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QUALITY ASSESMENT OF ORGANIC `PLAPINK` RASPBERRY FRUITS UNDER DIFFERENT STORAGE CONDITIONS

Andrei PETRE, Mihai FRÎNCU, Andreea BARBU (STAN), Andrei LESNIC, Liliana BĂDULESCU, Adrian ASĂNICĂ

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: mihai.frincu@qlab.usamv.ro

Abstract

Raspberry (Rubus idaeus L.) is one of the most appreciated fruits in the world. According to FAO, the annual production in 2021 was about 886.000 t, with Europe which reached the largest input (approximately 68%). Due to the perishable nature of the fruits, there is a continuous need for improving the storage condition. The aim of the paper is to present the influence of storage conditions on organic raspberry fruits. Raspberries from `Plapink` cultivar, were harvested in 2021 and stored in three different conditions: 1) normal atmosphere (NA) with 1˚C and 85% relative humidity (RH), 2) controlled atmosphere (CA) conditions with 1˚C, 85% RH, 5% O_2 and 15% CO_2, and 3) CA conditions with 1˚C, 85% RH, 5% O_2, and 15% CO_2 for 3 days followed by NA for 6 days. Several quality indicators and physiological parameters were assed in order to verify the variations during the storage period. The total phenolic content values in NA decreased with about 6.28% compared to the initial moment, but no decreases were recorded during 3 days of storage in CA.

Key words*: raspberry, quality indicators, controlled atmosphere, bioactive compounds.*

INTRODUCTION

Worldwide, the total production of raspberries was more than 899 thousand of tons in 2020. The largest producers of raspberry fruits are in Russia, where more than 180 thousand tons are obtained annually, Mexico with more than 140 thousand tons and Poland with more than 123 thousand tons in 2020 (www.fao.org).

According to FAO, the total production of raspberries in Romania, in 2020 was 130 tons, on a cultivation area of 70 ha.

The special quality of the raspberry, as a result of the natural conditions specific to our country, has made this fruit more and more in demand on the international market, and as currently the highest production of fruit is obtained from the spontaneous flora, it is imperative the expansion of raspberry areas both in commercial plantations, exploited on modern bases, but also in family gardens. (Hoza, 2005).

Raspberries are very perishable fruits, being essential to be harvested at the right moment of maturating. (Haffner et al., 2002).

To minimize losses and prolong the postharvest longevity of organic raspberries, controlled atmosphere conditions are becoming more prevalent as a key postharvest technology. (Kruger et al., 2011).

Highly effective in extending the postharvest period of raspberries were the storage methods like cold, frozen and controlled atmosphere. (Forney et al., 2015).

Application of postharvest storage and processing techniques mentioned earlier, each operating under distinct parameters such as temperatures and processing times, could induce potential variations at biochemical, physical, biological levels (Bustos M.C. et al., 2018). As a result, these fluctuations may modify the content of bioactive chemical compounds in the fruit, ultimately impacting the nutraceutical properties valued by consumers (Michalska A. et al., 2015).

The aims of the paper are:

- monitoring and characterization of physico-chemical indicators and nutritional parameters of organic raspberry fruits during storage under normal and controlled atmosphere conditions;
- identification of optimal storage conditions in a controlled atmosphere for organic raspberry fruits.

MATERIALS AND METHODS

Samples

'Plapink' variety, harvested in 2021 was delivered to Posharvest Lab., being analysed before storage immediately after (initially moment).

The fruits were divided in three aliquots and stored in three different conditions:

1) normal atmosphere (NA) with 85% RH and 1˚C;

2) controlled atmosphere (CA) conditions with 15%CO_2, 5% O_2, 1°C, 85% RH

3) CA conditions with 15%CO_2, 5% O_2, 1°C, 85% RH for 3 days followed by NA for 6 days, similar with Haffner et al. 2002. Samples were analyzed in four moments in all storage conditions: initially, after 3, 6, and 9 days of storage.

Figure 1. Organic raspberries `PLAPINK` cultivar before storage

Quality indicators

Quality indicators followed were represented by: the average weight of 10 fruits, shape index, pH, total soluble solids (TSS), dry matter content, total titratable acidity (TTA), ascorbic acid content, total phenolic content (TPC) and antioxidant activity. The average weight of 10 fruits were measured using Radwag Partner PS 6000.R2 technical balance. Shape index were determined using a Parkside calliper, the results were reported using the formula h/D (h-height; D-transversal diameter). Using the index, the fruit form varies: shape index =1-round fruits; shape index ≤1-flattened fruits; shape index ≥1-elongated fruits. pH and TTA were determined with the pH electrode of automatic titrometer TitroLine easy. The procedure involves weighing around 5 g ± 10% of fresh homogenous sample, combining it with 25 mL of bi-distilled water, measuring the initial pH values, and subsequently titrating it with 0.1N NaOH until the pH value reaches 8.1, following AOAC Official Method 942.15. The TTA results were presented as grams of malic acid per 100 grams of fresh fruit, similar to the method described by Frîncu et al., 2023.

Total soluble solids (TSS) results were expressed using Kruss DR301-95 digital refractometer (Cătuneanu et al., 2017).

The dry matter content was determined by thermogravimetric method using a UN110 Memmert oven by drying 1 g ± 10% of the sample at 105°C, following the method similar with Stan et al. (2019), until constant weight was achieved.

Ascorbic acid was determined using HPLC method, similar with Stan et al., 2019.

Phenolic content and antioxidant activity

The quantification of total phenolic content (TPC) was performed using the Folin-Ciocâlteu method protocol. Initially, 1 g ± 10% of the fresh sample underwent trituration with 10 mL

of 70% methanol, and the resulting mixture was incubated overnight in darkness at ambient temperature (approximately 22°C) within 15 mL centrifuge tubes. Subsequently, the extraction procedure extended to stir for 1 hour at 500 rpm followed by centrifugation at 7000 rpm at 4°C, for 5 minutes. The supernatant was collected in 50 mL tubes, and the residual material underwent two successive extractions until reaching a final extract volume of 30 mL. The initial step in the determination of TPC involved combining 0.5 mL of the extract with 2.5 mL of Folin–Ciocâlteu reagent, followed by a 2 minutes incubation at ambient temperature (approximately 22°C). The subsequent step entailed the addition of 2 mL of 7.5% sodium carbonate (Na_2CO_3), followed by incubation for 15 minutes at 50°C. The final step represents measuring the absorbance at a wavelength of 760 nm using a Specord 210 Plus UV-VIS spectrophotometer (Analytik Jena, Jena, Germany). The results were noted in of mg GAE/100 g FW.

For the determination of antioxidant activity, the DPPH (2,2-diphenyl-1-picrylhydrazyl) method, similar to the approach described by Bujor et al. (2016) with some adaptations. This involved combining 0.2 mL of the extract with 2 mL of a 0.2 mM solution of DPPH in methanol, followed by a 30 minutes incubation in darkness with homogenization. The absorbance of the resulting samples was measured at a wavelength of 515 nm, and the outcomes were expressed as mg Trolox/100 g FW, with methanol serving as the reference.

Statistical analysis

Standard deviation was the statistical analysis applied to all samples, representing the average from the same sample, of three replicates

RESULTS AND DISCUSSIONS

Quality indicators

The raspberry samples, both the fresh ones and the ones stored in the cold room and in the two controlled atmosphere conditions, were analyzed in order to determine their quality, following parameters such as: the average weight of 10 fruits, their caliber, pH, total soluble matter (% Brix), total dry matter (%), total titratable acidity, ascorbic acid content, total polyphenol content and antioxidant activity.

Thus, upon entering the cold room, the average weight of 10 fruits was 5.85 g, registering a 16% decrease until the last day of storage (Figure 2).

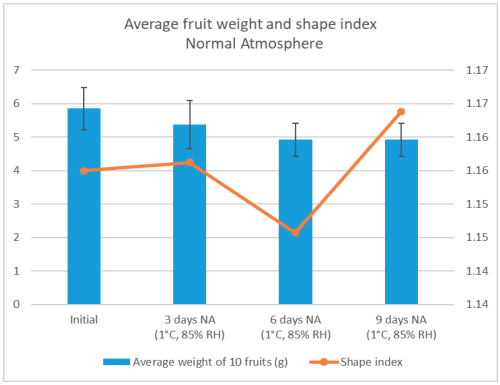

Figure 2. Average fruit weight and shape index values in Normal Atmosphere storage conditions

Before storage under controlled atmosphere conditions, the average weight of 10 organic raspberry fruits of the 'Plapink' variety was 5.29 g, registering a decrease of 23% by the last day of storage (Figure 3).

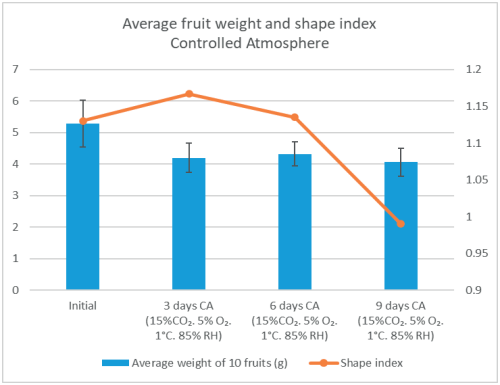

Figure 3. Average fruit weight and shape index values in Controlled Atmosphere storage conditions

Organic raspberry of the 'Plapink' variety was analyzed before storage in the controlled atmosphere room for 3 days, followed by storage in the cold room for 6 days. The average weight of 10 fruits was 5.29 g at the initial moment of analysis, registering a decrease of 18.3% after the 9 days of storage in the two experimental conditions (Figure 4).

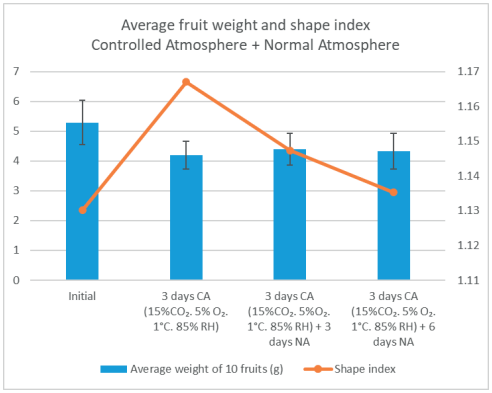

Figure 4. Average fruit weight and shape index values in Controlled Atmosphere followed by Normal Atmosphere storage conditions

Variations of pH and total titratable acidity were monitored during storage in the cold room yielding pH values of 2.82 initially moment and 2.83 after 9 days. The total titratable acidity at the initial moment of analysis was 2.21 mg malic acid/100 g fresh sample and 1.82 mg malic acid/100 g fresh sample after 9 days of storage in the cold room (Figure 5).

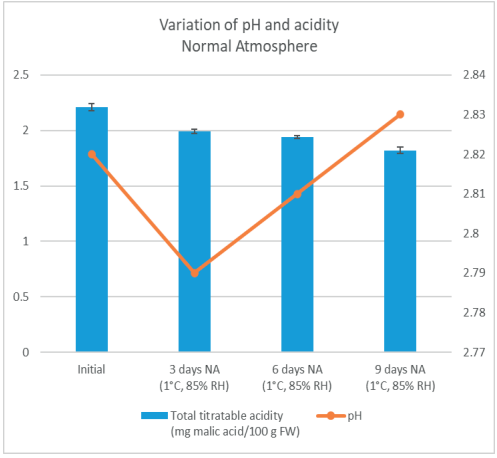

Figure 5. Variation of fruit pH and acidity in Normal Atmosphere storage conditions

Following the determinations made, after 9 days of storage in NA, the pH of the fruits registered a slight increase of 0.5% compared to the initial moment and the total titratable acidity registered a decrease of 17.64% compared to the moment initial.

Variations in pH and total titratable acidity were also monitored during controlled atmosphere storage with pH values of 2.73 at the initial moment and 2.72 after 9 days. The total titratable acidity at the initial moment was 2.00 mg malic acid/100 g fresh sample and 1.84 mg malic acid/100 g fresh sample after 9 days of storage in the cold room (Figure 6).

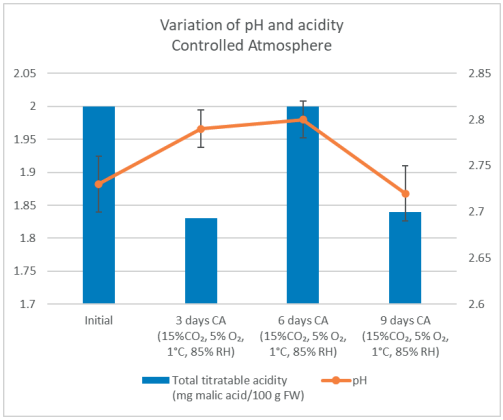

Figure 6. Variation of fruit pH and acidity in Controlled Atmosphere storage conditions

After 9 days of controlled room storage (15% CO_2, 5% O_2, 1°C, 85% RH), the pH of the fruits registered a slight decrease of 0.5% compared to the initial moment and the total titratable acidity decreased by 8% compared to the initial moment.

Changes in pH and total titratable acidity were also monitored during combined storage, controlled atmosphere for 3 days (15% CO_2, 5% O_2, 1°C, 85% RH), and normal cold room atmosphere for 6 days, obtaining pH values of 2.73 at the initial moment of analysis and 2.82 after 9 days. The total titratable acidity at the initial time of analysis was 2.00 mg malic acid/100 g fresh sample and 1.83 mg malic acid/100 g fresh sample after 9 days of storage in the cold room (Figure 7).

After 3 days of Normal Atmosphere storage followed by 9 days of Controlled Atmosphere storage (15% CO_2, 5% O_2, 1°C, 85% RH), the pH of the fruits registered a slight increase of 3.5% compared to the initial moment and the total titratable acidity decreased by 8.5% compared to the initial moment.

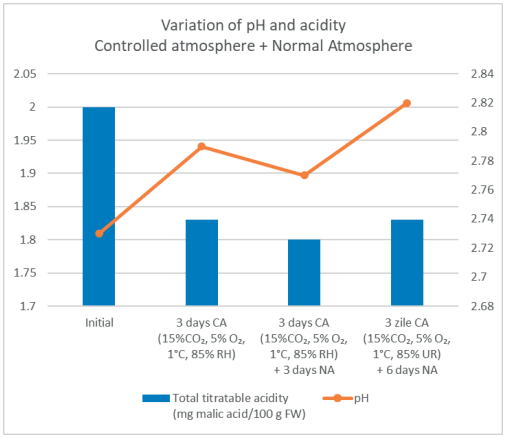

Figure 7. Variation of fruit pH and acidity in Controlled Atmosphere for 3 days followed by Normal Atmosphere storage conditions

Variations of total soluble matter (% Brix) and total dry matter (% DM) were monitored during storage in the cold room obtaining values of 11.40% for Brix and 10.87% SU when analyzing organic raspberry fruits at the initial moment (Figure 8).

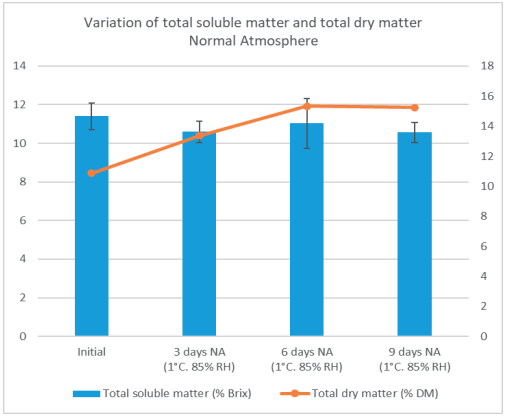

Figure 8. Variation of total soluble matter and total dry matter in Normal Atmosphere storage conditions

Following the determinations made, after 9 days of storage in a normal atmosphere in the cold room, the pH of the total soluble substance registered a decrease of 7.4% compared to the initial moment and the total dry matter registered an increase of 40.3% compared to the initial moment.

The variations of total soluble matter (% Brix) and total dry matter (% DM) were monitored during storage under controlled atmosphere conditions obtaining values of 10.66% for Brix and 12.74% DM when analyzing the fruits of organic raspberry at the initial moment (Figure 9).

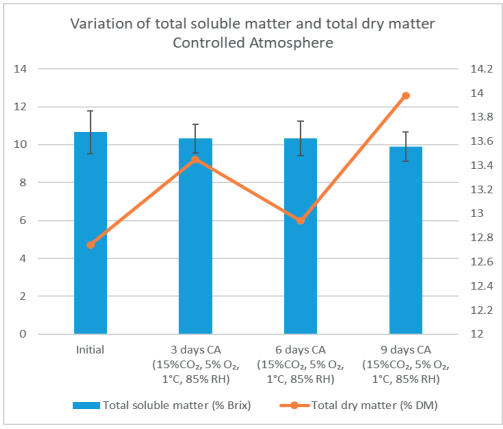

Figure 9. Variation of total soluble matter and total dry matter in Controlled Atmosphere storage conditions

After 9 days of controlled room storage (15% CO_2, 5% O_2, 1°C, 85% RH), the total soluble substance registered a decrease of 7.13% compared to the starting moment and the total dry matter registered an increase of 9.74% compared to the initial moment.

Variations in total soluble matter (% Brix) and total dry matter (% DM) were also monitored during combined storage, controlled atmosphere for 3 days and normal cold room atmosphere for 6 days, yielding values of 10, 66% for Brix and 12.74% DM when analyzing organic raspberry fruits at the initial moment and 9.68% for Brix and 13.94% DM after the 9 days of storage (Figure 10).

As a result of the experiment carried out, after 9 days of combined storage, controlled atmosphere for 3 days and normal atmosphere in the cold room for 6 days, it can be seen that the total soluble substance decreased by 9.2% compared to the initial moment, and the total dry matter registered an increase of 9.4% compared to the initial moment of the analysis.

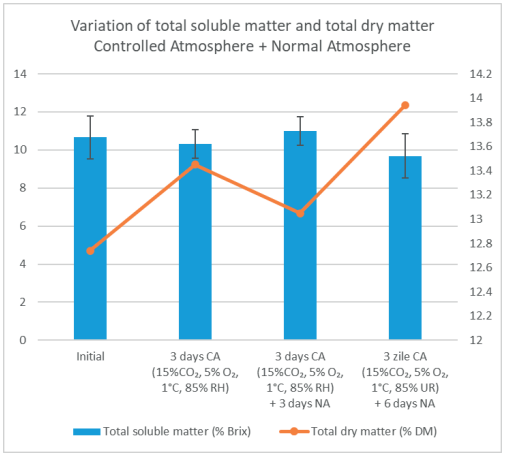

Figure 10. Variation of total soluble matter and total dry matter in Controlled Atmosphere followed by Normal Atmosphere storage conditions

Determining vitamin C (acid ascorbic content) in organic raspberries of the 'Plapink' variety at the time of harvesting and before being placed in the cold room (initial moment) recorded the value of 21.68 mg ascorbic acid/100g (Figure 11). After 3 days of storage in the cold room, vitamin C increased by 26.38% compared to the initial time, and by the end of storage in the normal atmosphere in the cold room, it increased by 46.4%. This increase in the content of vitamin C can be correlated with the concentration in the total dry matter of up to 40.3% compared to the initial moment which basically implies the dehydration of organic raspberry fruits due to storage in normal atmosphere in the cold room.

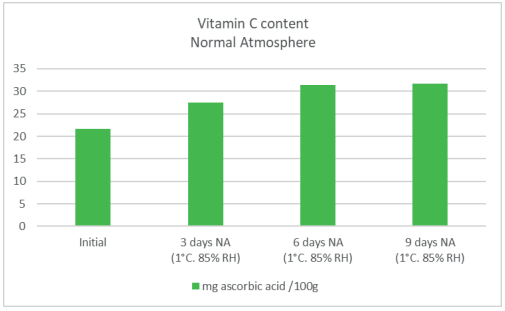

Figure 11. Vitamin C content - Normal Atmosphere storage conditions

The determination of ascorbic acid content in organic raspberries of the 'Plapink' variety at the time of harvest and before storage under controlled atmosphere conditions recorded the value of 20.76 mg ascorbic acid/100 g (Figure 12). After 3 days of storage under controlled atmosphere conditions (15% CO_2, 5% O_2, 1°C, 85% RH), the vitamin C content increased by approximately 9.4% compared to the initial moment, but up to the end of the storage period presented a 5.5% decrease.

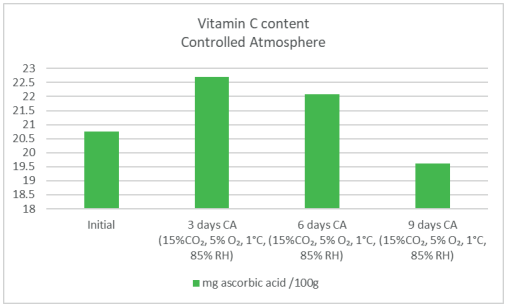

Figure 12. Vitamin C content - Controlled Atmosphere storage conditions

Vitamin C determination in organic raspberries of the 'Plapink' variety at the time of harvest and before combined storage (controlled atmosphere for 3 days and normal atmosphere in the cold room for 6 days), recorded the value of 20.76 mg of acid ascorbic/100 g (Figure 13).

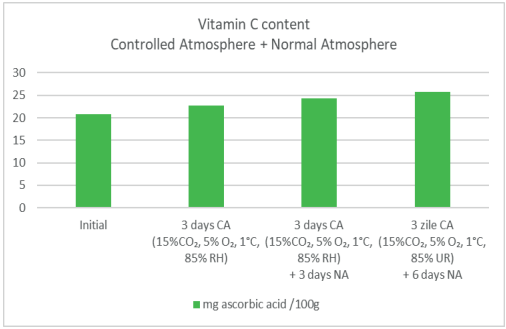

Figure 13. Vitamin C content in Controlled Atmosphere followed by Normal Atmosphere storage conditions

The 3 days of storage under controlled atmosphere conditions (15% CO_2, 5% O_2, 1°C, 85% RH) were common with the second experimental variant, which is why the results obtained for vitamin C are identical. However, during the 6 days of normal atmosphere in the cold room, the vitamin C content increased by 24.13%, which also can be correlated with the total dry matter concentration during storage.

The determination of TPC (total phenol content) in organic raspberries of the 'Plapink' variety at the time of harvest and before being stored in the cold room (initial time) recorded the value of 183.33 mg GAE/100 g (Figure 14). After 3 days of storage in the cold room, TPC increased by 4.67% compared to the initial time, and by the end of the storage period in the normal atmosphere in the cold room, there was an increase of about 17%.

Regarding the antioxidant activity, for the initial moment, the value of 2373.46 mg Trolox equiv/100 g was recorded. After 3 days of storage in the cold room, the antioxidant activity recorded approximately similar values compared to the initial moment, and by the end of the storage period in the normal atmosphere in the cold room, it recorded an increase of approximately 12.57% compared to the initial moment, fact which can be determined, as in the case of total polyphenols, by the concentration of nutrients, implicitly the content of total polyphenols, due to the dehydration of the fruit during storage.

A similar behavior was also observed by Gunes et al. (2002) when they stored cranberries under normal atmospheric conditions for 2 months, noting that the antioxidant activity of the fruits increased by 50% compared to the time of harvesting. Moreover, they also observed that antioxidant activity values for fruits stored in CA (21% O_2 + 30% CO_2) remained constant, which may result from a bottleneck in the release of phytochemicals during storage in CA, which contributes to antioxidant activity.

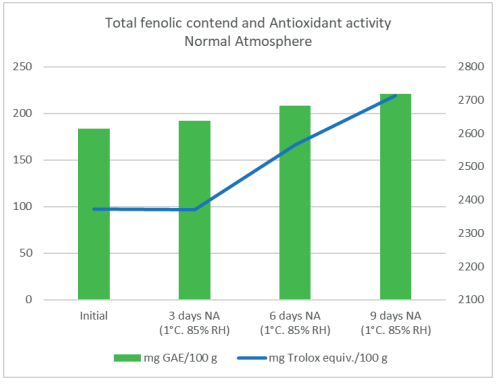

Figure 14. Total phenol content and Antioxidant activity of organic raspberries stored in Normal Atmosphere conditions

The determination of TPC in organic raspberries of the 'Plapink' variety at the time of harvest and before storage under controlled atmosphere conditions recorded the value of 229.94 mg GAE/100 g (Figure 15). After 3 days of storage under controlled atmosphere conditions (15% CO_2, 5% O_2, 1°C, 85% RH), TPC decreased by approximately 6.3% compared to the initial moment. Still, by the end of the period of storage, the TPC registered a slight increase of approximately 7.5% compared to the initial moment.

Regarding the determination of the antioxidant activity in organic raspberries of the 'Plapink' variety at the time of harvest and before storage under controlled atmosphere conditions was recorded the value of 2865.32 mg Trolox equiv/100 g. After 3 days of storage under controlled atmosphere conditions (15% CO_2, 5% O_2, 1°C, 85% RH), the antioxidant activity decreased by approximately 9.8% compared to the initial moment, but by the end of the period of storage the antioxidant activity registered a slight increase of 4.13% compared to the initial moment

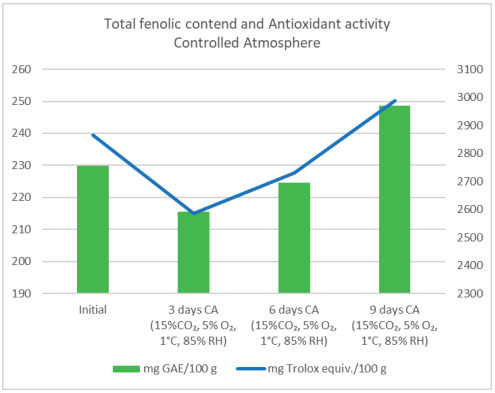

Figure 15. Total phenol content and Antioxidant activity of organic raspberries stored in Controlled Atmosphere conditions

The determination of TPC in organic raspberries of the 'Plapink' variety at the time of harvest and before combined storage, controlled atmosphere for 3 days and normal atmosphere in the cold room for 6 days, recorded the value of 229.94 mg GAE/100 g (Figure 16). The 3 days of storage under controlled atmosphere conditions (15% CO_2, 5% O_2, 1°C, 85% RH), were common with the second experimental

variant, which is why the results obtained for polyphenols are identical. However, during the 6 days of normal atmosphere in the cold room, the TPC registered a slight decrease of about 6.28% compared to the initial moment.
The determination of the antioxidant activity in organic raspberries of the 'Plapink' variety at the time of harvest and before combined storage, controlled atmosphere for 3 days and normal atmosphere in the cold room for 6 days, recorded the value of 2865.32 mg Trolox equiv/100 g. The 3 days of storage under controlled atmosphere conditions (15% CO_2, 5% O_2, 1°C, 85% RH), were common with the second experimental variant, which is why the results obtained for the antioxidant activity are identical. However, during the 6 days of normal atmosphere in the cold room, the antioxidant activity registered a decrease of approximately 9.85% compared to the initial moment.

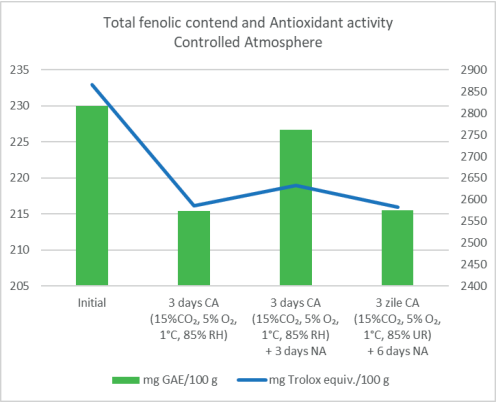

Figure16. Total phenol content and Antioxidant activity of organic raspberries stored in Controlled Atmosphere followed by Normal Atmosphere conditions

The determination of the antioxidant activity in organic raspberries of the 'Plapink' variety at the time of harvest and before combined storage, controlled atmosphere for 3 days and normal atmosphere in the cold room for 6 days, recorded the value of 2865.32 mg Trolox equiv/100 g (Figure 16). The 3 days of storage under controlled atmosphere conditions (15% CO_2, 5% O_2, 1°C, 85% RH), were common with the second experimental variant, which is why the results obtained for the antioxidant activity are identical. However, during the 6 days of normal atmosphere in the cold room, the antioxidant activity registered a decrease of approximately 9.85% compared to the initial moment.

CONCLUSIONS

In current experiment, all samples of organic raspberries present variation of quality indicators during the storage in all three conditions.
According to our results, it is recommended to store fruits in normal atmospheric conditions at a temperature of 1°C and a relative humidity of 85% for a maximum of 6 days. Longer storage will affect the nutritional and organoleptic qualities of the fruits.
Regarding storage in controlled atmosphere conditions with 5% O2 and 15% CO2, at a temperature of 1°C and a relative humidity of 85%, a maximum of 9 days can be achieved, the period in which the fruits maintain their optimal consumption qualities.

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