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Seasonal Variation of Sugars and Organic Acids in Apple (*Malus domestica* Borkh.) in Different Growing Systems

By

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Summary

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Influence of different tree densities and growing systems (6000, 9000 and 18000 trees per hectare) on accumulation of individual sugars (glucose, fructose and sucrose), sugar alcohol sorbitol and organic acids (malic, citric, shikimic and fumaric acid) during the fruit growth and development was studied. Fruit samples of apple cvs. 'Elstar', 'Jonagold' and 'Idared' were analyzed using HPLC in fourteen-day intervals from the June drop to the time of technological ripeness. Sorbitol content was the highest at the time of the first sampling (27th June), then slowly decreased, and rose again at the time of ripening. Fructose and sucrose demonstrated an even development during the whole growth period, whereas glucose content decreased and demonstrated notable oscillations. The contents of malic, citric and shikimic acids decreased with ripening. During fruit ripening significant differences in the contents of the studied components were noted among the genotypes planted in same systems. At the time of fruit picking the highest content of sorbitol was found with higher densities, whereas the content of glucose at that time seems to be less dependent on tree density. Similar to fructose, the contents of sucrose and malic acid at harvest time were higher with lower planting densities.

Introduction

In most modern apple orchards at high planting densities source limitations such as low light interception and alternate bearing are becoming more prominent. The number of plants and the number of vegetative, reproductive and storage

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organs per land area unit are important factors of apple yield and quality. The metabolism of cellular components important for fruit taste, such as sugars, organic acids, polysaccharides, pigments and aromatic compounds change drastically with fruit development (YAMAKI 1995). It is important to improve the quality of fruit and to increase the yields by controlling the sugar metabolism during fruit development. Fruits are strong sinks of assimilates in cropping apple trees and modify biomass partitioning in the plants. The carbohydrates assimilated in leaves are loaded into the growing apple fruit and finally accumulate in the vacuoles. Apple fruit enlarge and accumulate sugars after cell division has ceased (YAMAKI & INO 1992). These sugars are formed in the flesh of apple fruit from sorbitol (ACKERMANN & al. 1992), the main C-translocate between leaf and fruit (BERÜTER 1985), therefore sugar metabolism is closely associated with the various steps in the movement of assimilates (YAMAKI 1995).

The objective of this work is to determine the influence of different planting densities on accumulation of individual sugars (glucose, fructose, sucrose), sugar alcohol sorbitol and organic acids (malic, citric, shikimic and fumaric) during growth and development of apple fruit of different cultivars.

Materials and Methods

Experiments took place in 1997 at the Fruit Growing Center Maribor – Experimental Center Gačnik. The six-year old trees of cultivars 'Elstar', 'Jonagold' and 'Idared' on the rootstock M9 were trained in super spindle shape in following systems and planting distances:

- one - row system 2.5 x 0.6 m (6000 trees/ha),
- one - row system 2.5 x 0.4 m (9000 trees/ha),
- one - row "V" system 2.5 x 0.2 m (18000 trees/ha).

Five apple fruits per treatment were sampled in fourteen-day intervals from the June drop to the time of technological ripeness for individual sugars and organic acids determination. Subsamples from each sampled fruit were performed for HPLC (High Performance Liquid Chromatography) analyses according to the DOLENC & ŠTAMPAR 1997 method. Standard error estimations were calculated for each compound/cultivar combination using analysis of variance.

Results and Discussion

Mean calculated standard errors ranged from 0.06 for sorbitol and 0.08 for fumaric acid, 0.14 for malic acid, 0.21 for sucrose, 0.30 for glucose, and 0.42 for fructose. Unless stated, only the mean values of all five analyses performed per treatment were used in graphical data (Fig. 1 to Fig. 6) and discussion. Individual sugars and organic acids showed characteristical seasonal dynamics, which are performed only for some cultivars.

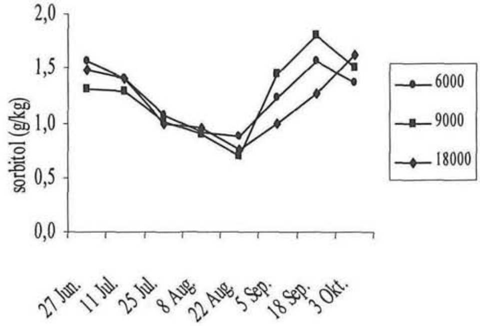

Fig. 1. Changes in sorbitol content (g/kg) of apple cv. 'Idared' during ripening.

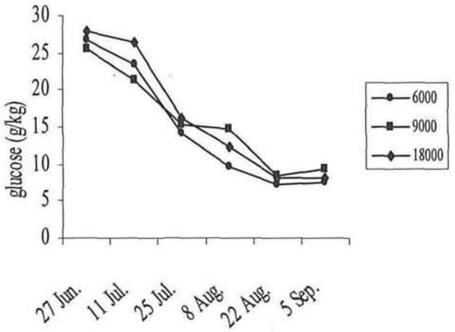

Fig. 2. Changes in the glucose content (g/kg) of apple cv. 'Elstar ' during ripening.

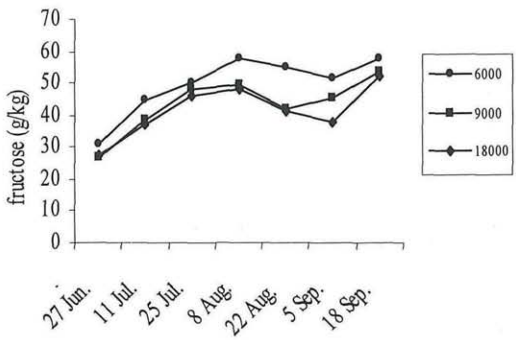

Fig. 3. Changes in the fructose content (g/kg) of apple cv. 'Jonagold' during ripening.

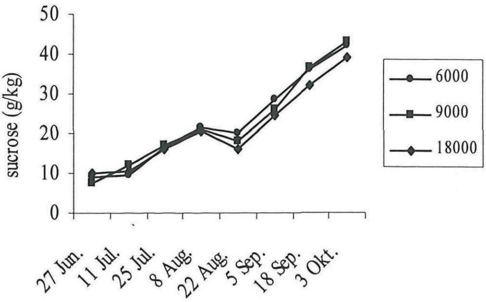

Fig. 4. Changes in the sucrose content (g/kg) of apple cv. 'Idared' during ripening.

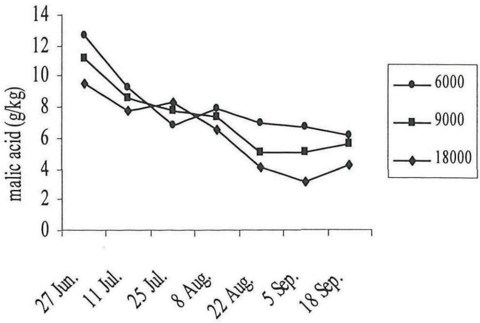

Fig. 5. Changes in the malic acid content (g/kg) of apple cv. 'Jonagold' during ripening.

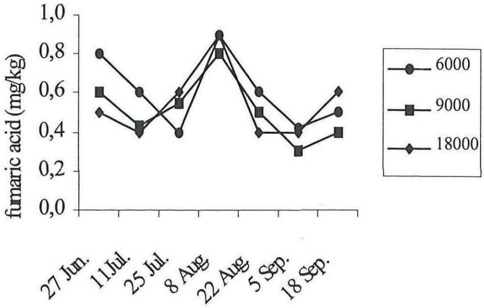

Fig. 6. Changes in the fumaric acid content (mg/kg) of apple cv. 'Jonagold' during ripening.

The content of sorbitol decreased from the time of first sampling (27th June) until the end of August and after that time it started to increase again and somewhere exceeded the starting concentration. The highest concentrations at harvest were observed in the planting densities 18000 trees per hectare with all cultivars (1.6 g/kg). It was suggested that the higher relative sorbitol content of apple cultivars during the late fruit growth is associated with watercore development and therefore with lower quality of the fruits (CHAN & al. 1972) as a consequence of source limitations in environment.

On average of all cultivars the glucose content decreased during vegetation. A strong oscillation was observed in the middle of August, probably caused by starch accumulation, which according to BERÜTER 1985 reaches its peak in that time. The lowest content at harvest had cv.'Elstar' (8.4 g/kg) and the highest cv. 'Jonagold' (15.8 g/kg). The results show that there is no important influence of planting densities on the glucose content.

Values for fructose content with cvs. 'Jonagold' (28.7 g/kg) and 'Idared' (27.6 g/kg) at first sampling were very close to glucose content. However after that time fructose accumulated rapidly and attained 53.3 and 59.3 g/kg with cvs.'Jonagold' and 'Idared', respectively. Similar values of fructose content were found by cv.'Elstar' at first sampling, yet at the picking date the contents were lower (45.2 g/kg). The comparison of the fructose content of most samplings show that the highest values were achieved with planting densities 6000 and 9000 trees/ha.

The content of sucrose extensively increased from 12.8 g/kg at first sampling up to 39.2 g/kg at picking with cv.'Elstar', from 8.1 up to 34.1 g/kg with cv.'Jonagold' and from 8.9 g/kg up to 40.6 g/kg with cv.'Idared'. Similar to fructose, the content of sucrose was higher with lower planting densities.

At first sampling the content of malic acid was the highest with all cultivars by 6000 trees per hectare where 12.3 g/kg was found in cvs.'Elstar' and 'Jonagold' and 10.5 g/kg with cv.'Idared'. The values then decreased to 4.7 and 5.7 g/kg. The decrease can be attributed to a dillution effect caused by mass increase and increased respiration since the malic acid is the principal metabolic substrate together with sugars. At the harvest time the highest content was found in fruits from lower plantings. The content of shikimic acid (data not shown) strongly decreased with ripening, especially with cv.'Elstar' (41.3 mg/kg), to nearly equal values for all cultivars (3.3 to 4.5 mg/kg) and planting densities.

Fumaric acid was found in low quantities during fruit development in apples (from 1.2 mg/kg to 0.4 mg/kg), however a strong oscillation in the middle of August in its content was noticed with all cultivars and planting densities. Minor changes in the dynamics of sugars were observed at the same time, too. At the time of harvesting the content of citric acid, which has the similar dynamics as malic acid, was from 140 mg/kg with cvs.'Jonagold' and 'Elstar' to 580 mg/kg with cv.'Idared'. Those findings are in agreement with ACKERMANN & al. 1992.

During the fruit ripening significant differences in the contents of the studied components, which have a marked influence on the sensory quality of the fruit, were noted among the genotypes and individual plant densities.

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