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POST-HARVEST TECHNOLOGIES INFLUENCES IN ORGANIC 'TITA' PLUMS QUALITY

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Abstract

The paper aims to present the influences of post-harvest technologies on organic 'Tita' plums during storage period, taking in consideration the variation of quality indicators, physiological parameters, and bioactive compounds. Organic 'Tita' plums were harvested in 2019, at the end of July and stored in three different condition, i.e.: 1) normal atmosphere (NA) with 1˚C and 95% relative humidity (RH), 2) controlled atmosphere (CA) conditions with 1˚C, 95% RH, 3% O_2 and 5% CO_2, and 3) CA conditions with 1˚C, 95% RH, 1.5% O_2, and 10% CO_2. Organic plum samples were evaluated at 4 moments: initially (before storage), after 3, 5, and 7 weeks of storage. Obtained results showed that total phenolic content and antioxidant activity registered the same variation trend during storage period for all samples. Differences were observed during storage period, which was shorter with 2 weeks for plums stored in NA than for those stored in both controlled conditions. Taking into consideration these results, present work suggests that plums stored in both controlled atmosphere conditions were better preserved than those stored in NA, but further trials and studies are required.

Key words*: CA, storage, respiration, transpiration, antioxidant activity.*

INTRODUCTION

In Romania, plums represent the major fruit species with highest diversity in native cultivars and are very well adapted to climatic conditions and soils (Butac et al., 2019). Moreover, almost all cultivated plums belong to *Prunus domestica* L. species (Butac et al., 2019). Beside *P. domestica* cultivars like 'Carpatin', 'Roman', 'Romanta', 'Agent', and 'Andreea', 'Tita' variety is part of Romanian plums breeding program (Butac et al., 2019).
Generally, plums (*Prunus domestica* L.) are climacteric fruits which means that respiration and transpiration processes continue after harvesting (Rozo-Romero et al., 2015) and lose their nutritional value in short time after harvesting (Hussain et al., 2015; Panahirad et al., 2020). Due to these, early harvesting is necessary in order to withstand transport which often causes the fruits to not reach the consumption maturity required by consumers (Rozo-Romero et al., 2015). As consequences of climacteric behaviour of plums are reduced shelf life, commercial problems and decreased quality parameters like color, firmness, fruit turgidity and finaly the decay occurrence and off-flavours (Peano et al., 2010), total soluble solids and total tritatable acidity (Zapata et al., 2014; Valero and Serrano, 2010). Storage conditions like 0-5°C and 80-95% RH were reported to delay softening, but also may promote disorders development like translucency, flesh browning, bleeding, and ripen failure (Manganaris & Crisosto, 2020; Manganaris et al., 2008). Many postharvest techniques were tested and reported to reduce the losses and to extend the shelf life of plums (Martínez-Romero et al., 2017) such as cold storage (Serrano et al., 2009), force air-cooling (Martínez-Romero et al., 2003), cold storage combined with 1-MCP (methylcyclopropene) (Minas et al., 2013; Valero et al., 2004), alginate edible-coating (Valero et al., 2013), polyamines (Serrano et al., 2003), calcium and

heat (Valero et al., 2002), and modified atmosphere packaging (Díaz-Mula et al., 2011). In order to reduce the losses and to extend the postharvest life of organic plums, the controlled atmosphere conditions as postharvest technologies are more and more used. As many authors reported, cold storage at 0°C combined with controlled atmosphere (CA) conditions are beneficial in extending postharvest life of plums (Peano et al., 2010; Crisosto et al., 2004). But storage technologies like CA and modified atmospheres are not widely used commercially because the benefits are not as pronounced as in other fruit species, moreover the contradictory results about the cost/benefit of plums CA storage are open (Manganaris & Crisosto, 2020).

The paper aims to present the influences of post-harvest technologies based on cold storage and controlled atmosphere conditions on organic 'Tita' plums during storage period, taking in consideration the variation of quality indicators, physiological parameters, and bioactive compounds.

MATERIALS AND METHODS

Chemicals

DPPH (1,1-diphenyl-2-picrylhydrazyl) AND Folin & Ciocalteu's reagent were purchased from Sigma-Aldrich Chemie GmbH (Riedstrasse, Steinheim). Gallic acid was purchased from Carl Roth and Trolox (6 - hydroxy - 2, 5, 7, 8 - tetramethylchroman - 2 - carboxylic acid) from Acros Organics, Fisher Scientific (Geel, Belgium). Anhydrous sodium carbonate was purchased from Lach-Ner, s.r.o. (Neratovice, Czech Republic). Methanol used in experiments was bought from Honeywell (Riedel-de Haën, Seelze, Germany) and sodium hydroxide 0.1N was from Cristal R Chim S.R.L. (Bucharest, Romania). Ultrapure water used it was made with a Milli-Q equipment (Millipore, Bedford, MA).

Samples

Organic plums from 'Tita' variety were harvested in July 2019, from Research Institute for Fruit Growing Pitesti, Romania and stored for one day at 2°C, 90% relative humidity (RH). Then were transported to Postharvest Technologies Laboratory from Research Center for Studies of Food Quality and Agricultural Products, University of Agronomic Sciences and Veterinary Medicine of Bucharest. Plums were stored in Cold Rooms with normal atmosphere, 1°C and 95% RH, 24 hours, until initially analyses were performed. After these, organic plums were equally divided and stored in three different conditions, i.e.: 1) normal atmosphere (NA) with 1˚C and 95% RH, 2) controlled atmosphere conditions with 1˚C, 95% RH, 3% and 5% CO_2 (CA 5% CO_2), and 3) controlled atmosphere conditions with 1˚C, 95% RH, 1.5% O_2, and 10% CO_2 (CA 10% CO_2). Organic plum samples were analysed in 4 moments, first one being realised before storage (noted with 0 - zero), after 3, 5, and 7 weeks of storage (noted with 3, 5, and 7).

Quality indicators

Quality parameters were represented by pH, total titratable acidity (TTA), total soluble solids (TSS), dry matter (DM) and firmness, their methods of analyse being described forward.

The pH and TTA analysis were realised using the TitroLine automatic system, equipped with pH electrode. The analysis consist in mixing 5 g of fresh sample with 25 mL of distillate water, measuring the initially pH values and then titration with 0.1N NaOH up to a 8.1 pH according with Saad et al. (2014) and AOAC Official Method 942.15. For TTA, results were expressed in g malic acid /100 g of fresh fruit (Stan et al., 2020, Gherghi et al., 2001). The total soluble solids (TSS) analysis were performed similar as Turmanidze et al. (2017), using Kruss DR301-95 digital refractometer, in accordance with Brix reading. Dry matter results were obtain using UN110 Memmert oven and drying approximately 1 g of sample at 105°C (Ticha, 2015) until constant weight. Firmness results were obtained and expressed in N/cm² using a digital penetrometer (53205 TR Italy) equipped with an 8 mm piston (Stan et al., 2019).

Physiological parameters

The respiration rate was performed using Lambda T NDIR Monitor, ADC BioScientific LTd. and results were expressed in mg CO_2/kg FW/hour (Rozo-Romero et al., 2015). Similar methods were used and described by Popa et al.

(2019), Bezdadea-Cătuneanu et al. (2019) and Farcuh et al. (2019).
The transpiration rate was determined by gravimetric measurements (Fante, 2014) before and after 30 minutes and results were expressed in g water/100 g FW/hour similar with those presented by Bezdadea-Cătuneanu et al. (2019) in their work.

Bioactive compounds
For total polyphenol content (TPC) quantitative determination was used the Folin - Ciocâlteu method adapted after Georgé et al. (2005) protocol. Samples extraction consist in trituration of 1 g fresh sample with 10 mL of 70% methanol and incubated overnight at room temperature (aprox. 21°C) and dark. Extraction continue next day through 1 h and 500 rpm homogenization, then centrifugation for 5 min at 4°C and 7000 rpm. The supernatant was recovered and the residue re-extracted two more times and the final volume of extract was 30 mL. By mixing 0.5 mL of extract with 2.5 mL of Folin - Ciocâlteu reagent and incubated for 2 minutes at room temperature (aprox. 21°C) is the first step in total polyphenol content determination. Second step is represented by adding 2 mL of 7.5% sodium carbonate solution (Na_2CO_3) and incubate the obtained mix for another 15 minutes at 50°C. Third and final step is based on the absorbance read at Specord 210 Plus UV-VIS spectrophotometer (Analytik Jena, Jena, Germany) at the 760 nm wavelength. Results are expressed in mg GAE/100 g fresh weight and Gallic acid is used as standard solution.
For antioxidant activity determination was used the DPPH (2,2-diphenyl- 1-picrylhydrazyl) method, similar as described Bujor et al. (2016) with modifications presented forward. Mixing 0.2 mL of extract with 2 mL of 0.2 mM solution of DPPH in methanol and incubated for 30 minutes, in dark with continuous homogenising. The absorbance was measured at 515 nm wavelength. Results were expressed as mg Trolox/100 g FW and blank reference was realised with methanol.

Statistical analysis
Statistical analysis of obtained data was performed using Microsoft Excel for standard deviation. Standard deviation represent the average of three replicates with independent sample preparation.

RESULTS AND DISCUSSIONS

Quality indicators
During storage period organic 'Tita' plums registered quality indicators variations for all three post-harvest technologies used. Experiments were performed during 7 weeks of storage, but physiological disorders were observed after 3 weeks of NA conditions storage and after 5 weeks for those stored in CA 5% CO_2 and CA 10% CO_2, 1˚C and 95% RH. Candan et al., 2008, reported flesh translucency as being first symptom of chilling injury, which appeared after 30 days of storage at 0˚C. In our case (Table 1) it can be observed that physiological disorders as translucency appear after 3 weeks of storage for organic 'Tita' plums stored in CA 5% CO_2 and CA 10% CO_2 conditions. Comparing with organic 'Tita' plums stored in NA conditions were the overripe disorder is already installed after 3 weeks of storage, those stored in CA 5% CO_2 and CA 10% CO_2 conditions the overripe disorder appear after 5 weeks of storage. These physiological disorders observed in our work are related with chilling temperatures, and similar behavior was described by Manganaris & Crisosto (2020) in their study which present that commercial storage conditions (0-5°C and 80-95% RH) are delaying softening, but may promote the storage disorders development, manifested as translucency, bleeding, flesh browning, and/or failure to ripen. The delayed onset of physiological disorders for plums stored in CA conditions was due to low O_2 and increased CO_2 concentrations which slowed metabolic process and consequently the respiration (Figure 1) and transpiration (Figure 2) processes.
CA conditions should be monitored in different ways, by measuring the respiration rate (Díaz-Mula et al., 2011), intensity (Wang et al., 2016) and measurements of the stored fruit respiratory quotient (Bessemans et al., 2016).
The initially TTA values (Tabel 2) of organic 'Tita' plums were 1.16 ± 0.01 g malic acid/100 g FW, similar with results presented by Bozhkova (2013). During storage the TTA values decreased up to 0.95 ± 0.01 malic

acid/100 g FW for organic 'Tita' plums after 3 weeks and 0.74 ± 0.04 malic acid/100 g FW after 5 weeks of NA storage, which means that plums acidity increased. Majeed & Jawandha (2016) observed similar behavior in their study. For plums stored in CA 5%CO_2 and CA 10% CO_2 conditions were observed smaller decreases of TTA results. Important decreases of firmness were registered for organic 'Tita' plums stored in NA conditions, while for those stored in CA 5% CO_2 and CA 10% CO_2 conditions firmness presented smaller decreases. Correlation between firmness decreases and storage period were described also by Majeed & Jawandha (2016). Manganaris & Crisosto (2020) explain in their work that most studies indicate that fruits wich were stored at temperatures above 0°C and CA were firmer than those air-stored.

Table 1. Influences of post-harvest technologies based on cold storage and controlled atmosphere conditions on organic 'Tita' plums appearance

Moment of analysis (weeks) / Storage conditions	0	3	5	7
Before storage		n/a	n/a	n/a
NA with 1˚C, 95% RH	n/a			After 5 weeks analysis, no healthy fruits remained
1˚C 95% RH 3% O_2 5% CO_2	n/a			
1˚C 95% RH 1.5% O_2 10% CO_2	n/a			

Table 2. Variation of pH, total titratable acidity (TAA), total soluble solids (TSS), and dry matter (DM) content during storage of 'Tita' plums

Variety	Storage conditions	Analysis moment (weeks)	pH	TAA (g malic acid/100 g FW)	TSS %	DM %	Firmmnes (N/cm²)
'Tita' Organic	NA with 1˚C, 95% RH	0	3.42±0.06	1.16±0.01	17.85±1.10	8.13±1.47	15.14±1.86
		3	3.34±0.05	0.95±0.01	15.93±2.29	14.38±0.36	7.54±1.73
		5	3.60±0.20	0.74±0.04	16.87±2.14	15.74±0.87	6.50±2.31
		7	After 5 weeks analysis, no healthy fruits remained				
	1˚C, 95% RH, 3% O_2, 5% CO_2	3	3.29±0.09	1.00±0.01	15.91±2.30	13.86±0.24	15.22±4.81
		5	3.46±0.07	0.98±0.005	14.48±1.49	13.48±0.59	16.29±3.79
		7	3.50±0.25	0.87±0.03	16.79±1.62	15.49±4.27	10.59±1.19
	1˚C, 95% RH 1.5% O_2, 10% CO_2	3	3.38±0.05	1.11±0.01	12.89±1.07	11.97±0.49	18.97±2.17
		5	3.45±0.01	1.07±0.02	14.07±1.62	12.73±1.50	19.07±8.89
		7	3.36±0.10	0.99±0.02	15.23±1.64	14.57±1.53	16.17±3.93

Data represent mean ± standard deviation of three replicates.

Also, Manganaris & Crisosto (2020) explain that CA has a rather limited use for plums storage for periods longer than 4 weeks. TSS results shown variation in all three storage conditions experimented in our work and were similar with those obtained by Butac et al., (2019).

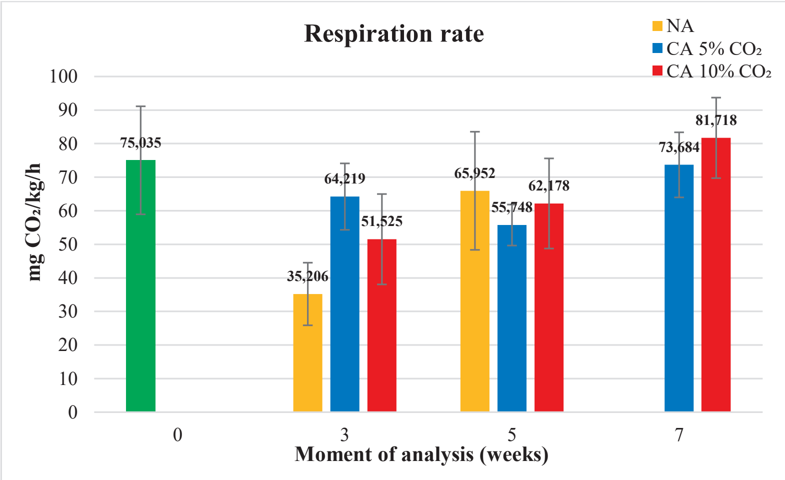

Figure 1. Respiration rate results for organic 'Tita' plums, registered during storage period

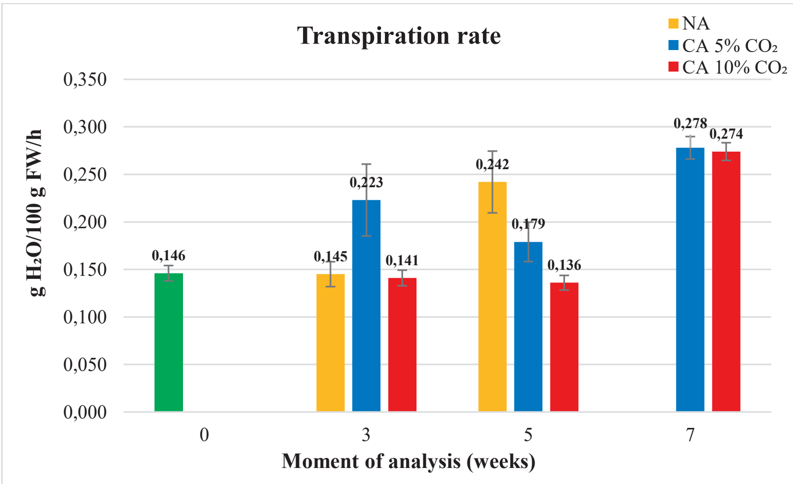

Figure 2. Transpiration rate results for organic 'Tita' plums, registered during storage period

Bioactive compounds

The content of bioactive compounds were determined from whole plum and showed similar behavior for all tested storage conditions. For organic 'Tita' plums stored in NA conditions with TPC values 129.9 mg GAE/100 g FW demonstrate small decreases after 3 and 5 weeks of storage up to 120.3 mg GAE/100 g FW, respectively 117.3 mg GAE/100 g FW. Organic 'Tita' plums stored in CA 5% CO_2 and CA 10% CO_2 conditions also presented decreased TPC values in comparison with those from the initially moment of analyses. After 7 weeks of storage the TPC values were smaller than those obtained after 5 weeks, which indicate that organic 'Tita' plums were no longer safe to be consumed.

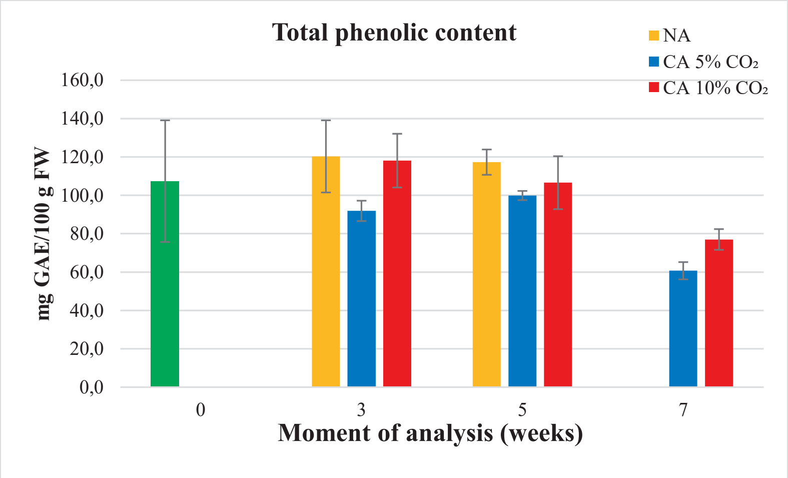

Figure 3. Total phenolic content variations for organic 'Tita' plums, registered during storage period

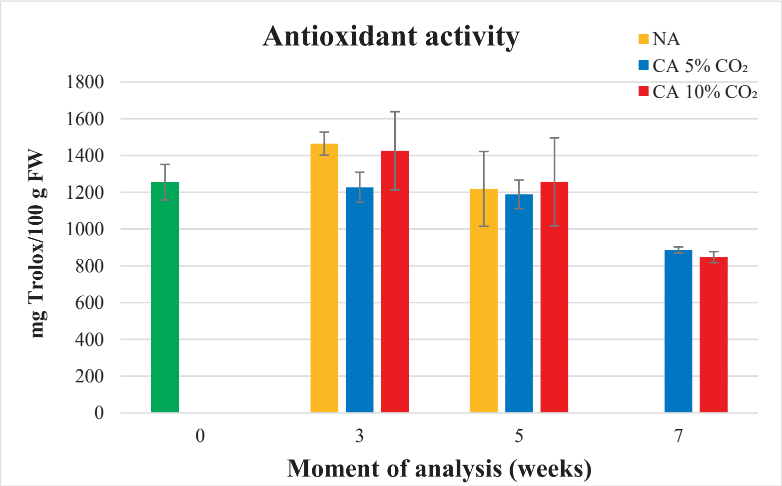

Figure 4. Antioxidant activity variations for organic 'Tita' plums, registered during storage period

All analyzed samples present an increased antioxidant activity during storage period for all three different applied conditions. Similar behavior of antioxidant activity increasing during storage in plums was observed by Martínez-Romero et al. (2017), in both peel and pulp, when they analyzed the hydrophilic antioxidant activity (H-TAA) and the lipophilic antioxidant activity (L-TAA). As Puerta-Gomez & Cisneros-Zevallos (2011) observed in their study, in case of present study, the antioxidant activity trolox, mg/100 g FW, did not registered major changes during storage, presenting similar behaviour as total phenolic content.

CONCLUSIONS

Results showed that total phenolic content and antioxidant activity registered the same variation trend during storage period for all samples. Differences were observed during storage period, which was shorter with 2 weeks for plums stored in NA than for those stored in CA 5% CO_2 and CA 10% CO_2 conditions. Physiological disorders as translucency appear after only 3 weeks of storage in CA 5% CO_2 and CA 10% CO_2 conditions, and after 5 weeks appear the overripe disorder. For organic 'Tita' plums stored in NA conditions the overripe disorder was already installed after 3 weeks of storage. Physiological disorders observed in our work are related with chilling temperatures. The delayed onset of physiological disorders for plums stored in CA conditions was due to low O_2 and increased CO_2 concentrations which slowed metabolic process. Taking these results in consideration, present work suggests that plums stored in both controlled atmosphere conditions were better preserved than those stored in NA, but further trials and studies are required.

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