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RESEARCH REGARDING THE ECONOMICAL EFFICIENCY AND QUALITATIVE ASPECTS OF SOME NEW APPLE VARIETIES DURING STORAGE UNDER MODIFIED ATMOSPHERE

Lenuta CHIRA, Adrian CHIRA, Ligia ION

University of Agricultural Sciences and Veterinary Medicine, Bucharest, 59 Marasti Blvd, District 1, 011464, Bucharest, Romania, Phone: +400212243617, Emails: lenutachira@yahoo.com, achira63@yahoo.com, ligiadion@yahoo.com

Corresponding author: achira63@yahoo.com

Abstract

The research carried out at the Faculty of Horticulture in Bucharest for the Fuji, Luna, Golden, Orange and Sirius apple varieties have given a proof of the superiority of storing the fruit in modified atmosphere in comparison with the classic storing method in the refrigerator (cold storage). The atmosphere modified by approximately 3% O_2 and 5% CO_2 was obtained 3 weeks after storage and after packing the fruit in semi-permeable low-density polyethylene film (LDPE). The recorded losses at the end of the storage period were 2.6 times lower for the fruit that were stored in modified atmosphere in comparison with those stored in normal refrigeration conditions for the Luna variety. As far as the economic efficiency is concerned, profit between 331.7RON/ton for the Fuji I and 771.3RON/ton for the Luna variety was obtained when the fruit was stored in modified atmosphere, compared to those stored in normal refrigeration conditions.

Key words**:** *economic efficiency, cold storage, modified atmosphere, total losses*

INTRODUCTION

Extending storage duration as well as maintaining an adequate level of quality for the apples to be consumed fresh during the winter and spring season represents one of the main objectives of the higher exploitation of these fruit varieties.

An intense concern in this regard is storing apples in modified atmosphere conditions, which is obtained with low costs and can be kept constant throughout the whole storage period [1].

The results of the research carried aut worldwide have highlighted the superiority of this storage method, in comparison to keeping the fruit in cold storage with normal atmosphere [3, 4, 6].

Research carried out at the Horticulture Faculty in Bucharest aimed to highlight the main aspects (weight losses, qualitative depreciation and economic efficiency etc.) regarding the behaviour of some new apple varieties when being stored in modified atmosphere, in comparison to the same varieties being stored in cold storage with normal atmosphere [2].

MATERIALS AND METHODS

Research was carried out on 4 new apple varieties from the 2019 harvest (Fuji, Luna, Golden Orange, Sirius), which originated from the didactic – experimental field of the Faculty of Horticulture in Bucharest from an intensive orchard.

The degree of ripening of the fruit was measured so that good storage could be ensured. The optimum moment of harvesting was decided based on experience from previous years.

The main physical-chemical characteristics of the apples at the moment of harvesting are shown in Table 1.

The apples were inserted in the climatic chamber one day after having been harvested, on October 5th 2019. Only fruit that observed the technical requirements for Extra Quality and Quality I were used, in conformity with the Regulation (EC) 543/2011.

The experimental variants with the 4 varieties were put together by 3 repetitions each – one repetition meaning a crate with around 2kg fruit.

Table 1. The main physical-chemical characteristics of the apple fruits at the harvesting time

Variety	Average weight -g-	Firmness kgf/cm^2	Soluble dry matter -%-	Total Titratable acidity -%-	Ascorbic acid mg/100g
FUJI	170	6.0	14.20	0.41	5.50
LUNA	185	6.2	13.40	0.57	6.60
GOLDEN ORANGE	225	6.8	13.80	0.49	6.20
SIRIUS	200	5.8	12.40	0.64	7.80

Source: own determination.

Based on the results of the research obtained worldwide and due to the limited possibility of creating modified atmosphere, different from the ambient one, the experiences were carried out by obtaining a gaseous composition with 3% O_2 and 5% CO_2 [7].

This type of modified atmosphere was done by covering the fruit wrapping with a semi-permeable low-density polyethylene film having a thickness of 15µ (microns) [5], Photos 1, 2, 3, and 4.

The average temperature in the climatic chamber during the storage period was 3 – 3,5^{o}C and the relative air humidity was 80-85% in normal refrigeration conditions, and respectively of 85 – 90% inside the wrappings with modified atmosphere.

The observations and measurements carried out after harvesting and during the storage period of the apples tracked:

-the evolution of the main physio-chemical characteristics of fruit (the firmness of the pulp, the soluble dry matter, the total titratable acidity and the content of ascorbic acid).

The measurement of the firmness of the fruit pulp was carried out using the Effegi penetrometer with the 11 mm diameter. plunger. The measurement of the content of soluble dry matter was done using the Atago electronic refractometer. The measurement of the total titratable acidity was done by titration with a NaOH 0.1N solution. The measurement of the ascorbic acid content was done through the iodometric method.

-the determination of the weight losses and qualitative depreciation, expressed by quantity and rendered percentage;

-the determination of the concentration of the main component gases (O_2 and CO_2) from the modified atmosphere gases, using the Oxybaby gas analyser.

Photo 1. Fuji variety – packed in modified atmosphere
Source: Original.

Photo 2. Luna variety - packed in modified atmosphere
Source: Original.

In order to analyse the economic efficiency of storing the apples in modified atmosphere conditions, calculations were made regarding the valorisation of the remaining production at the end of the 6 month storage period, taking into study the fruit categories Extra Quality and Quality I (suitable to be consumed when

fresh), the downgraded fruit (suitable for industrial processing for compotes and juices) and the bad fruit (suitable for processing by distillation).

The retail price of the apples at the end of the storage period at the beginning of April 2020 was 5.4RON/kg for Extra Quality and Quality I, 2.5RON/kg for the downgraded fruit and 0.45 RON/kg for the bad fruit.

Photo 3. Golden Orange variety - packed in modified atmosphere
Source: Original.

Photo 4. Sirius variety - packed in modified atmosphere
Source: Original.

RESULTS AND DISCUSSIONS

Because of the apple fruits perspiration, after 3 weeks a composition of the atmosphere was created inside the modified atmosphere wrappers, which was different from the one of the air. The concentration of Oxygen varied between 2.8% and 3.5% and that of Carbon Dioxide was between 4.5% and 5%.

These values had very little oscillations inside each wrapper and were constant throughout the entire apple storage, thanks to the semi-permeable low-density polyethylene film, LDPE.

By examining the data in Table 2, showing the weight losses, one can see that in the same storage duration the highest values recorded for normal cold storage were for the Golden Orange and Sirius varieties.

Thus, after 6 months of storage these losses amount to 7.45% for Sirius and 7.07% for the apples in the Golden Orange variety.

The fewest weight losses are shown for the Luna variety, the value recorded after 6 months of storage being of only 5.29%.

In the case of storing the fruit in modified atmosphere there is a decrease of the weight losses and the lowest values were recorded for the Luna variety, 3.52% after 6 months and the highest for Sirius, 4.26%.

Another aspect that is highlighted is that the positive influence of the modified atmosphere is stronger mainly for the apple fruits in the Golden Orange and Sirius variety.

In comparison with the cold storage the fruit stored in modified atmosphere show weight losses decreased by 3.19%, while for the Luna variety the decrease is only by 1.77%.

Generally, for the 4 varieties studied, the weight losses recorded at the end of the 6 storage months were 6.38% in cold storage and only 3.8% for the fruit stored in modified atmosphere, which means they were lower by 1.7%.

This general reduction of the weight losses is owed mainly to the positive effect of the modified atmosphere on the slowing down the metabolic processes in fruits.

As far as qualitative depreciations are concerned, from the results shown in table 3 it should be pointed out that all the fruit that did not meet the technical requirements for the Extra and I quality after sorting were included, according to the Regulation EC 543/2011.

Table 2. Weight losses registered during the apple fruits storage in different conditions (%)

Variety	Cold storage		Modified atmosphere	
	after 3 months	after 6 months	after 3 months	after 6 months
FUJI	2.97	5.71	2.25	3.55
LUNA	3.08	5.29	2.19	3.52
GOLDEN ORANGE	4.15	7.07	2.70	3.88
SIRIUS	4.52	7.45	2.81	4.26
AVERAGE	3.68	6.38	2.48	3.80

Source: Own determination.

These depreciations were grouped into 2 categories: Quality II fruits for those which can still be processed by industrialization (compotes, juices) and rotted fruits, which can be processed through distillation.

For the Quality II fruits the physiological disorder called lenticular spot was mainly visible (Photo. 5).

Photo 5. Lenticelar spot of the Sirius variety
Source: Original.

As for the apples stored in modified atmosphere, in comparison to those kept in cold storage, it can be seen that the qualitative depreciations have fairly high variations depending on the variety and on the storage condition.

Thus, in modified atmosphere conditions, after 6 months of storage, the qualitative depreciations are as follows:

-the lowest values for the downgraded fruits are recorded for the Fuji variety (1.28%) and Luna (1.78%) and the highest for the Golden Orange (2.29%);

-for the rotted fruits the lowest losses were recorded for the Luna variety (3.36%) and Sirius (3.98%), and the highest for the apples of the Golden Orange (6.07%) and Fuji varieties (5.44%). The rottenness of the fruit was mainly caused by the grey mould *Botrytis cinerea* (Photos 6 and 7).

Photo 6. Rotted fruits in the Luna variety
Source: Original.

Photo 7. Rotted fruits in the Fuji variety
Source: Original.

As a result of the data obtained regarding the qualitative depreciations for the fruit stored in cold storage, the following should be mentioned:

-the lowest values for the II category fruit are recorded for the apples of the Sirius (7.26%) and Fuji (8.9%) varieties, and the highest for the Luna variety (22.52%);

-for the rotten fruits the lowest values are for the Luna variety (6.88%) and Sirius (6.92%). The highest values were recorded for the apple fruits of the Golden Orange variety (9.84%).

On the whole of the 4 varieties analysed, the total of the qualitative depreciations resulted after storing the apples for 6 months is that of 20.77% for cold storage and 6.53% for the fruits stored in modified atmosphere, which represents 3.2 times decrease.

Table 3. Qualitative losses registered during the apple fruits storage in different conditions (%)

Variety	Cold storage				Modified atmosphere			
	after 3 months		after 6 months		after 3 months		after 6 months	
	second class	rotted fruits	second class	rotted fruits	second class	rotted fruits	second class	rotted fruits
FUJI	3.23	2.16	8.90	7.34	0.88	2.64	1.28	5.44
LUNA	2.86	1.93	22.52	6.88	1.04	1.47	1.78	3.36
GOLDEN ORANGE	2.24	3.46	13.41	9.84	1.24	3.16	2.29	6.07
SIRIUS	1.11	2.47	7.26	6.92	1.02	1.86	1.92	3.98
AVERAGE	2.36	2.51	13.03	7.75	1.05	2.28	1.82	4.71

Source: Own determination.

After analyzing the apple fruits behavior during storage as far as the total losses are concerned (Table 4), after 6 months of storage the following results are visible:

-in modified atmosphere conditions, the best results are obtained for the Luna (8.66%) and Sirius (10.16%) varieties and the lowest for the Golden Orange variety (12.24%);

-for the fruits stored in normal cold storage conditions, the lowest total losses were visible for the Sirius variety (21.63%), and the highest for Luna (34.69%) and Golden Orange (30.32%);

-the average of the total losses as a result of the storage of the 4 apple varieties is only 10.22% for the fruit stored in modified atmosphere, which is 2.6 times lower than the average for the fruit stored in normal cold storage conditions (27.15%).

-in general, the positive influence of modified atmosphere is manifested mainly for the apple fruits in the Luna variety, in comparison to those stored in normal cold storage conditions.

The fruits kept in modified atmosphere have recorded lower total losses by 26%, while for the Sirius variety, this reduction was by only 11.47%.

Table 4. Total losses registered after 6 month of apple fruits storage in different conditions (%)

Variety	Cold storage	Modified atmosphere	Cold storage/ Modified atmosphere
FUJI	21.95	10.27	2.14
LUNA	34.69	8.66	4.01
GOLDEN ORANGE	30.32	12.24	2.48
SIRIUS	21.63	10.16	2.13
AVERAGE	27.15	10.33	2.63

Source: Own determination.

During the storage of the apples, as a result of the development of the metabolic activity, the main physio-chemical characteristics of the fruits underwent changes compared to the values measured at harvesting, and the results obtained are to be seen in Table 5 [8, 9].

As far as the firmness of the pulp is concerned, it could be seen that during the storage period the values decreased in comparison to those at the moment of harvesting, both depending on the variety and on the storage conditions.

Table 5. The main physio-chemical characteristics of the apple fruits after 6 months of storage in different conditions

Variety	Firmness - Kgf/cm^2 -		Soluble dry matter -%-		Total titratable acidity -%-		Ascorbic acid - mg/100 g-	
	cold storage	modified atmosphere	cold storage	modified atmosphere	cold storage	modified atmosphere	cold storage	modified atmosphere
FUJI	4.4	5.2	15.2	14.8	0.28	0.35	4.6	5.0
LUNA	5.0	5.6	14.2	14.0	0.42	0.48	5.4	5.9
GODEN ORANGE	5.2	6.0	14.8	14.4	0.38	0.42	5.0	5.4
SIRIUS	4.0	5.0	13.6	13.3	0.50	0.56	6.4	6.9
AVERAGE	3.65	4.45	14.45	14.10	0.40	0.45	5.35	5.8

Source: Own determination.

Table 6. The economic efficiency of apple fruits storage after the 6 months, in different conditions (calculation performed for 1 tone of fruits)

Variety and fruits category	Cold storage		Modified atmosphere		The value difference -lei-
	Quantity -kg-	Value -lei-	Quantity -kg-	Value -lei-	
FUJI Extra and I-st quality	780.5	4,214.7	897.3	4,845.4	
Second quality	89	225.5	12.8	32	
Rotted fruits	73.4	33	54.4	24.5	
TOTAL		4,470.2		4,901.9	431.7
LUNA Extra and I-st quality	653.1	3,526.7	913.4	4,932.4	
Second quality	225.2	563	17.8	44.5	
Rotted fruits	68.8	30.96	33.6	15.1	
TOTAL		4,120.7		4,992	871.3
GOLDEN ORANGE Extra and I-st quality	696.8	3,762.7	877.6	4,739	
Second quality	134.1	335.3	22.9	57.2	
Rotted fruits	98.4	44.3	60.7	27.3	
TOTAL		4,142.3		4,823.5	681.2
SIRIUS Extra and I-st quality	783.7	4,231.9	898.4	4,851.4	
Second quality	72.6	181,5	19.2	48	
Rotted fruits	69.7	31.4	39.8	17.9	
TOTAL		4,444.8		4,917.3	472.5

Extra and I-st quality = 5.4 lei/kg
Second quality = 2.5 lei/kg
Rotted fruits = 0.45 lei/kg

Thus, after 6 months, the values registered for the fruits stored in normal cold storage conditions were between 3 kgf/cm^2 and 4 kgf/cm^{2,} with an average of 3.65 kgf/cm^2 for the 4 varieties.

For the apple fruits stored in modified atmosphere, the values varied between 4 kgf/cm^2 and 5 kgf/cm^2, the average of the 4 varieties being of 4.45 kgf/cm^2.

The highest increases in comparison with the initial value were registered after 6 months of storage for Sirius (2.8 kgf/cm^2 in normal cold storage conditions and 1.8 kgf/cm^2 in modified atmosphere) and Golden Orange (2.6 kgf/cm^2, 1.8 kgf/cm^2 respectively), and the lowest for the apple fruits of the Luna variety (2.2 kgf/cm^2 in cold storage and 1.6 kgf/cm^2 in modified atmosphere).

As far as the other measured characteristics are concerned, the soluble dry matter, the total titratable acidity and the ascorbic acid, during the storage of the apples a decrease of the determined values was found.

The decrease was higher in the case of the apple fruits stored in normal cold storage. Thus, after the 6 months of storage, the average of the relative values for the 4 varieties analysed was – 14.45% soluble dry matter, 0.4% total titratable acidity and 5.35 mg/100g ascorbic acid.

For the fruits kept in modified atmosphere the average values were 14.15% soluble dry matter, 0.45% total titratable acidity and 5.8mg/100g ascorbic acid.

In order to assess the economic efficiency of the two storage methods, Table 6 shows a number of economic calculations regarding their comparative situations, starting from the apple quantities for each quality ranking left at the end of storage and the average retail prices.

The additional expenses required for the modified atmosphere storage method with the semipermeable low-density polyethylene film consisted solely of the price of the film and the costs needed for the handling of the fruit wrappings.

These expenses amount to around 100 RON/ton annually.

From the data shown in Table 6 it can be seen that in the case of the apples stored in modified atmosphere, in comparison to those in cold storage, profit ranging between 331.7RON/ton for Fuji and 771.3RON/ton for Luna was obtained (after the additional 100 RON/ton were deducted for the fruit in modified atmosphere).

CONCLUSIONS

As a result of storing the apples in modified atmosphere, carried out using the semipermeable low-density polyethylene film (LDPE), superior results are obtained in comparison to the fruits kept in cold storage.

The weight losses recorded after 6 months of storage were 1.7 times lower in modified atmosphere than in cold storage.

The quality depreciations recorded after 6 months of apple storage were 3.2 times lower in the case of the modified atmosphere method, in comparison with the cold storage.

The total losses determined at the end of the storage period were 2.6 times lower in the case of the modified atmosphere method, in comparison with the cold storage.

The positive influence of the modified atmosphere was visible mainly for the Luna variety, the total losses being lower by 26%, which represents a decrease of 4 times in comparison to the normal cold storage.

As a result of the development of the metabolic activity during the storage of the apples, the main physio-chemical characteristics of the fruits showed a descending tendency, with the exception of the soluble dry matter, because the fruits continued their maturation even after harvesting. The decreases were more important in the case of the cold storage.

The calculations regarding the economic efficiency of apple storage have highlighted the advantage of the storage in modified atmosphere, the profit obtained being between 331.7 RON/ton for the Fuji variety and 771,3 RON/ton for the Luna variety, in comparison with cold storage.

REFERENCES

[1]Chira, A., Chira, L., Delian, E., 1998, Modified atmosphere packing of apples and strawberries treated by fumigation with acid acetic. Annual Meeting ESNA, Brno, Czech Republic, 196 - 200.

[2]Chira, A., Chira, L., Săvulescu, E., Costea, A., 2008, The prerefrigeration and modified atmosphere – physical methods for preventing and controling some peach diseases during storage. XXXIII Annual Meeting ESNA, Krakow, Poland, 79.

[3]Cortellino, G., Gobi, S., Bianchi, G., Rizzolo, A., 2015, Modified atmosphere packaging for shelf life extension of fresh-cut apples. Trends in Food Science and Technology, Vol 46, 47-53.

[4]Fante, C. A., Vilas Boas, A. C., Aguiar Paira, V., Freitas Pires, C. R., De Oliviera Lima, L., C., 2014, Modified atmosphere efficiency in the quality maintenance of Eva apples. Food Science and Technology, Vol. 34(2), 84-90.

[5]Mangaraj, S., Goswami, T. K., Mahajan, P. V., 2009, Applications of plastic films for modified atmosphere packaging of fruits and vegetables: A review. Food Engineering Review, Vol 1, 133-158.

[6]Rocha, A. M. C. N, Barreiro, M. G., Morais, A. M. M. B., 2004, Modified atmosphere for apple Bravo de Esmolfe. Food Control, no.15, 61-64.
[7]Singh, S., 2010, Modified atmosphere packaging of fresh produce: Current status and future needs. Food Science and Technology, Vol. 43, 381-392.
[8]Sypula, M., Pietron, A., Struzyk, A., 2018, Changes in qualitative characteristics of apples stored in modified atmosphere packaging. Engineering for rural development, Vol. 17, 1308-1314.
[9]Viskelis, P., Rubinskiene, M., Sasnauskas, A., Bobinas, C., Kvikliene, N., 2011, Changes in apple fruit quality during a modified atmosphere storage. Journal of Fruit and Ornamental Plant Research, Vol. 19 (1), 155-165.