

## Preliminary data on the behavior of apple varieties stored in controlled atmosphere (CA) rooms

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**Abstract** Fresh fruits are essential for human diets by contributing minerals, vitamins and polyphenols to the human body and improving the overall health. For this reason it is important to know the biochemical changes that fruits undergo during storage periods. In order to identify these changes, a storage experiment has been organized in conditions of controlled atmosphere for four apple varieties (*Malus domestica* Borkh. cv. Topaz, Redix, Florina and Rubinola) to observe and quantify, in time, how the storage conditions affect fruit quality.

In this experiment, the storage conditions that have been chosen for three rooms had the following common parameters: temperature ( $t$  °C) 1° C, oxygen content ( $O_2$ ) 3% and relative humidity (RH) 95%; and had different  $CO_2$  levels - without  $CO_2$  (the control), 2%  $CO_2$  and 5%  $CO_2$ .

The quality indicators analyzed in the four varieties were: the water and dry matter content, fruit firmness, soluble solids (°Brix) content, titratable acidity and total anthocyanins content at three different moments: the initial moment ( $T_0$ ), the intermediate moment ( $T_1$ ) and the final moment ( $T_2$ ). A very good storage behavior for Topaz and Florina varieties has been observed, which retained the best of the fruit turgescence and organoleptic properties. Also, in all varieties of apples kept in  $CO_2$ , there was a decrease in disease incidence and a higher turgescence of fruits compared to those in the room without  $CO_2$ .

### Key words

apple, storage, postharvest, controlled atmosphere

The World Health Organization recommends eating fresh fruits and vegetables, which are essential for human diets by contributing with minerals, vitamins and polyphenols to protect against various diseases, including cancer [10], [16], [18]. The most important fruit produced and consumed in the temperate zone is the apple [6], [7]. For example, in Canada's total apple production of the country, 65% is consumed fresh and 35% processed [9] and Romania ranks 6th in the European Union in the production of apples with 620,000 tons [12].

Consumer acceptability and their choices on apple consumption depend on the quality and texture of the fruit [3] such as crisp [4], firm and succulent it is [5] but also for their price [8]. Most supermarkets ask producers, depending on the variety, for their products to have values close to a quality standard for firmness and fruit soluble solids content [15]. The quality of fruits whose firmness and crispness is higher [4], is considered to be superior to those who have a juicy and soft pulp. [15]. Long-term storage of apples in refrigeration can adversely affect their firmness over time. Instead, apples stored in the controlled atmosphere recorded an increase in firmness [15]. The

firmness of the apples is also influenced by their size, such as smaller diameter of fruits have higher firmness than those of a larger diameter and this characteristic is maintained during storage [15]. The best and common way to store apples is under CA conditions [2], due to the fact that they can be stored for up to 1 year [19].

Anthocyanins are a branch of polyphenols that are responsible for the red color, representing 8% of them, their biggest share being in peel [9]. Fresh fruits and vegetables are living organisms that breathe and sweat and change their biochemical composition over time, which is why a producer has to correlate consumer demand with the cost-effectiveness of cold rooms and the behavior of fruit while in storage [13].

This study aims to support apple producers, who want, besides the economic contribution of storage their products in controlled atmosphere, to know that their product contributes biochemically to the health of consumers.

## Material and Methods

### Sample preparation

For this study 4 varieties of apple were selected: Topaz, Redix and Florina (in conventional system) and Rubinola (in ecological system). The samples were purchased from the experimental orchard of University of Agronomic Sciences and Veterinary Medicine of Bucharest, the fruits being selected as an average sample with similar visual characteristics for all three rooms that were used. Fruit harvesting was carried out in mid-September and the introduction of samples was carried out in rooms with a controlled atmosphere at the beginning of October, within the Postharvest Technology laboratory of Research Center for Studies of Food Quality and Agricultural Products - University of Agronomic Sciences and Veterinary Medicine of Bucharest. The following common parameters from storage rooms were: temperature (t °C) 1° C, oxygen content (O<sub>2</sub>) 3% and relative humidity (RH) 95%. In this experiment three conditions with different CO<sub>2</sub> levels were chosen - without CO<sub>2</sub>, 2% CO<sub>2</sub> and 5% CO<sub>2</sub> and analyzes were performed at three different moments: the initial moment (T<sub>0</sub>), the intermediate moment – 7 months (T<sub>1</sub>) and the final moment – 12 months (T<sub>2</sub>).

### Physico-chemical analysis

To determine the dry matter and water content from samples, approximately 10 g of the average sample in the crucibles was introduced at 105 °C [17] for 24 hours [11]. For the determination of fruit firmness the electronic penetrometer TR was used, with a piston of 11 mm diameter [14], the results being expressed in kg/cm<sup>2</sup>. The samples were pre-peeled in 2 areas for the introduction of the piston into the fruit, and the fruit juice obtained by determining the pulp fertility was used to determine the soluble solids (°Brix) content of the fruits with refractive device Kruss DR301-95 (°Brix). The titratable acidity was determined by titration with 0.1N NaOH to pH 8.1 [17] and the results were expressed in g malic acid/100g. Titratable acidity calculation was done using the

$$F \times C \times a \times b \times 100$$

formula:  $\frac{b \times c}{b \times c}$ , where F is the factor NaOH solution 0.1 N (1.002), C = coefficient of correction for malic acid (0.0067), a = quantity of 0.1 N NaOH titrated with automatic titrator TitroLine, b = volume of the extraction solution, c = mass of the sample.

To determine **total anthocyanin content**, 5 g of the mean sample was filtered under vacuum and completed

up to 50 ml volume with acidified methanol (1.0% (v/v) hydrochloric acid in methanol), and was read spectrophotometrically, with Specord 210 Plus spectrophotometer. The results were calculated, with some modifications, using the formula: Total anthocyanins = DO<sub>540</sub> x F, where DO<sub>540</sub> is absorbance at wavelength λ = 540 nm and factor F = 11.16 [1]. The total anthocyanins content was expressed in mg/100g in fresh weight.

## Results and Discussions

The common indicators for apples fruit quality are the: firmness, soluble solids, titratable acidity, dry matter and water content. The quality indicators had different values both at harvest and during storage for all the apples varieties as seen in Table 1.

For Topaz, the values recorded for the dry matter were higher, and the values of water content were lower than the initial moment, registering a slight dehydration of the variety during one year's storage in the room with the controlled atmosphere. The Redix variety behaved differently from the Topaz variety, so the water content decreased and the dry matter increased in control room (0% CO<sub>2</sub>) and 2% CO<sub>2</sub> room and in the 5% CO<sub>2</sub> room the values for dry matter and water content were close to the values recorded in the initial moment (T<sub>0</sub>).

For Florina and Rubinola varieties in rooms with CO<sub>2</sub> content, small fluctuations in dry matter and water content, during the year of storage, were observed compared to the room without CO<sub>2</sub>. The small differences in dry matter and water content of the samples could also be due to differences in apple size and diameter.

The firmness of the Topaz and Redix varieties decreased during storage as compared to the initial moment, registering to lower the firmity of samples in the room without CO<sub>2</sub>. For Florina and Rubinola varieties, the firmness was maintained (even slightly increased) for the first 7 months in the 5% CO<sub>2</sub> room only as compared to the initial moment. In the other two rooms, a gradual decrease of fruit firmness has been maintained during storage.

Fruit firmness values over one year of storage were generally lower for apples in the room without CO<sub>2</sub> than for those in the CO<sub>2</sub> rooms.

In all varieties, there was a tendency of decreasing titratable acidity and an increase in soluble solids content during storage as compared to initial moment, that can be explained as a post-ripening process.

Table 1

Variation of firmness and content of: dry matter, water, TA and soluble solids during storage period in CA for Topaz, Redix, Florina and Rubinola varieties

Sample	Time of analyzes	Dry Matter (D.M.%)	Water Content (%)	Titration Acidity (TA) (g malic acid /100 g)	Soluble solids (°Brix)	Firmity (kg/cm <sup>2</sup> )
Topaz	T <sub>0</sub>	13.637	86.363	0.572 ± 0.004	11.96 ± 0.96	7.55 ± 0.92
Topaz r. 1	T <sub>1</sub>	14.614	85.386	0.539 ± 0.004	12.8 ± 1.28	5.70 ± 0.45
Topaz r. 2		14.872	85.128	0.748 ± 0.013	13.46 ± 1.15	7.24 ± 0.96
Topaz r. 3		15.361	84.639	0.570 ± 0.001	14.18 ± 1.08	6.71 ± 1.22
Topaz r. 1	T <sub>2</sub>	15.154	84.846	0.449 ± 0.006	13.78 ± 0.94	5.36 ± 1.17
Topaz r. 2		15.091	84.909	0.463 ± 0.006	14.26 ± 0.55	6.57 ± 0.61
Topaz r. 3		15.088	84.912	0.460 ± 0.004	12.9 ± 1.24	7.04 ± 1.80
Redix	T <sub>0</sub>	16.742	83.258	0.419 ± 0.001	11.38 ± 0.95	7.91 ± 1.43
Redix r. 1	T <sub>1</sub>	18.011	81.989	0.405 ± 0.002	15.62 ± 0.97	5.72 ± 1.08
Redix r. 2		18.455	81.545	0.319 ± 0.001	15.86 ± 0.98	5.73 ± 0.65
Redix r. 3		16.550	83.450	0.331 ± 0.002	14.62 ± 0.69	6.36 ± 0.95
Redix r. 1	T <sub>2</sub>	17.386	82.614	0.297 ± 0.040	14.36 ± 1.21	5.65 ± 0.93
Redix r. 2		16.320	83.680	0.254 ± 0.001	13.98 ± 1.46	5.42 ± 1.64
Redix r. 3		16.746	83.254	0.280 ± 0.001	13.82 ± 0.68	5.89 ± 0.48
Florina	T <sub>0</sub>	14.793	85.207	0.410 ± 0.002	11.48 ± 0.85	8.24 ± 0.83
Florina r. 1	T <sub>1</sub>	14.112	85.888	0.308 ± 0.001	13.36 ± 1.35	6.37 ± 0.77
Florina r. 2		13.398	86.602	0.340 ± 0.001	11.58 ± 0.89	7.10 ± 0.71
Florina r. 3		14.188	85.812	0.423 ± 0.001	12.84 ± 0.72	8.28 ± 0.67
Florina r. 1	T <sub>2</sub>	12.540	87.460	0.332 ± 0.001	12.26 ± 0.63	6.19 ± 1.28
Florina r. 2		14.620	85.380	0.307 ± 0.001	13.7 ± 1.36	6.67 ± 1.62
Florina r. 3		14.395	85.605	0.307 ± 0.001	11.7 ± 1.77	6.56 ± 1.41
Rubinola	T <sub>0</sub>	13.658	86.342	0.360 ± 0.001	12.64 ± 0.70	6.16 ± 0.89
Rubinola r. 1	T <sub>1</sub>	12.455	87.545	0.316 ± 0.002	12.88 ± 1.39	5.03 ± 0.47
Rubinola r. 2		14.215	85.785	0.347 ± 0.001	13.22 ± 0.65	5.36 ± 0.51
Rubinola r. 3		14.055	85.945	0.365 ± 0.001	13.06 ± 1.18	6.29 ± 0.83
Rubinola r. 1	T <sub>2</sub>	14.159	85.841	0.332 ± 0.001	13.3 ± 0.71	4.92 ± 1.00
Rubinola r. 2		12.266	87.734	0.282 ± 0.004	11.38 ± 1.31	5.86 ± 1.31
Rubinola r. 3		13.703	86.297	0.336 ± 0.001	12.88 ± 1.03	5.32 ± 0.91

For the Topaz, Redix and Florina varieties, in the rooms without CO<sub>2</sub> and 5% CO<sub>2</sub> the anthocyanin content was observed to have dropped during the storage until T1 intermediate moment from the initial moment, followed by an increase in the total anthocyanin content to the end storage period. The same behavior was observed in the Rubinola variety in

the room with 5% CO<sub>2</sub>. The Redix and Rubinola varieties recorded a high content in total anthocyanins due to favorable atmospheric conditions in 2016 but those values did not remain during storage. The behavior of total anthocyanins content during storage can be seen in Figure 1.

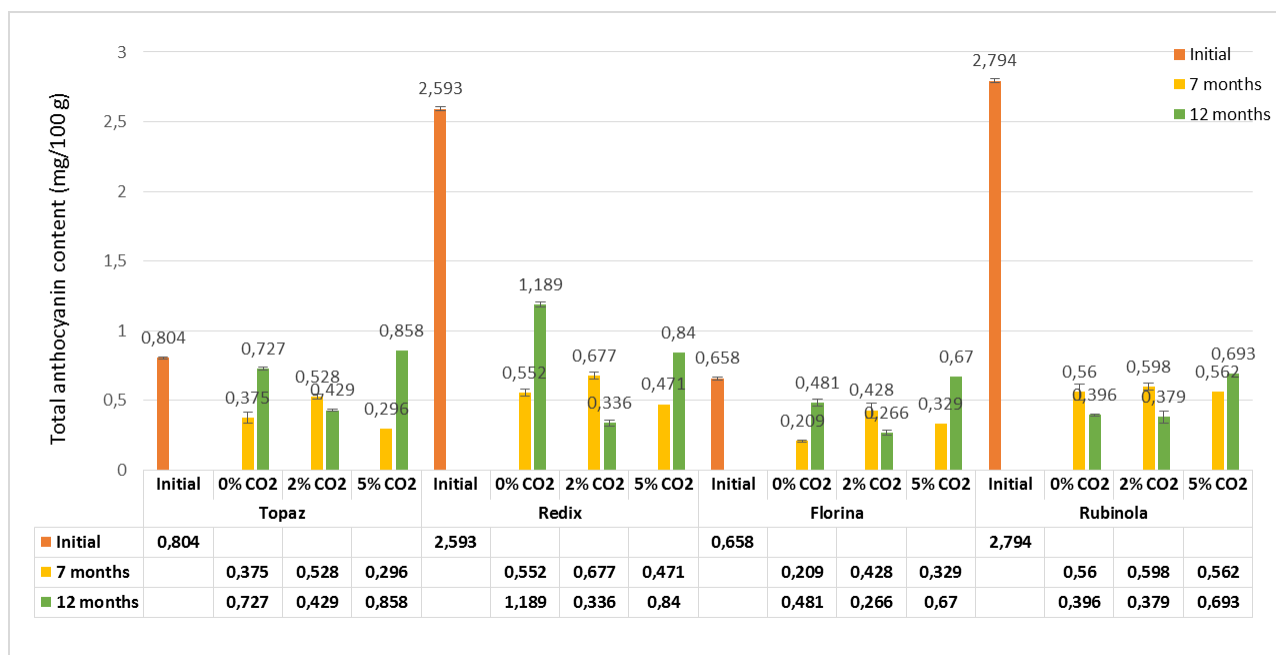


Figure 1. Variation of total anthocyanin content (mg/100g) during the controlled atmosphere (CA) storage for Topaz, Redix, Florina and Rubinola

## Conclusions

From this preliminary research, it can be observed that better values were recorded for fruits stored in the 2% and 5% CO<sub>2</sub> rooms. Apples stored in room without CO<sub>2</sub> were slightly dehydrated. Fruit crispness has been maintained in Topaz and Florina varieties compared to Redix and Rubinola varieties. Based on the results obtained with the total anthocyanin content, we can conclude that the climatic fruits slow down their metabolic processes.

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