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Investigation on mechanical and textural properties of apples during refrigeration storage

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Abstract

In this study there were analyzed three different varieties of apple Golden Delicious, Jonathan and Starkrimson, which were stored by refrigeration in three variants (bulk, packed in LDPE foil and ordinary paper) in a professional refrigerator for 24 days. The penetration tests were lead to determine the mechanical properties including penetration force and the textural one as microstructure.

The determinations were unrolled with a 7 days frequency. The values for penetration force associated with the sensorial attribute – firmness, applied to apple varieties range from 20.49 N for bulk Jonathan in the 7th day of refrigeration storage to 69.54 N for Starkrimson LDPE foil packed at the 14th day.

In case of textural modifications there were some sensitive differences between the three varieties, but the most affected structure was those for Starkrimson and even at the bulk storage there weren't quality deficiency, the packed apples were less influenced by refrigeration.

Keywords: Golden Delicious, Jonathan, Starkrimson, structure, texture, firmness

1. Introduction

The apple is a tree and its pomaceous fruit, of species Malus domestica. In the rose family Rosaceae, is one of the most widely cultivated tree fruits. Even these are some very sold fruits, one of the most important problem limiting exportation increase is realized loss of postharvest operations. Postharvest evaluation gives possibilities for delivering a high quality product and a basic understanding of apple texture is necessary for the development of technology for postharvest evaluation [1,2].

Fruits are attractive and nutritional foods, because of their color, shape, unique taste and smell, enriched minerals, vitamin and other beneficial components [3].

The market value of the foods is determined by their quality. For apples, the texture seems to be a primary quality attribute which together with flavour and appearance, should be taken into account when evaluating overall quality of the fruit [10].

The fresh apples are often firm, crisp and juicy, but the texture can deteriorate during storage and during shelf life. It was a reported that apples picked later tend to lose more water during cold storage and shelf display which usually cause significant wilting, soft, shriveling, dry and mealy taste [11].

According to [4], apple contains 2-30 mg ascorbic acid per 100 g. This concentration decreases progressively from the peel to the core of the fruit [5] and there is twice as much ascorbic acid in the red part of apple peel than in the green part.

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Vitamin C is present in two forms in apples- ascorbic acid, and its oxidized form, dehydroascorbic acid [6]. The total level of the two forms is constant per unit weight during growth, although the ascorbic acid/dehydroascorbic acid ratio increases to at least 95/5 at fruit maturity. The variability of ascorbic acid levels between fruits of a same variety and between years can be very high.

Mechanical properties of the tissue, which are affected by factors such as ripening stage and water status, also determine the susceptibility to mechanical damage that can occur during harvest, transport and storage and the eventually leads to a profound reduction in commercial value [7].

Mechanical properties such as failure stress and strain as well as modulus of elasticity can also be used to evaluate the behaviour of the fruits mechanically under the static loading. Firmness or hardness is another important attribute of fruits and it is often used for fruits quality assessment [8].

Firmness and sugar content are important quality attributes that directly influence consumers on purchasing fresh apple fruit. Nondestructive sensing of fruit for internal quality, especially firmness and sugar content, would allow the fruit industry to provide better, more consistent fruit to the consumer and, thus, improve industry competitiveness and profitability [9,12]. Flavor is most complex to analyze, and over 350 volatile compounds have been detected in apple [13].

In addition to taste, texture is a quality attribute that is critical in determining the acceptability of apple fruits by consumers [14,15].

Fruit wholesalers are therefore particularly interested in the measurement of fruit texture. However, direct measurement of texture through sensory analysis is very complex and time consuming. For this reason, many attempts have been made to replace sensory analysis with instrumental measurements.In order to find the objective parameters to measure fruit sensory quality, [16] showed that sensory hardness, chewiness and mushiness correlated well with instrumentally measured force and work required for penetration of apple flesh.

2. Materials and methods

Materials: fruits (pome fruits – apples – Golden Delicious, Starkrimson and Jonathan), LDPE (Low Density Polyethylene) foil and alimentary paper, lancet.

Instalations/equipments: professional refrigerator with temperature and humidity sensor, epifluorescence microscope, penetrometer (Fruit texture analyzer).

*Methods.*The fruits were stored, using a professional refrigerator, at 5˚C. The storage was made in three variants: bulk and packed using LDPE foil and alimentary paper for a total period of 24 days.

As main analyses there were determined: apples' texture and structure.

Texture measurements were made with a penetrometer named Fruit texture analyzer and the structure was determined with an epifluorescence microscope.

The texture measurements were made on a whole apple applying different forces in different points of the same apple.

Regarding the structure it was determined using apple pulp samples which were dimensioned as a microfilm.

3. Results and discussions

The main role of these determinations was to supervise the texture and structure modifications during the storage in restaurants or public alimentary units.

The apples were stored in three variants: bulk and packed using LDPE foil or alimentary paper for a total period of 24 days. Relative humidity had been kept between 85 and 90%, in the apple storage area.

In order to satisfy the costumer's preferences regarding fruits structure and texture stored by refrigeration (5˚C), there were monitored the sensorial properties of the apples over the 24 days of storage with a 6 days frequency.

In Figure 1 is represented the structure variation of the Starkrimson variety at the initial and the final determination.

The structure was determined with the epifluorescence microscope with a 1392x1040 resolution and 1.4 Megapixeli, sensor CCD2/3" and the samples were photographed with a x10 objective.

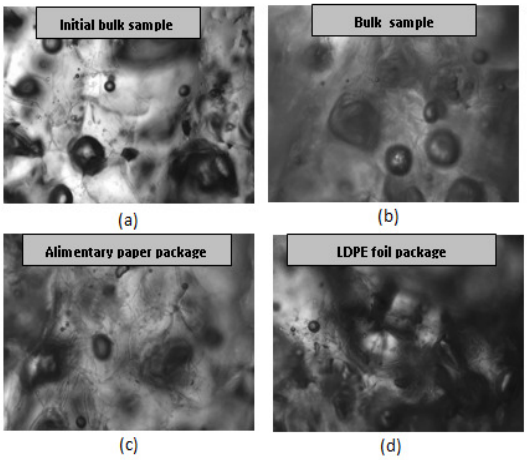

Figure 1. Structure modifications for Starkrimson variety a. initial bulk sample, b. bulk sample stored for 24 days, c. alimentary paper sample stored for 24 days, d. LDPE foil sample stored for 24

Thinking of the starch and pectin content of the apples, especially Starkrimson variety, the degradation of the parenchyma sugars can be observed in the pictures below, as the macro globules and the micro globules structure can be associated to starch and phenols, while the smooth links can be associated to pectin. Their transformation over storage is dependent on package type, as it seems the liquid quantity from the cellular space is not the same for the initial sample as for the three samples stored for 24 days.

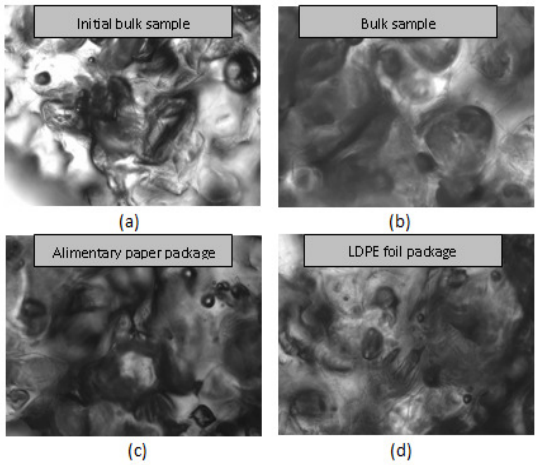

Figure 2. Structure modifications for Jonathan variety (a) initial bulk sample, (b) bulk sample stored for 24 days, (c) alimentary paper sample stored for 24 days, (d) LDPE foil sample stored for 24 days

As it can be seemed the phenol quantity from the initial bulk sample is bigger for the Jonathan than for the Starkrimson variety and also its degradation is faster in the bulk case than for the packed one.

Also the alimentary paper package and the LDPE foil have almost the same action over the structure modifications. And in the both case the pectin chains are more visible than in the Starkrimson case.

In figure 3 is presented the structure modifications for Golden Delicious variety.

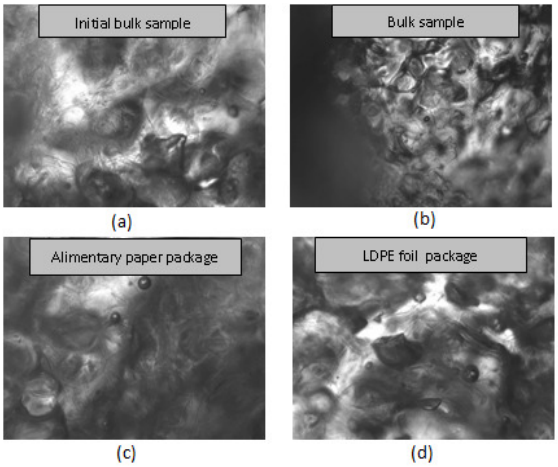

Figure 3. Structure modifications for Golden variety (a) initial bulk sample, (b) bulk sample stored for 24 days (c) alimentary paper sample stored for 24 days, (d) LDPE foil

Also the starch and phenol structure is not the same, the most affected is that alimentary paper packed.

In figure 2 is presented the structure modifications for Jonathan variety.

From the figure 3a it can be observed the water quantity which is preponderant comparing with the other two varieties. The starch is almost indistinguishable, but there is a relevant quantity of pectin and a moderate one of phenols.

It can be observed that the more affected structure during 24 days of storage is the bulk sample, the less affected is the LDPE foil packed apple.

Also very affected seemed to be the alimentary paper packed apple.

The apples structure was determined with the penetrometer generating a curve for three locations in one apple. In figure 4 are presented the Texture variation of the Starkrimson variety before and after the storage.

The initial firmness of the Starkrimson apple variety is around the 53,82 N for 3 mm of penetration. As the penetration is deeper the values of the firmness are lower (35 N to 5 mm, 32 N to 7 mm), so the first coating rich in natural waxes cuticle and pectin which are harder to be penetrated at the initial determination.

The deeper layers are made off cellular walls so it has a smaller resistance to an extern force action. After the storage the values of the firmness are not in a bigger decreasing as it was maybe expected, the bigger variation has been registered at 4 mm – 67,18 N, and the other values for the cellular layers denotes the same transformation.

So in Starkrimson variety case for the bulk storage by refrigeration during 24days the firmness is not affected. This particular result means that the specific sensorial properties of the apple like crunchiness, chewiness, juiciness, mealiness and fondant.

The firmness of the Starkrimson variety is affected by the storage only in the LDPE foil package, but even in this case, comparing with the initial determination this type of package has not noted fluctuations during the 24 days of storage, while the bulk variant and the paper packed one registered variation even the firmness is apparently bigger this not means always a better texture than the initial.In figure 6 is presented the texture transformation of the Jonathan variety before and after the storage.

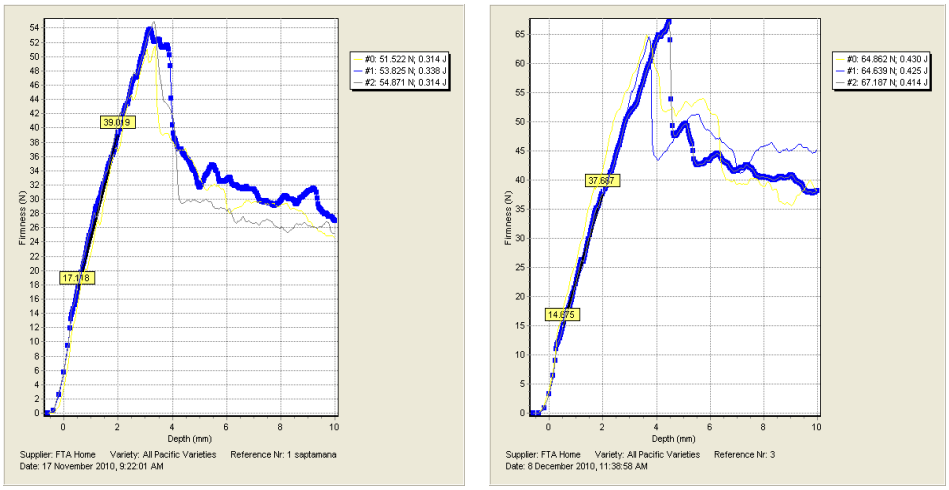

Figure 4. Texture representation of the Starkrimson variety before and after the storage

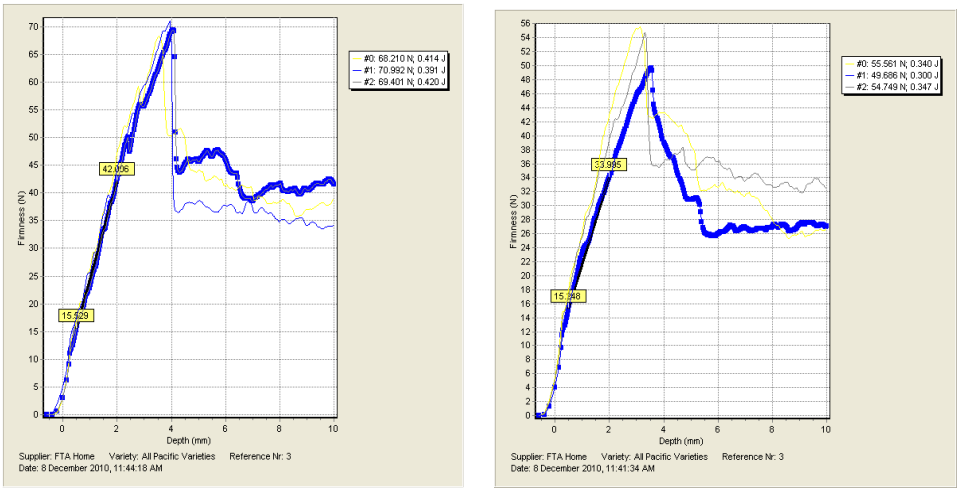

Figure 5. Texture representation of the Starkrimson variety after storage alimentary paper and LDPE foil package

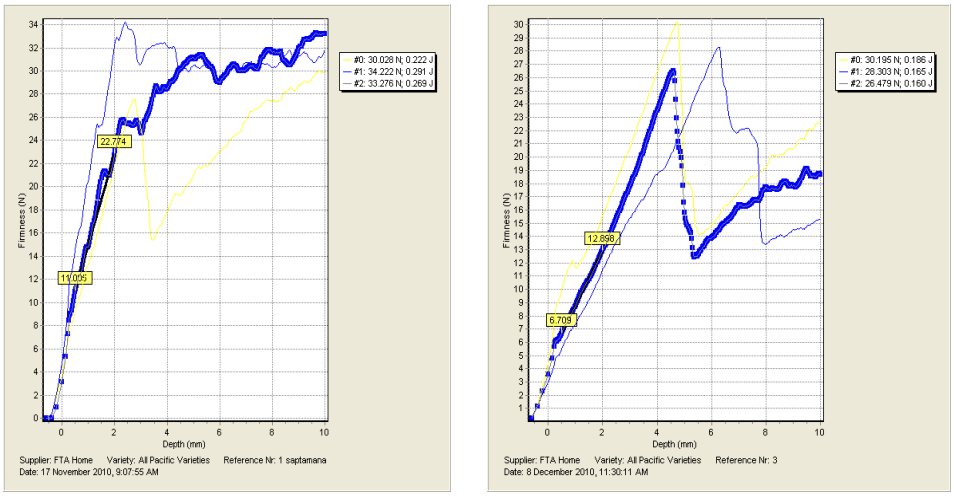

Figure 6. Texture representation of the Jonathan variety before and after the storage

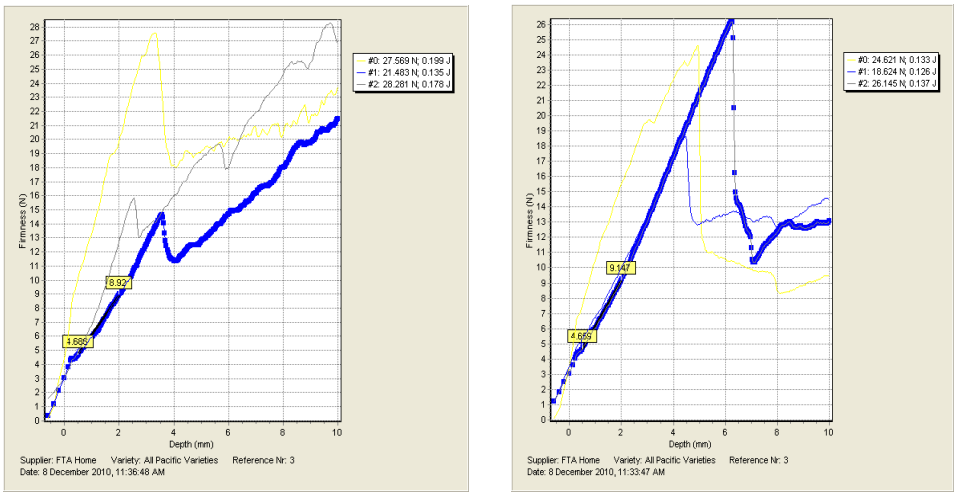

Figure 7. Texture representation of the Jonathan variety after storage alimentary paper and LDPE foil package

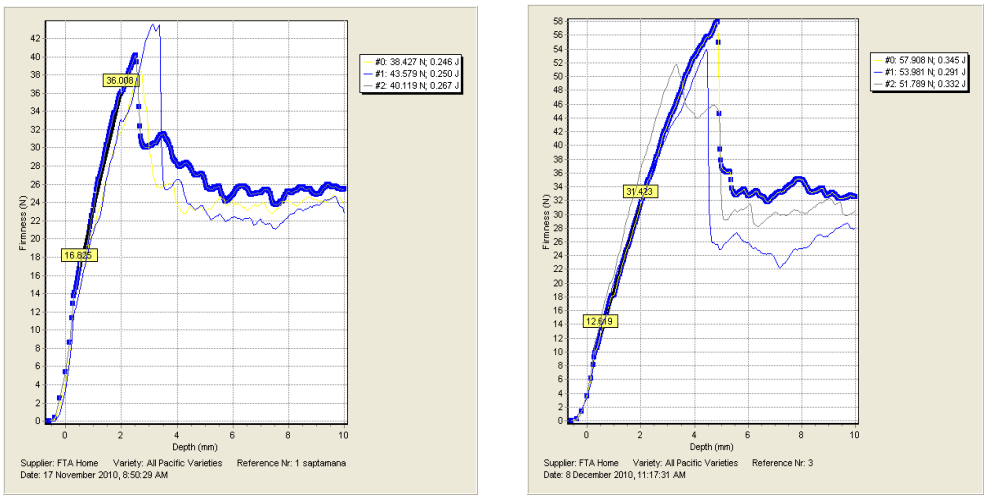

Figure 8. Texture representation of the Golden Delicious variety before and after the storage

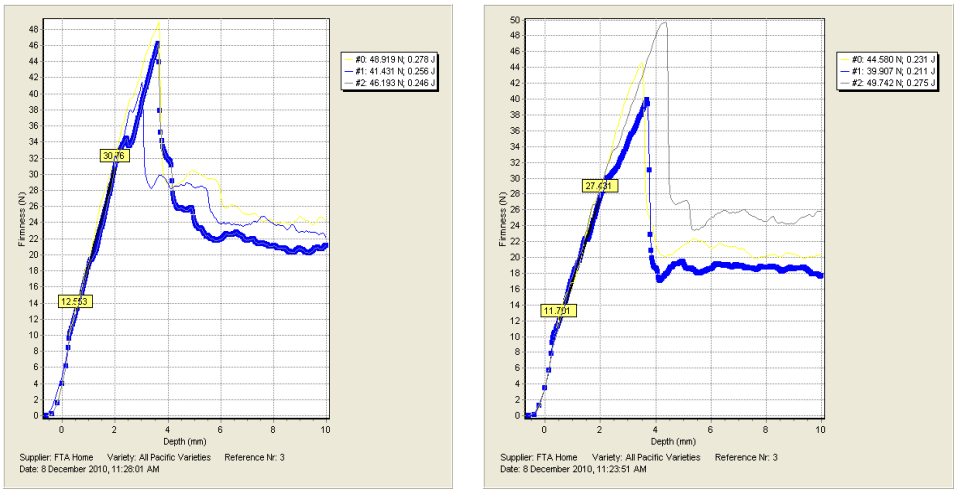

Figure 9. Texture representation of the Golden Delicious variety after storage alimentary paper and LDPE foil package

For the initial texture determination of Jonathan variety, the force value registered for 2 mm depth is 34.22 N, a value smaller than for Starkrimson which realise a different composition especially in waxes, cuticle and pectin content; but similar to the first case after penetrating the firs layers the force to puncture the cellular tissues is lower than the initial one (30.02 N to 10 mm). After 24 days of storage at refrigeration temperatures the penetration force is lower as for 4 mm is 30.19 N, for 6 mm is 28.30 N. These determinations denote that the Jonathan variety texture is affected by the storage period regarding especially the firmness of the apple.

In figure 7 is represented the texture representation of the Jonathan variety after storage alimentary paper and LDPE foil package.

Comparing the two graphs there is a sensitive difference between the two types of package, using the alimentary paper preserves betters the cellular structure of the apple, but the superior layers are affected by the storage, registering lower force values as 21.48 N at 3 mm; while for the LDPE foil package the things are inverted the superior layers are better preserved and the cellular tissues are mellow, as for 5 mm the force is 24.62 N and for deeper layers the values are decreasing.

So as a general conclusion the LDPE foil package is useful than alimentary paper because in an apple texture is important that at the first bite the sensation to be crunchy and then the pulp can be mellow a characteristic which can assure almost the fruit juiciness.

In figure 8 is represented the texture modifications of the Golden Delicious variety before and after the storage.

The initial determination for Golden Delicious variety texture is marked by a force of 40.11 N for 3 mm and then the other values concordant with the cellular layers are smaller at deeper depth. After 24 days of storage at refrigeration temperature the firmness values are higher (51.78 N) for the same depth. These results are not related for sure with an improvement of the firmness, maybe about a preservation of this characteristic during storage.

Also this kind of determination can be justified by the quantity of air from the intercellular space or also by a higher water quantity.

In figure 9 is illustrated the texture representation of the Golden Delicious variety after storage alimentary paper and LDPE foil package.

In comparison with the bulk variation of the same variety the packed one preserved also the characteristics of the initial fruit the force values being similar (48.91 N and 49.74N for 3 mm) for the both types of package (alimentary paper and LDPE foil). Also similar values are also for the deeper layers in the pulp (22 N and 19 N for 6 mm). These determinations denote that the both package types are suitable to store Golden Delicious variety.

4. Conclusions

The most underprivileged apple variety was Jonathan because it structural and textural transformations are bigger than for the other varieties.

A final conclusion can be drawn also for the package type utility, the most suitable package is LDPE foil while the alimentary paper is not adapted to apple storage, as for Jonathan the texture variations observed from the graphs are correlated with the factual situation, where after 24 days of storage the alimentary paper packed apples were deteriorated.

The most suitable apple type to be stored at refrigeration temperature is Golden Delicious following also the structure and texture modifications.

The study demonstrated the importance of the fruit firmness over storage taking into account the final destination of the apples – the costumer's meal.

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