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RESEARCH REGARDING THE PRINCIPAL CHEMICAL COMPONENT LOSS IN THE APPLE FRUIT DURING STORAGE

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Abstract. The study presents a comparison of the loss that the fruit suffer during the storage period in both traditional and refrigerating storage, at the Fruit Research Station Cluj-Napoca, Romania. There were gathered biochemical data for four winter maturation apple varieties: Jonathan, Golden Delicious, Starkrimson and Wagener Premiat, during the months of October (at storage), December and March. The determined biochemical aspects were water, total sugar, and ascorbic acid. The refrigerating storage was better in comparison with the traditional storage, confirmed by biochemical composition. The lowest dehydration was for the apples stored in the refrigerating room. By storage method and apples varieties comparison, the lowest water loss was shown by Wagener Premiat varieties and the highest by Jonathan in refrigerating storage in comparison with traditional storage. Wagener Premiat varieties showed the best qualities even for total sugar and ascorbic acid in comparison with the others apples varieties studied. To keep the apples in optimum conditions, the genetic characters of each cultivar and the cultivar behaviour to CA storage is required.

Key words: apple, storage, refrigeration

INTRODUCTION

The apples must be harvest at the right time in their ripening cycle, when they are firm and will hold over a period of time until they are put to market. The apples which are not sold yet, especially the winter apple, are rushed to cold storage warehouses, consisting of large refrigerated storerooms, where the temperature is kept at 0-2°C and high humidity is maintained. The cold temperature slows ripening process, but does not stop it. Apples of winter varieties put in regular cold storage, and sold by late winter until late spring. Regular cold storage is less expensive than controlled atmosphere storage. Throw optimal storage (eg controlled atmosphere) depending on genetic characteristics of the fruits of varieties, the apples stay crisp and juicy, at good organoleptic qualities (Sestras et al., 2006). For long term storage, fruit need to be harvested before they begin producing ethylene (Roth et al., 2003; Godling et al., 2004). Known simply as "CA" in the industry, controlled atmosphere storage involves careful control of temperature, oxygen, carbon dioxide and humidity (Berceanu, 2003; Niculiță, 1998). The apple storage by refrigeration is a technique for quality fruit preservation using low temperatures but higher then the freezing temperature. For using this technique it is necessary to take in consideration many criteria like lot quality and stability and also the estimated economical efficiency (Hoehn et al., 2003; Berceanu, 2003). For many

years apples have been cooled by storing them in refrigerating rooms. One of the least expensive methods for cooling apples, room cooling is accomplished by simply stacking bulk boxes inside a refrigerating room where the heat is allowed to dissipate slowly. This method requires a minimum of handling and labour. After cooling is completed, the facility can be used for short-term storage as well (Sanz, 2005). Because cooling occurs over a period of several days or even longer, the electrical energy demand from the refrigeration system is relatively low. As a result, a smaller, less expensive cooling system can be used, and the cost of electricity is lower than for more rapid cooling methods. The softening of fruits, including apples, is the results of modification of their cell walls. These modifications include the degradation and solubilization of polysaccharides, loss of sugar units from pectic side chains, and a reduction in site of hemicelluloses (Redgwell et al., 1997). Two major factors play a role in apple softening: water loss and enzymes causing cell wall breakdown (Johnstone et al., 2002).

Controlled Atmosphere Storage (CA storage) is a non-chemical process; temperatures are kept at a constant 0 to 2 degrees Celsius. Exact conditions in the rooms are set according to the apple variety. Researchers develop specific regimens for each variety to achieve the best quality. The optimum temperatures are established according to species, varieties, the fruit chemical composition (water, sugars, acidity) and the fruit ripening level (Berceanu, 2003; Gherghi, 1989; Gherghi et al., 1973).

Long time cooling may lead to the loss of fruit quality if they are not sold in time and that loss is caused by the differential or inexistent activity of some enzymes (Berceanu, 2003). Researches regarding the fruit storage, mainly the loss that the fruit suffer during the storage period, have as a goal determining and advising the best apple storage methods, so that they can be sold at a higher quality and with better economical efficiency.

The term quality implies the degree of excellence of a product comprising sensory properties (appearance, texture, taste and aroma), nutritive values, chemical constituents, mechanical properties, functional characteristics and defects (Abbott, 1999).

MATERIALS AND METHODS

In order to compare the traditional storage and refrigerating storage at the Fruit Research Station Cluj-Napoca, Romania, there were harvested four apple varieties with winter ripening, widely spread in the centre of Transylvania: Jonathan, Golden Delicious, Starkrimson and Wagener Premiat.

The apple harvesting was made in autumn at the end of September, at technical ripening. Each fruit was harvest with peduncle, without snatching and with slight turning of the fruit.

The pre-sorting was made in the harvest moment and the fruits were packed in plastic boxes, each holding about 25 kg. The apples were stored two days after harvesting. Firmness and the level of soluble solids in the apple are good indicators of maturity to use in determining the harvest time. Also it used the amidine hydrolysis level with iodine in potassium iodide.

The fruit representative sample, 100 fruits / 3 lots / varieties, was stored in refrigerating storage and in traditional storage, equally. The fruits' control was made each month in the October-December period and weekly in January-March period. There were made biochemical analysis: water, total sugar and ascorbic acid, in October, December and March.

The data was statistically processed with variance analysis (ANOVA), Duncan test, for a bifactorial experience (the factors are the cultivar with four graduations Jonathan, Golden Delicious, Starkrimson and Wagener Premiat, and storage method - traditional storage and refrigerating storage). It has been shown that the water, total sugar, ascorbic acid loss depends on the analysis moment, correlating the varieties and storage method.

RESULTS AND DISCUSSIONS

The evolution of fruit composition in water, total sugar and ascorbic acid depending on apple varieties and storage method is shown in Table 1.

Among studied apple varieties, Wagener Premiat showed the lowest loss in the studied biochemical components in traditional and refrigerating storage.

Table 1

The studied biochemical components loss in traditional and refrigerating storage

Cultivars	Month of analysis	Water (%)		Total sugar (%)		C vitamin (mg/100g fruit)	
		Refrigerating storage	Traditional storage	Refrigerat. storage	Tradition. storage	Refrigerat. storage	Tradition. storage
Jonathan	October	83.95	83.95	12.72	12.72	8.28	8.28
	December	83.80	82.50	12.50	11.80	7.20	5.93
	March	82.20	80.20	12.10	10.50	6.95	5.34
Golden Del.	October	84.00	84.00	9.27	9.27	6.69	6.69
	December	83.20	82.65	9.25	9.21	6.40	5.28
	March	82.85	80.20	9.80	8.62	6.15	4.21
Wagener Pr.	October	85.75	85.75	8.62	8.62	6.20	6.20
	December	85.50	85.20	8.60	8.20	5.92	5.80
	March	85.35	84.25	8.53	7.80	5.30	4.40
Starkrimson	October	85.50	85.50	11.62	11.62	6.69	6.69
	December	85.01	81.50	11.30	10.80	6.50	5.11
	March	84.15	81.45	10.92	9.14	6.20	3.52

The lowest dehydration was for the apples' storage in the refrigerating room. By storage method and apples varieties comparison, the lowest water loss was shown by Wagener Premiat varieties and the highest by Jonathan in comparison with traditional storage.

The total sugar composition was best preserved by the Wagener Premiat variety and in opposition was Starkrimson variety. The most sensitive biochemical component of fruits on storage was ascorbic acid which was degrading more in traditional storage.

The analyses of water loss data by statistical processes show that both the storage method and the varieties and the interaction between the variety and the used storage method have significantly affected the fruits dehydration on analyses period (Tables 2, 3 and 4).

The storage in refrigerating storeroom induces significantly the reduction of fruits water loss in October-December and October-March periods but not in the December –March period in comparison with apple storage in traditional storeroom.

In the October-December period, Wagener Premiat, followed by Jonathan, shown the lowest water loss. In the same period Stakrimson cultivar showed the higher water loss. General analysis period overview, October-March, Wagener Premiat cultivar show the lower water loss from apple fruits, with significantly lower deviation in comparison with Jonathan, Golden Delicious and Starkrimson cultivars.

Table 2

The water component (%) loss in traditional and refrigerating storage in the October-December period depending on both variety and storage method

Cultivars	Storage method		Mean for cultivar
	Refrigerating storage	Traditional storage	
Jonathan	0.15 [c]	1.45 [bc]	0.80 [M]
Golden Delicious	0.80 [bc]	1.35 [b]	1.08 [LM]
Wagener Premiat	0.25 [c]	0.55 [bc]	0.40 [M]
Starkrimson	0.49 [bc]	4.00 [a]	2.25 [L]
Mean for storage conditions	0.42 [X]	1.84 [Y]	-

The differences between two variants with a common letter are not significant
SD5% for cultivars interactions x storage method: 1.12-1.27
SD5% for cultivars: 1.28-1.37
SD5% for storage method: 1.39

Table 3

The water component (%) loss in traditional and refrigerating storage in the December-March period depending on both variety and storage method

Cultivars	Storage method		Mean for cultivar
	Refrigerating storage	Traditional storage	
Jonathan	1.60 [ab]	2.30 [a]	1.95 [J]
Golden Delicious	0.35 [bc]	2.45 [a]	1.40 [JK]
Wagener Premiat	0.15 [c]	0.95 [bc]	0.55 [K]
Starkrimson	0.86 [bc]	0.05 [c]	0.45 [K]
Mean for storage conditions	0.74 [R]	1.44 [R]	-

The differences between two variants with a common letter are not significant
SD5% for cultivars interactions x storage method: 1.25-1.42
SD5% for cultivars: 1.15-1.24
SD5% for storage method: 1.06

Table 4

The water component (%) loss in traditional and refrigerating storage in the October-March period depending on both variety and storage method

Cultivars	Storage method		Mean for cultivar
	Refrigerating storage	Traditional storage	
Jonathan	1.75 [b]	3.75 [a]	2.75 [P]
Golden Delicious	1.15 [bc]	3.80 [a]	2.48 [P]
Wagener Premiat	0.40 [c]	1.50 [bc]	0.95 [R]
Starkrimson	1.35 [bc]	4.05 [a]	2.70 [P]
Mean storage conditions	1.16 [M]	3.28 [N]	-

The differences between two variants with a common letter are not significant
SD5% for cultivars interactions x storage method: 1.15-1.33
SD5% for cultivars: 1.33-1.44
SD5% for storage method: 1.52

Table 5

The total sugar composition (%) loss in traditional and refrigerating storage in the October-December period depending on both cultivars and storage method

Cultivars	Storage method		Mean for cultivar
	Refrigerating storage	Traditional storage	
Jonathan	0.22 ^{abc}	0.92 ^{ac}	0.57 ^{S}
Golden Delicious	0.02 ^{c}	0.06 ^{b}	0.04 ^{T}
Wagner Premiat	0.02 ^{c}	0.42 ^{abc}	0.22 ST
Starkrimson	0.32 ^{abc}	0.82 ^{ab}	0.57 ^{S}
Mean for storage conditions	0.15 ^{V}	0.55 ^{V}	-

The differences between two variants with a common letter are not significant
SD5% for cultivars interactions x storage method: 0.72-0.82
SD5% for cultivars: 0.40-0.43
SD5% for storage method: 0.49

Table 6

The total sugar composition (%) loss in traditional and refrigerating storage in the December-March period depending both cultivars and storage method

Cultivars	Storage method		Mean for cultivar
	Refrigerating storage	Traditional storage	
Jonathan	0.40 ^{c}	1.30 ^{ab}	0.85 ^{LM}
Golden Delicious	0.01 ^{c}	0.59 ^{bc}	0.30 ^{M}
Wagner Premiat	0.07 ^{c}	0.40 ^{c}	0.24 ^{M}
Starkrimson	0.38 ^{c}	1.66 ^{a}	1.02 ^{L}
Mean for storage conditions	0.22 ^{B}	0.99 ^{D}	-

The differences between two variants with a common letter are not significant
SD5% for cultivars interactions x storage method: 0.80-0.91
SD5% for cultivars: 0.59-0.64
SD5% for storage method: 0.62

Table 7

The total sugar composition (%) loss in traditional and refrigerating storage in the October-March period depending on both cultivars and storage method

Cultivars	Storage method		Mean for cultivar
	Refrigerating storage	Traditional storage	
Jonathan	0.62 ^{b}	2.22 ^{a}	1.42 ^{J}
Golden Delicious	0.53 ^{b}	0.65 ^{b}	0.59 ^{K}
Wagner Premiat	0.09 ^{b}	0.82 ^{b}	0.46 ^{K}
Starkrimson	0.70 ^{b}	2.48 ^{a}	1.59 ^{J}
Mean storage conditions	0.49 ^{G}	1.54 ^{H}	-

The differences between two variants with a common letter are not significant
SD5% for cultivars interactions x storage method: 0.87-0.98
SD5% for cultivars: 0.70-0.76
SD5% for storage method: 0.95

The total sugar loss was not affected significantly by storage method in the October - December period, but this component was significantly higher in traditional storage in the December-March period and in the whole analyse period, October-March (Tables 5, 6, 7). Among cultivars, in both storage methods, Wagner Premiat and Golden Delicious showed the lowest total sugar loss.

Table 8

The ascorbic acid composition (mg/100g fruit) loss in traditional and refrigerating storage in the October-December period depending on both cultivars and storage method

Cultivars	Storage method		Mean for cultivar
	Refrigerating storage	Traditional storage	
Jonathan	1.08 ^{bc}	2.35 ^{a}	1.72^{X}
Golden Delicious	0.29 ^{cd}	1.41 ^{b}	0.85^{Y}
Wagner Premiat	0.28 ^{cd}	0.40 ^{cd}	0.34^{Y}
Starkrimson	0.19 ^{d}	1.58 ^{ab}	0.89^{Y}
Mean for storage conditions	0.46^{A}	1.44^{B}	-

The differences between two variants with a common letter are not significant
SD5% for cultivars interactions x storage method: 0.83-0.94
SD5% for cultivars: 0.62-0.67
SD5% for storage method: 0.75

Table 9

The ascorbic acid composition (mg/100g fruit) loss in traditional and refrigerating storage in the December-March period depending on both cultivars and storage method

Cultivars	Storage method		Mean for cultivar
	Refrigerating storage	Traditional storage	
Jonathan	0.25 ^{c}	0.59 ^{bc}	0.42^{S}
Golden Delicious	0.25 ^{c}	1.07 ^{abc}	0.66^{RS}
Wagner Premiat	0.62 ^{bc}	1.40 ^{ab}	1.01^{R}
Starkrimson	0.30 ^{c}	1.59 ^{a}	0.95^{RS}
Mean for storage conditions	0.36^{C}	1.16^{C}	-

The differences between two variants with a common letter are not significant
SD5% for cultivars interactions x storage method: 0.91-1.03
SD5% for cultivars: 0.49-0.53
SD5% for storage method: 0.68

Table 10

The ascorbic acid composition (mg/100g fruit) loss in traditional and refrigerating storage in the October-March period depending on both cultivars and storage method

Cultivars	Storage method		Mean for cultivar
	Refrigerating storage	Traditional storage	
Jonathan	1.33 ^{cd}	2.94 ^{a}	2.14^{K}
Golden Delicious	0.54 ^{d}	2.48 ^{ab}	1.51^{KL}
Wagner Premiat	0.90 ^{cd}	1.80 ^{bc}	1.35^{L}
Starkrimson	0.49 ^{d}	3.17 ^{a}	1.83^{KL}
Mean storage conditions	0.82^{E}	2.60^{F}	-

The differences between two variants with a common letter are not significant
SD5% for cultivars interactions x storage method: 0.97-1.10
SD5% for cultivars: 0.65-0.70
SD5% for storage method: 0.87

Ascorbic acid fruit composition was affected in the research period by both storage conditions and the cultivars and also by the cultivar-storage method interaction (Tables 8, 9, 10). The ascorbic acid loss was significantly lower to the apples storing by refrigeration in the October-December period and in the whole analysis period (October-March) than classical storage.

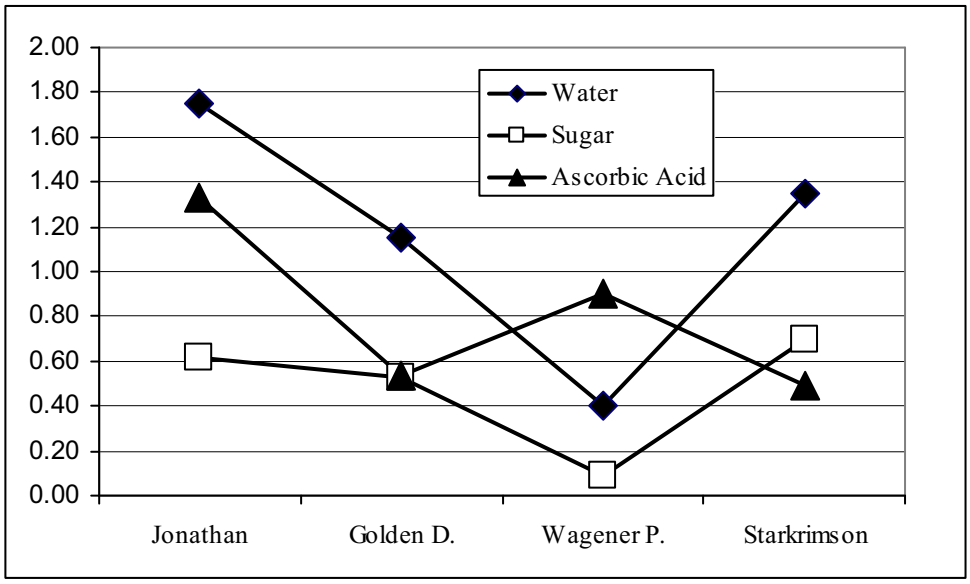

Figure 1. The water (%), total sugar (%) and ascorbic acid (mg/100g fruit) loss at apples in refrigerating storage in the October-March period

In the October–December period, Jonathan cultivar showed higher ascorbic acid loss then the other analysed cultivars. In the next period Jonathan showed the lowest ascorbic acid loss. It is interesting to observe that the same cultivar, in the whole analysis period, October-March, showed the highest ascorbic acid loss.

The data from Figures 1 and 2 shows the biochemical modification of apple fruits in storage are significantly different, depending on the storage method and genetic specific feature of each cultivar. Because the diagram aspect suggested some connection between the fruits' biochemical loss among the cultivars, there was calculated the correlations coefficient among analyzed components (Table 11).

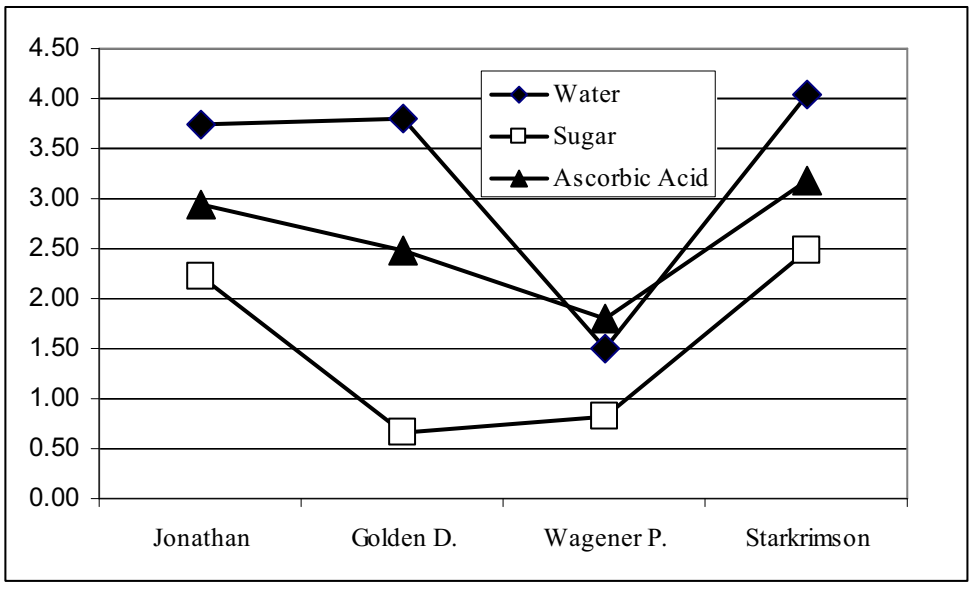

Figure 2. The water (%), total sugar (%) and ascorbic acid (mg/100g fruit) loss at apples in traditional storage in the October-March period

Table 11

The correlations among the loss suffered by fruits in the October-March period, depending on the storage method

Correlated characteristics	Refrigerating storage		Traditional storage	
	Sugar	Ascorbic Acid	Sugar	Ascorbic Acid
Water	0.908	0.273	0.554	0.908
Sugar		-0.146		0.850

r%5= 0.878; r1%= 0.959; r0.1%= 0.991

The closest correlations were found between water and sugar loss in refrigerating storage and between water and ascorbic acid in traditional storage. For apple in traditional storage, the most pronounced degradation of biochemical fruits composition was manifested in the same way, fact shown by identified positive correlations.

CONCLUSIONS

The apple storage by refrigeration is a technique for quality fruit preservation using low temperatures but higher then freezing temperature, due to the preservation of the main chemical components and thus obtaining better fruit quality. The lowest dehydration was for the apples stored in the refrigerating room. By storage method and apples varieties comparison, the lowest water loss was shown by Wagener Premiat varieties and the highest by Jonathan in traditional storage in comparison with traditional storage. The total sugar loss was not affected significantly by storage method in the October-December period but this component was significantly higher in traditional storage in the December-March period and in the whole analysis period, October-March. Among cultivars, in both storage methods, Wagner Premiat and Golden Delicious showed the lowest total sugar loss. In the October–December period, Jonathan cultivar showed ascorbic acid composition higher then the others analysed cultivars. In the next period Jonathan showed the highest ascorbic acid loss. It is interesting to remark the same cultivar, in the whole analyse period, October-March, shown the highest ascorbic acid loss. For the apples kept in optimum conditions, the genetic characters of each cultivar and also the cultivar behaviour to CA storage are recommended.

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REZUMAT

CERCETĂRI PRIVIND PIERDERILE ÎN PRINCIPALELE COMPONENTE CHIMICE ALE FRUCTELOR LA MĂR, PE PARCURSUL DEPOZITĂRII

Pentru compararea pierderilor care au loc în fructe pe parcursul păstrării în condiţii de depozit tradiţional şi prin refrigerare, la Staţiunea de Cercetare-Dezvoltare pentru Pomicultură Cluj, România, s-au efectuat determinări biochimice în lunile octombrie (la depozitare), decembrie şi martie, în privinţa conţinutului fructelor în apă, zahăr şi vitamina C la patru soiuri de măr, cu maturare de iarnă, larg răspândite în cultură în Transilvania: Jonathan, Golden Delicious, Starkrimson şi Wagener Premiat. S-a confirmat faptul că depozitarea în spaţii frigorifice asigură faţă de cea tradiţională o păstrare mult mai bună a fructelor, prin prisma conservării principalelor componente chimice, şi implicit a calităţii merelor. Deshidratarea fructelor a fost semnificativ mai scăzută la merele depozitate în celula frigorifică comparativ cu cele păstrate în depozit tradiţional. Cea mai mică pierdere de apă din fructe a fost înregistrată la soiul Wagener Premiat, iar cea mai ridicată la Jonathan. Wagner Premiat a avut cele mai mici pierderi şi în zahăr total şi vitamina C. Vitamina C a constituit cea mai sensibilă componentă biochimică la depozitare, care s-a degradat mai accentuat în condiţiile depozitării în depozit tradiţional. În perioada octombrie-martie, cele mai mari pierderi în vitamina C s-au înregistrat la Jonathan. Pentru păstrarea fructelor în condiţii optime, este recomandabil să se ţină seama şi de particularităţile genetice ale fiecărui soi, respectiv de comportarea fructelor în funcţie de soi la condiţiile controlate de păstrare.