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MODIFIED ATMOSPHERE INFLUENCE IN ORGANIC 'TITA' PLUMS QUALITY

Andreea STAN[1], Mihai FRÎNCU[1], Violeta Alexandra ION[1], Liliana BĂDULESCU[1, 2]

[1]Research Center for Studies of Food Quality and Agricultural Products, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania;
[2]Faculty of Horticulture, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: andreea.stan@qlab.usamv.ro

Abstract
The modified atmosphere is intensively studied as a fruit storage method due to consumers growing demands regarding the fresh fruit quality. The aim of this study was to extend the organic plums shelf life, by packing them in biodegradable, eco-friendly trays, and to ensure that the physicochemical and nutritional characteristics are maintained throughout the storage period. The experiments were performed in 2019 and 2020 with organic 'Tita' plums harvested at the end of July, packed immediately and cold stored at 1 ± 0.5 °C and 85 ± 5 % RH. The modified atmosphere was realised in passive way through respiration and transpiration processes of organic plums. As control, unpacked plums were kept in same storage conditions. The results showed small decreases for physicochemical characteristics of organic 'Tita' plums stored in modified atmosphere, after more than 40 days, for both years of study. Based on the physicochemical and nutritional properties we can state that organic 'Tita' plums packed in biodegradable and compostable trays were better preserved.
Key words*: antioxidant activity, biodegradable package, cold storage, passive MA, respiration.*

INTRODUCTION

Modified atmosphere packaging is a technique used for prolonging the shelf-life period of fresh or minimally processed foods (Sandhya, 2010). Modified atmosphere packaging (MAP) is defined as "the packaging of a perishable product in a changed atmosphere and different by air concentration". This preservation technique is based on air surrounding the food in the package is changed to another gaseous composition and the initial product freshness may be prolonged.

Modified atmosphere packaging (MAP) technology is largely used for minimally processed fruits and vegetables (Sandhya, 2010) and can be realized as an active or passive dynamic process (Jalali et al., 2017). Passive MAP relies on natural initial gaseous composition as well as the interaction between the respiration rate of the produce, and packaging material gases permeation, while in active MAP gaseous composition is additionally flushed into the package in order to achieve faster equilibrium atmosphere (Jalali et al., 2017; Caleb et al., 2012; Farber et al., 2003; Mahajan et al., 2007).

Plums (*Prunus domestica* L.) are climacteric fruits with highest diversity in native cultivars in Romania (Stan et al., 2020; Butac et al., 2019). Due to their climacteric characteristic, after harvesting plums continue the respiration and transpiration processes, which can be used in passive modified atmosphere packaging. One of the most common plum cultivars is 'Tita' variety, wich belong to *Prunus domestica* L. species. In the last years the passive or active MAP utilization as postharvest technologies was more extesively studied, with the main scope of prolonging the freshness and shelf life of fruits, especially for plums. The MAP efficacy in reducing chilling injury symptoms in some plums varieties was studied in several papers (Díaz-Mula et al., 2011a; Cantín et al., 2008; Guan and Dou, 2010) and it was observed that ripening parameters like dehydration, softening, respiration rate, colour changes, total soluble solids increasing, and acidity losses are delayed (Díaz-Mula et al., 2011b).

The aim of this study was to extend the organic plums shelf life, by packing them in biodegradable, eco-friendly trays, and to ensure that the physicochemical and nutritional

characteristics are maintained throw the storage period.

MATERIALS AND METHODS

Chemicals

Chemicals used in experiments were purchased from different producers: Gallic acid from Carl Roth; Trolox from Acros Organics, Fisher Scientific (Geel, Belgium); Folin-Ciocâlteu's reagent and DPPH (1,1-diphenyl-2-picrylhydrazyl) from Sigma-Aldrich Chemie GmbH (Riedstrasse, Steinheim); anhydrous sodium carbonate from Lach-Ner, (Neratovice, Czech Republic); sodium hydroxide 0.1N from Cristal R Chim S.R.L. (Bucharest, Romania); methanol from Honeywell (Riedel-de Haën, Seelze, Germany) and ultrapure water was obtained with Milli-Q water equipment (Millipore, Bedford, MA).

Samples

Organic plums from 'Tita' variety were harvested in July 2019 and 2020 from ICDP Pitesti (Research Institute for Fruit Growing from Pitesti, Romania), and stored at 2°C, 90% relative humidity (RH) until were transported to the Research Center for Studies of Food Quality and Agricultural Products (USAMV of Bucharest) in the Postharvest Technologies Laboratory. Plums were packed immediately after reception and cold stored at 1 ± 0.5°C and 85 ± 5% RH. The modified atmosphere was realized in passive way through respiration and transpiration processes of organic plums. As control, unpacked plums were kept in same storage conditions. Organic plum samples were evaluated during 41 days of storage in modified atmosphere.

Quality indicators

Quality parameters represented by pH, total titratable acidity (TTA), total soluble solids (TSS), dry matter (DM), and firmness; were analyzed during storage period, their methods being described below.

TTA analysis was performed with the automatic system TitroLine, equipped with pH electrode. 5 g of fresh sample were mixed with 25 mL of distillate water and titrated with 0.1N NaOH up to 8.1 pH according with Saad et al. (2014) and AOAC Official Method 942.15. Results were expressed in g malic acid / 100 g of fresh fruit similar with Stan et al. (2020). pH was obtained by measuring the pH values of sample before titration. TSS analysis was realized with digital refractometer Kruss DR301-95, in accordance with Brix reading (Turmanidze et al., 2017). Dry matter content was obtained by oven drying (UN110 Memmert) 1 g of sample at 105°C (Ticha et al., 2015) until constant weight. Firmness was expressed in N/cm² and performed with digital penetrometer 53205 TR Italy and 8 mm piston (Stan et al., 2020). During storage period the passive modified atmosphere was monitorized by measuring oxygen and carbon dioxide concentrations with OxyCheck equipment.

Bioactive compounds

Bioactive compounds like total polyphenol content (TPC) and antioxidant activity were also monitored during experiment development. TPC quantitative determination using Folin-Ciocâlteu method was realised besed on a previous developed protocol (Bădulescu et al., 2019). Extraction consist in 1 g fresh sample mixed with 10 mL of 70% methanol, incubated in dark at room temperature (approx. 21°C), then homogenized for 1 h and 500 rpm, followed by centrifugation for 5 min at 4°C and 7000 rpm, with supernatant recovering and re-extracting the residue for two more times. The final volume was 30 mL. Sample preparation for spectrophotometric measurements: 0.5 mL of extract was mixed with 2.5 mL of Folin-Ciocâlteu reagent and incubated at room temperature (approx. 21°C) for 2 minutes. Then 2 mL of 7.5% sodium carbonate solution (Na_2CO_3) were added and incubated at 50°C for 15 min. Spectrophotometric measurements of the samples were realized using the Specord 210 Plus UV-VIS spectrophotometer (Analytik Jena, Jena, Germany) at the 760 nm wavelength. Results were expressed in mg GAE/100 g fresh weight.

Antioxidant activity was determined using the DPPH (2,2-diphenyl- 1-picrylhydrazyl) method (Bujor et al., 2016). Therefore 0.2 mL of extract were mixed with 2 mL of 0.2 mM solution of DPPH in methanol and incubated in dark with continuous homogenising for 30 minutes. The Specord 210 Plus UV-VIS

spectrophotometer (Analytik Jena, Jena, Germany) was used to measure the sample absorbance at 515 nm wavelength. Results were calculated as mg Trolox eq./100 g fresh weight.

Statistical analysis

All data were obtained from average of three independent replicates and were statistically analysed with standard deviation using Microsoft Excel.

RESULTS AND DISCUSSIONS

Quality indicators

Quality indicators of organic 'Tita' plums were monitored during 41 days of cold storage and modified atmosphere. Analysis were performed initially, after 28, respectively 41 days for both plum storage conditions. In Table 2 are presented oxygen and carbon dioxide variation during storage of organic 'Tita' plums. It can be observed that after packaging, due to respiration and transpiration processes oxygen concentration decrease and carbon dioxide increased in both years of study. In Table 1 it can be observed that translucency appear after 28 days of both organic 'Tita' plums storages (packed in modified atmosphere and bulk). Same physiological disorder were observed by Stan et al. (2020) for organic 'Tita' plums stored controlled atmosphere conditions with 5% CO_2, respectively 10% CO_2. After 41 days of storage in 2019 the organic 'Tita' plums stored as bulk presented a more sever decay appearance comparing with those from 2020 experiment. When organic 'Tita' plums packed in modified atmosphere were analyzed, it was observe that translucency also appear after 28 days of cold storage and after 41 days similar results like in the case of bulk plums storage were noted. The translucency disorder was present after 28 days of storage (passive modified atmosphere and bulk), comparing with same organic plums from Stan et al., (2020) paper, stored in controlled atmosphere with 3% O_2 and 5% CO_2, respectively with 1.5% O_2 and 10% CO_2 when disorder appear after 5 weeks of storage (35 days). It can be see that a high concentration of carbon dioxide and low oxygen prolong the shelf life of organic 'Tita' plums. In the case of organic 'Tita' plums packed in passive modified atmosphere, the carbon dioxide and oxygen concentrations were high, therefore the storage capacity was considerably lower.

In Table 3 the following quality indicators are present TTA, pH, TSS, DM and firmness. The TTA values of organic plums registered a similar variation for both storage methods used and for both studied years. Similar results were observed by Majeed & Jawandha (2016) and Stan et al. (2020). Dry matter content registered increases during storage periods in 2019 with 51% for plums packed in passive MA and with 93% for those stored bulk after 41 storage days. TSS shown smiliar variations for both studied years. In 2019 experiment, firmness registered decreases of 19% for plums packed in passive MAP comparing with those stored bulk, which registered decreases with 57% after 41 storage days. These result are in accordance with those observed by Manganaris & Crisosto (2020) in their study were they mentioned that fruit stored in air are less firm than those stored in CA and temperatures above 0°C.

Bioactive compounds

Bioactive compounds were represented by total phenolic content and antioxidant activity and present similar variations during storage period for both storage conditions and years. In 2020 study the organic 'Tita' plums showed smaller values comparing with those obtained in 2019, but kept a similar trend for both TPC and AA.

For plums packed in passive MAP, higher values for TPC - 128.11 mg GAE/100 g FW comparing with bulk stored - 117.27 mg GAE/ 100 g FW after 41 days of storage were observed. Comparing with the initial moment of analysis, the TPC values registered increases in both study years (Figure 1).

An increase in AA values for plums packed in passive MA in 2019 (1468.09 mg Trolox eq./ 100 g FW) after 41 storage days was observed when compared to the initial results (1255.10 mg Trolox eq./100 g FW). On a contrary basis, in 2020 a small decrease (1033.58 mg Trolox eq./100 g FW) was observed after 41 storage days, comparing with the initial analysis (1205.99 mg Trolox eq./100 g FW) (Figure 2).

The obtained variation for both TPC and AA are small, less than 10% for passive MA in both years, and for bulk plums in 2020, except

for the AA for bulk plums in 2019, which showed a decrease of 14.08%. This suggest that passive MA stored plums can be stable for at least 41 days without high degradation of TPC and AA.

Table 1. Influences of modified atmosphere and cold storage on organic 'Tita' plums appearance

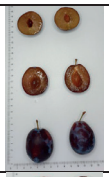
Year	Moment of analysis (weeks) / Storage conditions	0	28 days	41 days
2019	Before storage		n/a	n/a
	Modified atmosphere	n/a		
	Bulk	n/a		
2020	Before storage		n/a	n/a
	Modified atmosphere	n/a		
	Bulk	n/a		

Table 2. Oxygen and carbon dioxide variation during storage of organic 'Tita' plums

Variety	Storage conditions	Analysis moment (weeks)	Oxygen concentration (%)	Carbon dioxide concentration (%)
'Tita'/ 2019	N/A	**0**	20.9 ±0.001	0.74 ±0.05
	Modified atmosphere	**28**	19.04 ±0.0074	6.90 ±0.003
		41	18.54 ±0.008	6.37 ±0.004
'Tita'/ 2020	N/A	**0**	20.89 ±0.01	0.78 ±0.02
	Modified atmosphere	**28**	19.18 ±1.01	6.06 ±3.06
		41	20.075 ±0.7	5.90 ±0.007

Data represent mean ± standard deviation of five replicates.

Table 3. Variation of quality indicators during storage of 'Tita' plums in modified atmosphere and bulk in cold storage

Variety	Storage conditions	Analysis moment (weeks)	pH	TAA (g malic acid/100 g FW)	TSS %	DM %	Firmmnes (N/cm²)
'Tita'/ 2019	N/A	**0**	3.42 ±0.06	1.16 ±0.01	17.85 ±1.10	8.13 ±1.47	15.14 ±1.86
	Modified atmosphere	**28**	3.39 ±0.05	1.17 ±0.00	15.17 ±1.72	14.06 ±1.27	8.46 ±1.73
		41	3.43 ±0.03	0.89 ±0.01	13.94 ±1.93	12.3 ±0.90	12.15 ±4.87
	Bulk	**28**	3.34 ±0.05	0.95 ±0.01	15.93 ±2.29	14.38 ±0.36	7.54 ±1.73
		41	3.60 ±0.20	0.74 ±0.04	16.87 ±2.14	15.74 ±0.87	6.50 ±2.31
'Tita'/ 2020	N/A	**0**	3.25 ±0.02	0.96 ±0.01	13.31 ±2.06	14.89 ±5.18	18.05 ±4.85
	Modified atmosphere	**28**	3.26 ±0.02	0.83 ±0.003	13.04 ±0.27	11.36 ±0.88	8.97 ±3.16
		41	3.43 ±0.14	0.75 ±0.01	13.49 ±0.99	10.46 ±1.57	9.00 ±1.68
	Bulk	**28**	3.20 ±0.05	0.94 ±0.005	15.90 ±2.06	14.94 ±1.13	10.62 ±3.29
		41	3.28 ±0.03	0.77 ±0.01	14.73 ±0.38	14.04 ±0.56	7.32 ±2.05

Data represent mean ± standard deviation of three replicates.

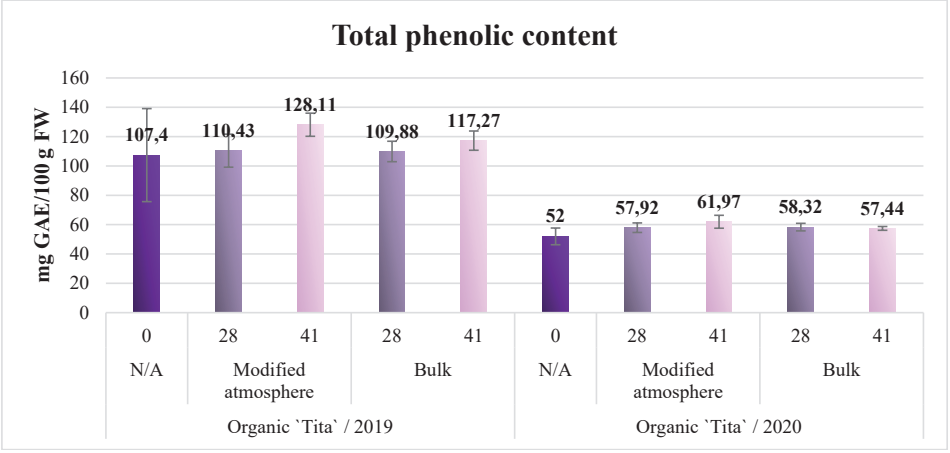


Figure 1. TPC variation for organic 'Tita' plums in modified atmosphere and cold storage

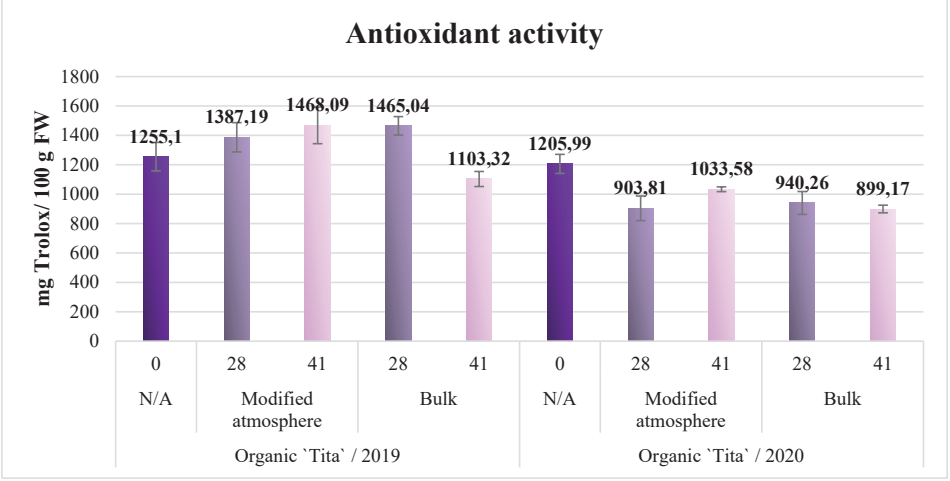


Figure 2. AA variation for organic 'Tita' plums in modified atmosphere and cold storage

CONCLUSIONS

The results showed firmness decreases of organic 'Tita' plums stored in modified atmosphere and bulk, after 41 days, for both years of study.
Even if the translucency disorder appear after 28 days both storage methods, the quality indicators present better values for organic 'Tita' plums packed in passive MA than those stored as bulk. Moreover the bioactive compounds of organic 'Tita' plums packed in biodegradable and compostable trays were better preserved.

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