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INFLUENȚA TEHNOLOGIILOR DE PĂSTRARE ASUPRA PARAMETRILOR DE CALITATE AI FRUCTELOR LA UNELE SOIURI DE MĂR CULTIVATE ÎN SISTEM ORGANIC

INFLUENCE OF STORAGE TECHNOLOGIES ON QUALITY PARAMETERS FOR APPLE'S GROWTH IN ORGANIC SYSTEM

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Abstract

Nowadays, the consumer demand for organic fresh fruits with better nutritional quality has increased; therefore the market pressure for a prolonged shelf life is growing. For this reason, improving storage conditions and technologies is important and becomes highly relevant. The storage in controlled atmosphere conditions represent an efficient technology used for fruits and vegetables and is also accepted in organic system when gases like O_2, CO_2, and N_2 are used. Therefore, controlled temperature and humidity enhances the benefits of long-term storage and better shelf life, especially for organic fruits. Apples represent one of the most common organic fruits which require long-term storage. The aim of this work was to determine the optimal storage technologies for organic apples based on quality parameters. Apple varieties grown in the experimental orchard of University of Agronomic Sciences and Veterinary Medicine of Bucharest were harvested, stored and monitored for several months. The storage technologies applied were normal atmosphere with 1˚C and 95% relative humidity (RH) (for 2 months), combined with controlled atmosphere: 1˚C, 95% RH, 3% O_2 and two different CO_2 concentrations 5%, respectively 10% (for another 5 months). Quality parameters monitored consist in analysis of pH, total soluble solids (TSS), dry matter content (DM%), firmness, total titratable acidity (TAA) and ascorbic acid content. For all apple samples in all storage conditions, the ascorbic acid content registered decreases during storage.

Cuvinte cheie: ecologic, depozitare la rece, oxigen, dioxid de carbon, mere.
Key words: organic, cold storage, oxygen, carbon dioxide, apples.

1. Introduction

Nowadays, consumers demand for organic fresh fruits with better nutritional quality and the market pressure for a prolonged shelf life are growing and for this reason the improved storage conditions and technologies are important and become highly relevant. Studies showed that consumers have increased their positive perception on organic and local grown apples (Denver & Jensen 2014).

Apples grows especially in temperate zones, and they represent one of the most appreciated fruits (Musacchi & Serra 2018), which have received more attention because of fiber content, polyphenols content, and their positive effect on human health, especially if they are grown in organic cultures (Persic et al. 2017).

Apples harvesting at appropriate time is of major importance, because it determines both the quality and the shelf life. Both fruits harvested at advanced maturity, and unripen fruits induce postharvest losses by shortening storage life and greater susceptibility to pathogens and physiological disorders (Ganai et al. 2018). But also organic apple losses occurs because of diseases (Morales et al. 2010), physiological disorders, handling, transportation (Springael et al. 2018) and postharvest storage (Tarabay et al. 2018).

Fruit quality is a consequence of diverse physiological, biochemical, physical and pathological processes that result in changes of its properties such as color, texture, flavor and aroma, together with their appearance (size, color and shape) and nutritional value (Rizzolo et al, 2014). Postharvest changes during storage have been correlated with a number of factors including fruit firmness, fruit weight loss (WL), total soluble solids (TSS) content and effective acidity (pH). Because polyphenols are closely related to health benefits (Kalinowska et al. 2014), the variation of its content should also be an important factor identifying post-harvest changes in apples (Persic et al., 2017; Li et al., 2019), even though its composition notably depend on apple varieties (Costa et al., 2012). Also, for apples, red skin color (due to anthocyanin content) is an important factor for market acceptance, colored fruits generally earn higher prices, (Saure, 1990) and consumers knows that better color often means better taste. Vitamin C is one

of the most common vitamins, and important for both human nutrition and as well as food industry (Mditshwa et al. 2017). Despite the importance of vitamins in fruits, very few studies have investigated the content of vitamins in organic fruits as a factor in storage conditions.

Different studies have been conducted in order to determine appropriate storage conditions such as: MCP (1-methylcyclopropene) treatment of apples at various storage periods (Melnyk et al., 2014); cold storage under modified atmosphere (Ma, 2017); cold storage preceded by MCP treatment, low oxygen content chambers (Juhņeviča - Radenkova et al., 2016); dynamic controlled atmosphere (Mditshwa et al., 2018); dynamic controlled atmosphere based on chlorophyll fluorescence or respiratory quotient (Both, 2017). In this study it was experimented the cold storage preceded by two different controlled atmosphere conditions in order to determine the optimal storage conditions of four organic apple varieties based on the variation of quality indicators and such as: firmness, pH value, total titratable acid (TAA), total soluble solids (TSS), dry matter (DM), respiratory intensity, transpiration rate, ascorbic acid and total anthocyanin content.

2. Material and methods

The four cultivars of apples (*Malus domestica*) 'Rubinola', 'Topaz', 'Gemini' and 'Renoir' were harvested at the optimal ripening stage in the beginning of October 2018, from the experimental orchard of University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania, and transported immediately to the Research Center for Studies of Food Quality and Agricultural Products. Before the analysis the samples were divided in different storage condition as follows: *1* - cold storage (1˚C and 95% RH), noted 0% CO_2; *2* - cold storage (1˚C and 95% RH) for 2 months followed by controlled atmosphere conditions 1˚C, 95% RH, 3% O_2, 5% and 10% CO_2 for another 3 months, noted 5% CO_2 respectively 10%CO_2; *3* - normal atmosphere (1˚C and 95% RH) for 2 months followed by controlled atmosphere 1˚C, 95% RH, 5% and 10% CO_2 for another 4 months, noted 5% CO_2 respectively 10%CO_2; and *4* - normal atmosphere (1˚C and 95% RH) for 2 months followed by controlled atmosphere 1˚C, 95% RH, 5% and 10% CO_2 for another 5 months noted 5% CO_2 respectively 10%CO_2

All samples were analyzed in different moments of storage, as follows: initial (after harvesting) noted with ”0 - zero”, and at different point during the storage like: 2 - after 2 months of cold storage, 5 - after 2 months of cold storage and 3 months of controlled atmosphere storage, 6 - after 2 months of cold storage and 4 months of controlled atmosphere storage and 7 - after 2 months of cold storage and 5 months of controlled atmosphere storage).

Reagents. Analytical standard such as ascorbic acid, was purchased from Merck (KgaA, Darmstadt, Germany). All other reactive used for analysis were purchased from Merck (KgaA, Darmstadt, Germany), except for formic acid which was purchased from Sigma-Aldrich (GmbH, Germany). Water used in the study was produced with the Milli-Q Direct Water Purification System (Millipore SAS, France).

Firmness was determined using a digital penetrometer (53205 TR Italy) equipped with an 8 mm piston, and the results reported as kg/cm^2, represent the average of 6 to 10 different measurements. Dry matter content was performed using Partner MAC 50 thermal balance at 105°C using 1 g of homogenized sample. The results were expressed in percentage (w/w).

Total soluble solids were measured with using digital refractometer (Kruss DR301-95) as previously described in our work (Stan et al., 2019) and the results were expressed in percentage (w/w). pH values and total titrable acidity were measured using a TitroLine automatic titrator. Before analysis the samples were grinded and homogenized; 5 g of fresh sample was weighed and 25 mL of distillated water was added. The initial pH was measured and the samples were titrated with 0.1N NaOH up to a 8.1 pH (Saad A.G. et al., 2014; AOAC Official Method 942.15). The total titrable acidity was expressed in g malic acid /100g of fresh fruit (Gherghi et al. 2001).

The respiratory intensity was measured for 30 minutes, in containers with hermetic closure with a volume of 1180 mL. Respiratory intensity was measured with Lambda T NDIR Monitor, ADC BioScientific LTd., and the results obtained were expressed in mg CO_2/kg/hour (Popa et al., 2019).

The transpiration rate was measured by gravimetric measurement (Fante, 2014), after 30 minutes for apples and the results obtained were expressed in g water/100g fresh weight/hour (Bezdadea-Cătuneanu et al., 2019).

Ascorbic acid content was determined after extraction of 1 g of raw material, grinded with 2 mL of orthophosphoric acid (2%, v/v) for 1 minute at room temperature. The mixture was quantitatively passed into a 15 mL centrifuge tubes, and brought to a final volume of 10 mL with orthophosphoric acid (2%, v/v). After extraction, all samples were centrifuged, filtered and stored for HPLC analysis (Stan et al. 2019,). Ascorbic acid quantification was realized using HPLC-DAD equipment (Agilent Technologies 1200 Chromatograph).

Chromatographic separation of compounds was performed using an ZORBAX XDB-C18 (4.6 x 50 mm, 1.8 µm i.d.) column. The following conditions were used for analysis: column temperature was 30°C,

injection volume was 2 µL, isocratic flow rate of 0.5 mL/min using 0.05% formic acid in water as mobile phase (Chanforan et al., 2012).

For the total anthocyanin content, 0.3 g of fresh sample was extracted with 5 mL of methanol acidified with 1% hydrochloric acid (v/v), stirred for 30 min and centrifuged. The obtained supernatant was passed into 15 ml centrifuge tubes, and then remaining residue was subjected at successive extractions until the residue becomes colorless. The final extract was filtered for analysis with a Specord 210 Plus spectrophotometer at a wavelength of 530 nm. Results were expressed in mg /100 g fresh weight: Total anthocyanins = A530 x F, where DO530 is absorbance at wavelength λ = 530 nm and factor F = 11.16.

Statistical analyses were realised with TIBCO Statistica® 13.5.0 software for the ANOVA single factor and Microsoft Excel for standard deviation, correlations, and T Test (Pomohaci, 2017).

2. Results and discussions

After 2 months of cold storage (1˚C and 95% RH) followed by another 5 months of controlled atmosphere conditions 1˚C, 95% RH, 3% O_2, 5% and 10% CO_2 it was observed that all analyzed apple cultivars registered variations of quality indicators (Table 1). In particular case the firmness registered decreases for all analyzed apples cultivars from 5% for 'Gemini' cv. stored in controlled atmosphere conditions with 10% CO_2 up to 45% for 'Topaz' cv. stored in controlled conditions with 5% CO_2. Similar behavior it was observed by Militaru (2016), in their experimental work on quality apples during 4 months of cold storage. Also, they concluded that the rapid post-harvest softening of apples was caused by water loss due to transpiration and cell wall breakdown due to enzymatic activities (Kweon et al., 1998, Militaru et al., 2016).

Meanwhile, the results obtained for water content and total soluble solids shown a high negative and significant correlations when ANOVA ($p<0.05$) and T test were applied for 'Rubinola' and 'Gemini' cvs. stored for 2 months of cold storage (1˚C and 95% RH) followed by another 5 months of controlled atmosphere conditions 1˚C, 95% RH, 3% O_2, 5% and 10% CO_2. Also, the water content values of all apple cultivars were similar with results estimated by Chira (2008) between 83-89%.

Another strong and significant correlation, positive this time, it was observed between the respiratory intensity (Figure 1) and transpiration rate (Figure 2) for Renoir cv. at initially moment of analysis (linear regression equation: Transpiration rate = 0.0018 x respiratory intensity – 0.012; R^2=0.847). Also for 'Renoir' cv. was observed a significant correlation between transpiration rate and water content for both storage conditions experimented.

When results of ascorbic acid content (Figure 3) from initial moment were compared with those obtained after 6 months of storage in both controlled atmosphere conditions, all apple cultivars registered decreases (the major decrease it was registered by 'Topaz' cv. with 80% respectively 92% in controlled atmosphere conditions at 5% CO_2 respectively 10% CO_2). After 7 months of storage the concentration of ascorbic acid was not in a quantifiable amount being below the limit of quantification for all analyzed apples cultivars.

The total anthocyanin content showed contrasted variations among both controlled atmosphere conditions in all cultivars of apples (Figure 4). A significant increase in TAC is exhibited at 6 months of storage with 5% CO_2 and 10% CO_2 for 'Rubinola' cv. and 'Gemini' cv., whereas for 'Topaz' cv. higher levels of TAC were observed after 2 months of storage at 0% CO_2.

According to Francis (1989) the anthocyanin are labile in nature and susceptible to deterioration during processing and storage. The presence of oxygen was found as a major factor influencing anthocyanin stability during food processing and storage (Jackman and Smith, 1992).

4. Conclusions

'Rubinola' and 'Gemini' cultivars registered good results in the given experimental conditions, with an increase in anthocyanin content and maintaining the other qualitative parameters at the level of those recorded at 2 months of cold storage.

'Topaz cultivar is not recommended for these experimental conditions.

After six months of combined storage conditions the ascorbic acid content registered decreases for all analyzed apple cultivars, moreover in the seventh month it was under quantification limits.

Further studies and trials are required in order to find new postharvest conditions that could decrease the total costs of storage.

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Tables and figures

Table 1. Physical-chemical results

Cultivar	Months	Storage condition	pH	TAA (g malic acid/100 g FW)	TSS %	Water content %	Firmness kg/cm²
'Rubinola'	0	initially	3,65 ±0,02	0,34 ±0,01	14,72 ±0,48	81,49 ±0,16	5,02 ±0,32
	2	0% CO_2	3,48 ±0,03	0,36 ±0,07	13,88 ±0,56	83,79 ±1,16	1,93 ±0,19
	5	5% CO_2	3,57 ±0,08	0,36 ±0,01	11,14 ±0,7	84,75 ±1,75	3,62 ±0,19
		10% CO_2	3,67 ±0,1	0,37 ±0,002	11,86 ±0,83	83,77 ±2,47	3,25 ±0,15
	6	5% CO_2	3,93 ±0,02	0,30 ±0,005	12,56 ±1,44	84,06±0,33	3,50 ±0,08
		10% CO_2	3,81 ±0,02	0,47 ±0,004	14,36 ±1,25	82,74 ±0,2	4,42 ±0,22
	7	5% CO_2	3,45 ±0.06	0,27 ± 0,009	13,68 ± 1,66	81,87 ±1,36	3,32 ±0,54
		10% CO_2	3,36 ±0.04	0,27 ± 0,009	13,92 ± 1,95	83,01 ±0,93	3,34 ±0,77
'Topaz'	0	initially	3,31 ±0,1	0,61 ±0,03	14,15 ±1,45	82,55 ±0,53	7,10 ±0,72
	2	0% CO_2	3,25 ±0,09	0,39 ±0,01	14,45 ±1,12	82,64 ±0,65	2,32 ±0,17
	5	5% CO_2	3,56 ±0,06	0,56 ±0,01	10,25 ±1,23	80,60 ±1,75	3,86 ±0,11
		10% CO_2	3,69 ±0,2	0,48 ±0,003	12,18 ±0,89	83,54 ±0,24	4,25 ±0,26
	6	5% CO_2	3,77 ±0,08	0,42 ±0,003	13,68 ±0,69	83,67 ±0,06	4,47 ±0,21
		10% CO_2	3,83 ±0,02	0,24 ±0,003	12,58 ±1,26	84,57 ±0,3	3,4 ±0,26
	7	5% CO_2	3,41 ±0.01	0,38 ± 0,004	12,38 ± 1,12	82,61 ±0,98	3,88 ±0,29
		10% CO_2	3,44 ±0.04	0,39 ± 0,002	14,10 ± 0,66	81,97 ±1,03	4,54 ±0,59
'Gemini'	0	initially	3,71 ±0,15	0,18 ±0,02	12,17 ±0,97	84,62 ±0,57	4,97 ±0,41
	2	0% CO_2	3,52 ±0,05	0,16 ±0,01	12,3 ±0,41	81,57 ±4,82	2,38 ±0,11
	5	5% CO_2	3,77 ±0,11	0,21 ±0,02	10,48 ±0,54	82,11 ±0,40	3,98 ±0,3
		10% CO_2	3,75 ±0,06	0,21 ±0,002	10,18 ±0,9	85,20 ±0,28	4,45 ±0,49
	6	5% CO_2	4,05 ±0,15	0,18 ±0,009	11,24 ±0,55	86,07 ±0,37	3,8 ±0,83
		10% CO_2	3,97 ±0,03	0,18 ±0,003	11,36 ±0,79	84,92 ±0,86	4,27 ±0,23
	7	5% CO_2	3,68 ±0,05	0,18 ±0,014	11,36 ±0,38	84,94 ±0,23	4,37 ±0,51
		10% CO_2	3,7 ±0,06	0,18 ±0,009	11,24 ±0,87	85,45 ±0,07	4,73 ±0,4
'Renoir'	0	initially	3,60 ±0,09	0,24 ±0,005	16,5 ±0,5	81,52 ±0,58	6,47 ±0,6
	2	0% CO_2	3,46 ±0,18	0,24 ±0,03	16,87 ±0,72	78,62 ±0,33	2,64 ±0,23
	5	5% CO_2	3,80 ±0,07	0,26 ±0,001	14,86 ±1,07	77,63 ±0,66	4,17 ±0,42
		10% CO_2	3,73 ±0,09	0,28 ±0,002	15,26 ±0,8	78,25 ±0,14	4,66 ±0,55
	6	5% CO_2	4,04 ±0,01	0,19 ±0,003	17,38 ±1,6	77,28 ±0,71	4,73 ±1,01
		10% CO_2	4 ±0,03	0,23 ±0,009	17,42 ±0,69	76,69 ±0,34	4,62 ±0,56
	7	5% CO_2	3,69 ±0,06	0,25 ±0,008	18,66 ±1,38	75,99 ±0,37	5,24 ±1,73
		10% CO_2	3,76 ±0,02	0,2 ±0,002	17,88 ±0,69	76,71 ±0,05	4,32 ±0,72

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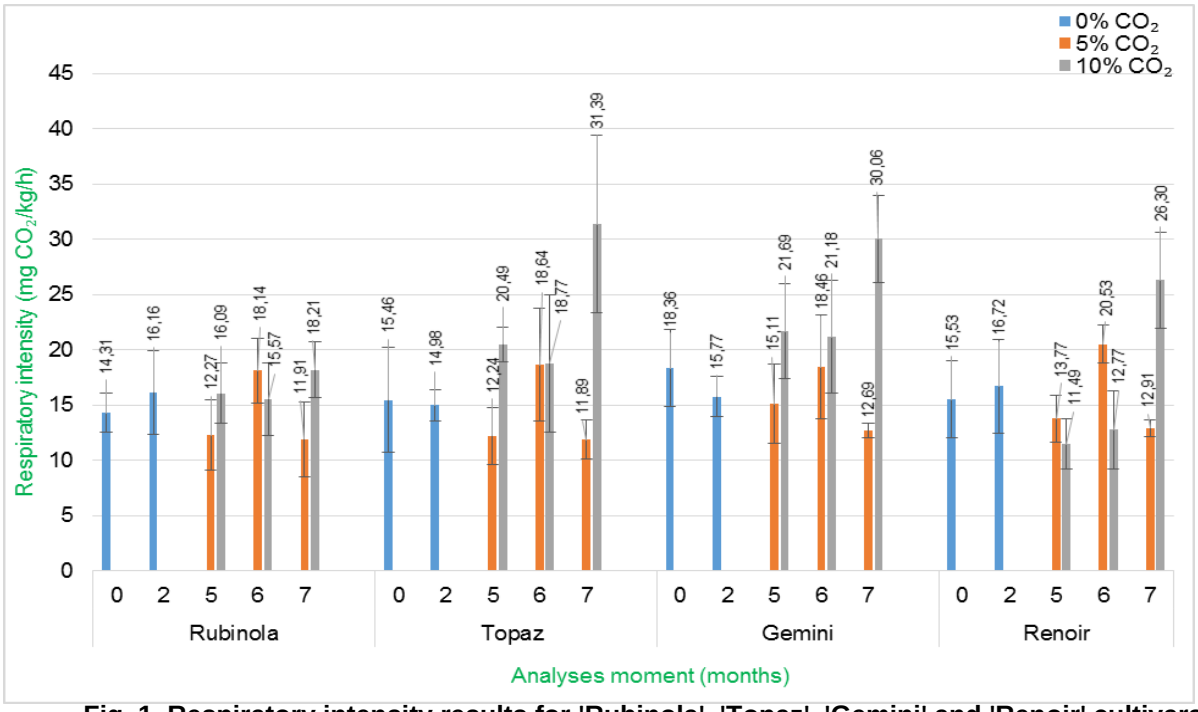

Fig. 1. Respiratory intensity results for 'Rubinola', 'Topaz', 'Gemini' and 'Renoir' cultivars, registered during storage period

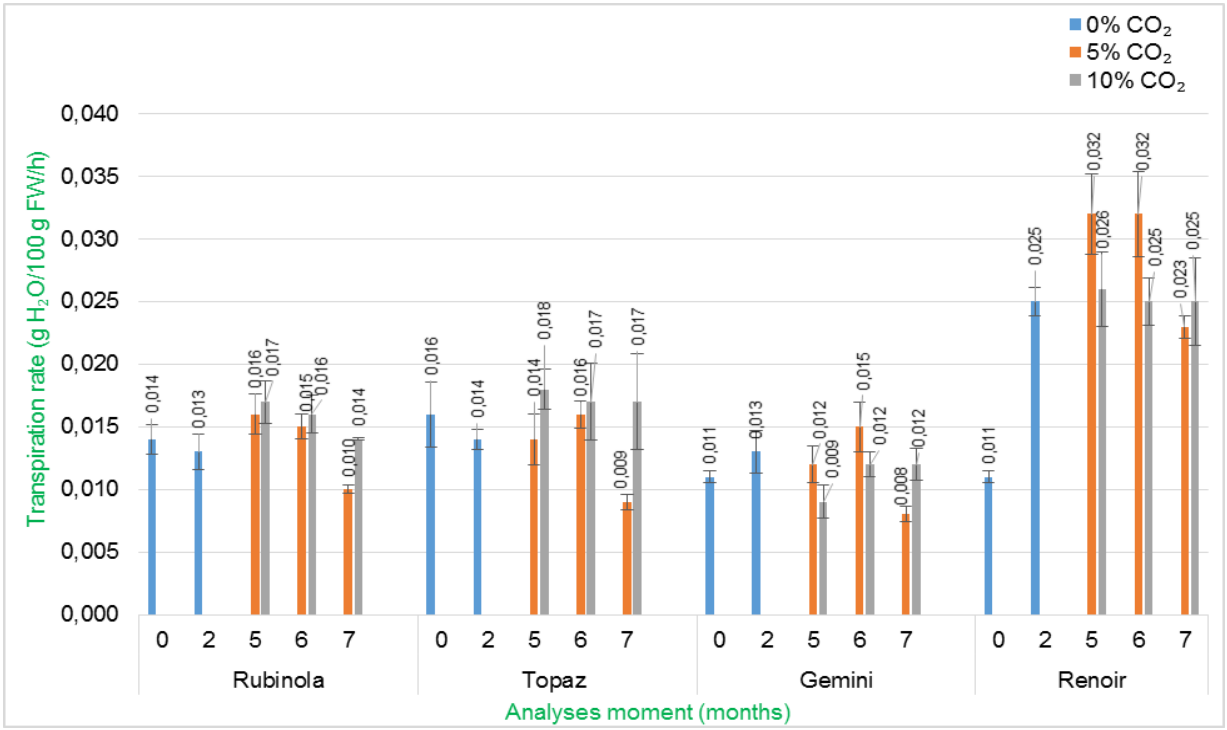

Fig. 2. Transpiration rate results for 'Rubinola', 'Topaz', 'Gemini' and 'Renoir'cultivars, registered during storage period

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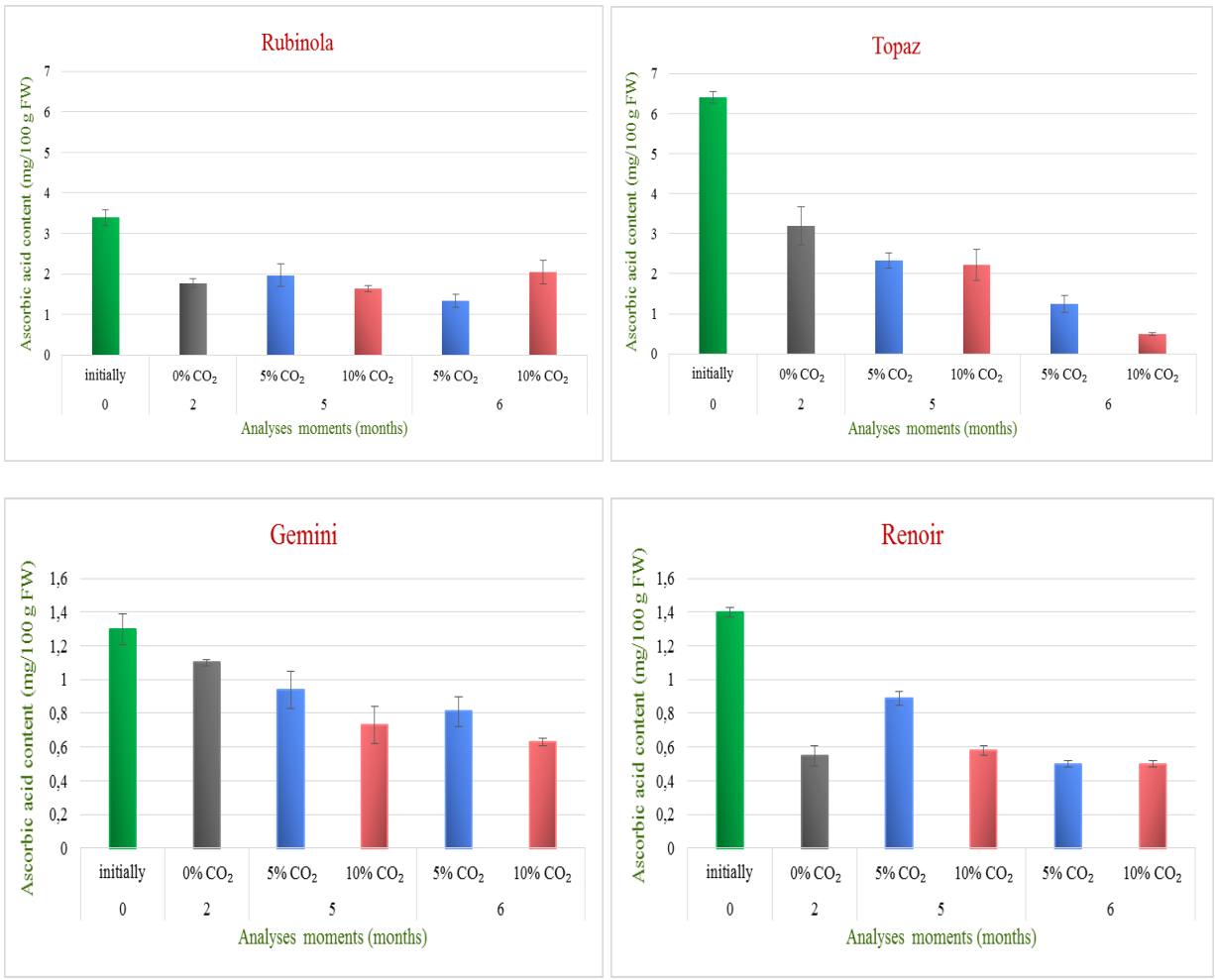

Fig. 3. Ascorbic acid content for 'Rubinola', 'Topaz', 'Gemini' and 'Renoir' cultivars, registered during storage period

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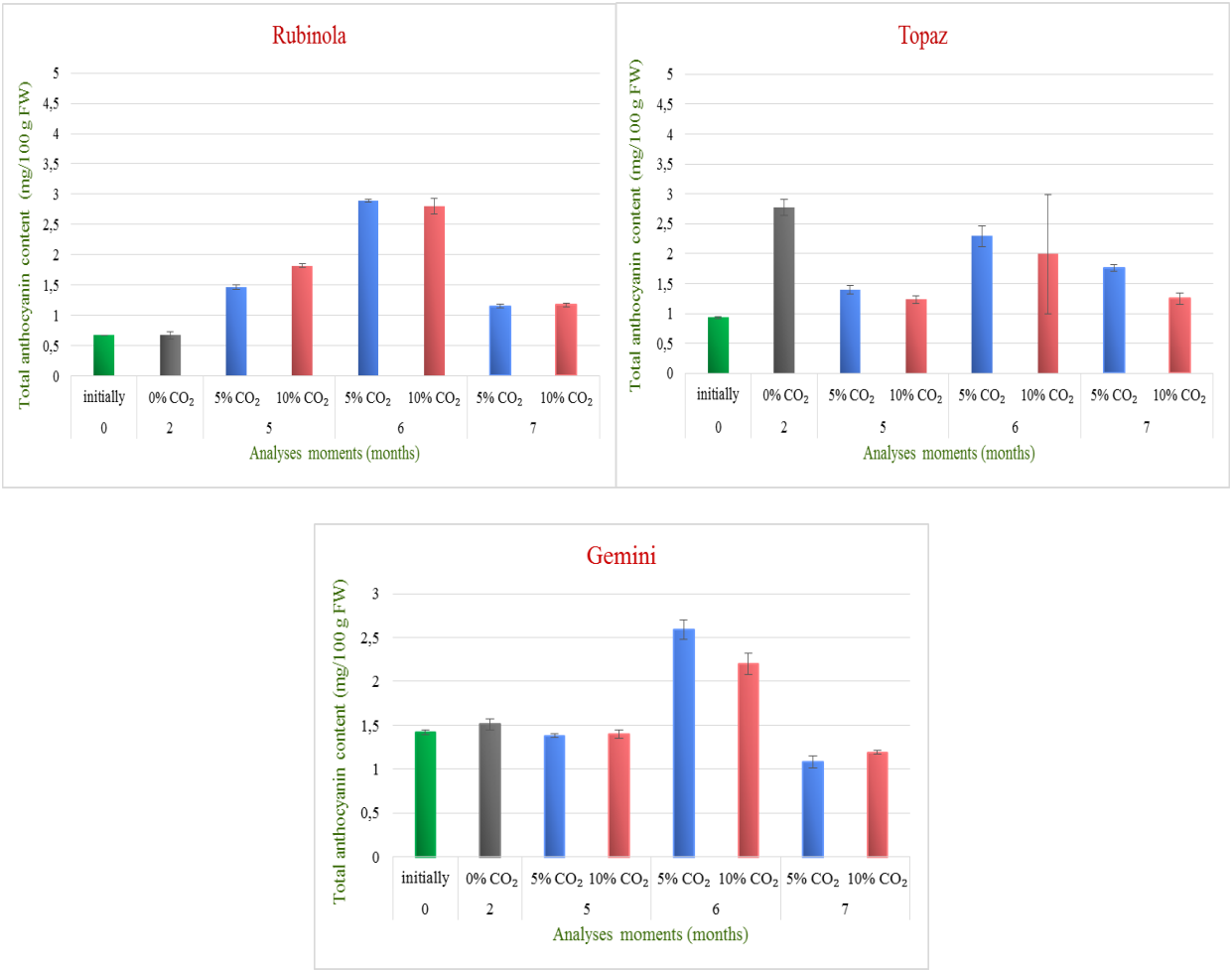

Fig. 4. Total anthocyanin content for 'Rubinola', 'Topaz' and 'Gemini' cultivars, registered during storage period