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RESEARCHES ON THE INFLUENCE OF STORAGE CONDITIONS ON BIOMETRIC AND PHYSIOLOGICAL INDICES OF PLUMS

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Abstract

The purpose of the study was to determine biometric and physiological indices during storage processes in four plum varieties, two of them originated from Romania ('Record' and 'Vinete Românești'), one from USA ('Stanley'), and one from Serbia ('Cacanska Lepotica'). The fruits were harvested at maturity and stored for 5 and 10 days at two different temperatures (4°C and 22°C, respectively). We analyzed 25 fruits for each variety and the following determinations were made: diameter, height, weight, sugar content, firmness, juice acidity and dry matter content. 'Record' and 'Cacanska Lepotica' plum varieties had the highest values in terms of fruit weight (60.37 g and 43.49 g, respectively), after 10 days of storage, at 22°C. Regarding the sugar content of the fruit, it was found that the 'Record' and 'Vinete Românești' varieties had a higher percentage, significantly positive $p < 0.01$ with 22.06 and 24.60%. After 10 days of preservation, the trend of increasing of the content of soluble carbohydrates continues possible due to the transformation of starch into glucose, following enzymatic hydrolysis processes. There was also found a pronounced decrease in fruits firmness, acidity of the fruit juice, but also an increase in fruits dry matter content.

Key words*: plum, firmness, dry matter, acidity.*

INTRODUCTION

The plum is on the first place from the fruit tree species cultivated in our country, as regard as the cultivated area and concerning the fruit yield obtained (Coman et al., 2012). For the temperate zone and especially for the Balkan countries, plum is a fruit species of great economic importance, due to the rusticity of the species, its therapeutic value, the food value. So, due to its many uses, it was spread on a large area of culture (Iordănescu, 2008; Iordănescu & Olaru, 2014).

The pomological, physical and biochemical proprieties of the local genotypes or biotypes of the cultivated fruit tree species can be influenced by the pedo-climatic factors (Ionică et al., 2013; Iordănescu and Costea, 2014; Vâtcă et al., 2020a; Puia et al., 2017). This information about these particularities, are useful for breeding or growing processes, or to enlarge the assortment of local fresh, preserved or conditioning fruits (Vitanova et al., 2004; Okatan et al., 2017). Fresh plum fruits contain all the microelements necessary for the human body: calcium (Ca), potassium (K), iron (Fe), magnesium (Mg), phosphorous (P) etc. From the vitamins, the most representative is carotene, vitamin C, vitamins B1, B2, PP and others. However, plums are poor in lipids and protein, thus having a low caloric value (Scedei et al., 2019).

From known cultivars or local varieties there are different researches on fruits proprieties, such as the nutritional characteristics of local cultivars (Rop et al., 2009; Păcurar et al., 2018) and the changes that occur in their physical or chemical characteristic during the fruits ripening or their storage (Usenik et al., 2008; Miletic et al., 2012; Oltenacu and Oltenacu, 2014; Vâtcă et al., 2020b), the chemical compounds content and their contribution to the fruit aroma, color (Usenik et al., 2009; Pino and Quijano, 2012) or to the antioxidant activity (Donovan et al., 1998).

The excessive softening is the major factor limiting the shelf life of plums. (Crisosto et al., 2004).

When chilling injury symptoms or degradation are not limiting factors, the ripening-related process most sensitive to ethylene and a suitable predictor of potential shelf-life for plums is fruit softening (Lelievre et al., 1997). When are mature to a soft melting texture, plums are considered perfect to eat (Beinșan et al., 2019). Like on the other fruit species, during maturation, the cell wall extracted from plum fruit showed considerable increase in swelling and high pectin solubilization. (Redgwell et al., 1997). Plums are highly perishable at ambient temperatures and cannot endure long storage periods after harvest. Thus, pre-harvest treatment of the fruits can effectively be used to increase the storage life of their freshness with the plant growth hormones (like auxins, gibberellins), calcium chloride and growth retardants (like cycocel) which would retard the rate of deterioration in quality after harvest and thereby will increase the shelf life of the fruits (Kirmani et al., 2015, Shazia et al., 2013).

In this experiment we studied the influence of temperature, as well as the storage duration on biometric and physiological indices of four plum fruits varieties 'Cacanska Lepotica', 'Vinete Românești', 'Stanley' and 'Record'.

MATERIALS AND METHODS

The biological material

The biological material was represented by four plum varieties, with different origin: two Romanian ('Record' and 'Vinete Românești'), one from the USA ('Stanley') and one Serbian variety ('Cacanska Lepotica'). The plums varieties properties were summarized in Table 1.

The fruits were harvested from Vînju Mare locality, Mehedinți county, at full maturity, in 2019 and stored for 5 and 10 days at two different temperatures (4°C and 22°C).

The analyzed biometric and physiological properties

The fruits (25 fruits/variety) were harvested from different parts of the tree. The fruits diameter and their length have been measured with the help of a caliper. The weight was established by using an analytical balance.

Fruits sugar content, expressed as soluble carbohydrates (Brix degree - %) has been obtained with a digital refractometer (Kruss DR 201-95)

Table 1. Principal properties of tested plum varietes

Properties	Variety			
	'Record'	**'Vinete Românești'**	**'Stanley'**	**'Cacanska Lepotica'**
Origin	Romania	Romania	USA	Serbia
Size	very large	small	medium	large
Taste	appetizing	sweet and slightly astringent	sweet, slightly acidic and slightly aromatic fruit	sweet-sour
Fruit quality	very good	very good	very good, asymmetric	very good
Consumption	Fresh	Fresh/ Industriali-zation	Fresh/ Industriali-zation	Fresh/ Industrialization
Other	Non-stick pulp	ellipsoidal, dark-hunted fruit, with a green-yellow pulp, with a thick silvery plum, consistent	Weight 30-40 g, oval, dark-colored	Weight 50 g, spherical shape in shades of blue easily pulp removal
Source	https://fructifer.ro/prun-Record	https://www.pestre.ro/blog/pomi-fructiferi-tot-ce-trebuie-sa stii/#Soiuri_propuse_pentru_cultura_de_prun	http://www.horticultorul.ro/pomi-fructiferi/soiuri-de-prun-stanley/	https://www.gardenexpert.ro/arbori/pomi-fructiferi/prun-cacanska-lepotica.html

Fruit flesh firmness was determined with the penetrometer (FORCE GAUGE PCE-FM 200) and results have been expressed in lbr.

The fruit juice acidity was determined using a multiparameter analyzer - pH (CONSORT C933).

Dry matter content was determined with thermobalance Kern MLS in percent units.

All the results were expressed as average ± standard error (SE). Statistical analysis was made with RStudio software version 4.0.5 (31.03.2021), ANOVA and Fisher LDS for all the parameters.

RESULTS AND DISCUSSIONS

Significant differences $p < 0.001$ to all parameters were seen between different varieties. The parameters assessed soluble glucids, fruit acidity, dry matter and firmness show significant $p < 0.001$ differences between the storage methods (Table 2).

The interaction between varieties type and storage methods did not result in a significant difference within the parameters tested.

Table 2. Statistical result for all the tested parameters with ANOVA

Parameters	Variety		Storage		Variety × Storage	
	F	p.val	F	p.val	F	p.val
Small diameter	319.12	p < 0.001	0.44	0.78	0.00	1.00
Large diameter	456.40	p < 0.001	1.81	0.15	0.01	1.00
Height	405.56	p < 0.001	0.43	0.78	0.01	1.00
Weight	492.71	p < 0.001	1.11	0.36	0.01	1.00
Soluble glucids	756.57	p < 0.001	37.16	p < 0.001	0.71	0.73
Fruit acidity	252.92	p < 0.001	56.32	p < 0.001	0.78	0.66
Dry matter	552.27	p < 0.001	56.86	p < 0.001	0.30	0.98
Firmness	362.64	p < 0.001	43.82	p < 0.001	0.45	0.93

Looking at large and small fruits diameters we can observe that compared with the first determination - fd, all the values decreased due to water loss. Significant differences $p < 0.05$ between large and small diameters were observed for 'Vinete Românești' and 'Stanley' (except for small diameter parameter at fd) (Table 3).

Table 3. Large and small diameter of fruits in the studied plum varieties (average ± SE)

Parameter/treatment	Variety			
	Cacanska Lepotica	Vinete Românești	Stanley	Record
Large fruits diameter - fd	41.00±0.57 ^{b}	28.00±1.15 ^{d}	36.33±0.88 ^{c}	45.33±0.88 ^{a}
5 days at 22°C	40.18±0.47 ^{b}	27.14±0.83 ^{d}	35.56±0.86 ^{c}	44.60±0.75 ^{a}
5 days at 4°C	40.86±0.63 ^{b}	27.63±0.98 ^{d}	35.95±0.73 ^{c}	45.11±0.75 ^{a}
10 days at 22°C	39.64±0.62 ^{b}	26.65±0.73 ^{d}	34.93±0.63 ^{c}	43.98±0.86 ^{a}
10 days at 4°C	40.33±0.73 ^{b}	26.96±0.66 ^{d}	35.47±0.67 ^{c}	44.71±0.89 ^{a}
Small fruits Diameter - fd	37.33±0.88 ^{b}	25.66±0.88 ^{e}	34.00±0.57 ^{cd}	43.66±1.20 ^{a}
5 days at 22°C	36.87±0.86 ^{b}	25.21±1.01 ^{e}	33.53±0.57 ^{d}	43.17±1.22 ^{a}
5 days at 4°C	37.19±0.86 ^{b}	25.46±1.01 ^{e}	33.69±0.53 ^{d}	43.40±1.22 ^{a}
10 days at 22°C	36.46±0.85 ^{bc}	24.90±0.98 ^{e}	33.21±0.55 ^{d}	42.91±1.24 ^{a}
10 days at 4°C	36.61±0.88 ^{bc}	25.11±0.97 ^{e}	33.38±0.53 ^{d}	43.13±1.21 ^{a}

fd = first determination, different letters are significant at $p < 0.05$, LSD test

Significantly higher ($p < 0.05$) large (45.33±0.88 - fd) and small diameter (43.66±1.20 - fd) was seen at 'Record' variety.
The lowest large diameter (26.65 ± 0.73) and small diameter (24.90 ± 0.98) was observed to 'Vinete Românești' variety after 10 days of storage at 22°C.
'Record' and 'Stanley' varieties had the highest height and differ significantly ($p < 0.05$) from the other two varieties.
The weight was higher at Record (61.20 ± 0.37 g) and 'Cacanska Lepotica' (44.19 ± 0.83 g) with significant differences ($p < 0.05$) between the varieties not before storage days or temperature. 'Cacanska Lepotica' (37.63 ± 1.36 g) and 'Stanley' (41.07 ± 1.19 g) weight was assessed in a study and with not significant difference between them (Milošević at al., 2012). Another study place 'Cacanska Lepotica' (37.77 g) variety as with small fruit weight (Zamfirescu et al., 2019).
The lower weight was observed at 'Vinete Românești' variety after 10 days of storage at 4°C (Table 4).

Table 4. Experimental results regarding height and weight in the tested plum varieties (average ± SE)

Parameter/treatment	Variety			
	'Cacanska Lepotica'	'Vinete Românești'	'Stanley'	'Record'
Height - fd	45.66±0.88 ^{b}	35.00±1.15 ^{c}	51.00±0.57 ^{a}	52.66±0.88 ^{a}
5 days at 22°C	45.41±0.90 ^{b}	34.69±1.07 ^{c}	50.63±0.64 ^{a}	52.04±0.84 ^{a}
5 days at 4°C	45.51±0.91 ^{b}	34.86±1.09 ^{c}	50.84±0.62 ^{a}	52.32±0.83 ^{a}
10 days at 22°C	45.09±0.96 ^{b}	34.24±0.98 ^{c}	50.19±0.56 ^{a}	51.67±0.81 ^{a}
10 days at 4°C	45.34±0.92 ^{b}	34.69±1.07 ^{c}	50.66±0.63 ^{a}	52.12±0.82 ^{a}
Weight - fd	44.19±0.83 ^{b}	16.73±0.63 ^{d}	34.30±0.56 ^{c}	61.20±0.37 ^{a}
5 days at 22°C	43.88±0.80 ^{b}	16.27±0.55 ^{d}	33.86±0.62 ^{c}	60.89±0.37 ^{a}
5 days at 4°C	44.07±0.80 ^{b}	16.53±0.60 ^{d}	34.18±0.56 ^{c}	61.06±0.36 ^{a}
10 days at 22°C	43.48±0.82 ^{b}	15.67±0.60 ^{d}	33.45±0.63 ^{c}	60.37±0.49 ^{a}
10 days at 4°C	43.85±0.79 ^{b}	16.12±0.64 ^{d}	33.90±0.59 ^{c}	60.86±0.34 ^{a}

fd = first determination, different letters are significant at $p < 0.05$, LSD test

At the beginning of the experiment-fd, the highest content in soluble carbohydrates was recorded in the 'Vinete Românești' variety with 24.60 ± 0.36% Brix, and the lowest in Stanley (12.18 ± 0.12%). After 5 and 10 days of storage at different temperatures (4°C and 22°C) it can be seen a trend of sugar content increasing, due to the transformation of starch into glucose following enzymatic hydrolysis processes.
After 5 days of storage at 22°C, the soluble glucides increased significantly $p < 0.05$ compared with the fd. At 4°C, after 5 days of storage, the % BRIX was significantly higher from fd value in all varieties except to 'Vinete Românești' variety (Figure 1).

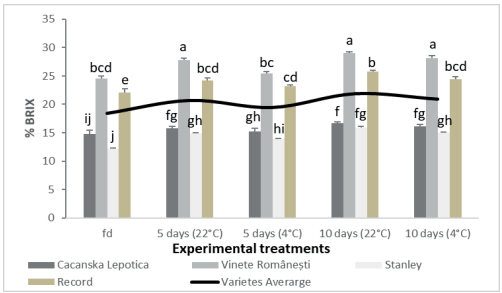

Figure 1. Results regarding the total content of soluble glucides in tested varieties (average ± SE); within overall different letters represent significant ($p < 0.05$, Fisher-LSD test) differences between the treatments

The highest sugar content after 10 days of storage at 22°C, was recorded in the varieties

'Vinete Românești' (29.08%) and 'Record' (25.78%), being significantly p < 0.05 higher than the other varieties 'Cacanska Lepotica' (16.72%) and 'Stanley' (15.92%). The sugar content values followed the same trend after 10 days of storage at 4°C.

The carbohydrate content increases higher to a temperature of 22°C than of 4°C.

The lowest amount of soluble solids overall varieties was observed at 'Stanley' variety with 15.92% with significant high difference compared to the initial record.

In the assessment of different plums hybrids, for 'Stanley' was obtained 17.95±1.34 % BRIX with 32% higher compared with our first determination for the same variety (Milošević at al., 2012). In case of 'Stanley' variety, the percent of soluble solids were 17.75±0.45 with only 16.79% higher that our first determination-fd (Milošević at al., 2012).

Here we can highlight and discuss also a better quality and higher sugar content to Romanian varieties like 'Vinete Romanești' and 'Record' with increased sugar content during storage, similar records were made to other Romanian varieties as 'Andreea' (19.30 % BRIX). However, to 'Andreea' variety, this high sugar contend was associated to the lowest yield production and number of fruits per tree, so not very productive (Zamfirescu et al., 2019).

Regarding the plum fruits pulp acidity, the lowest values were determined for 'Vinete Românești' and 'Record' varieties. The pulp acidity values compared with the fd determination decreased significantly $p < 0.05$, after 5 days of storage at 22°C for all the varieties and at 4°C only for 'Vinete Românești' with 5% (Figure 2).

The highest acidity of the plums pulp was highlighted in the 'Stanley' variety with an initial pH of 3.60, which decreased to 3.30 after 10 days of storage at 22°C and respectively 3.45 at 4°C. The initial obtained value for 'Stanley' variety was similar in other study respectively a pH of 3.66 ± 0.04 (Milošević at al., 2012). The lowest pH value was recorded at 'Vinete Românești' (3.12 initially), and decreased to 2.77 (at 22°C) and 2.86 (at 4°C), after 10 days of storage (Figure 2). Another reference similar with our finding place pH for 'Cacanska Lepotica' in a range between 3.42 ± 0.03 (fd) and 3.35 ± 0.04 (Milošević at al., 2012).

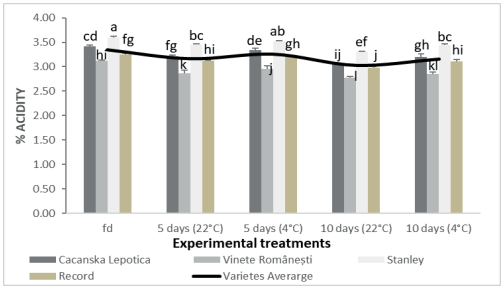

Figure 2. Results regarding the plum fruits acidity in tested varieties (average ± SE); within overall different letters represent significant ($p < 0.05$, Fisher-LSD test) differences between the treatments

The dry matter content first determination emphasis values between 13.82 ± 0.12% ('Stanley' variety) and 25.51 ± 0.34% ('Vinete Românești'). Between varieties type all the differences were significant $p < 0.05$ at the first determination. At a temperature of 22°C for 5 and 10 days of storage higher increases in dry matter content were seen compared with the storage at a temperature of 4°C.

Experiments have shown that dry matter content of the plum fruits tested show a significant increase during storage, both at 22°C and 4°C compared with the fd. At 22°C, after 10 days of storage, the lowest value was found in the 'Stanley' variety with 19.02 ± 0.53%, and the highest value was registered in the case of the 'Vinete Românești' variety with 31.36 ± 0.62%. After 10 days of storage, at 4°C, the 'Stanley' variety recorded the lowest value, of 16.28 ± 0.41%, and the highest also for 'Vinete Românești' (28.96 ± 0.55%) (Figure 3).

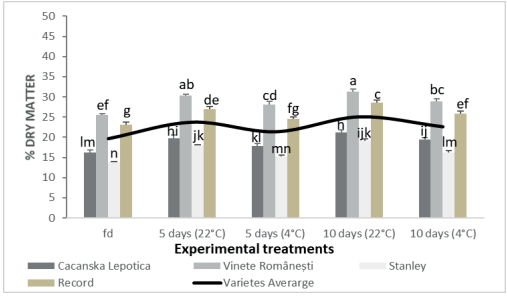

Figure 3. Results regarding the dry matter content in tested plum fruits varieties (average ± SE); within overall different letters represent significant ($p < 0.05$, Fisher-LSD test) differences between the treatments

Firmness is the best indicator of maturity. As the fruit matures, the pulp becomes softer.

The highest and significant ($p < 0.05$) firmness value was determined for 'Record' variety compared to the other varieties (Figure 4).
The lowest value in terms of firmness in plums, after 5 days of storage, both at a temperature of 4°C and at 22°C, is recorded at 'Vinete Românești' variety with 0.49 ± 0.01 lbr (22°C), while at the opposite pole is the 'Record' variety with 1.04 ± 0.02 lbr (22°C). After 10 days of storage, a reduction in fruit firmness can be observed, both at 4°C and at 22°C (Figure 4).

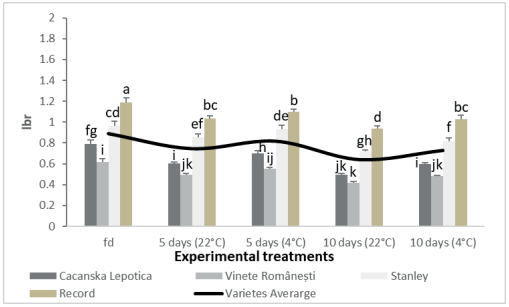

Figure 4. Results regarding the fruits firmness in tested plum varieties (average ± SE); within overall different letters represent significant ($p < 0.05$, Fisher-LSD test) differences between the treatments

CONCLUSIONS

All tested parameters were significantly different within the variety type.
Storage time produce significantly differences only for the following parameters: soluble glucids, fruit acidity, dry matter and firmness.
The parameters: small and large diameter, height and weight registered the highest values after 5 days of storage at 4°C with very low difference between the first determination. At 22°C, compared to 4°C, due to the post-ripening respiratory processes, a more drastic reduction of the fruit diameter was found.
After 5 and 10 days of storage at different temperatures (4°C and 22°C), the tendency to increase the sugar content continues, due to the transformation of starch into glucose following enzymatic hydrolysis processes.
The highest sugar content after 10 days of storage at 22°C, was recorded in the varieties 'Vinete Românești' and 'Record'.
Regarding the plums acidity, the overall values highlight higher PH at 'Stanley' variety and decreased only after 5 days of storage at 22°C and after 10 days of storage at 4°C.
Although the 'Vinete Românești' variety registered the smallest dimensions in terms of diameter, length and weight of the fruit, it had the highest percentage in sugars.
At a temperature of 22°C for 5 and 10 days of storage higher increases in dry matter content were seen compared with the storage at a temperature of 4°C.
The highest and significant firmness value was determined for 'Record' variety.
There was also an accentuated decrease of the firmness, of the acidity of the juice from the fruit pulp, but in the same time the dry matter content increased.

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