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Physico-chemical characterization for several Romanian plum cultivars at the time of harvest

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Abstract Fresh fruits are essential for the human diet, contributing with minerals, vitamins, and other organic compounds like polyphenols, which have an antioxidant effect on the human body. Fruits are both nourishing and improving overall health. Therefore, it is important to perform biochemical measurements at the time of fruit harvest to identify differences between different cultivars, to identify their best physico-chemical traits. Samples were collected for six Romanian plum (*Prunus domestica* L.) cultivars ('Gemenea', 'Record', 'Pescăruș', 'Brumării de Voinești', 'Elena', and 'Silvia') from the experimental orchard of University of Agronomic Sciences and Veterinary Medicine in Bucharest, in order to observe the fruit quality at the time of harvest. The measurements were performed in the Post-Harvest Technology Laboratory of the Research Center for Food and Agricultural Product Quality Studies - UASMV Bucharest. The quality indicators analysed for the six plum cultivars were height (mm), diameter (mm), shape index, fruit weight (g) and firmness (N/cm^2), total dry matter content (DM%), titratable acidity (TA), soluble solids content (Brix%), glucose (%), fructose (%), total anthocyanin content, total polyphenol content and antioxidant capacity (DPPH) at the time of harvest. Significant differences were observed for all plum cultivars, for all analyzes performed. The highest content in soluble solids was noted for the plums from 'Brumării de Voinești' cultivar and the highest firmness was registered for the 'Elena' cultivar. For Gemenea', and 'Elena' cultivars, positive correlations were recorded between antioxidant activity and the total polyphenol content.

Key words

fruit biochemical analyses**,**
fruit quality indicators**,**
nutraceutical,
Prunus domestica L.

Both vegetables and fresh fruits are essential for the human diet. They contribute minerals, vitamins, and other organic compounds. Fruits are nutritious as well as improve overall health (Rop et al., 2009) by their contribution such as polyphenols, which have an antioxidant effect on the human body. High nutritional levels of K, Mg and Ca reduce the risk of stroke, osteoporosis and high blood pressure, some researchers have concluded [17].

Scedei et al. (2021) claims that pedo-climatic factors influence the physico-chemical properties of fruits, which is why it is recommended to expand the range of local genotypes. The nutritional characteristics of some local varieties have been the subject of research for the physico-chemical determination that takes place during fruit ripening and storage [16; 23]. Therefore, it is important to perform biochemical measurements when harvesting fruits identify the differences between the different varieties, in order to identify their best physico-chemical traits.

Thus, in Romania, 75% of the total fruit production of 1058.5 thousand tons, are apples and plums, on the first place in the fruit production ranking the plum with 444.9 thousand tons [10]. Sumedrea et al. (2014) shows that orchards contribute to real progress through economic growth and reduction of rural poverty. Plums (*Prunus domestica* L.) are one of the most cultivated climatic fruits, on the first place for the yield of obtained fruit / cultivated area (Coman et al., 2012) in Romania, with innumerable local varieties [25; 5].

In Romania, more than 40 new plum varieties have been registered in 60 years of breeding activity, in different centers like Pitești, Vâlcea, Bistrița and Strejești, over 2,000,000 plum blossoms have been pollinated. About a thousand hybrids were obtained from the seeds of hybrids, which, due to their variability, allowed the selection of many valuable new hybrids [5].

In the first two stages of improvement (1955–1970), the varieties 'Tuleu timpuriu' (1967, 'Tuleu gras' x 'Peche'), 'Superb' (1968, 'Tuleu gras' x 'Abbaye d'Arton'), 'Gras ameliorat' ('Romanian fats' - self-pollination), 'Romanian eggplants 300' (1970, 'Vinete românești' - selection) and 'Tuleu dulce' (1968, 'Tuleu gras' x 'd'Agen') selected. As a basic parent, offering the largest number of promising selections was 'Tuleu gras' cultivar [5].

During this period, the varieties 'Renclod Althan', d'Agen', 'Early Rivers' and 'Wilhelmina Späth', used as parents of character, proved to be of great value. In the third stage of reproduction (1970–1980), the cultivars 'Silvia' (1978, 'Renclod Althan' x 'Early Rivers') and 'Pescăruș' (1979, 'Renclod Althan' x 'Wilhelmina Späth') were recorded [5].

In the fourth stage (1980–1990) the following varieties were recorded: 'Record' (1982, 'Renclod Violet' - open pollination), with large fruits and large yields. In the last stage (after 1990), which is still in progress, the highest number of cultivars was registered, such as 'Elena' (2005, 'Tuleu gras' x 'Stanley'), and some of registered varieties proved to be tolerant to plum pox virus in addition to their quality and high fruit yields [5].

Until recently, the aims of fruit tree breeders have been mainly the preservation of visual quality, as well as improving yield, disease resistance and postharvest life, in the detriment of flavour and nutritional value. However, nowadays, consumers are interested more and more in fresh products, and since visual quality and flavour quality usually are not positively correlated with postharvest life (Kyriacou & Rouphael, 2018), a new direction in plant breeding is needed.

The aim of this study was to characterize from physical and biochemical point of view 6 Romanian plum cultivars, obtained in the last 50 years, with the end goal of selecting the best cultivars as genitors to be used by the plant breeders for the creation of novel plum cultivars with improved organoleptic traits at the time of harvest.

Material and Method

Fruits from six Romanian plum (*Prunus domestica* L.) cultivars ('Gemenea', 'Record', 'Pescăruș', 'Brumării de Voinești', 'Elena', and 'Silvia') present in the experimental orchard of the University of Agronomic Sciences and Veterinary Medicine in Bucharest were harvested and analysed biochemically (Figure 1). In order to determine the quality of the fruits at the time of harvest, the measurements were performed in the Post-Harvest Technology Laboratory of the Research Center for Food and Agricultural Quality Studies - UASMV Bucharest.

For fruits' physical parameters analyses at the time of harvest, such as height (mm), diameter (mm), shape index, fruit weight (g) and firmness (N/cm^2), for five plum cultivars, ten fruits were used for an average sample.

The fruit shape index was determined by measuring the height (mm) and the diameter (mm) of the fruits with an electronic calliper with 0.1 mm accuracy [9]. The fruit weight was determined by a digital balance [21]. The dry matter was determined by drying the samples for 24 hours at 105°C using a UN110 Memmert oven, method used also by Bezdadea-Cătuneanu et al. (2017) and Stan et al. (2021). To determine the fruit firmness an electronic penetrometer TR was used, with a piston of 8 mm diameter, and the results were expressed in N/cm^2 [25].

Figure 1. The plum cultivars appearance

The fruit biochemical parameters analysed were total dry matter content (DM%), titratable acidity (TA), soluble solids content (Brix%), glucose (%), fructose (%), total anthocyanin content, total polyphenol content and antioxidant capacity (DPPH) at the time of harvest.

Soluble solids were determined from plums juice, with the refractive device Kruss DR301-95 (% Brix) [12; 14]. The contents of glucose and fructose were determined from 5 fruits for each sample with the refractive device Milwaukee MA873 (%) for glucose and with the refractive device Milwaukee MA872 (%) for fructose [7].

The titratable acidity was determined by titration of 5 g of fresh sample mixed with 25 mL bidistilled water with 0.1N NaOH, up to pH 8.1 [22; 20]. The titration was done with 0.1 N NaOH, with the automatic titrator TitroLine easy. The results were expressed in g malic acid/100 g fresh fruit [15; 24].

The total polyphenol content was determined using a modified Folin–Ciocâlteu method [1]. Briefly, the extract from 1 g fresh sample mixed with 10 mL of 70 % methanol, was incubated at room temperature (approximately 21°C), in the dark. After that, the samples were homogenised at 500 rpm for 1 hour, and centrifuged at 7000 rpm for 5 min at 4°C. The step was repeated two more times, recovering and re-extracting with supernatant the residue, up to 30 mL final volume. For spectrophotometric determinations, 0.5 mL of extract was mixed with 2.5 mL of Folin–Ciocâlteu reagent and incubated for 2 minutes at room temperature. Two mL of 7.5% Na_2CO_3 were added and the samples incubated at 50°C for 15 min. The wavelength used for measurements was λ = 760 nm. Results were expressed in mg GAE / 100 g fresh weight.

Antioxidant activity was determined using the DPPH (2,2-diphenyl-1-picrylhydrazyl) method [4]. The extract (0.2 mL) was mixed with 2 mL of 0.2 mM solution of DPPH in methanol and incubated for 30 minutes in dark, with continuous homogenization at 500 rpm. The wavelength used for measurements was λ=515 nm. The results were calculated as mg Trolox eq. / 100 g fresh weight.

The total anthocyanin content was determined by extraction of 0,3 g fresh sample milled with extraction solvent MeOH with 1% HCl, then homogenisation at 500 rpm for 15 minutes and centrifugation at 5000 rpm for 5 min at 4°C. The step was repeated two more times, recovering and re-extracting with supernatant the residue, up to 15 mL final volume. For spectrophotometric determinations, 5 mL of extract over which pH 1 / pH 4,5 buffer was added, was incubated for 30 minutes at room temperature. The wavelengths used for measurements were λ = 520 and 700 nm. Results were expressed in mg / 100 g fresh weight.

The total polyphenol content, the total anthocyanin content and the antioxidant activity were determined with the Specord 210 Plus UV-VIS spectrophotometer (Analytik Jena, Jena, Germany). All data were obtained from an average of three independent replicates and were statistically analysed using Microsoft Excel.

Statistical analyses were performed using Excel, like mean, standard deviation, ANOVA single factor, T Test and correlations [18].

Results and Discussions

Physical parameters

The differences between the cultivars studied, fruit hight, fruit diameter, shape index, fruit weight, and fruit firmness, are depicted in Figure 2.

The fruit height had registered values between 37.75 mm, for ‘Elena’ cultivar, and 53.87 mm, for ‘Record’ cv., values similar to those recorded by Scedei et al. (2021), with significant differences ($p<0.05$) between all cultivars, except for ‘Brumării de Voinești’ and ‘Elena’ cultivars, which recorded insignificant differences ($p>0.05$).

The diameter of the fruit had registered values between 29.1 mm, for ‘Brumării de Voinești’ cultivar, and 48.85 mm, for ‘Record’ cv., with insignificant differences between ‘Gemenea’ and ‘Silvia’ cv., and between ‘Brumării de Voinești’ and ‘Elena’ cultivars.

The shape index indicates a slightly spherical shape for the ‘Record’ and ‘Silvia’ cvs. and an elongated oval shape for ‘Brumării de Voinești’ and ‘Elena’ cvs., with significant differences ($p<0.05$) between all cultivars, except for ‘Record’ and ‘Silvia’ cultivars, between which no significant differences were noted.

The fruit weight had registered values between 17.84 g, for ‘Brumării de Voinești’ cultivar, and 65.95 g, for ‘Record’ cv., with significant differences ($p<0.05$) between all cultivars, except for ‘Brumării de Voinești’ and ‘Elena’ cultivars, which recorded insignificant differences ($p>0.05$). Similar values of fruit weight, for ‘Record’ cv. was recorded by Scedei et al. (2021).

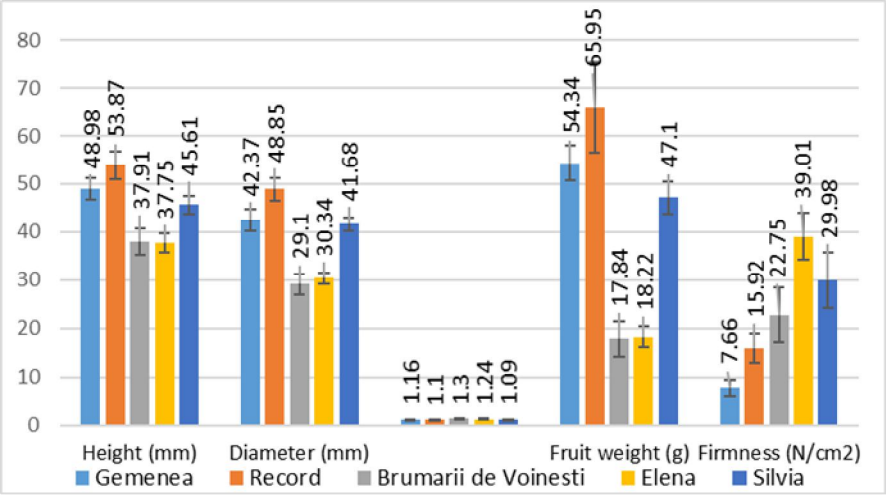

Figure 2. Variation of physical parameters: height (mm), diameter (mm), shape index, fruit weight (g) and firmness for six plum cultivars

Ertekin et al., (2009) measured the mean mass of the fruit for 'Stanley' cv., and it recorded values between 28.53 g and 37.89 g, and for 'Frenze' cv., recorded values between 45.53 g and 92.26 g, values similar to the values recorded for our research for the weight of the fruit.

The fruit firmness (Figure 2) had registered values between 7.66 N/cm^2, for 'Gemenea' cultivar, and 39.01 N/cm^2, for 'Elena' cv., with significant differences ($p<0.05$) between all cultivars.

Stan et al., (2021) measured the fruit firmness for 'Tita' plum cv. and it recorded a mean of 15.14 N/cm^2., similar to the values recorded for 'Record' cv., in this study.

For 'Brumării de Voinești' cv. it was observed a very strong significant positive correlation R^2 = 0.8693, with linear regression equation y = 0.6825x + 3.2222.a between the height and the diameter of the fruit.

Biochemical parameters

The differences between the cultivars studied, were total dry matter content (DM%), titratable acidity (TA), soluble solids content (Brix%), glucose (%), fructose (%), total anthocyanin content, total polyphenol content and antioxidant capacity (DPPH), are depicted in Figure 3.

The dry matter content (DM%) of plums had registered values between 14.16%, for 'Elena' cultivar, and 18.24%, for 'Silvia' cv., with significant differences ($p<0.05$). Between 'Gemenea' and 'Pescăruș', 'Brumării de Voinești' and 'Silvia' cultivars, between 'Record' and 'Pescăruș', and 'Elena' cvs., and between 'Pescăruș' and 'Brumării de Voinești' and 'Elena' cvs. no significant differences at $p<0.05$ were observed.

Bozhkova et al., (2013) measured the dry matter content for numerous plum cultivars, and it recorded values between 13.1%, for 'Opal' cv., and 22.1% for 'Kyustendilska' cv., values similar to the values recorded in our research for the DM% of the fruit. Oltenacu N. and Oltenacu C. V., (2014) recorded values between 15.57%, for 'Stanley' cv., values similar to the values recorded for our research for 'Record' and 'Pescaruș' cvs., and a higher value, 22.57%, for the 'Anna Spath' cultivar.

For 'Pescăruș' cv., between dry matter content and total soluble solids content of the fruit, it has been registered very strong significant negative correlations R^2 = 0.9878, with linear regression equation y = -0.7093x + 25.7.

The total soluble solids content (TSS) (Figure 3) had registered values between 13.72 %Brix, for 'Record' cultivar, and 20.53 %Brix, for 'Brumării de Voinești' cv., with significant differences at $p<0.05$. Between 'Gemenea' and 'Brumării de Voinești' and 'Silvia' cultivars, between 'Elena' and 'Record' and 'Pescăruș' cvs., as well as between 'Brumării de Voinești' and 'Silvia' cvs., were registered insignificant differences ($p>0.05$).

Nunea et al., (2009) measured the content of TSS and of TA from different stages of fruit ripening and for the 'Vila Viçosa' cv., recorded values for TSS 14.8 %Brix and 21.2 %Brix, and recorded values for TA between 0.90 mg/100 g f.w. and 1.12 mg/100 g f.w., and for 'Cano' cv., recorded values for TSS 12.8 %Brix and 21.9 %Brix, and recorded values for TA between 0.88 mg/100 g f.w. and 1.16 mg/100 g f.w., values similar to the values recorded in our research.

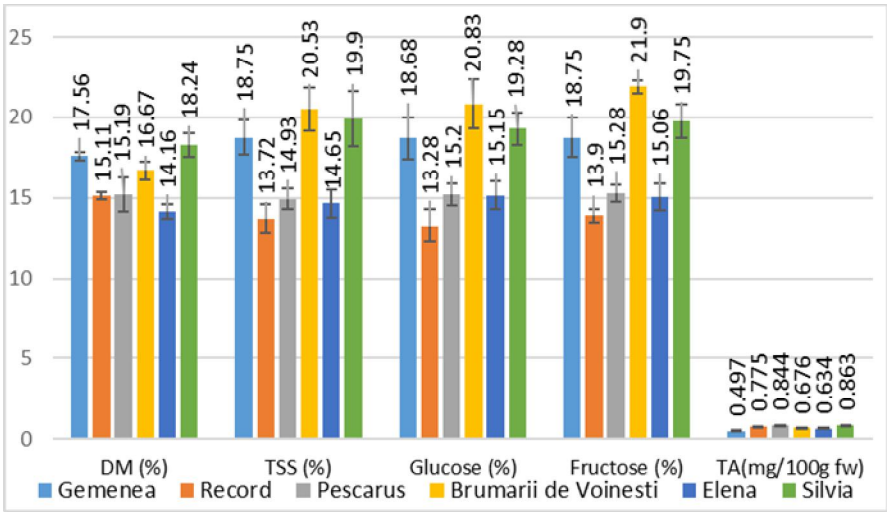

Figure 3. Variation of biochemical parameters: DM (%), TA, TSS (%), glucose (%), fructose (%) for the six plum cultivars

For 'Elena' cv., between total soluble solids content and the titratable acidity content of the fruit, it has been registered very strong significant positive correlations R^2 = 0.9191, with linear regression equation y = 72.254x – 31.128.

The glucose (%) content (Figure 3) had registered values between 13.28 %, for 'Record' cultivar, and 20.83 %, for 'Brumării de Voinești' cv., with significant differences. Between 'Gemenea' and 'Brumării de Voinești' cultivars; between 'Elena' and 'Pescăruș' cvs.; and between 'Brumării de Voinești' and 'Silvia' cvs., were registered insignificant differences ($p>0.05$).

Between total soluble solids content and glucose (%) content of the fruit, very strong significant positive correlations were observed, as follows: R^2 = 0.8446, with linear regression equation y = 1.1078x – 2.0971, for 'Gemenea' cv.; R^2 = 0.8707, with linear regression equation y = 1.0577x – 0.884, for 'Brumării de Voinești' cultivar. Also, a significant positive correlation has been noted for 'Record' cv., with linear regression equation y = 0.9589x + 0.1235, R^2 = 0.6868; and a significant negative correlation has been observed for 'Elena' cv. R^2 = 0.7202, with linear regression equation y = -0.8525x + 27.64.

The fructose (%) content had registered values between 13.9%, for 'Record' cultivar, and 21.9%, for 'Brumării de Voinești' cv., with significant differences at $p<0.05$. Between 'Gemenea' and 'Silvia' cultivars, as well as between 'Elena' and 'Pescăruș' cvs., were registered insignificant differences ($p>0.05$).

Between total soluble solids content and fructose (%) content of the fruit, very strong significant positive correlations have been noted: R^2 = 0.879, with linear regression equation y = y = 1.042x – 0.7878, for 'Gemenea' cv., and R^2 = 0.9651, with linear regression equation y = 0.8736x + 2.2359, for 'Pescăruș' cultivar.

Between glucose (%) content and fructose (%) content of the fruit, very strong significant positive correlations have been observed: R^2 = 0.98, with linear regression equation y = 0.9128x + 1.704, for 'Gemenea' cv., and R^2 = 0.9504, with linear regression equation y = 1.0331x – 0.1626, for 'Silvia' cultivar.

The titratable acidity content (TA) (Figure 3) had registered values between 0.497 mg/100 g f.w., for 'Gemenea' cultivar, and 0.863 mg/100 g f.w., for 'Silvia' cv., with significant differences ($p<0.05$) between all cultivars. Similar values of titratable acidity, for 'Elena' cv. was recorded by Bozhkova (2013).

Between the titratable acidity content and glucose (%) content of the fruit, very strong significant positive correlations were observed: R^2 = 0.8267, with linear regression equation y = 185.92x – 141.77, for 'Pescăruș' cv., and a very significant negative correlation, R^2 = 0.9085, with linear regression equation y -72.168x + 60.873, for 'Elena' cultivar.

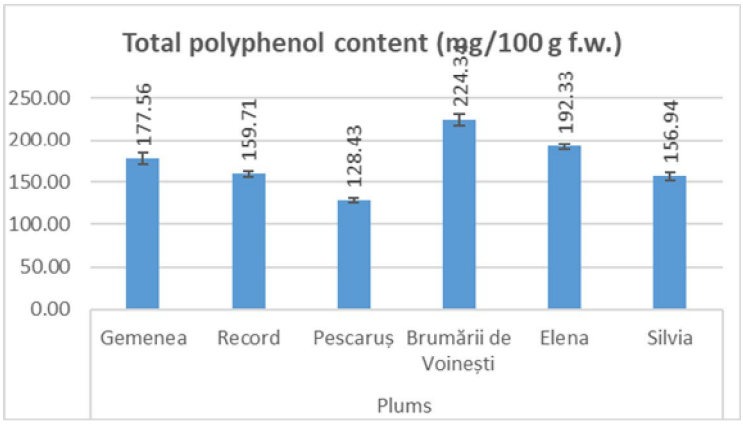

Figure 4. Variation of total polyphenol content for six plum cultivars

The total polyphenol content of plums (Figure 4) had registered values between 128.43 mg/100 g f.w., for 'Pescăruș' cultivar, and 224.34 mg/100 g f.w., for 'Brumării de Voinești' cv., with significant differences ($p<0.05$). Significant differences ($p<0.05$) were registered between all cultivars, except for 'Record' and 'Silvia' cultivars, which recorded insignificant differences ($p>0.05$). Stan et al., (2021) measured the total polyphenol content for 'Tita' plum cv. and it recorded a mean of 107.4 mg GAE/100 g f.w., a lower value that the ones recorded in our research.

Between total polyphenol content and total anthocyanin content of the fruit, very strong significant positive correlations ere noted: $R^2 = 0.9934$, with linear regression equation $y = 0.1671x + 1.2469$, for 'Record' cultivar. For 'Silvia' cv., between total polyphenol content and total anthocyanin content of the fruit, a very strong significant negative correlation had been observed, $R^2 = 0.9814$, with linear regression equation $y = -0.1985x + 60.177$. Also, a significant negative correlation has been registered for 'Brumării de Voinești' cv., $R^2 = 0.6835$, with linear regression equation $y = -0.122x + 55.97$.

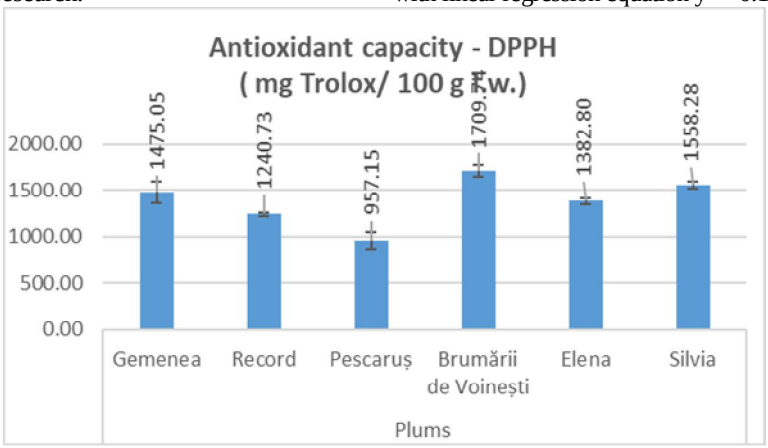

Figure 5. Variation of antioxidant capacity – DPPH (mg Trolox/100 g f.w.) for six plum cultivars

The antioxidant capacity of plums had registered values between 957.15 mg Trolox/100 g f.w., for 'Pescăruș' cultivar, and 1709.74 mg Trolox/100 g f.w., for 'Brumării de Voinești' cv., with significant differences ($p<0.05$). Significant differences ($p<0.05$) were registered between all cultivars, except for 'Gemenea' with 'Record', 'Brumării de Voinești', 'Elena', and 'Silvia' cultivars, which recorded insignificant differences ($p>0.05$) (Figure 5).

Stan et al., (2021) measured the antioxidant capacity for 'Tita' plum cv. and it recorded a mean of 1255.1 mg Trolox/100 g f.w., similar to the values recorded for 'Record' cv., from this research.

Between antioxidant capacity and total polyphenol content of the fruit, strong significant positive correlations were noted: $R^2 = 0.642$, with linear regression equation $y = 0.0439x + 112.76$, for 'Gemenea' cv., and $R^2 = 0.7803$, with linear regression equation $y = 0.0973x + 57.8$, for 'Elena' cultivar. For 'Silvia' cv., between antioxidant capacity and titratable acidity content of the fruit, avery strong significant positive correlation has been observed: $R^2 = 0.9907$, with linear regression equation $y = 6E\text{-}05x + 0.769$.

The total anthocyanin content of plums (Figure 6) had registered values between 27.16 mg/100 g f.w., for 'Gemenea' cultivar, and 29.58 mg/100 g f.w., for 'Elena' cv., with insignificant differences ($p>0.05$) between all cultivars, except for 'Record' and 'Elena' cultivars, which recorded significant differences ($p<0.05$).

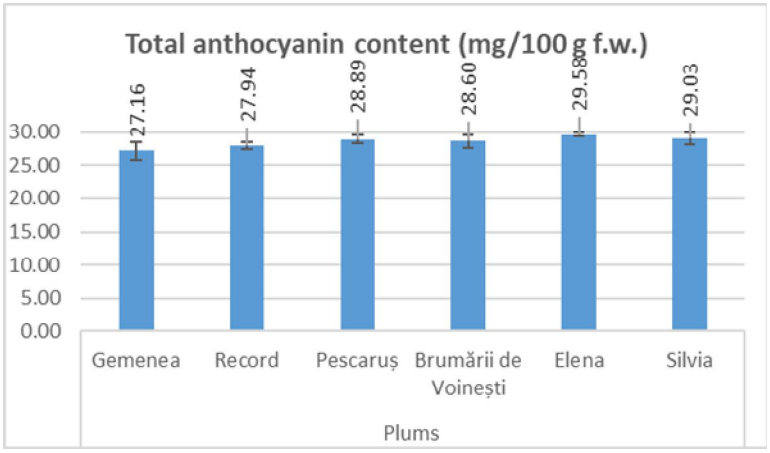

Figure 6. Variation of total anthocyanin content (mg/100 g f.w.) for six plum cultivars

Between antioxidant capacity and total anthocyanin content of the fruit, a very strong significant negative correlation has been noted: $R^2 = 0.9997$, with linear regression equation y = -0.0115x + 44.131, for 'Gemenea' cultivar.

Conclusions

The fruit firmness and the titratable acidity content has registered significant differences ($p<0.05$) between all cultivars.

For 'Gemenea' cv. were observed very strong significant negative correlations between antioxidant capacity and total anthocyanin content of the fruit, and strong significant positive correlations between antioxidant capacity and total polyphenol content, total soluble solids content and glucose (%) content, total soluble solids content and fructose (%) content, as well as between glucose (%) content and fructose (%) content of the fruit.

The total anthocyanin content of plums had registered insignificant differences ($p>0.05$) between all cultivars, except for 'Record' and 'Elena' cultivars, which recorded significant differences ($p<0.05$). For 'Record' cv. were observed very strong significant positive correlations between total polyphenol content and total anthocyanin content, as well as between total soluble solids content and glucose.

For 'Pescăruș' cv. were noted very strong significant negative correlations, between dry matter content and total soluble solids content, and very strong significant positive correlations between the titratable acidity content and glucose (%) content, as well as between total soluble solids content and fructose (%) content.

'Brumării de Voinești' cv. registered a very strong significant positive correlation between total soluble solids content and glucose (%) content. Also, a significant negative correlation has been registered for 'Brumării de Voinești' cv. between total polyphenol content and total anthocyanin content.

For 'Elena' cv. were observed strong significant positive correlations between antioxidant capacity and total polyphenol content, between the titratable acidity content and glucose (%) content, and between total soluble solids content and the titratable acidity content. Additionally, a significant negative correlation has been registered between total soluble solids content and glucose content.

For 'Silvia' cv. were noted very strong significant positive correlations between antioxidant capacity and titratable acidity content of the fruit, and between glucose (%) content and fructose (%) content of the fruit, and a very strong significant negative correlation between total polyphenol content and total anthocyanin content.

Future research is required in order to check if for the plum cultivars studied, the physical and chemical characteristics will have similar values in the following years, if the correlations between various parameters will be maintained, and finally if any or all of the cultivars studied will be acceptable as genitors in further breeding programs.

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