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PHYSICO-CHEMICAL PROPERTIES AND ANTIOXIDANT ACTIVITY OF SELECTED PLUM CULTIVARS FRUIT*

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Abstract. The aim of the study was to present and compare characteristics of pomological parameters, colour, dry matter and solids contents, as well as antioxidant activity of fruit of selected plum cultivars. Analyses were conducted on plums (*Prunus domestica*) of three cultivars: 'Węgierka Zwykła', 'Bluefre' and 'Elena'. Presented morphological parameters of fruit and stones included their length, width and weight, as well as mean fruit size and firmness. Fruit colour was measured by spectrophotometry in the L*a*b* system. Contents of dry matter and solids were determined in fruits. Moreover, Trolox-equivalent antioxidant capacity (TEAC) of plums was assayed by colorimetry using a cation radical ABTS. The biggest fruits were found for cv. 'Bluefre', while the highest value of dry matter and solids contents – in cv. 'Węgierka Zwykła'. Higher antioxidant activity (μM Trolox/g d.m.) was assayed in plums of relatively new cultivars, 'Bluefre' and 'Elena', in comparison to the traditional cultivar 'Węgierka Zwykła'.

Key words: plum, antioxidant activity, colour, physical and quality parameters

INTRODUCTION

Among fruit trees grown in Polish orchards, plums rank third after apple and cherry trees and Poland ranked 9th in Europe and 16th worldwide in terms of the volume of plum production in the years 2002-2006 [FAOSTAT... 2008].

Main processed products made from plums include compotes, mousse, pulp, dried and candied fruit, frozen fruit, jams, traditional Polish plum preserves "powidła" and alcoholic beverages. Thanks to their taste and dietary value they are willingly consumed by children and adults of different age groups. Plum fruit contain many sugars, organic acids and other compounds important from the dietary point of view. Plum is also an important export fruit, both fresh and frozen [Grzyb and Rozpara 2000].

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Plum trees in Poland are grown throughout the country both in commercial orchards and home gardens. The area of plum growing is gradually increasing after a collapse following a very harsh winter of 1986/87. The selection of cultivars, depending on local climatic and soil conditions, is of key importance in increasing the area and productivity of these cultures. We search for cultivars with attractive fruit, disease-resistant, productive, as well as those which may be kept in cold storage for a long time, since higher prices are paid for such fruit than for fruit at harvest time. Thus, one of the basic conditions determining profitability of plum production is the introduction of new, valuable cultivars suitable for intensive growing in commercial orchards.

The longer the period when a given plum cultivar is available on the market, the more competitive it is in terms of price in comparison to cultivars with a short keeping period. Consumer acceptance of plums is closely related with harvest date and maturation stage of fruit and their supply should be correlated with their potential keeping period, i.e. shelf life [Zuzunaga et al. 2001, Crisosto et al. 2004]. Consumers when making purchase decisions first of all evaluate the appearance of fruit and next its taste correlated with solids content and acidity [Crisosto et al. 2004]. Optimal harvest time guarantees fruit of good quality, with no unnecessary losses caused by physiological or fungal diseases [Taylor et al. 1993, Crisosto et al. 1995].

Plums have low calorie content and relatively high nutritive value. They contain carbohydrates, first of all sucrose, glucose and fructose, organic acids, e.g. citric and malic acids, fibre (pectins), tannins, aromatic substances and enzymes. These substances determine nutritive value and taste of plums [Ertekina et al. 2006]. This fruit is also rich in many minerals and vitamins (C, A, B_1, B_2, PP), essential for the appropriate functioning of the human organism. Contents of minerals in plums increase as fruits ripen. Plums contain the highest amounts of potassium, phosphorus, calcium and magnesium. Plums are fruit rich in phenolic compounds, characterized by relatively high antioxidant activity, higher than e.g. oranges, apples or strawberries [Kayano et al. 2002, Leong and Shui 2002]. These fruit influence peristaltic movements, slow down the absorption of carbohydrates, increase lipid breakdown in the human organism, enhance the sensation of satiety, reduce the levels of total cholesterol and its LDL fraction, blood serum triglycerol and homocystein concentrations and have a protective action on blood vessels. Due to the high potassium content and an advantageous sodium : potassium ratio, plums are recommended to patients suffering from arterial hypertension [Lucas et al. 2004, Tinker et al. 1991, 1994].

The aim of the study was to compare selected plum cultivars, both traditionally grown in Poland and those introduced relatively recently, in terms of their physicochemical properties and antioxidant activity.

MATERIALS AND METHODS

Material. Analyses were conducted on plums coming from the Agricultural and Fruit Farming Experimental Station in Przybroda, of the Department of Pomology, the Poznań University of Life Sciences. Fruit of the following plum cultivars: 'Bluefre', 'Elena' and 'Węgierka Zwykła' were tested. Fruit came from trees at full fruiting, growing on the Węgierka Wangenheima rootstock, on grey-brown podsolic soil at a 5 × 3 m spacing.

Analytical methods. Three linear dimensions of fruit, i.e. its length, width and thickness, as well as the length, width and thickness of fruit stones were measured using a caliper.

Individual fruit and stones were weighed using an electronic balance with sensitivity of 0.01 g.

Fruit skin colour was measured with a Konica Minolta CR-10 colorimeter under reflected light in the CIE L*a*b* system, where L* is lightness of colour, a* defines the proportion of red (positive values) and green colours (negative values), while b* defines the proportion of yellow (positive values) and blue colours (negative values). Parameters a* and b* define colour chromaticity, whereas parameter L* – its luminance, connected with the volume of the luminous flux, which is reflected from an object and reaches the eye of the observer.

Antioxidant activity was assayed by colorimetry using a cation radical of 2,2'-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid (ABTS), while results were expressed in equivalents of μM Trolox/g [Re et al. 1999]. Assays were performed in the methanol extract from comminuted fruit at a wavelength of 734 nm. Dry matter content was determined by gravimetry [PN-A-75101/03], while solids content by refractometry [PN--A-75101/02]. Determinations were performed for two batches of raw material with three replications each.

Firmness of fruit was measured on a randomly selected sample of 20 plums with an Effegi Penetrometr FT 327 mounted on a support. Measurements were taken twice on each fruit on its opposite sides.

RESULTS AND DISCUSSION

Fruit size is a varietal property, which may fluctuate depending on climatic and agricultural conditions as well as the number and position of fruit on a tree. The size of fruit may be expressed in terms of its weight or geometrical dimensions. Based on weight we distinguish very small fruit (5-10 g), small (10-20 g), medium-sized (20-40 g), rather large (40-50 g), large (50-60 g) and very large fruit (60-80 g). On the basis of mean geometrical size (height + thickness + width / 3) of plums we divide them into small (up to 30 mm), medium-sized (30-38 mm) and large fruit (38-45 mm) [Łucka 1994]. Among analysed cultivars the smallest fruit were found in cv. 'Węgierka Zwykła' (24 g and 36 mm), classified as small fruit of medium weight (Table 1). Cultivar 'Elena' had medium fruit in terms of weight (38 g) and large in terms of size (39 mm). The biggest fruit were reported for cv. 'Bluefre', with weight of 57 g and medium size of 45 mm, which classifies them as large fruit. According to Grzyb and Rozpara [2000], a plum of cv. 'Bluefre' may even weigh 70 g.

Tested plum cultivars differed considerably in terms of dry matter and solids contents. Fruit of cv. 'Węgierka Zwykła' and 'Elena' had comparable contents of dry matter and solids of 19% and 16-18°Brix, respectively. In turn, plums of cv. 'Bluefre' contained 12% dry matter and solids at 10°Brix, i.e. much less than the other two cultivars. However, it needs to be mentioned here that fruit size and dry matter content are highly variable parameters, dependent on weather conditions in a given vegetation season. Plums coming from the same orchards in previous years had different values of these parameters. In fruit of cv. 'Bluefre' a higher content of solids was recorded, approx.

Table 1. Characteristics of physical, chemical and quality parameters of plums during harvest

Pomological parameter	'Węgierka Zwykła'	'Bluefre'	'Elena'
Lenght of fruit, mm	47.15 ±5.4[a]	54.14 ±5.9[b]	44.65 ±4.5[a]
Width of fruit, mm	32.24 ±2.5[a]	43.20 ±4.3[b]	36.77 ±3.5[a]
Thickness of fruit, mm	31.12 ±4.6[a]	37.67 ±2.3[b]	35.6 ±4.6[a]
Lenght of stone, mm	30.35 ±4.2[a]	30.17 ±4.2[a]	30.00 ±4.0[a]
Width of stone, mm	12.07 ±1.7[a]	15.35 ±1.8[b]	13.02 ±1.5[a]
Mass of fruit, g	23.97 ±2.7[a]	57.70 ±5.5[b]	38.76 ±3.0[c]
Mass of stone, g	1.63 ±0.2[a]	2.44 ±0.3[b]	1.98 ±0.2[c]
Mean size, mm	36.84 ±4.1[a]	45.00 ±4.2[b]	39.01 ±4.2[a]
Firmness, N	28.53 ±5.2[a]	25.51 ±4.9[b]	18.63 ±4.6[c]
Dry matter content, %	19.9 ±0.47[a]	12.7 ±0.08[b]	19.1 ±0.12[c]
Extract content, Brix°	18.1 ±0.48[a]	10.3 ±0.35[b]	16.3 ±0.48[c]

Values followed by a difference letter within the same row are significantly different ($P < 0.001$).

14°Brix, at a lower fruit weight of 44-48 g [Łysiak 1999]. Similarly, plums of cv. 'Elena' were characterized by a higher solids content (19-22°Brix) and lower fruit weight (25-26 g), depending on harvest date, in comparison to the results reported in this study [Łysiak 2004]. Fruit size and contents of dry matter and solids are important fruit quality attributes. Especially these two latter characteristics determine the taste and processability of fruit; however, customers during purchase first of all pay attention to the size and colour of fruit. Larger fruit quench thirst more effectively, at the same time supplying fewer calories. Smaller fruit are generally sweeter, more suitable for processing, especially to produce dried fruit, i.e. prunes.

Fruit colour is one of the varietal characteristics of plums, thus its measurement is used when determining harvest date [Crisosto and Kader 2000]. Plums used in this study belong to cultivars with blue-navy blue coloured skin with light coating [Grzyb and Rozpara 2000]. Plum fruits were subjected to colour evaluation in the CIE L*a*b* system, measuring both fruit with a natural waxy coating and those with no coating, as it has a significant effect on colour parameters. In all case it was found that the L* value of fruit with coating was higher than that of fruit with no coating, whereas values of parameters a* and b* showed an opposite trend, i.e. had higher values for fruit with no coating (Table 2). This means that fruit with a waxy coating are characterized by bigger lightness and lower proportion of red colour than fruit with no coating, with shiny skin. Changes in parameter b*, from negative values for fruit with coating to positive values for fruit with no coating, show that as a result of coating removal the proportion of blue colour decreases, thus increasing the proportion of yellow colour. Based on determined values of colour parameters it may be stated that fruit of cv. 'Bluefre' had the darkest skin colour with the highest proportion of red and blue colours, which is probably connected with the highest content of anthocyanins in skin. However, such studies may be considered unreliable when comparing results of colour measurements with literature data, since other authors do not specify their measurement methods.

Table 2. Colour parameters of plums in harvest maturity stage

Cultivar	Colour parameters					
	with coating			no coating		
	L*	a*	b*	L*	a*	b*
'Wegierka Zwykła'	31.7 ±3.14[1]	4.3 ±1.61	–3.3 ±3.54	25.3 ±1.65	7.8 ±2.31	3.8 ±2.21
'Bluefre'	29.2 ±1.09	5.9 ±2.76	–5.0 ±1.93	26.1 ±0.82	11.4 ±0.71	4.0 ±1.75
'Elena'	34.8 ±3.10	4.2 ±1.30	–1.1 ±3.10	28.5 ±1.91	7.1 ±1.86	8.2 ±2.28

[1] Values represent means of 10 replications ± standard deviation.

Antioxidant activity in the analysed plum cultivars was around 17-20 µM Trolox/g f.w. (Fig. 1). The highest activity was recorded in plums of cv. 'Bluefre', while the lowest in cv. 'Węgierka Zwykła'. Due to the fact that fruit of tested cultivars differed considerably in terms of dry matter content, antioxidant activity was expressed in µM Trolox/g d.m., which makes it possible to compare analysed cultivars more precisely. The highest antioxidant activity was recorded for cv. 'Bluefre', at 159.0 µM Trolox/g d.m. Activity of the two other plum cultivars was much lower, amounting to 100.5 and 89.7 µM Trolox/g d.m., respectively, for cv. 'Elena' and 'Węgierka Zwykła'.

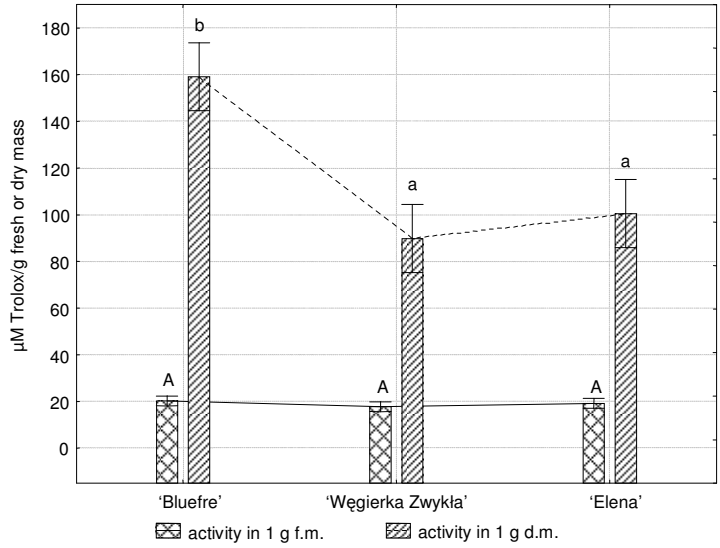

Fig. 1. Antioxidant activity in 1 g of fresh and dry mass of plums in dependent on cultivars (µM Trolox/g fresh or dry mass); a, b – significant

($p < 0.001$) different between antioxidant activity in 1 g dry mass of plums, A – non-significant difference between antioxidant activity in 1 g fresh mass of plums

It needs to be stressed that here antioxidant activity is correlated with values of colour parameter a, which reflects the proportion of red colour. Skin colouring in analysed plum cultivars is connected with the presence of anthocyanins, flavonoid pigments with high antioxidant activity [Borowska et al. 2005, Chun et al. 2003].

One of the most popular plum cultivars in Poland, i.e. 'Węgierka Zwykła', has very tasty fruit, highly valued by consumers, usually small in size, with a stone easily detached from the flesh, but it also exhibits relatively high susceptibility to plum brown rot (a dangerous viral disease of plum trees) and sensitivity to frost [Grzyb and Rozpara 2000]. Thus the area of its growing is decreasing in Poland. Moreover, results of this study show that this cultivar exhibited relatively low antioxidant activity, in terms of dry substance, in comparison to the other analysed cultivars. In this respect cv. 'Bluefre', with high antioxidant activity, should be recommended. Cultivar 'Bluefre' originates from the USA and it was introduced in Poland in the 1990's. Its advantages include high productivity, early fruiting and high weight of fruit with an excellent taste, at low susceptibility to plum brown rot and frost sensitivity [Łysiak 1999]. In turn, cv. 'Elena' comes from Germany, it is a hybrid of 'Węgierka Zwykła' × Stanley, in Poland introduced at the beginning of this century. Its advantage over 'Węgierka Zwykła' is its high tolerance to plum pox potyvirus (the most dangerous plum disease) and plum brown rot. Plum trees of cv. 'Elena' are characterized by high productivity, very tasty fruit with high solids content, excellent for processing and cold storage [Hartmann 1998].

CONCLUSIONS

1. Plums of new cultivars 'Elena' and 'Bluefre' were characterized by large fruit in comparison to fruit of cv. 'Węgierka Zwykła'.

2. Plums of cv. 'Węgierka Zwykła' and 'Elena' contained much more solids than cv. 'Bluefre'.

3. Values of colour parameters for plum skin depended on the method of measurement. Removal of coating from the skin resulted in a decreased value of colour lightness L*, at an increase in values of chromatic parameters a* and b*.

4. Plums of cv. 'Bluefre' had the darkest colour and the highest proportion of red and blue colour in skin, which is probably correlated with anthocyanins.

5. Plums of cv. 'Bluefre' exhibited much higher antioxidant activity (TEAC μM Trolox/g d.m.) in comparison to cv. 'Węgierka Zwykła' and 'Elena'.

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PARAMETRY FIZYKOCHEMICZNE I AKTYWNOŚĆ PRZECIWUTLENIAJĄCA OWOCÓW WYBRANYCH ODMIAN ŚLIWEK

Streszczenie. Celem pracy było przedstawienie i porównanie charakterystyki parametrów pomologicznych, barwy, zawartości suchej masy i ekstraktu oraz aktywności przeciwutleniającej owoców wybranych odmian śliwek. W badaniach użyto owoce śliwek (*Prunus domestica*) trzech odmian: 'Węgierka Zwykła', 'Bluefre' i 'Elena'. Przedstawiono parametry morfologiczne owoców i pestek, jak długość, szerokość i masę, a także średni wymiar owoców oraz ich jędrność. Mierzono barwę owoców spektrofotometrycznie w systemie L*a*b*. Oznaczono zawartość suchej masy i ekstraktu w owocach. Określono ponadto pojemność przeciwutleniającą śliwek (TEAC) metodą kolorymetryczną z użyciem kationorodnika ABTS. Największymi owocami cechowała się odmiana 'Bluefre', a największą zawartością suchej masy i ekstraktu odmiana 'Węgierka Zwykła'. Większą aktywność przeciwutleniającą [µM Trolox/g s.m.] stwierdzono w śliwkach stosunkowo nowych odmian 'Bluefre' i 'Elana', w porównaniu z tradycyjną odmianą 'Węgierka Zwykła'.

Słowa kluczowe: śliwka, aktywność przeciwutleniająca, barwa, parametry fizyczne i jakościowe

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