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# SENSORIAL ANALYSIS OF APPLES BEFORE AND AFTER STORAGE IN CONTROLLED ATMOSPHERE CONDITIONS

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***Abstract***

*Apples are the most consumed climacteric fruits in the cold season, due their biochemical contribution to the health of the human body. In this study, the main purpose is to compare the organoleptic attributes, provided through trained evaluators, like: exterior appearance and color, smell, taste and texture (crispness) for four apples cultivars (Topaz, Redix, Florina and Rubinola) stored for 350 days, in three different controlled atmosphere conditions with the following parameters: T: 1°C, RH: 95%, $O_2$: 3%, $CO_2$: 0%, 2% and 5%, in two different years. Taste is the most important sensorial indicator and is high correlated with the total soluble solids/acidity ratio of the apples. The quality indicators variations present specific behavior when apples are stored in different concentrations of carbon dioxide. Evaluators noted lower, the exterior appearance, for Topaz (in first year), Florina and Rubinola (in both years) apples stored without $CO_2$ compared to those stored in both $CO_2$ concentrations. Moreover, apples stored in both $CO_2$ concentrations, shown healthier appearance, without being affected by the specific storage diseases.*

***Key words***: *apple, crispness, appearance, sensorial analysis, quality.*

## INTRODUCTION

Apple is one of the most consumed fruit (Francini et al., 2013; Mureşan et al., 2012) all over the world (Yildirim et al., 2017), due to health benefits (Brovelli, 2006; Mitić et al., 2013) and good sweet-sour taste.

The main objective in postharvest technologies is maintaining the best organoleptic qualities of the agriculture products (Oltenacu et al., 2015).

The two most important attributes in sensory analysis are fruits firmness, considered by the consumers as a freshness indicator (Cortellino et al. 2017; Péneau et al., 2006) and the taste which is high correlated with the total soluble solids/acidity ratio of the apples (Weibel et al., 2004).

An important factor of consumer acceptability of fruits is the maturity index (Yoon et al., 2005).

One of the storage method used in postharvest for agricultural products is represented by controlled atmosphere (CA) conditions which can prevent quality loss of the fruit (Bessemans et al., 2016) and maintaining the same organoleptic characteristics during storage (Oltenacu et al., 2013).

It was observed that during storage there are changes in fruit quality indicators, dry matter and content and maturity index (TSS/TA) increase and firmness decreases (Jan et al., 2012), ascorbic acid and aroma volatiles decreases, the final values depending on the cultivar (Lemmens et al., 2020; Tough and Hewett, 2001). The total phenol content also decreases, depending on storage conditions and fruit origins (Lysiak et al., 2020).

To maintain better fruit firmness and to inhibit ethylene production, 0.625 $\mu L\ L^{-1}$ 1-methylcyclopropene (1-MCP) can be used, which also reduces the oxidative activity of ACC oxidase enzyme (Schmidt et al., 2020).

During the fruit storage period, depending on the storage temperature, ethylene is released, which helps ripen the fruits, but also are synthetized a various compounds that contribute through the volatiles to develop specific apple flavor (Qi et al., 2020).

The main purpose of this study was to compare the organoleptic qualities changes during postharvest storage, for apples varieties like Topaz, Redix, Florina and Rubinola in two different years.

## MATERIALS AND METHODS

The four apple cultivars: Topaz, Redix, Florina, and Rubinola, uniform in size and colour, were stored bulk in plastic boxes. The samples were stored and monitored in both years, under the same controlled atmosphere conditions, as follows: temperature (T): 1°C, $O_2$: 3%, $CO_2$: 0%, 2% and 5%, relative humidity (RH): 95%, in the Research Center for Studies of Food Quality and Agricultural Products, of the USAMV Bucharest.
Before sensorial analyses sesions the evaluators were trained to recognize the basic characteristics of each variety. The sensorial analyses questionaire contain questions in order to evaluate organoleptic attributes like: exterior appearance, color, smell, taste, and texture (crispness). The apples total titratable acidity was determined by titration with NaOH 0.1N to 8.2 pH, using the automatic titrator TitroLine. The firmness of the apples was determined using a piston of 1.1 cm diameter (Bessemans, 2016; Rizzolo, 2010) of an electronic penetrometer Turoni TR and the results were expressed in $kg/cm^2$. The total soluble solids content of the apples juice was obtained with refractive device Kruss DR301-95 (%Brix).
The the total soluble solids/acidity ratio, known also as maturity index, was calculated using the formula: TSS/TA, and it was correlated with the values of the organoleptic attribute: taste. The firmness of the samples was correlated with the values of the organoleptic attribute: texture. Statistical analyses were performed using Excel, for the samples results like: mean, standard deviation, correlations, T Test and ANOVA single factor (Pomohaci, 2017). In this study, the main purpose is to compare the organoleptic attributes, provided through trained evaluators, for the four apples cultivars stored for 350 days in CA conditions in two different years.

## RESULTS AND DISCUSSIONS

Topaz cv. registered scores like: 3.6 points for the first year (Figure 1) and 4.27 points for the second year (Figure 2) out of maximum 5 points, for the initial moment, without statistical differences between years for all five organoleptic attributes.

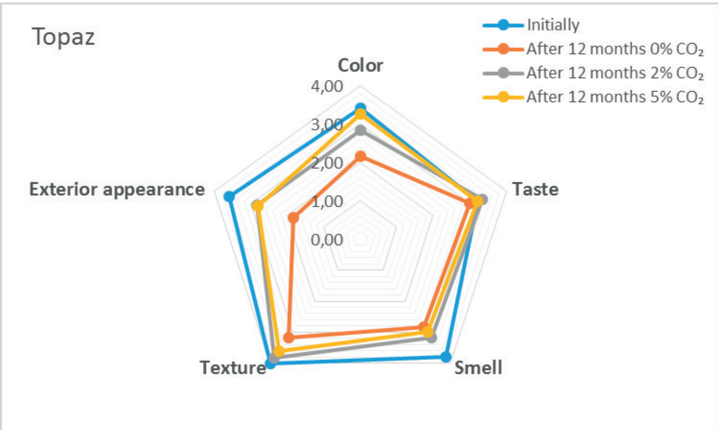


Figure 1. Sensory analysis for Topaz apple variety, during storage period in CA for the first year (october 2016- september 2017

After 350 days of storage in controlled atmosphere without additional injection of $CO_2$, the scores drop at: 2.6 points in the first year, and 3.77 points in second year, with semnificant differences ($P<0.05$) between years at exterior appearance and color. In this conditions, in both years, the apples presented dehydrated peel after storage. Vanzo et al. (2013) obtained the similar results for sensorial evaluation of Topaz. According to Bessemans

(2016), apple fruit cortex tissues are highly sensitive even to subtle differences in oxygen concentrations close to the anaerobic compensation point. That could explain the decrease of the exterior appearance scor of Topaz apples after storage.

In 2% $CO_2$, the scores drop at: 3.2 points in the first year, and 3.4 points in second year, without semnificant differences between years for all five organoleptic attributes.

Interesting fact is that the apples behavior stored in 5% $CO_2$ was different. In the first year obtained 3.23 points comparing with second year when obtained only 2.79 points.

Semnificant differences (*P<0.05*) were observed between years in taste and texture.

No significant correlations were obtained for Topaz in the first year (R = -0.0955), and also for the second year (R = -0.3874) between the apples taste and their maturity index (TSS/TA) (Table 1).

Significant positive correlations ($R^2$ = 0.7936), with linear regression equation y =–0.3432x + 1.3743 were obtained for Topaz in the first year and positive correlations ($R^2$ = 0.2831), with linear regression equation y = 0.5144x + 0.673 for the second year between the apples firmness (Table 1) and their texture (Figures 1 and 2).

Table 1. Variation of the taste, texture, firmness and maturity index during storage period for Topaz cultivar

| | | *Taste* | | *TSS/TA* | | *Texture* | | *Firmness* | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. | Mean | Std. | Mean | Std. | Mean | Std. |
| *Year 1* | Topaz initially | 3.20 | 1.30 | 20.884 | 1.74 | 4.00 | 1.00 | 7.55 | 0.92 |
| | Topaz - 0% $CO_2$ | 3.00 | 1.10 | 30.721 | 2.22 | 3.17 | 1.17 | 5.36 | 1.17 |
| | Topaz - 2% $CO_2$ | 3.33 | 0.82 | 30.869 | 1.11 | 3.83 | 0.75 | 6.57 | 0.61 |
| | Topaz - 5% $CO_2$ | 3.20 | 0.52 | 28.053 | 2.75 | 3.60 | 0.82 | 7.04 | 1.80 |
| *Year 2* | Topaz initially | 4.22 | 0.67 | 22.267 | 2.13 | 4.00 | 0.71 | 5.94 | 0.56 |
| | Topaz - 0% $CO_2$ | 3.57 | 0.98 | 40.097 | 2.57 | 3.43 | 0.98 | 4.34 | 0.43 |
| | Topaz - 2% $CO_2$ | 3.43 | 0.53 | 40.091 | 2.71 | 3.00 | 0.82 | 4.37 | 0.25 |
| | Topaz - 5% $CO_2$ | 2.36 | 0.75 | 32.820 | 3.10 | 2.29 | 0.76 | 4.84 | 0.50 |


Figure 2. Sensory analysis for Topaz apple variety, during storage period in CA for the second year (october 2017- september 2018)

For the initial moment, Redix cv. were registered 4.2 points for the first year (Figure 3) and 3.73 points for the second year (Figure 4) out of maximum 5 points. Statistical differences were observed when color values were compared between years. For the other four organoleptic attributes, no statistical differences between years were observed, for the initial moment.

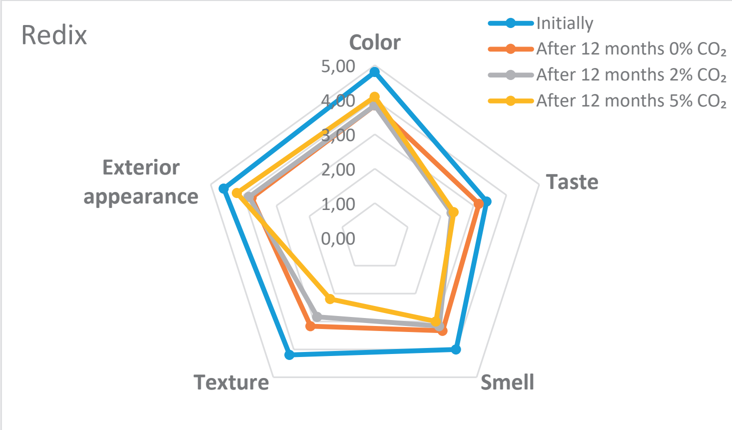


Figure 3. Sensory analysis for Redix apple variety, during storage period in CA for the first year (october 2016- september 2017)

After 350 days of storage in controlled atmosphere without additional injection of $CO_2$ the scores drop at 3.5 points in the first year, and 3.11 points in second year, with semnificant differences (*P<0.05*) between years at texture. In 2% $CO_2$, the scores drop at 3.2 points in the first year, and 3.47 points in second year, with semnificant differences between years for the taste.


Figure 4. Sensory analysis for Redix apple variety, during storage period in CA for the second year (october 2017- september 2018)

In 5% $CO_2$, the scores drop at 3.2 points in the first year, and 3.06 points in second year, without semnificant differences between both years, for all five organoleptic attributes.

Negative significant correlations ($R^2 = 0.6447$), with linear regression equation $y = -0.0353x + 4.4138$ were reported for Redix, for the first year, between the taste of the apples and their maturity index (TSS/TA) (Table 2). No significant correlations were reported for Redix in the second year ($R = -0.338$).

Significant positive correlations ($R^2 = 0.6606$, with linear regression equation $y = 0.5944x + 0.5961$ were reported for Redix in the first year and positive correlations ($R^2 = 0.3255$), with linear regression equation $y = 0.5146x + 0.4872$ for the second year between the fermity of the apples (Table 2) and their texture (Figures 3 and 4).

Table 2. Variation of the taste, texture, firmness and maturity index during storage period for Redix cultivar

| | | *Taste* | | *TSS/TA* | | *Texture* | | *Firmness* | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. | Mean | Std. | Mean | Std. | Mean | Std. |
| *Year 1* | Redix - initially | 3.40 | 0.55 | 27.142 | 2.27 | 4.20 | 0.84 | 7.91 | 1.43 |
| | Redix - 0% $CO_2$ | 3.17 | 0.98 | 48.042 | 7.38 | 3.17 | 0.41 | 5.65 | 0.93 |
| | Redix - 2% $CO_2$ | 2.33 | 0.82 | 54.986 | 5.85 | 2.83 | 0.41 | 5.42 | 1.64 |
| | Redix - 5% $CO_2$ | 2.40 | 0,84 | 49.438 | 2.51 | 2.20 | 1.21 | 5.89 | 0.48 |
| *Year 2* | Redix - initially | 3.44 | 0.73 | 34.757 | 1.88 | 3.56 | 0.73 | 5.74 | 0.95 |
| | Redix - 0% $CO_2$ | 2.93 | 0.84 | 54.938 | 7.52 | 2.14 | 0.38 | 4.62 | 0.54 |
| | Redix - 2% $CO_2$ | 3.43 | 0.79 | 65.049 | 2.87 | 3.29 | 0.49 | 4.45 | 0.69 |
| | Redix - 5% $CO_2$ | 2.93 | 1.30 | 60.676 | 3.27 | 2.71 | 0.95 | 4.14 | 0.38 |

Florina cv. registered scores like: 3.88 points out of maximum 5 points for the first year (Figure 5) and 4.42 points out of maximum 5 points for the second year (Figure 6), for the initial moment, with statistical differences between years for the color and exterior appearance.


Figure 5. Sensory analysis for Florina apple variety, during storage period in CA for the first year (october 2016 – september 2017)

After 350 days of storage in controlled atmosphere without additional injection of $CO_2$, the scores drop at 3.18 points in the first year, and 2.97 points in second year, with semnificant differences (P<0.05) between years at texture. In 2% $CO_2$, the scores drop at 3.07 points in the first year, and 4.03 points in second year, with semnificant differences between years for color and exterior appearance.

In 5% $CO_2$, the scores drop at 3.63 points in the first year, and 3.54 points in second year, without semnificant differences between both years, for all five organoleptic attributes.

According to Brizzolara et al. (2017) apples respond differently to low oxygen storage protocols, and the genetic background plays a key role in determining and modulating the metabolic changes under postharvest hypoxic conditions, mainly with a selective reconfiguration of the primary C/N metabolism. Cukrov et al. (2016) concluded that specific molecular and metabolic changes occur at the earliest stages of the imposed stress conditions and some of them appear to be transient. Some of these represent a sort of a rapid adaptation response to the stress.

Table 3. Variation of the taste, texture, firmness and maturity index during storage period for Florina cultivar

| | | *Taste* | | *TSS/TA* | | *Texture* | | *Firmness* | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. | Mean | Std. | Mean | Std. | Mean | Std. |
| *Year 1* | Florina - initially | 4.00 | 1.00 | 27.960 | 2.03 | 4.20 | 0.84 | 8.24 | 0.83 |
| | Florina - 0% $CO_2$ | 3.33 | 0.82 | 36.920 | 1.85 | 3.67 | 1.03 | 6.19 | 1.28 |
| | Florina - 2% $CO_2$ | 3.00 | 1.41 | 44.668 | 4.34 | 3.17 | 1.17 | 6.67 | 1.62 |
| | Florina - 5% $CO_2$ | 3.80 | 0.75 | 38.131 | 5.77 | 3.60 | 1.03 | 6.56 | 1.41 |
| *Year 2* | Florina - initially | 4.56 | 0.53 | 38.019 | 1.08 | 4.33 | 0.71 | 6.36 | 0.76 |
| | Florina - 0% $CO_2$ | 2.79 | 0.70 | 59.726 | 3.04 | 2.43 | 0.79 | 5.03 | 0.39 |
| | Florina - 2% $CO_2$ | 3.71 | 0.95 | 58.025 | 3.44 | 3.43 | 0.79 | 4.63 | 0.50 |
| | Florina - 5% $CO_2$ | 3.17 | 1.13 | 56.873 | 2.16 | 3.42 | 0.85 | 4.16 | 0.70 |

Negative significant correlations ($R^2 = 0.7334$), with linear regression equation $y = -0.0563x + 5.613$ were reported for Florina, for the first year, between the taste of the apples and their maturity index (TSS/TA) (Table 3).

For the second year negative significant correlations ($R^2 = 0.7538$), with linear regression equation $y = -0.0681x + 7.1503$ were reported for Florina, between the taste of the apples and their maturity index (TSS/TA) (Table 3).

Significant positive correlations ($R^2 = 0.5473$, with linear regression equation $y = 0.3443x + 1.2776$ were reported for Florina in the first year and positive correlations ($R^2 = 0.3036$), with linear regression equation $y = 0.4535x + 1.1145$ for the second year between the fermity of the apples (Table 3) and their texture (Figures 5 and 6).


Figure 6. Sensory analysis for Florina apple variety, during storage period in CA for the second year (october 2017- september 2018)

Rubinola cv. registered scores like 3.64 points out of maximum 5 points for the first year (Figure 7) and 4.09 points out of maximum 5 points for the second year (Figure 8), for the initial moment, with statistical differences between years for the exterior appearance. For the other four organoleptic attributes, no statistical differences between years was observed, for the initial moment.


Figure 7. Sensory analysis for Rubinola apple variety, during storage period in CA for the first year (october 2016- september 2017)

After 350 days of storage in controlled atmosphere without additional injection of $CO_2$, the fruits could't be evalueted, and the score drop at 1.8 points in second year. In 2% $CO_2$, the scores drop at 3.05 points in the first year, and 2.84 points in second year, with no semnificant differences between year. In 5% $CO_2$, the scores drop at 2.97 points in the first year, and 2.19 points in second year, with semnificant differences ($P<0.05$) between years, in color and exterior appearace. Iglesias et. al (2012) showed a high correlation between consumer acceptability and some of the volatile compounds emitted, especially 2-methylbutyl acetate. Sensory analysis for Rubinola apple variety shows high scores for smell and taste initially that was lost during long storage in hypoxia conditions.

Table 4. Variation of the taste, texture, firmness and maturity index during storage period for Rubinola cultivar

| | | Taste | | TSS/TA | | Texture | | Firmness | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. | Mean | Std. | Mean | Std. | Mean | Std. |
| *Year 1* | Rubinola initially | 4.00 | 1.00 | 35.061 | 1.91 | 4.00 | 1.00 | 6.156 | 0.89 |
| | Rubinola - 0% $CO_2$ | - | - | 40.052 | 2.10 | - | - | 4.922 | 1.00 |
| | Rubinola - 2% $CO_2$ | 3.17 | 1.33 | 40.311 | 4.42 | 3.50 | 1.05 | 5.864 | 1.31 |
| | Rubinola - 5% $CO_2$ | 2.20 | 1.21 | 38.304 | 3.06 | 3.00 | 0.98 | 5.316 | 0.91 |
| *Year 2* | Rubinola initially | 3.78 | 0.67 | 33.964 | 1.13 | 3.89 | 0.93 | 4.894 | 0.77 |
| | Rubinola - 0% $CO_2$ | 1.86 | 0.69 | 38.044 | 2.91 | 1.57 | 0.98 | 2.907 | 0.74 |
| | Rubinola - 2% $CO_2$ | 3.14 | 1.07 | 39.417 | 4.28 | 2.86 | 1.21 | 2.858 | 0.89 |
| | Rubinola - 5% $CO_2$ | 2.07 | 1.17 | 42.813 | 6.98 | 1.93 | 1.10 | 3.376 | 0.83 |

Negative correlations ($R^2 = 0.3239$), with linear regression equation $y = -0.1908x + 10.36$ were reported for Rubinola, for the first year, between the taste of the apples and their maturity index (TSS/TA) (Table 4). For the second year, for Rubinola, negative significant correlations ($R^2 = 0.6785$), with linear regression equation $y= -0.2013x + 10.553$. Significant positive correlations ($R^2 = 0.97$), with linear regression equation $y =–1.1547x – 3.1728$, were reported for Rubinola in the first year and positive correlations ($R^2 = 0.6154$), with linear regression equation $y = 0.8545x + 0.4369$ for the second year between the fermity of the apples (Table 4) and their texture (Figures 7 and 8).

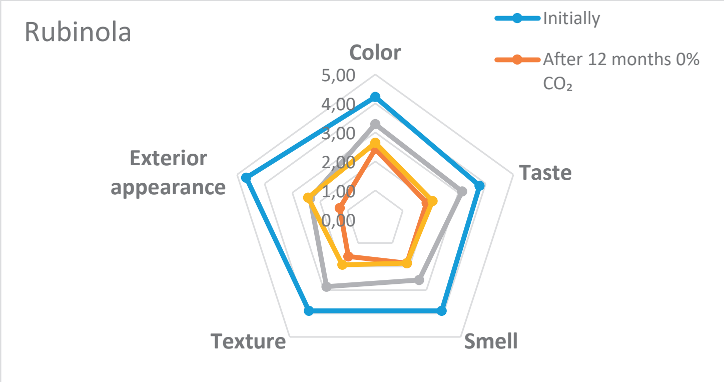


Figure 8. Sensory analysis for Rubinola apple variety, during storage period in CA for the second year (october 2017- september 2018)

## CONCLUSIONS

The present study showed that the yearly climatic conditions and the cultivar influenced the fruit quality during long storage. Thus, the Topaz variety, in the first year the fruits storage in a 2% $CO_2$ CA conditions had higher values at 4 analyzed indicators, except for the firmness, and for the second year, the best storage option was the one without $CO_2$. For the Redix variety, the values obtained for the two years were similar. For the first year, the storage conditions didn't influence quality parameters, but in the second year, for storage conditions with 2% $CO_2$, most of the analyzed parameters had slightly higher values. For the Florina variety, in the first year, the maturity index and firmness were positively influenced by the 2% $CO_2$ atmosphere. In the second year, the $CO_2$-free atmosphere influenced these two parameters, too. The fruits of the Rubinola variety in the second year had higher values for the maturity and firmness index in atmosphere with 5% $CO_2$, but in the first year at a concentration of 2%. The texture of the fruit varied greatly between years within varieties and from one variant of storage to another without being able to establish a direct correlation between these parameters.

The quality indicators variations present specific behavior if apples are stored in different concentrations of carbon dioxide. The exterior appearance had lower values for Topaz (in first year), Florina and Rubinola (in both years) apples stored without $CO_2$ compared to those stored in 2% and 5% $CO_2$ conditions. Apples stored in controled atmosphere with 2% and 5% $CO_2$ shown healthier appearance, without being affected by the specific storage diseases.

Further investigations are needed to clarify to how the pre-harvest climatic conditions influence the storage of the 4 studied apples varieties, so that recommendations can be made.

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