physical properties, plum

Introduction

Plums are a large and botanically diverse group of stone fruits with several named varieties being selected from over a dozen different of *Prunus* species. Currently, cultivated varieties are also diverse in their environmental preferences, as specific varieties have adapted to various climatic conditions throughout the entire temperate fruit-growing zones (Gomez-Plaza and Ledbetter, 2010). Plum trees can grow over the five continents of the world and production level exceeds 11 million tons (Milošević *et al*., 2012). Plum is a fruit crop quite spread on Earth, especially in the temperate Northern hemisphere, ranking fourth after apple, peach and pear (Visanu *et al*., 2012).

The common garden plum, *P. domestica* L., is known for its diversity of fruit sizes, colors and flavors and is one of the most desirable plum species in terms of fruit quality (Gomez-Plaza and Ledbetter, 2010)

Of the 23.8 million ha representing Romanian's territory, 61.7% is represented by the agricultural acreage of the country of which 1.5% is covered by the fruit orchards and nurseries. Among the fruit species grown in our country, the *European plum* (*P. domestica* L.) is the predominant species representing a food source, and at the same time providing profits to the population (Coman *et al*., 2012). Regarding the cultivar, assortment has been improved numerically and qualitatitively especially with cultivars bred and named in Romania, such as: 'Centenar', 'Silvia', 'Carpatin', 'Andreea' and 'Record'.

Due to the abundance of bioactive compounds as anthocyanins, pectins, carotenoids, plums constitute a valuable component of our diet, in terms of their nutritive and dietary value (Ionica *et al*., 2012). Also, plums are a source of vitamin A, calcium, magnesium potassium and fiber (Milošević and Milošević, 2012) and contain relatively large amounts of carbohydrates, constituting a source of available energy (Walkowiak-Tomczak, 2008). Furthermore, plums contain high amounts of antioxidant compounds (Auger *et al*., 2004). Also plums contain low amounts of vitamin C (Kazimierczak *et al*., 2006) and they represent an important source of boron.

The necessity of improving fruit quality is a priority for the modern plum culture. The changes into plum culture completed with new varieties assortments need new researches concerning the chemical composition of the fruits according with the various ecological conditions.

When growing introduced plum cultivars, it is important to determine their characteristics under local conditions such as fruit quality respectively chemical composition.

Several researches were made concerning the quality and the physical and chemical properties of plum fruits in various ecological conditions (Vitanova *et al*., 2004: Walkowiak-Tomczak, 2008: Vangdal *et al*., 2007: Usenik *et al*., 2009: Rop *et al*., 2009).

The aim of this paper is to characterize the physical and chemical properties of some plum varieties grown in the climatic conditions of Valcea County, Romania.

Materials and methods

Fruits belonging to twelve plum cultivars (*P. domestica* L.), were analyzed in terms of physical and chemical characteristics. Fruits were picked at harvest maturity. Several

analyzes were performed: dimensions, size index, average fruit weight, dry matter, soluble solids, titratable acidity, total anthocyanins, malic, tartaric and citric acids content.

Plums were grown in a trial at University of Craiova - Fruit Growing Research Station (SCDP) Valcea, located in Bujoreni, an important plum production area. To mention that more then 6.4% of the Romanian plum production is located in Valcea County.

The climate is characterized by an annual average temperature over 10.2 °C, without polar cold air invasions occurring during winter. The temperatures below -20 °C are rare. The average annual rainfall varies from 714 to 754 mm. Yet they are also negative characteristics such as: fragmented land and low productivity soils.

In this count almost all cultivars of temperate climate are grown, fruits having intense color and good density (Botu *et al*., 2012). Orchard management was consistent with cultural practice (summer pruning, fertilization with: ammonium nitrate 120 kg/ha, 75 kg/ha of P_2O_5 and 80 kg/ha of K_2O, pest and disease control), without irrigation in alluvial soil with pH 6.3.

The experiment was set up as a randomized block design in five replicates with 2 trees per cultivar. For evaluation, fruits of each cultivar from 2 trees (thirty fruits per tree) in five replicates were collected.

Plant material

Twelve plum cultivars were studied; nine of them are Romanian varieties or selections: 'Andreea': Romanian cultivar registered in 2000 by SCDP Valcea; ripening in the second half of August, medium size fruit (45 g) with high sugar content. 'Tuleu Timpuriu': Romanian cultivar, ripening in early August; the fruit is medium sized (35-45 g), ovoid asymmetric; the skin is purple and the flesh is yellowish-green, juicy with equilibrate taste. 'Tuleu de Sinesti': local Romanian cultivar; the fruits ripen in second half of august; fruit quality is very good; the fruit is medium sized, ovoid weight (28 g); fruit skin is purple-blue with defined fruit bloom and the flesh is yellowish-green, juicy with balanced taste. 'Tuleu Gras cl. 14': clonal selection of well known Romanian Tuleu gras cv.; fruits ripen in second half of August; the fruit is medium sized, ovoid, weight (32g); skin color is blue with defined fruit bloom; fruit flesh is yellowish-green, juicy, firm, balanced taste. 'Bărăgan 17': Romanian cultivar, with large fruits weight 40-50 g, ovoid with dark blue skin; the flesh is yellowish-green used for fresh consumption and cans industry; ripen in early August. 'Renclod Althan': old plum cultivar from Central Europe; it has tasty fruits with a good flavor, weight 45-58 g, golden-yellow juicy flesh; ripening second half of August. 'Alutus': Romanian cultivar registered in 2010 by SCDP Valcea with very large fruit (74 g). 'Alina': Romanian cultivar with large fruits (45-55 g), ovoid; the fruit's skin is light blue with brown shades; the flesh is yellowish-green, crispy; the fruits are ripening in first decade of August. 'Oltenal': new Romanian plum cultivar registred by SCDP Valcea; it has large fruits (51 g); fruit skin color is blue-purple and covered with bloom; fruit flesh is yellowish-green. 'Flora': Romanian cultivar with large fruits (48-60 g), ovoid-round slightly flattened shape, blue skin color covered with blue-gray bloom; the flesh is greenish-white, crispy with harmonious taste. 'Reeves': cultivar from U.K.; the fruit is very large, round red-purple, with good flavor used as dessert. 'Excalibur': plum cultivar originated in U.K.; it has large fruits, with reddish-purple skin, ripening in early August.

Analytical methods

Fruit linear dimensions (length, L; width, W; thickness, T) were determined with a Luthier digital caliper manufactured by Stewart-MacDonald (USA) and the results were expressed as mm. Average fruit weight (g) was determined by individual weighing on an analytical scale model ABT 320-4M manufactured by Kern (Balingen, Germany). Size index was calculated using the formula: (L+T+W)/3.

The percentage of total dry matter was determined by removing water from the sample in an oven at 105 °C. Soluble solids content was measured with a digital refractometer (Hanna Instruments, Woonsocket, USA) in the juice pressed from the whole fruit, the results being expressed as percentages. The titratable acidity was determined by titration of a known amount of water extract of fruits with 0.1 N NaOH using phenolphthalein as indicator and it was expressed as g malic acid/100 g fresh matter.

Determination of total anthocyanins

Total anthocyanins content was measured with the pH differential absorbance method, as described by Cheng and Breen (1991). The absorbance of the extract from 1g of fruits skin, was measured at 510 and 700 nm in buffers at pH 1.0 (hydrochloric acid-potassium chloride, 0.2 M) and pH 4.5 (acetate acid-sodium acetate, 1M). Anthocyanins content was calculated using a molar extinction coefficient of 29,600 (cyaniding-3-glucoside) and absorbance of A = [(A510 – A700)pH 1..0- (A510 – A700)pH 4.5]. Results were expressed as mg cyanidin-3-glucoside equivalents/100 g fresh weight.

Determination of tartaric, malic and citric acids

Five g of whole fruits were homogenized to puree in a porcelain mortar and diluted to 100 mL with 0.1 N HCl. After 30 min, the extraction solution was centrifuged at 4200 rpm for 10 min. The supernatant was filtered through a 0.2 μm pore-size filter.

Organic acid contents were determined by reversed-phase HPLC on a Surveyor Thermo Electron system equipped with a Diode Array Detector (DAD) using a Hypersil Gold aQ column (25 cm x 4.6 mm) with a particle size of 5 μm. A 50 mM water solution of KH_2PO_4 buffer at pH 2.8 was used as the mobile phase. The column

Tab. 1. Physical properties of plums

Cultivar	Width (W) (mm)	Thickness (T) (mm)	Length (L) (mm)	Size index	Weight (g)
'Andreea'	39.30±3.41 ^{de}	37.98±3.44 ^{cd}	40.66±3.48 ^{bc}	39.31	35.32±7.51 ^{bc}
'Tuleu Timpuriu'	37.36±2.59 ^{cd}	35.72±2.93 ^{bc}	43.64±1.62 ^{de}	38.90	32.24±6.77 ^{abc}
'Tuleu de Sineşti'	33.95±1.83 ^{b}	32.90±1.96 ^{b}	42.61±2.13 ^{cd}	36.49	26.80±3.89 ^{a}
'Tuleu Gras cl. 14'	35.20±1.41 ^{bc}	33.46±1.07 ^{b}	44.18±1.58 ^{de}	37.62	29.48±2.00 ^{ab}
'Bărăgan 17'	40.2±2.08 ^{de}	39.32±2.03 ^{de}	46.00±1.94 ^{ef}	41.85	40.12±4.66 ^{cd}
'Renclod Althan'	44.18±1.68 ^{f}	41.02±2.06 ^{ef}	39.25±1.06 ^{b}	41.48	41.22±4.16 ^{cd}
'Alutus'	44.452±2.19 ^{f}	43.31±2.34 ^{f}	51.68±2.22 ^{g}	46.48	52.96±7.54 ^{e}
'Alina'	48.69±2.03 ^{g}	47.03±1.43 ^{g}	57.35±3.31 ^{h}	51.02	71.70±8.56 ^{f}
'Oltenal'	23.29±2.10 ^{a}	22.84±2.10 ^{a}	29.21±2.00 ^{a}	25.11	48.20±6.27 ^{de}
'Flora'	40.67±0.71 ^{e}	40.02±0.46 ^{de}	39.65±0.73 ^{b}	40.11	44.96±1.53 ^{de}
'Reeves'	52.32±3.43 ^{h}	51.368±2.90 ^{h}	47.9±1.69 ^{f}	50.55	74.20±11.35 ^{f}
'Excalibur'	40.29±2.41 ^{e}	39.27±2.22 ^{de}	39.86±1.16 ^{b}	39.80	68.62±8.37 ^{f}

*Values in the same column followed by different letters are significantly different at P < 0.05

temperature was kept at 10 °C and the flow rate at 0.7 mL · min^{-1}. Detection of organic acids was at 254 nm and all the results were expressed in mg/100 g fresh weight.

Statistical analyses

Data were evaluated by one-way analysis of variance (ANOVA) using Statgraphics Centurion XVI Software (StatPoint Technologies, Warrenton, VA, USA). Differences in physical features and content levels among the cultivars were estimated using the least significant difference test (LSD) at P < 0.05.

Results and discussions

Varietal variation within plums cultivars results from their dimensions and weight (Tab. 1). The width ranged from 23.29 mm in 'Oltenal' to 52.32 mm in 'Reeves' with significant differences between each cultivar except the plums from 'Tuleu' group ('Tuleu Timpuriu', 'Tuleu de Sineşti', 'Tuleu Gras cl. 14'). The same variation is shown in terms of the thickness. The plums length ranged from 29.21 mm in 'Oltenal' to 57.35 mm in 'Alina'. In terms of fruit weight there are significant differences amongst cultivars. The fruit weight ranged from 26.8 g in 'Tuleu de Sineşti' up to 74.20 g in 'Reeves' values.

Also notice from the data presented that the fruits of 'Oltenal' have small size (size index 25.11) compared with Reeves (size index 50.55) and 'Alutus' (size index 46.48). The small size of 'Oltenal' fruits leads to the conclusion that this variety had problems during the season most likely due to the lack of irrigation. Beside dimensions and fruits weight the most important criteria of the consumer's acceptance of the fresh fruits are the chemical constituents that give the taste.

Significant differences of the chemical composition among the cultivars were observed (Tab. 2). The dry matter content ranged from 15.71% in 'Tuleu Timpuriu' to 25.2%

Tab. 2. Chemical properties of plums

Cultivar	Dry matter (%)	Soluble solids (%)	Titratable acidity (g malic acid·100g^{-1} fresh matter)	Total anthocyanins (mg cyanidin-3-glucoside equivalents/100 g fresh weight)
'Andreea'	20.93±0.79 ^{g}	14.70±0.26 ^{ab}	0.67±0.02 ^{e}	2.59±0.099 ^{b}
'Tuleu Timpuriu'	15.71±0.074 ^{bcd}	14.73±0.55 ^{ab}	0.45±0.01 ^{b}	198.89±0.96 ^{j}
'Tuleu de Sineşti'	25.20±1.021 ^{i}	20.4 3±1.25 ^{e}	0.73±0.038 ^{f}	11.38±0.42 ^{c}
'Tuleu Gras cl. 14'	22.59±0.66 ^{h}	17.60±0.72 ^{cd}	0.83±0.04 ^{h}	49.87±0.98 ^{f}
'Bărăgan 17'	18.12±0.18 ^{e}	14.50±0.72 ^{ab}	0.45±0.009 ^{b}	86.18±1.03 ^{h}
'Renclod Althan'	19.00±0.51 ^{f}	15.14±1.46 ^{b}	0.34±0.008 ^{a}	0.41±0.00 ^{a}
'Alutus'	15.63±0.39 ^{bc}	14.46±1.15 ^{ab}	0.56±0.009 ^{d}	121.13±1.09 ^{i}
'Alina'	22.55±0.19 ^{h}	19.13±2.14 ^{de}	0.77±0.031 ^{g}	62.72±1.003 ^{g}
'Oltenal'	14.75±0.20 ^{ab}	12.58±3.2 ^{a}	0.48±0.01 ^{bc}	10.11±0.90 ^{c}
'Flora'	13.76±0.52 ^{a}	12.40±1.21 ^{a}	0.37±0.00 ^{a}	41.19±1.005 ^{e}
'Reeves'	16.99±0.33 ^{de}	15.43±0.77 ^{bc}	0.50±0.009 ^{c}	13.56±0.09 ^{d}
'Excalibur'	16.22±0.58 ^{cde}	13.80±1.15 ^{ab}	0.50±0.009 ^{c}	0.41±0.01 ^{a}

*Values in the same column followed by different letters are significantly different at P < 0.05

in 'Tuleu de Sineşti'. The soluble solids content varied between 12.40% in 'Flora' and 20.43% in 'Tuleu de Sineşti', values close to those presented by Vangdal *et al*. (2007). Plums with less than 12.5% soluble solids are unacceptable to most consumers (Vangdal, 1980). On the other hand the high value found in 'Tuleu de Sineşti' show that fruits were over matured at the time of harvesting. One can also notice the high variability amongst cultivars.

The titratable acidity of plums varied between 0.34 g malic acid·100g^{-1} fresh matter in 'Renclod Althan' and 0.77 g malic acid·100 g^{-1} fresh matter in 'Alina'. The acidity of fruits is given by the organic acids present in fruits especially malic, tartaric and citric acids.

Anthocyanins are some of the most important chemical constituents of plums. They give the colour of the fruits skin which can attract the consumer. The total anthocyanins content in fruits skin ranged from 0.41 mg cyanidin-3-glucoside equivalents per 100 g fresh matter in 'Renclod Althan' to 198.89 mg cyanidin-3-glucoside equivalents per 100 g fresh matter in 'Tuleu Timpuriu'. These high differences amongst cultivars were observed by the different colour of the fruits which varied from golden – yellow in 'Renclod Althan' until dark purple in 'Tuleu Timpuriu', values which are in accordance with the results presented by Tomas-Barberan *et al*. (2001).

It also shows that malic acid is the predominant acid in plums registering the highest content values amongst all cultivars (Tab. 3) to the detriment of tartaric and citric acid, values which are in line with the results presented by Usenik *et al*. (2008). The highest content of malic acid was found in 'Tuleu Gras cl. 14' (780.07 mg/100 g fresh matter) and the lowest values in 'Renclod Althan' (177.53 mg/100g fresh matter). Yet, the low value of malic acid content in 'Renclod Althan' plums is compensated by the tartaric acid content which recorded the highest value of all of the cultivars i.e. 175.63 mg/100g fresh matter. As for the citric acid content in plums, the lowest values compared with malic and tartaric acid for all cultivars range from 10.49 mg/100g fresh matter in 'Alina' to 83.80 mg/100g fresh matter in 'Oltenal'.

Tab. 3. Organic acids content of plums

Cultivar	Tartaric acid (mg/100 g fresh matter)	Malic acid (mg/100 g fresh matter)	Citric acid (mg/100 g fresh matter)
'Andreea'	36.31±0.66 ^{b}	627.02±1.90 ^{i}	32.34±0.99 ^{e}
'Tuleu Timpuriu'	34.02±0.51 ^{a}	469.52±1.40 ^{g}	52.70±1.16 ^{j}
'Tuleu de Sineşti'	97.02±0.70 ^{g}	363.48±1.14 ^{f}	33.93±0.91 ^{ef}
'Tuleu Gras cl. 14'	82.11±0.76 ^{e}	780.07±2.00 ^{j}	37.31±0.93 ^{h}
'Bărăgan 17'	51.73±0.31 ^{c}	352.73±1.007 ^{d}	35.61±0.90 ^{g}
'Renclod Althan'	175.63±0.87 ^{k}	177.53±0.80 ^{a}	26.35±0.88 ^{d}
'Alutus'	96.92±0.66 ^{g}	469.82±0.99 ^{g}	42.41±1.005 ^{i}
'Alina'	98.62±0.69 ^{h}	483.38±0.77 ^{h}	10.49±0.88 ^{a}
'Oltenal'	86.60±0.57 ^{f}	315.95±1.002 ^{c}	83.80±1.226 ^{k}
'Flora'	154.98±0.81 ^{j}	249.9±0.93 ^{b}	34.37±0.90 ^{fg}
'Reeves'	101.54±0.61 ^{i}	361.31±0.88 ^{e}	21.33±0.73 ^{c}
'Excalibur'	64.15±0.44 ^{d}	317.84±0.75 ^{c}	15.35±0.93 ^{b}

*Values in the same column followed by different letters are significantly different at P < 0.05

Conclusions

All studied plums cultivars had physical and chemical properties which make them suitable to be grown in Romania. Nevertheless, the Romanian cultivars showed a better adaptability to the climatic conditions in this region. A few cultivars might be less accepted for fresh consumption due to their low soluble solids content and high acidity. This was the case of 'Flora'. The study showed the importance of choosing the best cultivars for the consumption acceptance and profitability. The most suitable plums cultivars in terms of physical and chemical characteristics proved to be 'Alina', 'Alutus', 'Tuleu timpuriu', 'Oltenal' and 'Renclod Althan'.

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