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# THE EFFECT OF GROWING SYSTEM ON THE STORABILITY OF APPLE

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The effect of organic growing was studied on the storability of apple cv. Jonica, Liberty, Mutsu and Pinova. Fruits from integrated and organic orchards were stored at 2–4 °C, 95–99% relative humidity for 6 months. Firmness, activity of β-galactosidase and polygalacturonase enzymes were examined. There was no difference in the activity of β-galactosidase and polygalacturonase enzymes at harvest between the organic and integrated apples, but a significant difference was noted between the cultivars except for Mutsu and Pinova. The activity of β-galactosidase enzyme increased significantly during storage except for cv. Pinova and that of polygalacturonase enzyme also increased significantly. The difference in the activity of polygalacturonase became significant between the cultivars during storage except for cv. Jonica and Pinova. The firmness decreased significantly during storage, with the least change in case of cv. Liberty. It can be established that there is, in general, neither a considerable difference between the growing systems nor between varieties at harvest. The differences became higher during storage. It can be stated that the effect of cultivar on the storability is much more considerable than the effect of growing system.

**Keywords:** organic apple, storability, firmness, β-galactosidase, polygalacturonase

Healthy nutrition is in focus and its importance is growing everywhere in the world. People should eat food products, which contain only a minimal amount of chemicals. Environmental effects and human health risks associated with synthetic chemicals have prompted several fruit growers to convert to integrated, and even more so to organic production all around the world. Based on the above we have decided to study the effect of organic growing on the storability of apples. Integrated growing system is an ecologically safer method aiming to minimise the undesirable side-effects and use of agrochemicals (replacing them with environmentally friendly alternatives) and enhance the safeguards to the environment and human health. Organic farming seeks to eliminate the use of agricultural chemicals and apply natural materials both in plant protection and in nutrition supply (FERREE & WARRINGTON, 2003).

Are organically produced products better or healthier, though? WEIBEL and co-workers (1999) tried to find the answer to this question examining 'Golden Delicious'

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apples from organic and integrated (IP) orchards in Switzerland. Fruits from both production systems had many similar characteristics, but compared with fruits from IP plots, organically produced fruits were firmer, had a higher technical quality index (°Brix + 2 × firmness in kg $cm^{-2}$ + 3 × malic acid in g $l^{-1}$), had higher phosphorus, fibre and phenolic compounds contents (particularly flavonoids) and higher scores in the taste panel test.

Also the difference between conventionally and organically grown products was studied from the point of view of postharvest quality. The storability of horticultural products considerably depends on inner features and metabolism of plants. But these significant characteristics are strongly influenced by the conditions of growing, i.e. nutrient supply, watering and plant protection, etc. However, the high amounts of nitrogen fertiliser possibly applied to apples in conventional growing can have negative effects on, among other things, fruit colour and storage quality (SAITOH, 1995).

Crops grown organically, with slower growth rates and greater physiological maturity at harvest, were shown in carefully controlled trials to have a longer storage life. Respiration rates and enzyme activity have also been proved to be lower in organically produced vegetables, leading to reduced storage losses (LAMPKIN, 1990).

## 1. Materials and methods

### *1.1. Raw material*

Four apple cultivars (*Malus domestica* cv. Jonica, Liberty, Mutsu, and Pinova) were studied during storage. Cultivar Liberty is scab-resistant. The apples were harvested at the end of September in 1999 in the experimental orchard of the Debrecen University (Pallag). The experimental orchard (1 ha) was planted in 1997 (at 4×1.5 m spacing, M26 rootstock). Different varieties were planted in blocks (7 trees per block) in 5 replicates. Fruits were stored at 2–4 °C, 95–99% relative humidity (RH) for 6 months. The results of the first year experiment are the subject of this article.

### *1.2. Methods*

*1.2.1. Determination of the activity of β-galactosidase and polygalacturonase enzymes.* The preparation of cell wall was carried out according to the method of KOVÁCS and co-workers (1997). β-Galactosidase (EC. 3.2.1.23.) assay was based on the hydrolysis of nitro-phenyl galactopyranoside (BARTLEY, 1974); and polygalacturonase assay (EC. 3.2.1.67.) was based on an acidic Cu-reducing end group assay (SAJJAANANTAKUL et al., 1989). Samples were investigated at harvest and after 6 months of storage. Eight replicate measurements were done each time.

*1.2.2. Firmness measurements.* The firmness of apples was examined by acoustic impulse-response technique (FELFÖLDI, 1996) at monthly intervals from October to March. The same 24 marked apples were studied from each sample during storage.

The acoustic stiffness coefficient (s) characterises the firmness of fruits, vegetables and other products. There is a significant correlation between the $f_0$ characteristic frequency of the acoustic response and the firmness of the produce.

$$s=f_0^2 \times m,$$

where s: acoustic stiffness coefficient; $f_0$: characteristic frequency; m: weight.

As the acoustic stiffness coefficient depends also on the mass of the apple we also measured the mass change during storage.

*1.2.3. Statistical analysis.* Data of firmness measurements were evaluated by analysis of variance and regression analysis using the STATGRAF program and SAS System 8.0 program (ANON, 1991). Factorial variance analysis (FVA7) was used for evaluating data of mass loss (SVÁB, 1981).

General linear modelling (using SAS System 8.0 program) and Welch-test was used for evaluating the data of activity of enzymes (BARÁTH et al., 1996).

## 2. Results and discussion

### *2.1. Activity of β-galactosidase*

The activity of β-galactosidase enzyme was measured as a function of growing method, cultivar and storage time at harvest and after storage (Fig. 1).

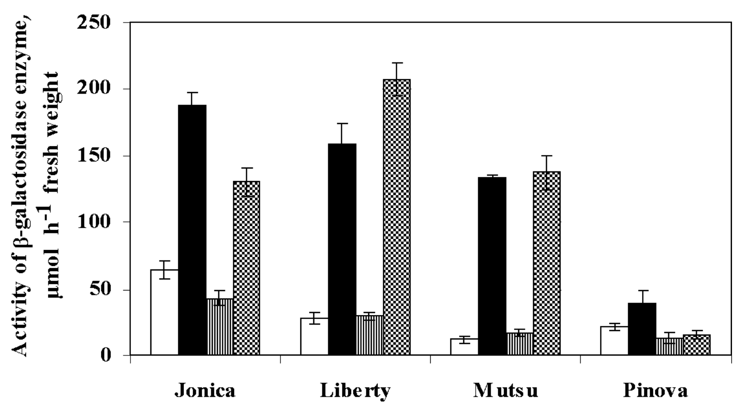


*Fig. 1.* The activity of β-galactosidase enzyme in apple at harvest and after 6 months storage (2–4 °C, 95–99% RH). □: Integrated apple after harvest; ■: organic apple after harvest; ▥: integrated apple after storage; ▩: organic apple after storage

It can be established that there was a considerable difference between the organically and integrated grown apples in the activity of β-galactosidase enzyme after harvest in case of cv. Jonica. There was also a significant difference (at 95% confidence level) between the cultivars at harvest except for cv. Mutsu and Pinova. There was a significant difference between the growing systems in the activity of β-galactosidase enzyme after storage except for cv. Mutsu. The activity of β-galactosidase was significantly lower in cv. Pinova than in the other varieties after storage. The enzyme activity increased significantly during storage except for cv. Pinova grown organically, where this increase was not significant (Fig. 1). As the activity of enzymes causing cell wall breakdown strongly depends on the ripening stage, the enzymes have to be studied more frequently to be sure about the difference between the organic and integrated apples.

*2.2. Activity of polygalacturonase*

The activity of polygalacturonase enzyme was investigated at harvest and after storage as a function of growing method, cultivar and storage time (Fig. 2).

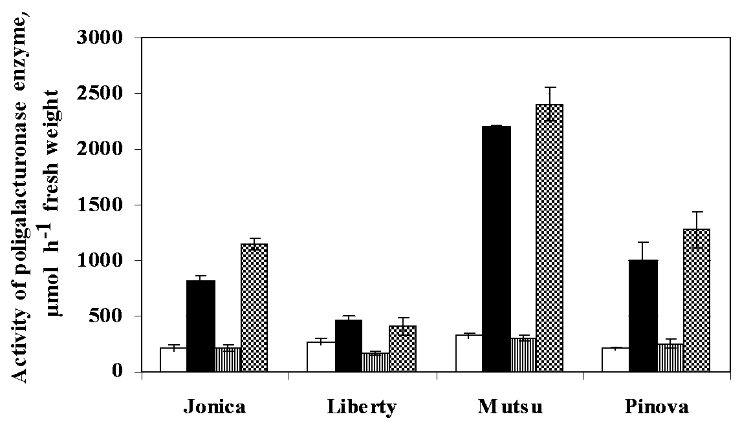


*Fig. 2.* The activity of polygalacturonase enzyme in apple at harvest and after 6 months storage (2–4 °C, 95–99% RH). ☐: Integrated apple after harvest; ■: organic apple after harvest; ▥: integrated apple after storage; ▩: organic apple after storage

It can be stated that no considerable differences were found either between the growing methods or between the cultivars in the activity of polygalacturonase enzyme at harvest. There was a considerable difference between the growing systems after storage in case of cv. Jonica and Mutsu. The differences between the cultivars became significant except for cv. Jonica and Pinova. The activity of polygalacturonase enzyme increased significantly as a function of storage time, as it can be seen in Fig. 2. The cv. Liberty has changed the least which can be explained by the varietal differences.

*2.3. The firmness measurement*

The firmness of samples is shown in Fig. 3. Mutsu was the firmest variety at harvest, while the other three had similar firmness. There were no significant differences between the growing systems. The acoustic stiffness coefficient decreased significantly in all cases during storage. The firmness changed the least in case of cv. Liberty.

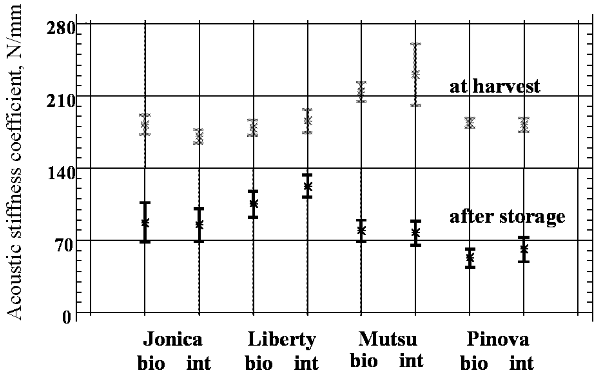


*Fig. 3.* Means and 95% confidence intervals of acoustic stiffness coefficient in apple at harvest and after 6 months storage (2–4 °C, 95–99% RH). bio: Organic apple; int: apple from integrated orchard

The change of acoustic stiffness coefficient can be seen in Fig. 4 (mean values of 25 data per sample) during storage (for 6 months).

Exponential functions have been fitted to the individual data using the SAS System program. The initial firmness ($y_0$) and the reciprocal value of the slope (k) of the exponential curve (estimated values with standard errors) can be seen in Table 1.

The slope of the exponential function shows the tendency of softening. The softening of apples in increasing order is Liberty, Jonica, Mutsu and Pinova. The reciprocal of the slope is a constant (called time constant), and it shows the storage time, while the firmness values decrease to the $e^{th}$ part of their original value. From practical point of view this time constant can be used as the optimal length of storage in months. According to this parameter, the optimal length of storage time is 7.64/6.55 months for Jonica organic/integrated, 9.94/11.37 months for Liberty organic/integrated, 5.74/4.73 months for Mutsu organic/integrated, 3.98/5.04 months for Pinova organic/integrated, respectively. There was only 1 month difference between the organic and integrated apples in the optimal storability, except for cv. Liberty, where the integrated apple could be stored 1.4 months longer (but this difference was significant only in case of cv. Pinova at 95% significance level). In two cases (Jonica and Mutsu) the organic sample softened slightly slower than the integrated one – thus it can be stored longer, while in the other two cultivars a more rapid softening was experienced in organic samples. Comparing the varieties it can be stated that cv. Liberty can be stored significantly longer (95% significance level) than the other varieties.

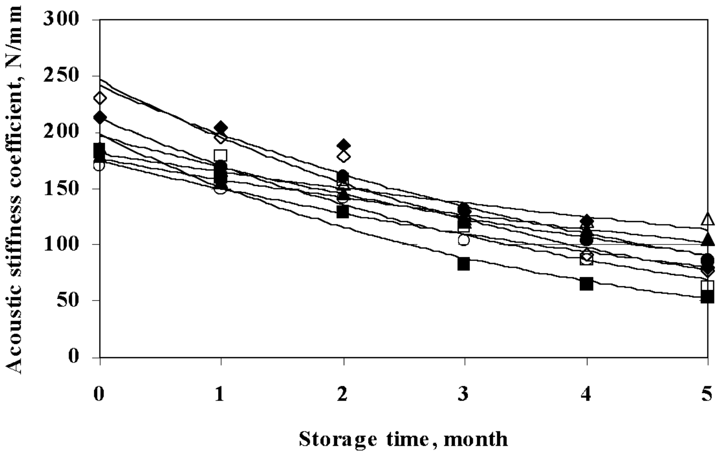


*Fig. 4.* Changes in acoustic stiffness coefficient during storage. ●: Jonica, organic; ❍: Jonica, integrated; ▲: Liberty, organic; Δ: Liberty, integrated; ◆: Mutsu, organic; ◊: Mutsu, integrated; ■: Pinova, organic; □: Pinova, integrated; ─: exponential trends fitted to the stiffness data

*Table 1.* The parameters of exponential curves fitted to the firmness data

| | | Initial firmness ($y_0$)* | Time constant (k)* |
|---|---|---|---|
| Jonica | integrated | 175.2 ± 4.32 | 6.55 ± 0.43 |
| | organic | 190.8 ± 4.66 | 7.64 ± 0.58 |
| Liberty | integrated | 180.8 ± 3.60 | 11.37 ± 0.88 |
| | organic | 175.2 ± 3.76 | 9.94 ± 0.75 |
| Mutsu | integrated | 238.3 ± 6.53 | 4.73 ± 0.27 |
| | organic | 230.7 ± 4.96 | 5.74 ± 0.29 |
| Pinova | integrated | 201.0 ± 4.64 | 5.04 ± 0.25 |
| | organic | 193.4 ± 4.19 | 3.98 ± 0.17 |

* Estimated values and standard errors are shown.

Further studies are needed in this topic for proving these results. DE ELL and PRANGE (1992) evaluated the postharvest quality and sensory attributes of organically and conventionally grown apple cultivars McIntosh and Cortland. Organically grown

McIntosh apples were perceived by sensory panelists as being firmer than conventionally grown ones at harvest but not after storage, possibly due to maturity differences. No difference in firmness due to production method was detected in Cortland.

The deviation of the mass was 6–11% for the individual apples at harvest and also during storage. Figure 5 shows the mass loss during storage as a percent of the original value (average values of the same 24 marked apples per sample during storage). The weight loss of apples was monotonous as a function of storage time. The mass loss was the lowest in cv. Liberty grown integrated and the highest in cv. Jonica grown organically. The mass loss considering the effect of variety only was significantly higher (P=0.01) in cv. Jonica than in the case of Mutsu and Pinova. The mass loss of cv. Liberty was significantly smaller (P=0.01) than that of cv. Mutsu and Pinova. The mass loss was significantly higher (P=0.01) in organic apples than in integrated ones in case of cv. Jonica and Liberty. The tendency was the same for cv. Pinova but at P=0.05 significance level. There was no significant difference between the growing systems for cv. Mutsu.

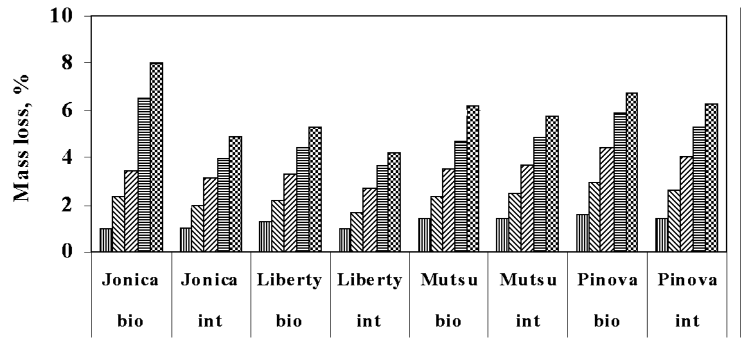


*Fig. 5.* The mass loss during storage as a percent of the original value. bio: Organic apple; int: integrated apple. ▥: Nov.; ▧: Dec.; ▨: Jan.; ▤: Febr.; ▩: March

Summarising the data of the statistical analysis it can be established that the effect of cultivar was the main factor in mass loss followed by the effect of growing system.

## 3. Conclusion

According to the results it can be established that, in general, there is no considerable difference in the firmness and activity of enzymes causing cell wall breakdown neither between the growing systems nor between varieties at harvest. The differences between the growing systems and varieties became bigger during storage.

It can be stated that the effect of cultivar on the storability is much more considerable than the effect of growing system.

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