STORAGE CONDITIONS EFFECT ON THE *DELICIOUS PILAFA* APPLES TEXTURE

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Abstract

Delicious Pilafa apples were stored in two traditional warehouses and in a steady conditions cold room (10 ^{o}C, RH=85%), in order to study the firmness change and investigate a relationship between firmness change and mass loss (dehydration). According to experimental data, the firmness change of apples stored in warehouses is linearly related to mass loss. However this linear model cannot be extended to the steady conditions cold room. Thus, wider variety of storage conditions, more replicates, as well as a more complex and effective model are required.

[Keywords] Storage, apple, *Delicious Pilafa,* mass loss, moisture loss, dehydration, firmness.

1. Introduction

Apple preservation is necessary to cover consumer demand for a long market period around the year. Fruit storage in cold room is the most common procedure. Often controlled atmosphere (CA) or modified atmosphere packaging (MAP) is used in addition to cold storage. However, in some cases, such as mountain Greek regions where industrial refrigerated rooms are not available and local weather is cold enough, common warehouses could be used for a short period of commercial storage (Mitropoulos & Lambrinos 2000a).

Independently of the preservation procedure, fruit quality must be easily assessed during storage in order to meet consumer acceptance. Fruit texture and appearance are major factors of consumer preference.

Apple firmness has been expressed as the maximum force required to push a (usually) cylindrical probe of specified shape (rounded face of 11mm diameter) into the tissue of the fruit equator up to 8 mm of depth (Bourne, 1974). Some more sophisticated electronic devices have been developed in recent years, which conduct much more accurate measurements. Except of these destructive techniques some other nondestructive ones have been developed using sonic or vibrational methods (Chen et al. 1993).

Often, panels of experts are used for texture assessment via sensory evaluation procedures. However, according to Harker et al. (2002), the relationship between instrumental and sensory methods does not lead always to reliable results.

Fruit dehydration (water loss), during storage, is another quality factor, which for some sensitive apple varieties such as the well-known Golden Delicious and *Delicious Pilafa*, a Greek local variety, can be critical for quality degradation (Gorini et al. 1979). Loss of water is related to significant wilting, softening, shriveling and poor mealy taste (Hatfield and Knee, 1998). Moreover, water loss seems to be related to changes in lightness color factor (L), since dehydrated fruits become darker (Mitropoulos and Lambrinos 2000b).

While texture and moisture loss (dehydration) are two characteristics strongly related to quality deterioration, no specific relationship between them is known. The existence of a certain relation between water loss and texture evolution could be a useful tool in quality assessment of stored fruit, mostly for easily dehydrated varieties of apples, fact which seems to be possible since both characteristics are based on objective measurements.

The aim of this study is the investigation of a relationship between mass (moisture) loss and texture loss for the *Delicious Pilafa* variety. Data have been collected from traditional warehouses of a mountainous Greek region as well as from a controlled conditions storage room.

2. Materials and Methods

Delicious Pilafa apples of two cultivation periods (1999-2000) were used for this study. Fruits were manually harvested at their commercial maturity at the end of October. They were selected on the basis of size and shape homogeneity, as well as of their position on the tree, in order to reduce cultural or environmental factors effect, as much as possible.

Some apples were stored in a chamber at controlled temperature (10 ^{o}C) and relative humidity (RH= 85%) conditions. Some other fruits were stored in two different types of traditional warehouses very close to Tripolis (middle Peloponnisos), the production place. The climate of this area is typically continental (cold autumn and winter), so good results could possibly be achieved. The first warehouse (W1) was an old small size building, built with cement tiles, while the second one (W2) had walls made of stones. These two types of warehouses are very common in the above area. A simple ventilation system, which was controlled by a timer, was inserting ambient air in the room during the night (00:00-06:00). This ventilation system was capable of changing the air ten times per hour. During storage, temperature and RH were recorded by electronic data loggers (Hobo 8H, Onset Computer Corporation, Bourne, USA).

In each storage room (warehouse or cold room), 9 samples containing 15 apples each, were stored. Fruits were individually weighted and packaged in single layer plastic baskets, which were covered with paper sheets (usual commercial package). In each basket there were fruits of only one sample. In addition, a basket with 20 apples was placed in every room in order to estimate weekly mass loss, by successive fruit weighting, for each treatment. The exact time of each texture test was estimated by the mass loss evolution of these fruits.

The exact Mass Loss (ML) of each tested fruit was calculated by weighing measuring just after shorting and before the destructive texture measurement. A balance (FY 300, AND, Tokyo, Japan) with 0.02 g accuracy was used for this purpose. Results are expressed as percentage % of initial weight. The *Delicious Pilafa* respiration activity contributes little (less than 10%) to the overall mass loss. Therefore, mass loss is attributed solely to water loss (dehydration) (Mitropoulos et al. 2004).

Firmness was measured with a drill press mounted 'Effegi' penetrometer (FT 327, Effegi, Milano, Italy) fitted with an 11 mm diameter probe. The maximum force required to puncture the tissue, on opposite sides of the fruit equator, to a depth of 8 mm was recorded. Because of the dehydration effect on superficial tissues texture, the firmness tests were conducted without skin removing. Test results have finally expressed in pressure units (Kp/cm^2).

Mass loss (humidity loss) is considered to be equal to zero at harvesting time that coincides with the start of the storage period. As this study focuses on the effect of storage time on texture evolution, it is necessary to use a texture variable, starting always from the same level. The change of this texture variable between harvesting time and any storage time, instead of texture itself (which varies from year to year at harvesting time) seems to be an appropriate variable. Texture change, at time t, is defined as $\Delta F_t = F_t - F_0$, where F_t and F_0 are the firmness value at any storage time t and at the starting time respectively.

For data analysis SPSS 8.0 (SPSS Inc, Chicago, USA) statistical package was used. In graphs and tables, regression lines are characterized with three characters where the first (1 or 2) denotes the storage period and the second and third ones the storage treatment (W1, W2, R1). In all cases, linear regression procedure was conducted and the slopes a,b,c of equations $\Delta F = a \cdot t$, $ML = b \cdot t$, $\Delta F = c \cdot ML$ (where ΔF=Firmness change ML=Mass Loss and t=time), the upper and lower limit of each slope for 95% level of significance and the square of the correlation coefficient (R^2) were calculated.

3. Results – Discussion

A daily temperature variation of almost 7 ^{o}C is observed in the first warehouse, while this variation is significantly lower (2 ^{o}C) in the second one. The daily average temperature, decreasing, tends to a lower value of almost 4 ^{o}C at the middle of January (70th day of storage). Then, average temperature increases again, reaching 10 ^{o}C in March.

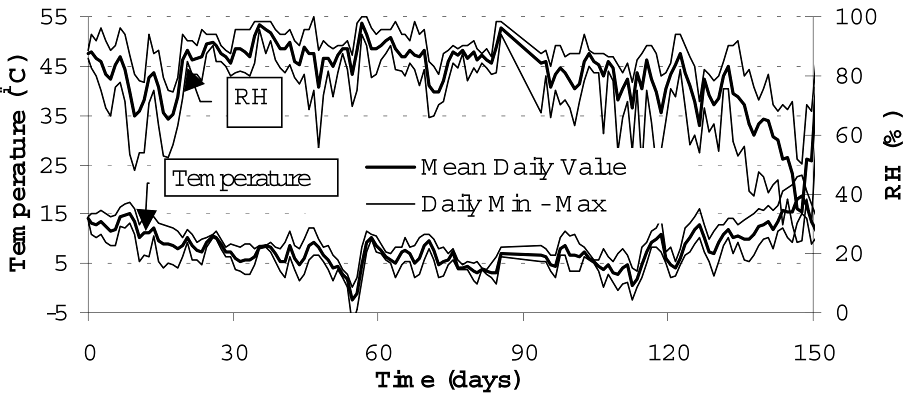

Fig. 1. Temperature and RH evolution vs. time at the 1st warehouse (A1)

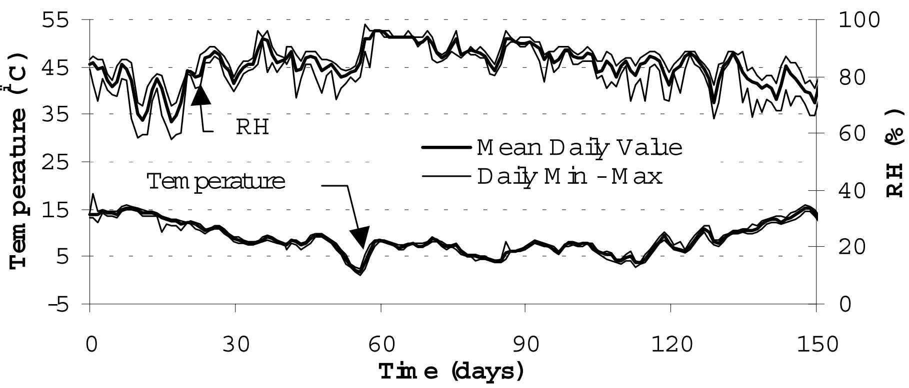

Fig. 2. Temperature and RH evolution vs. time at the 2nd warehouse (A2)

Daily RH mean variation was about 20% in the first warehouse and 12% in the second one. Generally, the evolution of daily average RH values against time presents, as it was expected, an inverse pattern than the temperature's ones. In figures 1&2, the temperature and RH evolution against time for the first and second warehouse respectively are presented. These two figures refer to the second storage period.

Regression results of firmness (ΔF) against time for all simple cases (storage period x storage treatment) are presented in table 1. In the first column each case of the combination storage period x storage treatment is presented. In the second column the coefficient a of the equation $\Delta F = a \cdot t$ is apparent. In the third and the fourth columns the upper and lower limit of this coefficient for 95% level of significance are presented, while the square of the correlation coefficient (R^2) is presented in the last one.

Table 1. Regression of Firmness change vs. Storage Time

$\Delta F = a * t$ [Kp/cm^2]				
Storage Treatment x Storage Period	a_{mean}	a_{upper}	a_{lower}	R^2
1A1	-0.0259	-0.0202	-0.0315	0.773
1A2	-0.0296	-0.0253	-0.0339	0.623
1R1	-0.0359	-0.0309	-0.0408	0.918
2A1	-0.0413	-0.0351	-0.0476	0.815
2A2	-0.0427	-0.0346	-0.0509	0.707
2R1	-0.0494	-0.0432	-0.0557	0.969

Comparisons in pairs, among rows of table 1, show that there are significant differences in many cases. There are differences between storage periods as well as among storage treatments. Thus, the existence of a certain linear relationship, which could describe firmness evolution against time for all three treatments, or even for only two of them, for both storage periods, is considered to be statistically impossible.

In table 2, there are regression results of mass loss against storage time in the same way as in table 1. Generally, there are many statistically significant differences among cases of table 2. These results show that there is no linear relation, which could describe mass loss evolution against time in a unique way.

Table 2. Regression of Mass Loss vs. Storage Time

$ML = b * t$ [%]				
Storage Treatment x Storage Period	b_{mean}	b_{upper}	b_{lower}	R^2
1A1	0.0791	0.0907	0.0675	0.918
1A2	0.0817	0.0964	0.0670	0.891
1R1	0.1753	0.1829	0.1676	0.994
2A1	0.1278	0.1490	0.1066	0.942
2A2	0.1339	0.1519	0.1159	0.964
2R1	0.1705	0.1821	0.1588	0.992

Regression results between firmness change (ΔF) and mass loss (ML) are shown in table 3. In the second column, the coefficient c of the equation $\Delta F = c \cdot ML$ is presented, in the third and fourth ones its upper and lower limit (for 95% level of significance) are presented and in the last one the square of the correlation coefficient (R^2) appears.

Comparison of every pair of cases (rows) of table 3, which is completely presented in table 4, concludes that there are few statistically significant differences, fewer than in the cases of the firmness or mass loss evolution against time. Nevertheless, the existence of a certain linear relation, which could describe in a unique way all studied cases, is not possible.

Table 3. Regression of Firmness change vs. Mass Loss

	ΔF=c*ML [Kp/cm^2]			
Storage Treatment x Storage Period	c_{mean}	c_{upper}	c_{lower}	R^2
1A1	-0.3282	-0.2807	-0.3758	0.902
1A2	-0.3722	-0.3068	-0.4375	0.836
1R1	-0.2054	-0.1342	-0.2766	0.942
2A1	-0.3261	-0.2751	-0.3772	0.937
2A2	-0.3259	-0.2632	-0.3885	0.897
2R1	-0.2910	-0.2739	-0.3082	0.993

As it is shown in table 4, only in the case of controlled conditions storage room, at the first storage period, there are statistically significant differences. In this case, firmness change evolution is significantly lower than in all other studied cases.

Table 4. Regression results comparisons of Firmness change vs. Mass Loss

Storage Treatment x Storage Period	**1A1**	**1A2**	**1R1**	**2A1**	**2A2**	**2R1**
1A1						
1A2	X					
1R1	----	---				
2A1	X	X	X			
2A2	X	X	X	X		
2R1	X	X	X	X	X	

X: combination without statistical significant difference.

If this difference of the controlled conditions storage room is not a result of raw material (apples) it could be a result of a different way that higher varied temperature and RH conditions affect the fruits. However, the fact that the results of the second storage period do not show any significant difference between controlled conditions storage room and warehouses does not reinforce the possibility of a different affecting way of varied conditions. In addition, the use of linear model (simplest) could be another limitation factor on the trial to find a unique relationship that could describe firmness change against mass loss.

According to table 4 results, it is feasible to find a single relationship that describes firmness change against dehydration for both warehouses. This equation is shown below and is graphically presented with the upper and lower limit for 95% level of significance is in fig. 3.

$$\Delta F = (-0{,}336 \pm 0{,}025) \cdot D \qquad (R^2=0{,}82)$$

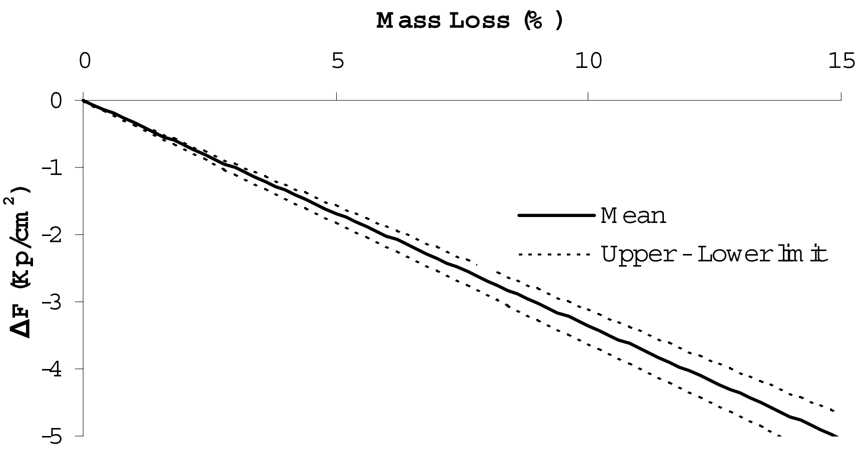

Fig. 3. Regression line of Firmness change vs. Mass Loss for both warehouses

4. Conclusion

The linear relationship between dehydration and firmness, that relate two objectively measured factors of *Delicious Pilafa* apples stored in the specific warehouses, is a significant progress for the estimation of quality degradation during storage.

The research should be continued using not only data from a greater variety of storage conditions (controlled conditions rooms or warehouses) but also more sophisticated regression models which might describe the relationship between dehydration and firmness in a better way.

In addition, the raw material effect (maturity stage at harvesting time, pre-harvest environmental conditions etc) on the studied relationship should be more investigated using more replicates (cultivation periods).

Finally, temperature variation effect on quality degradation should be examined both for stable and varied conditions storage rooms.

References

1. Bourne, M. C., 1974. Comparison of results from the use of the Magness-Taylor pressure tip in hand – and machine – operation. *J Texture Studies,* 5, 105-108.
2. Chen, H. de Baerdemaeker H. and de Baerdemaeker J., 1993. Effect of apple shape on acoustic measurements of firmness. *J Agric Eng Res,* 56, 259-266.
3. Gorini, F. L., Sozzi, A., Rosati, P. and Faedi, W., 1979. Weight losses of standard and spur clones of Golden Delicious apples during storage. *Proc. of XVth Int. Congress of Refrigeration,* Vol. III 799-806. Venice.
4. Harker, F. R., Maindonald, J., Murray, S. H., Gunson, F. A., Hallett, I. C., and Walker, S. B., 2002. Sensory interpretation of instrumental measurements 1: texture of apple fruit. *Postharvest Biology and Technology*, 24 (3), 225-239.
5. Hatfield, S.G.S and Knee, M., 1988. Effects of water loss on apples in storage. *Int. J. Food Sci*., 23, 575-583.
6. Mitropoulos, D., Lambrinos, G. and Xanthopoulos, G. (2004). Moisture loss prediction of *Delicious Pilafa* apple during storage. *Proceedings of the AgEng 2004 Conference, Engineering the Future,* **2:** 1110-1111. Leuven-Belgium, September 12-16, 2004.
7. Mitropoulos, D. & Lambrinos, G. (2000a). Dehydration of *Delicious Pilafa* and Granny Smith apple during storage. *Proceedings of the second Agricultural Engineering National Congress,* 433-440. Volos (Greece), September 28-30, 2000.
8. Mitropoulos, D. & Lambrinos, G. (2000b). Color change of *Delicious Pilafa* and Granny Smith apple during storage in warehouses. *Proceedings of the second Agricultural Engineering National Congress*, 441-448. Volos (Greece), September 28-30, 2000.