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BASIC PHYSICO-CHEMICAL PARAMETERS OF THE FRUITS OF SOME PLUM CULTIVARS, RELATED TO THEIR SUITABILITY FOR FRESH CONSUMPTION AND PROCESSING

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Abstract

The study was conducted in the period 2019-2020 in plum plantations of RIMSA Troyan. The pomological and physico-chemical parameters of widespread and newly studied plum cultivars with different directions of use were studied. It was found that cv. 'Strinava', 'Stanley', 'Jojo' and 'Elena' have a dry matter of over 19%, and in 'Stanley' and 'Jojo' the total sugars are also at most 11.5-12.5%. 'Hanita' cv has the highest content of titratable acidity (1.0%), all others are <1.00%. The large-fruited cultivars with an early ripening period 'C. Naibolya', 'C. Lepotitsa', 'Tuleu timpuriu', as well as the later ripening 'Jojo' have a well-balanced taste, glucoacidimetric coefficient of about 20, which makes them suitable for fresh consumption. 'Kyustendilska', 'Elena', 'Gabrovska', 'Valevka' cultivars have low fruit weight, the late ripening period allows them to accumulate a high content of dry matter, which makes them suitable for industrial processing and distillation.

Key words: *plum, pomological and physicochemical parameters, fruit qualities.*

INTRODUCTION

Plums (*Prunus domestica* L.) have long been of interest in the human diet, as food for fresh consumption, dried or processed. The modern consumers are becoming more and more demanding to the quality of fruits, so they seek information about the sensory characteristics and chemical composition of the widespread old cultivars and the new recently introduced plum cultivars.

Trends in the world selection of new commercial plum cultivars are focused on the large fruit size, the dark color of their skin and their resistance or tolerance to Plum pox virus. In many cases, however, the chemical and sensory characteristics do not improve. Such cultivars are attractive to producers, but not acceptable to consumers (Bozhkova, 2014).

In human nutrition, plums are valued as a rich energy source with high protective, dietary and therapeutic value. Fresh fruits are low in calories and relatively high in nutritional value. They can make a significant contribution to human nutrition due to their richness in antioxidants. Plums are also a major natural source of phytochemicals such as flavonoids, phenols, anthocyanins, etc., which have been shown to have antioxidant capacity and can help protect cells against oxidative damage caused by free radicals (Ertekin et al., 2006; Voca et al., 2009; Božović et al., 2017).

Usenik et al. (2014) examined the maturity at harvest, which determines the quality, potential shelf life and acceptance of fruits by consumers, who evaluate plum fruits by their color and taste. The qualities of four plum cultivars ('Haganta', 'Jojo', 'Stanley' and 'Toptaste') were measured, showing high variability in pomological characteristics among different cultivars and vegetation seasons, especially at the ripening stage when the fruit quality changes. Plums become delicious when the skin is completely colored and the fruit flesh color is changed from green to the characteristic of the cultivar. Skin color is one of the most important criteria for ripening of stone fruit, but it is not suitable for determining their ripeness, as many genotypes develop pigmentation at the beginning of their growth (Usenik et al., 2008).

The introduction of new cultivars improves the technological characteristics of plum production, which increases yields,

productivity and fruits have a more attractive appearance, size and balanced nutritional composition. Markuszewski and Kopytowski (2013) believe that most late ripening plum cultivars have higher dry matter and sugar content than early ripening cultivars. The resistance of new cultivars to sharka (Plum pox virus) is also important, as these cultivars are more tolerant.

The structure of the assortment of plum cultivars is created depending on: the production capacity and the environmental impact on the genotypes, the quality of the fruits and the trends in the use (Botu, 2012).

The objective was to study the main physico-chemical parameters of fruits of some plum cultivars and their suitability for use in different trends.

MATERIALS AND METHODS

The study was conducted in the period 2019-2020 in RIMSA Troyan. The climatic conditions for the foothills are characterized by moderately cool winters and dry but not very hot summers. The altitude is 380 m, the terrain is inclined from 5 to 8°.

The trees are grown using standard plum technology, keeping the soil surface grassy, without irrigation, without additional fertilization, without plant protection.

The following indicators were registered:

1. Ripening period of fruits
2. Biometric (physical) characteristics of fruit:

- Fruit weight (g);
- Stone weight (g);
- Height (mm);
- Diameter (mm);
- Stalk length (mm);

3. Chemical composition of fresh plum fruit;

- Dry matter (DM) according to (refractometer) Re (%);
- Determination of sugars (total, invert and sucrose) and acid, according to the method of Schoorl (Donchev et al., 2001),
- Tanning substances according to the method of Levental (Donchev et al., 2000),
- Anthocyanins (mg/%) according to the method of Fuleki and Francis (1968),
- Total polyphenols (mg GAE/100 g FW) - according to Singleton and Rossi (1965)

The experimental data were subjected to statistical analysis by Fisher's single-factors ANOVA. The significance of differences between the mean values of the factors and the interaction means was determined by LSD test at significance levels of $P \leq 0.05$.

Fruits were determined at the laboratory of RIMSA Troyan.

RESULTS AND DISCUSSIONS

The studied cultivars cover the harvest period from the second ten days of July to the second half of September. The fruits of 'Katinka' cultivar became ripened first, and 'Elena' cultivar had the latest ripening fruit. Fruits of 'Stanley', in most cases reach harvest maturity at the end of August (Table 1).

Table 1. Harvest ripening stage for plum cultivars (2020)

Cultivars	Ripening stage period
Katinka	27.07
TuleuTimpuriu	29.07
Čačanska Najbolja	31.07
Tegera	3.08
Čačanska lepotica	5.08
Čačanska Rodna	14.08
Hanita	16.08
Strinava	16.08
Gabrovska	17.08
Mirabella de Nancy	25.08
Valevka	27.08
Stanley	2.09
Jojo	5.09
Elena	10.09
Kyustendilska	15.09

The following measurements were made in 2019: 'Jojo' had the largest fruit weight (87.13 g,), diameter (50.38/46.87 mm) and height 62.93 mm, followed by 'Čačanska Najbolja', respectively (73.32 g), diameter (45.38/48.98 mm) and height (56.14 mm). The lowest values were measured in: 'Kjustendildka sinia sliva' with 21.39 g, diameter 29.48/30.35 mm, height 40.42 mm, followed by 'Gabrovska' and 'Elena'. The other cultivars ranged from 30.21 g for 'Katinka' to 43.68 g for 'Stanley' (Table 2).

Table 2. Biometric indicators of fruits by cultivars (2019-2020)

Cultivars	Fruit weight (g)	Stone weight (g)	Relative share of stone (%)	Height (mm)	Diameter (mm)	Fruit stalk length
			2019			
Katinka	34.09±2.13	1.38±0.26	0.25	43.37±0.99	34.42/36.27	12.15±1.57
T. Timpuriu	43.66±2.86	2.04±0.11	0.21	45.73±1.47	39.40/38.82	7.58±1.08
C. najbolja	73.31±8.06	2.38±0.22	0.31	57.10±1.44	45.38/48.98	15.86±1.43
Tegera	37.84±4.12	1.72±0.19	0.22	48.32±2.36	36.00/37.78	12.53±0.56
C. lepotica	57.47±5.62	2.08±0.19	0.28	48.83±2.00	37.30/40.29	13.18±2.37
C. rodna	33.271±3.44	1.38±0.08	0.24	45.53±2.65	33.10/36.64	16.94±1.28
Hanita	43.45±5.96	2.52±0.19	0.17	46.56±2.76	38.80/38.25	14.18±0.76
Strinava	38.27±2.01	1.24±0.11	0.31	46.55±1.26	36.71/37.70	15.63±1.06
Gabrovska	29.88±2.63	1.50±0.10	0.20	43.85±1.83	33.79/33.76	13.27±1.56
Mirabella de Nancy	11.93±1.31	1.00±0.14	0.12	28.21±1.30	26.73/26.74	12.16±0.93
Valevka	30.98±1.81	1.48±0.19	0.21	46.24±3.70	34.69/33.54	16.32±0.88
Stanley	50.45±5.68	2.46±0.21	0.21	51.78±2.55	38.04/37.12	18.03±1.01
Jojo	87.13±5.97	3.26±0.09	0.27	62.75±2.14	50.38/46.87	8.77±1.33
Elena	36.12±3.20	1.46±0.09	0.25	42.40±2.13	34.45/32.90	15.81±0.63
Kyustendilska	21.36±1.46	0.94±0.09	0.23	41.01±1.99	29.48/30.35	16.85±0.71
LSD 0.05	*3.75*	*2.20*		*2.72*		*1.56*
			2020			
Katinka	25. 00±3.36	0.84±0.15	0.30	39.81±3.10	31.44/32.48	11.04±1.22
T. Timpuriu	36.25±3.66	1.54±0.13	0.24	44.17±1.40	38.17/36.12	12.53±0.67
C. najbolja	48.44±5.61	2.70±0.12	0.18	48.26±2.12	41.82/40.90	13.31±1.24
Tegera	27.69±2.12	1.42±0.6	0.20	43.46±1.80	32.40/34.02	8.44±1.41
C. lepotica	38.01±1.88	1.68±0.13	0.23	42.64±1.00	36.51/38.37	11.18±2.14
C. rodna	31.83±2.35	1.38±0.08	0.23	44.55±1.25	33.69/36.49	13.62±1.40
Hanita	29.85±3.28	1.80±0.25	0.17	44.38±1.73	34.87/36.71	10.47±1.96
Strinava	32.08±2.62	1.22±0.25	0.26	44.49±1.51	34.70/34.83	12.65±1.78
Gabrovska	24.00±2.55	1.30±0.12	0.18	44.00±2.93	32.16/31.10	12.49±2.75
Mirabella de Nancy	12.10±1.78	0.46±0.05	0.26	27.31±0.54	25.72/26.12	10.67±1.60
Valevka	24.24±1.95	1.26±0.05	0.19	44.91±0.73	31.88/31.23	11.64±0.69
Stanley	37.35±3.15	2.18±0.16	0.17	49.61±2.75	36.43/36.38	17.62±1.52
Jojo	55.92±6.43	2.40±0.35	0.23	57.41±1.96	42.60/39.05	12.33±2.62
Elena	29.78±4.49	1.44±0.18	0.21	42.40±3.08	34.55/32.07	15.05±3.19
Kyustendilska	17.75±1.17	0.64±0.05	0.28	38.30±1.13	28.35/28.77	12.38±0.83
LSD 0.05	*3.01*	*0.22*		*2.50*		*2.30*

Ertekin et al. (2006) presented the following measurements for 'Stanley': average weight 36 g, average fruit length 48.25 mm, 33.24 mm and 31.32 mm, far smaller compared to our results.

According to the degree of separation of the stone from the fruit flesh, it is from separating to semi-separating. The fruit skin of the studied cultivars has a basic blue color with a shade of purple in 'Čačanska Rodna' and 'Katinka' (Minev et al., 2017).

Relative share of stone in the standard cultivar 'Stanley' in 2019 was 0.21, in other cultivars it varied from 0.17 ('Hanita') to 0.31 in 'Čačanska Najbolja' (Table 2). In 2020 the lowest value of the coefficient was in 'Hanita'

(0.17), and the highest in ‘Kyustendilska’ and ‘Katinka’ (0.28; 0.30), compared to ‘Stanley’ (0.17). During the study period, the highest fruit stone weight was reported in ‘Jojo’ cultivar (2.3-3.2 g *LSD 0.05* = 0.22).

The largest fruit stalk length was measured in ‘Stanley’ (18.03 mm) *LSD 0.05* = 1.56 (Table 2).

The dry matter content in the fresh fruits of the studied cultivars varied from 14% (‘Katinka’, 2019) to 23% (‘N. Mirabela’, 2019), as the standard cultivar ‘Stanley’ they were respectively 19.0% in 2019, 19.6% in 2020. In the group with the lowest dry matter content were ‘Tuleu timpuriu’, ‘Tegera’, ‘Hanita’, ‘Gabrovska’ (Table 3).

In 2019, the average monthly temperatures in July and August were around 20°C, in September 16.2°C and the precipitation was less than for the same period in 2020 (Figure 1). Thus, the late-ripening cultivars ‘Stanley’, ‘Jojo’, ‘Elena’ for this year had 11.45-12.95% content of total sugars. The organic acids in these cultivars were 0.35%, which determined a very high glucoacidimetric index (32.71-37.00).

At the end of August 2020 (28-31.08) and the beginning of September (1-5.09), a very high temperature amplitude was reported between the minimum and maximum value of T (°C), around 20.0-22.5°C. This is extremely conducive to the accumulation of more total sugars (8.7%-10.9%) in the fruits of cultivars ripening in this period (late ripening - ‘Valevka’, ‘Stanley’, ‘Jojo’, ‘Elena’).

An exception is ‘Kyustendilska’, where the content of total sugars was low for both years (6.7%-7.7%) due to the cultivar susceptibility to PPV. In the earlier ripening cultivars, this indicator had lower values, especially 'Čačanska lepotica' (5.85%), ‘Tuleu timpuriu’ (6.00%).

The lowest glucoacidimetric coefficient for the studied plum cultivars was registered in ‘Hanita’ in 2019 (6.87) and 'Čačanska lepotica' in 2020 (7.31), and the highest (37.00) for ‘Elena’ cultivar in 2019, as the values of the coefficient by years differed depending on the abiotic factors (temperature and precipitation) (Figure 1).

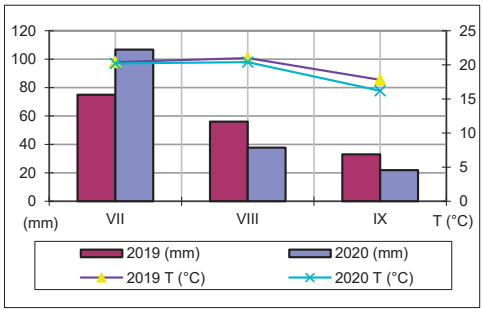

Figure 1. Climatic conditions (2019-2020)

The closest to the optimal value of glucoacidimetric coefficient (according to Stanchev et al. (1968) were ‘Katinka’ 22.75 (2019) and Čačanska Najbolja (2020) with 17.69, formed by 14.15% total sugars and 0.80% acids, for ‘Stanley’ cultivar in 2020 was 16.27 (Table 3).

The organic acids of the fruits largely determine their taste. In general, the studied cultivars had a low acid content, ranging from 0.35% (‘Elena’, 2019) to 1.07% (‘Hanita’, 2020). Voca et al. (2009) report the acid content in the range of 0.40% and 0.69% in the plum cultivars ‘Top’, ‘Bistritsa’ and ‘Elena’, i.e. the data are comparable with the results obtained in our study for other cultivars grown in different climatic conditions.

Tannins and dyeing substances varied widely depending on the cultivar characteristics, the exposure of the slope (direction to sunlight), the intensity of fruit bearing (fruit load).

The polyphenols in the second year of the study were much higher compared to 2019. In Bulgaria they vary from 119.09 (mg/g) in ‘Mirabelle de Nancy’ to 595.34 (mg/g) in ‘Strinava’. Voca et al. (2009) reported a total phenol content ranging from 157.70 mg in ‘Elena’ to 344.10 mg in ‘Bistritsa’, expressed as gallic acid equivalents (GAE), based on fresh weight. Under our conditions, ‘Elena’ cultivar in 2020 had 341.48 (mg/g) polyphenols (Table 3).

The present study determined high correlation among the content of dry matter, total and inverted sugars (r = 0.837) (Figure 2), which confirms the findings of Dzhuvinov et al. (2012) (r = 0.852).

Table 3. Chemical analysis of fresh plums (2019-2020)

	Soluble Solids (%)	Total sugars (%)	Inverted sugars (%)	Sucrose (%)	Acids (%)	Glucoacidi-metric index	Tanning Substances (%)	Total polyphenols (mg/g)	Anthocyanins (mg/%)
2019									
Katinka	14.00	11.60	5.35	5.94	0.51	22.75	0.15	27.78±0.12	33.71
T.Timpuriu	14.50	9.20	5.20	3.80	0.76	12.11	0.09	31.90±0.10	12.74
C.najbolja	17.00	8.20	4.05	3.94	0.76	10.79	0.13	89.57±0.12	15.32
Tegera	15.60	10.05	6.00	3.85	0.63	15.95	0.15	25.49±0.18	19.03
C.lepotica	18.50	8.90	8.90	-	0.63	14.13	0.16	73.19±0.27	39.84
C.rodna	18.00	10.40	6.35	3.85	0.63	16.51	0.11	38.83±0.30	21.13
Hanita	15.30	8.70	7.85	0.81	1.01	8.61	0.20	113.27±0.16	12.10
Strinava	19.50	8.70	7.35	1.28	0.50	17.40	0.13	40.40±0.46	21.61
Gabrovska	16.00	7.00	2.70	4.09	0.57	12.28	0.13	52.50±0.18	23.71
Mirabella de Nancy	23.00	5.35	2.55	2.66	0.38	14.08	0.13	9.37±0.05	5.97
Valevka	17.00	8.20	3.85	4.13	0.76	10.79	0.18	21.88±0.33	44.19
Stanley	19.60	11.45	8.20	3.09	0.35	32.71	0.17	11.09±0.06	9.19
Jojo	19.50	12.60	8.55	3.85	0.38	33.16	0.08	11.97±0.18	5.00
Elena	19.60	12.95	5.20	7.36	0.35	37.00	0.19	69.05±0.05	13.77
Kyustendilska	16.00	6.65	3.20	3.28	0.63	10.56	0.19	13.31±0.05	9.84
2020									
Katinka	15.00	7.70	6.00	1.62	0.60	12.83	0.19	412.31±1.41	19.84
T. Timpuriu	13.50	6.00	2.40	3.42	0.80	7.50	0.06	349.97±2.83	13.71
C. najbolja	13.50	14.15	9.05	4.85	0.80	17.69	0.10	163.74±0.71	4.68
Tegera	15.00	7.35	4.50	2.71	0.80	9.19	0.10	25.49±0.61	4.03
C. lepotica	15.60	5.85	4.05	1.71	0.80	7.31	0.10	173.18±0.71	3.06
C.rodna	21.50	9.55	5.70	3.66	0.60	15.92	0.17	621.73±0.72	15.32
Hanita	16.00	7.35	5.00	2.23	1.07	**6.87**	0.08	350.78±0.64	8.55
Strinava	21.00	6.00	3.85	2.04	0.67	8.96	0.23	595.34±0.33	14.03
Gabrovska	16.50	7.85	2.85	3.80	0.67	11.72	0.19	413.22±0.18	11.77
Mirabella de Nancy	19.00	7.70	5.35	2.32	0.74	10.41	0.13	119.09±0.06	4.52
Valevka	16.70	9.20	5.70	3.33	0.87	10.57	0.19	228.49±0.37	5.32
Stanley	19.00	10.90	5.38	5.27	0.67	16.27	0.17	281.96±0.04	3.71
Jojo	19.50	8.70	5.35	3.18	0.67	12.99	0.17	465.41±0.21	3.39
Elena	19.00	8.05	5.35	2.57	0.67	12.01	0.15	341.48±1.05	13.39
Kyustendilska	18.90	7.70	7.70	-	0.80	9.63	0.17	280.82±0.14	17.58

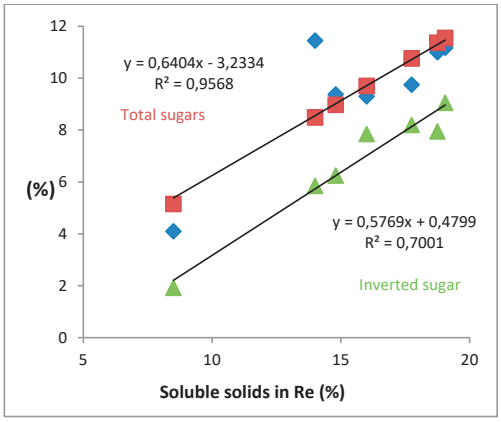

Figure 2. Correlation dependence, among soluble solids content, total and invert sugars

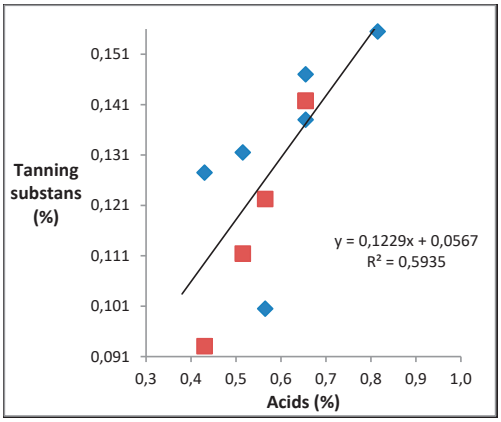

Figure 3. Correlation dependence, between the content of acids and tannins

The same dependence was found between the content of organic acids and tannins by the function y = 0.1229x + 0.0567, where $R^2 = 0.5935$ (Figure 3).

Based on the ripening period, biometric indicators and chemical composition of fruit we have the reason to distribute the studied cultivars in 3 trends.

Fresh consumption, due to early and late ripening, attractive appearance - early ripening 'Katinka', 'Tuleu timpuriu', 'Čačanska Najbolja', 'Tegera', 'Čačanska lepotica' and late ripening cultivars, such as 'Jojo' and 'Elena'.

For drying: based on the high content of dry matter, dark blue skin and averaged-sized fruit for this group are suitable cultivars, such as: 'Gabrovska', 'Valevka', 'Stanley', 'Čačanska Rodna' and the standard of taste and drying 'Kyustendilska'.

For processing. due to completely detachable stone and balanced taste 'Gabrovska', 'Valevka', 'Kyustendilska' are suitable for processing into jam, marmalades, etc., as well as for distillation, incl. 'Stanley', 'Strinava', 'Hanita'.

CONCLUSIONS

The studied cultivars cover the harvest period from the second ten days of July to the second half of September.

The largest fruit weight was registered in 'Jojo' (87.13 g), diameter (50.38/46.87 mm) and height 62.93 mm, followed by 'Chachanska najbolja', respectively (73.32 g), diameter (45.38/48.98 mm) and height (56.14 mm). The lowest values were measured in: 'Kjustendildka sinia sliva' 21.39 g, followed by 'Gabrovska' and 'Elena'.

The lowest dry matter content in fresh fruits was registered in 'Katinka' with 14% (2019), and the highest in 'Mirabelle du Nancy' with 23% (2019), in the standard cultivar 'Stanley' it was respectively 19.0% in 2019; 19.6% in 2020.

The lowest glucoacidimetric index for the studied plum cultivars was registered in 'Hanita' in 2019 (6.87) and 'Čačanska lepotica' in 2020 (7.31), and the highest (37.00) in 'Elena' in 2019, as the values of the index over the years differed depending on the abiotic factors.

An exceptional correlation dependence was found among the content of dry matter, total and inverted sugars, as well as the content of organic acids and tannins.

Based on the studied indicators, the plum cultivars are grouped in 3 technological trends for use.

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