Quality of Apple Fruits (*Malus domestica*) from Organic Versus Integrated Production

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Abstract

The aim of the study was to investigate organically produced cultivars, as well as integrated ones toward the impact of production technologies on the carbohydrate (sucrose, glucose, fructose), organic acids (malic, citric) and phenolic composition (total phenolics analysed in the pulp and peel) of fruits. The compounds were analysed using high performance liquid chromatography. We can conclude that the type of production did not affect the carbohydrate and organic acid levels in the fruits. The differences observed in the experiment were probably due to different genotypes. With regard to the content of total phenolics analyzed in the apple peel we did not notice differences between different types of production. Organically grown apples, however showed higher contents of phenolic substances in the apple pulp compared to the apple cultivars of integrated production. Higher concentrations of phenolic compounds in organically grown cultivars could be a mechanism of plant response to stress, which occurs due to the avoidance of synthetic chemicals. Due to a higher content of phenolics in organically produced cultivars, these fruits can be considered as beneficial for health, although more research should be performed on the impact of phenolics on human healthiness.

INTRODUCTION

Organic fruit production is characterized by the absence of synthetic compound (herbicides, pesticides) and readily soluble fertilizers and relies more on natural mechanisms of controlling the growth, yield and diseases. These plants are more exposed to environmental stress and form specific stress metabolites which could contribute beneficially also to fruit quality (Treuttter, 2000). In general the consumers agree that organically produced fruits are healthy, environmental friendly and more tasty and nutritious than conventionally grown (Saba and Messina, 2003).

The orchard management practices are the key factors in the production of high and qualitative yields of apples (*Malus domestica* Borkh.). These practices can influence the chemical composition of fruits, even within the same variety (Šturm et al., 2003; Lee et al., 2003). Chemical composition of fruits (carbohydrates, organic acids, phenolics) influences the taste of fruits and therefore contributes to internal fruit quality as well as also influences external quality parameters such as appearance, flavor and health promoting properties (Hudina and Štampar, 2000; Treutter, 2001; Lattanzio, 2003). In recent years, this health promoting properties of fruits were associated especially with phenolics. These naturally occurring antioxidants have been reported to contribute ameliorative against oxidative damage caused by free radicals. Phenolic compounds have beneficial influence also against development of diseases like cancer and coronary heart diseases (Lattanzio, 2003). In the plant defense mechanism it is known, that phenolic composition of a plant tissue can determine the level of susceptibility/tolerance to fungal infections and pests (Usenik et al., 2004).

The aim of our study was to scan the carbohydrate, organic acid and phenolic composition of the apple fruits of different cultivars, which were grown either organically, or in integrated production. We hypothesized that the fruits of organically grown apples, which are exposed to higher stress due to pests and diseases, have higher contents of phenolic compounds as well as different composition of sugars and organic acids compared to the apples of integrated production.

MATERIALS AND METHODS

Plant Material

Harker (2004) suggests that the studies on the fruit quality of organic and non-organic system should have a regional or even multi-region approach sourcing small samples of fruit from many sites in preference to large samples of fruits from a few sites. This was successfully done in our study. Fruits for analysis were collected from orchards with either organic (O) or integrated (I) production. Organic production means that in the production of those fruit trees no synthetic chemicals were used, but only natural substances. Integrated production (also called environment friendly production) includes the use of chemicals according to precise guidelines and restrictions for their use, especially in the protection of the plants against pests and diseases.

Organically grown cultivars:
'Großer rheinischer Bohnapfel', 'Kronprinz Rudolf', 'Steirischer Maschanzker', 'Geflammter Kardinal', 'Goldparmäne', 'Roter Pogatscher', 'Champagner Renette'

Cultivars of integrated production:
'Royal Gala', 'Elstar', 'Jonagold Decosta', 'Jonatan', 'Majda',

The fruits were harvested at optimal ripening time. Phenolic compounds were analyzed in the pulp and peel of apples. For the analysis of the carbohydrates and organic acids the whole fruit without core was taken. For every cultivar 3 replications were done (n=3), each replication included 15 apples sampled from 5 trees. The fruits were stored at –20 ^{o}C until the preparation of the samples.

Extraction and the HPLC Analysis

1. Carbohydrates and Organic Acids

Fruit samples were prepared according to the Dolenc and Stampar (1997) method. 10 g of apple fruits was homogenized to puree and diluted to 50 ml with bi distilled water. After 30 minutes the extraction solution was centrifuged at 4200 rpm for 7 minutes. The supernatant was filtered through 0,25 µm pore size filter (Mecherey-Nagel).

The analysis of carbohydrates (sucrose, glucose, fructose) and organic acids (malic, citric) was performed with High performance liquid chromatography - HPLC (Thermo separations products). The detector for carbohydrates was a Shodex RI - 71 detector and for organic acids a Knauer K-2500 UV-Vis detector at 210 nm. The elution solvent for carbohydrates was bi distilled water and for organic acids aqueous 4 mM sulphuric acid (flow rate = 0,6 ml/min). The column used for carbohydrates was an Aminex-HPX 87 C Column, operated at 85 ^{o}C and for organic acids an Aminex-HPX 87 H operated at 65 ^{o}C.

2. Phenolic Compounds

The samples were prepared according to the method described by Escarpa and Gonzalez (1998). The samples of 10 g and 5 g of pulp and peel were extracted with methanol containing 1% 2,6-di-tert-butyl-4-methylphenol using an ultrasonic bath. The samples were extracted with 10 ml of solvent for 1 h, 10 ml for 30 min, and finally 5 ml for 30 min. The tree extraction fractions were combined to final volume of 25 ml and filtered through 0,25 µm membrane filter (Mecherey-Nagel) prior to the injection to HPLC.

The samples were analyzed on Thermo Finnigan Surveyor HPLC system with diode array detector at 280 nm. Also the spectra of compounds were recorded between 210 and 350 nm. The elution solvents were aqueous 0.01 M phosphoric acid (A) and 100% methanol (B). The samples were eluted according to a linear gradient described by Escarpa and Gonzalez (1998). The injection amount was 20 µl and the flow rate was 1 ml/min. The column used was a Varian Hypersil 5 ODS, operated at 25 ^{o}C.

The determined phenolics in the peel and pulp were: chlorogenic acid, p-coumaric acid, protocatechuic acid, (-)-epicatechin, phloridzin, catechol, caffeic acid and syringic acid. The total analyzed phenolics were the sum of detected individual phenolics.

3. Statistical Analysis

The significance of a type of cultivation was analyzed with the program Statgraphics plus 4.0 using the analysis of variance (ANOVA). The differences between the treatments in content of carbohydrates, organic acids and total analyzed phenolics were estimated with a multiple range test using the least significant difference (LSD) or Duncan test at α <0,05.

RESULTS

Carbohydrates

The most abundant carbohydrate in nearly all analyzed apple cultivars was fructose (Table 1) ranging on average up to 73,10 g kg^{-1} fresh weight (FW). The highest values were achieved in some cultivars of organic production (‘Roter Pogatscher’, ‘Kronprinz’, ‘Goldparmäne’) however there were no significant differences between different production technologies.

The sugar with the second highest average concentration of analyzed carbohydrates in apple fruits was sucrose with 39,64 g kg^{-1} FW. The highest rates were again achieved by two organic cultivars (‘Roter Pogatscher’, ‘Steirischer Maschanzker’) and one integrated grown cultivar (‘Elstar elanared’).

Glucose accounted on average up to 17,87 g kg^{-1} FW. The highest contents were achieved by cultivars ‘Roter Pogatscher’ (organic) and ‘Jonagold decosta’ (integrated).

Organic Acids

The main organic acid was malic acid accounting up to 8,35 g kg^{-1} FW (Table 2). The highest quantities were achieved by organically grown cultivars (‘Steirischer Maschanzker’, ‘Roter Pogatscher’, ‘Kronprinz’), which are all termed as sweet-sour cultivars. The cultivars of organic production differed significantly from the cultivars of integrated production. The lowest rates were achieved by sweet cultivar ‘Gala’.

Citric acid was present in lower quantities compared to malic acid. No significant differences between the types of production were noticed. The highest content was achieved by the sour cultivar 'Champagner renette' and the lowest content by the integrated grown cultivar 'Majda'.

Total Analyzed Phenolics in Peel and Pulp

Organically grown cultivars showed significantly higher contents of total phenolic compounds analyzed in the apple pulp compared to the apples of integrated production. The highest content of total phenolic compounds was in the cultivar 'Bohnapfel' and the lowest content of total phenols was measured in the cultivars 'Majda' (Table 3).

Considering all analyzed phenols in apple peel, we can see that the organically grown cultivar 'Bohnapfel' had the highest content of total phenols. Also other organically grown cultivars showed high contents although there were no significant differences in the total phenols between organically grown cultivars and intensively grown cultivars.

Comparing the data of phenolics in the peel and pulp, higher rates of phenolics in the apple peel can be observed. Apples with higher contents of phenolics in the pulp exhibited also higher concentrations of phenolics in the pulp and vice versa.

DISCUSSION

The major carbohydrate in the ripen fruits of cultivars in our study was fructose, followed by sucrose and glucose. Similar division between carbohydrates was reported in the study of Veberic *et al* (2003). DeEll and Prange (1992) evaluated quality parameters on the basis of total soluble solids and titratable acids in two apple cultivars grown organically and conventionally. Although they noticed some differences in the content of soluble solids (organically grown apples had higher contents), the sensory panelists did not perceive any differences in the intensity of sweetness. Their study showed no consistent quality or sensory differences between organically and conventionally grown apples. Although we studied carbohydrates and organic acids in detail, we can agree with DeEll and Prange (1992) that there were not basic differences between the types of production. Higher sugar content does not automatically mean sweeter taste of apples, because the amount of organic acids is also important for perceiving the sweetness. The levels of malic acid were higher in organically grown apples than in integrated or resistant cultivars. This is probably due to the fact that modern cultivars are selected for less acid taste. In addition to this, Fischer et al. (1995) report that sweeter taste is more often inherited from the parents than acid taste. Therefore we conclude that a higher concentration of malic acid in organic cultivars is probably due to the genotype and less the consequence of special production technology. In our study we did not notice any differences in the contents of citric acid between the types of production. Carbonaro et al. (2002) report that in their study there was an increase in the content of citric acid in the organically grown peaches compared to conventionally grown, while the increase was not noticed in organically grown pears.

Increase of phenolics in fruits of organic production was noticed in various fruit species. For example, a parallel increase in polyphenol content of organic peaches and pears as compared with the corresponding conventional samples was observed in the study of Carbonaro et al. (2002). Also in our study the cultivars of organic production showed significantly higher contents of total phenolic compounds analyzed in the apple pulp compared to the apples of integrated production and resistant cultivars. Organically grown cultivars also showed high contents of total phenolics in apple peel, although there were no significant differences between organically grown and intensively grown cultivars. The higher content of phenolics in apple pulp and peel is not only the consequence of the fact that organically grown apples are more exposed to biotic and abiotic stressors (diseases, pests, lack of mineral nutrients, …), but it appears also due to the selection of modern cultivars towards less tough fruits with not such astringent taste. The consumers prefer fruits with gentler taste (Lattanzio, 2003), what leads to choosing those modern cultivars, which exhibit lower contents of some groups of phenolics.

We can conclude that the type of production did not affect the carbohydrate and organic acid levels in the fruits. The differences noticed in the research are probably due to different genotypes. With regard to the content of total phenolics analyzed in the apple peel we did not notice differences between different types of production. Organically grown apples, however, showed higher contents of phenolic substances in the apple pulp compared to apple cultivars of integrated production. Higher concentrations of phenolic compounds in organically grown cultivars could be a mechanism of plant response to stress that occurs due to the avoidance of synthetic chemicals. Because of the higher content of phenolics in organically produced cultivars, these fruits can be considered as beneficial for health, although more research should be performed on the impact of phenolics on human healthiness.

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Tables

Table 1. Contents of carbohydrates in the apple fruit (g kg^{-1} FW) in different apple cultivars. Means are presented. Legend: O = cultivars of organic fruit production; I = cultivars of integrated fruit production. R = scab resistant cultivars; n=3

Cultivar	TYP	Sucrose	Glucose	Fructose
Kronprinz	O	44,40	7,87	102,10
Roter Pogatscher	O	71,42	38,03	103,31
St. Maschanzker	O	77,29	10,53	75,49
Champagner Renette	O	30,55	18,29	63,58
Bohnapfel	O	16,97	21,10	47,95
Goldparmäne	O	32,64	12,84	103,06
Gef. Cardinal	O	38,15	14,79	52,30
Jonagold decosta	I	31,09	23,91	69,08
Elstar elanared	I	60,15	16,06	77,87
Royal Gala	I	16,95	18,9	68,19
Jonatan	I	19,41	17,06	57,16
Majda	I	36,68	15,09	57,05
$\alpha = 0.05$	O I	NS	NS	NS

Table 2. Contents of organic acids in the apple fruit (g kg^{-1} FW) in different apple cultivars. Means are presented. Legend: O = cultivars of organic fruit production; I = cultivars of integrated fruit production. R = scab resistant cultivars; n=3

Cultivar	TYP	Citric acid g kg^{-1}	Malic acid g kg^{-1}
Kronprinz	O	0,19	12,03
Roter Pogatscher	O	0,14	12,16
St. Maschanzker	O	0,43	14,11
Champagner Renette	O	0,46	7,79
Bohnapfel	O	0,28	7,24
Goldparmäne	O	0,43	8,50
Gef. Cardinal	O	0,43	10,52
Jonagold decosta	I	0,20	3,49
Elstar elanared	I	0,44	9,41
Royal Gala	I	0,22	2,31
Jonatan	I	0,14	4,58
Majda	I	0,13	8,08
	O	NS	a
α = 0.05	I		b

Table 3. Total phenols analyzed in the peel and pulp of different cultivars (mg g^{-1} FW).

Cultivar	TYP	Pulp	Peel
Kronprinz	O	0,09	0,25
Roter Pogatscher	O	0,30	0,78
St. Maschanzker	O	0,35	0,78
Champagner Renette	O	0,34	0,88
Bohnapfel	O	0,43	1,11
Goldparmäne	O	0,14	0,55
Gef. Cardinal	O	0,16	0,29
Jonagold decosta	I	0,09	0,36
Elstar elanared	I	0,06	0,42
Royal Gala	I	0,15	0,40
Jonatan	I	0,06	0,35
Majda	I	0,02	0,32
	O	a	NS
α = 0.05	I	b	

*Qualité Comparée de Pommes (***Malus domestica***) Issues d'Agriculture Biologique et de Production Fruitière Intégrée*

Mots-Clés: *sucres, acides organiques, composés phénoliques*

Résumé

L'objectif de cette étude était d'appréhender l'impact de la production biologique comparativement à celui de la production fruitière intégrée (PFI) sur la teneur des pommes en sucres (saccharose, glucose, fructose), en acides organiques (malique, citrique) et en composés phénoliques (composés phénoliques totaux de la pelure et de la chair). Les composés ont été étudiés par chromatographie liquide haute performance. Les résultats montrent que le mode de production ne modifie pas les teneurs en sucres et en acides organiques dans les fruits. Les différences observées au cours de cette étude sont probablement dues aux différents génotypes. En ce qui concerne la teneur en composés phénoliques totaux dans la pelure, il n'a pas été observé de différences en fonction des modes de production. Les pommes produites en agrobiologie ont cependant montré des teneurs accrues de composés phénoliques dans la chair comparativement à celles issues de PFI. Les teneurs accrues en composés phénoliques dans les fruits issus de vergers bio pourraient résulter des mécanismes de défense des plantes aux stress, se produisant en l'absence d'intrants chimiques de synthèse. Par suite de leur teneur accrue en composés phénoliques, les fruits issus du mode de production bio peuvent être considérés comme bénéfiques pour la santé, bien que des recherches plus approfondies doivent être entreprises pour caractériser l'impact des composés phénoliques sur la santé humaine.