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ORIGINAL ARTICLE

Sugar-, acid- and phenol contents in apple cultivars from organic and integrated fruit cultivation

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Objective: This study was carried out to obtain data about the sugar-, acid- and phenol content of apple cultivars from organic and integrated fruit cultivation, with reference to their role in human health and especially for diet recommendations.
Setting: Styria (Austria) and Slovenia.
Interventions: HPLC, Spectral Photometry, organoleptic and olfactory tests.
Results: The total sugar content of most cultivars from integrated cultivation ranged between 115 and 160 g/kg. Some cultivars from organic growing reached higher values. The acid content of both cultivar types was similar. The phenol content in organically grown cultivars was much higher than that of the ones from integrated cultivation.
Conclusion: Knowledge of the sugar content is very important for diabetic patients, owing to the assumption of general diet recommendations that 100 g fruit contain 12 g carbohydrates. This applies to most well-known cultivars like Golden Delicious or Gala, but not to most of the regional cultivars. For diabetics, it is necessary to know the carbohydrate content of food precisely, in order to adapt the amount of insulin to the ingestion. So, it is helpful to know the sugar content of each regional cultivar. Moreover, very high levels of phenolic compound in organically grown cultivars, and with it its importance for human health leads to the recommendation to eat regional fruits from organic fruit growing instead of those grown under integrated cultivation.
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Introduction

In the times of supernutrition, people care more and more about eating habits. Apples are still a popular snack, owing to their high water and roughage sing compounds and their low-calorie count. An apple is a 'healthy fast-food' that refills the reserves of vitamins, minerals and trace elements of the human body (Gartler, 2003). Additionally apples contain phenols, pectin, sugar and acids, which have a generally positive effect on health. Moreover, the high antioxidant pools in apples are able to scavenge free radicals in human cells (Schirrmacher and Schempp, 2003).

In recent years, the range of apple varieties in the supermarkets has dramatically decreased. Only about 12 apple varieties, from integrated cultivation (e.g. Jonagold, Gala, Granny Smith) are sold all over Europe. In contrast to this small number, there are about 400 apple varieties from organically grown field sites (e.g. Kronprinz Rudolf, Cox Orange, Gravensteiner) even in a country as small as Austria; most of these can only be bought at farmers' markets. These old, natural orchard-grown varieties offer a wide range in flavour, aroma, sugar- and acid-content and phenolic compounds (Herbinger *et al*., 2004a, b).

The varying content of sugars and acids in different apple varieties, which can also vary according to weather and soil, might be a problem for diabetic patients. Therefore, knowledge of the sugar concentration in different apple cultivars should be of great interest to these patients.

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Attention should also be paid to the phenolic compounds of apples, because a higher absorption of phenols leads, among other effects, to a reduction in heart disease and lower cholesterol levels (Craig and Beck, 1999).

The present study has focused on the content of sugar, acid and phenols in well-known cultivars from integrated cultivation, but also in organically grown cultivars. More knowledge about the differences between these varieties helps people to decide which apple cultivar is the best for them.

Materials and methods

Apple fruits from comparable sites were collected between August and October at the ripening period of each cultivar. The cultivars from integrated cultivation – Braeburn, Elstar, Fuji, Gala, Golden Delicious, Idared and Jonagold – were collected at the Research Center Haidegg/Styria. The organically grown varieties – Baumanns Renette, Cox Orange, Danziger Kantapfel, Gravensteiner, Weißer Klarapfel, Kronprinz Rudolf, Lavanttaler Bananenapfel, London Pepping, Roter Boskoop, Steirische Schafnase, and Steirischer Maschanzker – were collected all over Styria. Ten apples of each cultivar were taken from the sunny crown and were pressed. The juice was stored at $-20^{\circ}C$ before analysis. For every cultivar, analyses of the pooled samples of 10 apples were made. Total sugar content and its single compounds (sucrose, glucose, fructose and sorbitol), and total acid content and its single components (citric-, malic-, shikimic- and fumaric acid) were determined by high-performance liquid chromatography (HPLC) analysis according to Dolenc-Sturm *et al.*, 1999. Total phenol content was determined by the spectral photometry method adapted from Düsterloh, 2003. Additionally all cultivars were assessed by organoleptic and olfactory tests of their general impression, performed by eight well-trained persons. Statistical analysis was performed by means of the 'general linear model' (GLM) of the SPSS 12 software (SPSS Inc., Chicago, IL, USA). The significance of the type of cultivation was analysed with univariate analysis with a significance level of $P \leqslant 0.05$.

Results

Total sugar content of the cultivars Gala, Elstar, Idared, Golden Delicious, Braeburn and Fuji ranged between 115 and 150 g/kg; the cultivar Jonagold had – with 183 g/kg fresh-weight (FW) – a higher sugar concentration (Figure 1). Among the single components, fructose and sucrose are the major items (Figure 1). The sucrose concentration of Jonagold was about 85 g/kg, higher than all the sucrose concentrations of the other cultivars. Jonagold and Fuji had higher fructose concentrations than Braeburn and Golden Delicious, followed by Idared, Elstar and Gala. Glucose concentration ranged between 5 and 20 g/kg in order from Braeburn, Fuji, Idared, Gala, Jonagold and Elstar to Golden Delicious (Figure 1). The highest sorbitol concentration was measured at about 6 g/kg in Fuji, Jonagold, Braeburn and Elstar (Figure 1).

Cultivars from organically grown field sites had a broader range of total sugar concentrations. Three varieties (Steirische Schafnase, Steirischer Maschanzker and Lavantaler Bananenapfel) showed a sugar content of 200 g/kg FW (Figure 1). The lowest sugar content was found in Baumanns Rentte and Gravensteiner. The content of sugar in the other

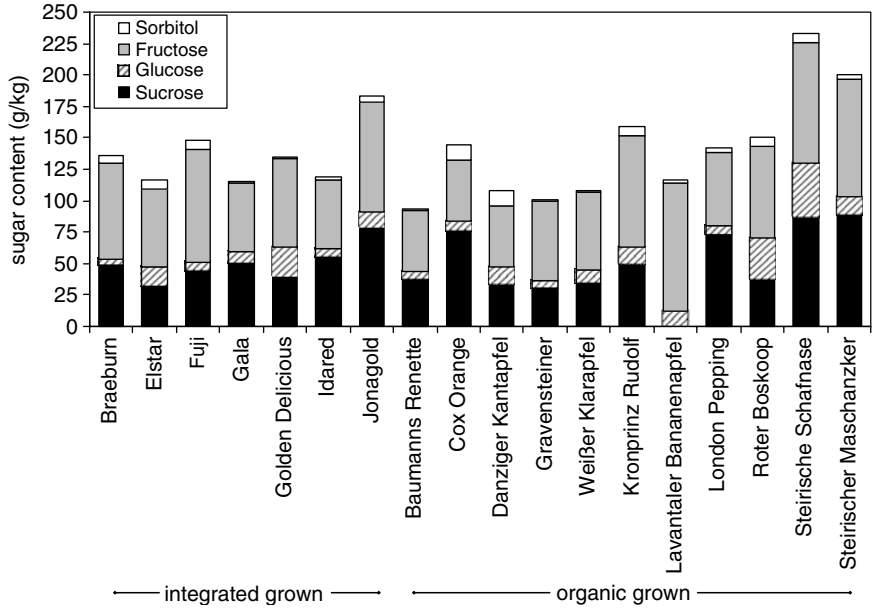

Figure 1 Proportion of sugar components of integrated and organically grown cultivars.

varieties ranged between 115 and 160 g/kg FW, values similar to the cultivars from integrated cultivation. Also, in the organically grown cultivars, sucrose and fructose are the main compounds of the total sugar content. A high glucose content was found in Roter Boskoop. Cox Orange and Danziger Kantapfel showed a particular increase in sorbitol content (Figure 1).

The total acid concentration of all cultivars ranged between 6 (Golden Delicious) and 14 (Elstar) g/kg FW (Table 1). Malic acid is the main single component of the total acids of the cultivars. Citric acid concentrations were found in Fuji, Jonagold, Idared and Golden Delicious, but could not be detected in Braeburn, Elstar and Gala (Table 1), owing to the necessary optimization of HPLC methods. Shikimic acid concentrations were highest in Gala, but did not reach a value above 0.05 g/kg in any cultivar (Table 1). Very low concentrations of fumaric acid were found (0.5–1.9 mg/kg) in all cultivars except Elstar, which showed up to 10 times more fumaric acid than the other cultivars under investigation (Table 1).

Most of the organically grown cultivars contained total acid concentrations similar to those of the ones grown under integrated cultivation. Noticeably higher acid concentrations were found in the cultivars Steirische Schafnase, Roter Boskoop and Steirischer Maschanzker. Also, in organically grown varieties, malic acid is the dominant acid component. Citric acid was found in Baumanns Renette, Cox Orange and Gravensteiner (Table 1).

The phenol concentration of the cultivars grown under integrated conditions was lowest in Golden Delicious (1334 μg/ml). Braeburn, Gala, Fuji, Jonagold and Idared showed similar concentrations of phenolic compounds, which ranged between 2142 and 2642 μg/ml (Figure 2). Some organically grown cultivars showed much higher concentrations of phenols. Steirischer Maschanzker had values higher than 3000 μg/ml, Lavanttaler Bananenapfel, Roter Boskoop, Weißer Klarapfel and Steirische Schafnase showed concentrations even higher than 6000 μg/ml (Figure 2). Lower levels of phenols were found in London Pepping, Cox Orange and Danziger Kantapfel. Statistical analyses between the two groups 'organically grown' and 'integrated cultivation' cultivars showed no siginificant differences between integrated and organically grown cultivars, as to total sugar content ($P = 0.520$), but a clear tendency to higher phenol ($P = 0.092$) and malic acid contents ($P = 0.055$) in organically grown cultivars.

Discussion

The sugar–acid ratio is responsible for the taste and flavour of the apple fruit. It is primarily the organically grown cultivars that contain fruit acids, especially high levels of malic acid, although this can also be true of some varieties from integrated cultivation. The regular consumption of fruit acids is helpful in preventing illness and slight metabolic disorders in the human body. For example, fruit acids work as a 'natural' tooth brush. Additionally, it is known that malic acid dissolves uric acid, and is therefore an important source of relief when someone suffers from gout or rheumatism (Buchter-Weisbrodt and Schöber, 1998). But people who react sensitively to fruit acids – and also breast-feeding mothers – are recommended to eat apple varieties with low acid concentrations (Buchter-Weisbrodt, 1999).

Table 1 Flavour, citric-, malic-, shikimic-, fumaric- and total acid content of integrated cultivation and organically grown cultivars

Cultivar name	*Flavour*	*Citric acid* (g/kg)	*Malic acid* (g/kg)	*Shikimic acid* (g/kg)	*Fumaric acid* (g/kg)	*Total acid* (g/kg)
Integrated grown						
Braeburn	Sweet	ND	10.43	0.021	0.0019	10.45
Elstar	Sweet-sour	ND	14.08	0.031	0.0055	14.12
Fuji	Highly sweet	1.12	7.37	0.016	0.0051	8.51
Gala	Sweet	ND	10.13	0.044	0.0019	10.18
Golden Delicious	Sweet	0.61	5.64	0.012	0.0008	6.26
Idared	Sweet–sour	0.91	9.91	0.002	ND	10.82
Jonagold	Sweet, slightly sour	1.12	11.35	0.015	0.0008	12.49
Organic grown						
Baumanns Renette	Harmonic	0.86	11.59	0.025	ND	12.48
Cox Orange	Harmonic	0.75	9.53	0.003	0.0004	10.28
Danziger Kantapfel	Harmonic	ND	12.06	0.028	0.0014	12.09
Gravensteiner	Harmonic	1.81	9.95	0.018	0.0009	11.78
Weißer Klarapfel	Harmonic	ND	12.07	0.050	0.0021	12.12
Kronprinz Rudolf	Sweet	ND	9.77	0.016	ND	9.79
Lavanttaler Bananenapfel	Sweet	ND	12.57	0.036	0.0009	12.61
LoNDon Pepping	Harmonic					8.30
Roter Boskoop	Sour–sweet	ND	17.8	0.044	0.0019	17.85
Steirische Schafnase	Sour	ND	16.5	0.057	ND	16.85
Steirischer Maschanzker	Sweet, slighly sour	ND	16.79	0.051	ND	16.31

Abbreviation: ND, not determined.

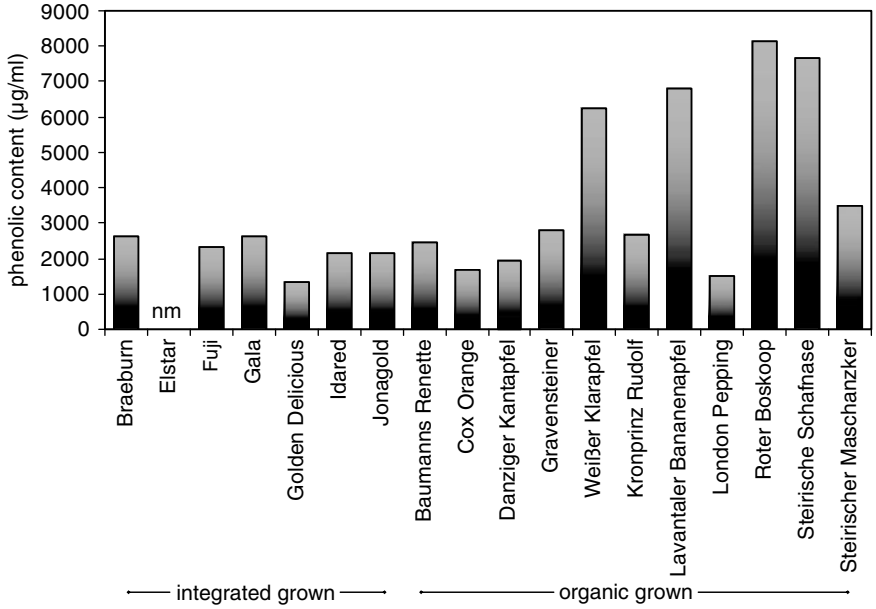

Figure 2 Phenolic content of integrated and organically grown cultivars, nm = not measured owing to unavailable material.

Such varieties can be found among cultivars from integrated cultivation (e.g. Golden Delicious, Fuji), but also among organically grown varieties (e.g. Cox Orange, Kronprinz Rudolf, London Pepping).

Knowledge of the sugar content of fruits is of crucial importance today – in particular for the diabetic diet. Apples are recommended for diabetic patients. Generally, diet recommendations assume that 100 g fruit contains 12 g carbohydrates. We have seen that this fact is nearly correct when applied to cultivars from integrated cultivation – except Jonagold with its higher values. But many of the regional, organically grown apple varieties do not fit into this pattern. Many of these varieties show higher sugar values (e.g. Steirische Schafnase, Lavanttaler Bananenapfel, Steirischer Machanzker), but there are also many varieties, such as Baumanns Renette, Danziger Kantapfel and Gravensteiner, that show lower sugar values. For diabetics, it is important, even necessary to know the carbohydrate content of food precisely, in order to adapt the amount of insulin to ingestion. So it is extremely helpful to know the sugar values, especially for each apple variety.

All cultivars – whether grown organically or under integrated cultivation – contain more fructose and less glucose, a fact that is an advantage for diabetes patients, since it helps to keep the blood-sugar level constant. Apple fruits show a constant ratio between glucose, fructose and sucrose. During fruit ripening, the sugar pattern follows a dynamic pattern: the longer a fruit is stored, the more sucrose will be shifted to glucose and fructose (Chardonnet *et al*., 2003). Also fructose can be shifted to glucose to keep physiological processes in the human body functioning (Friedrich *et al*., 1986).

By focusing on the phenols in different apple varieties, we found that organically grown varieties contained many more phenols in contrast to those grown in an integrated manner. The same results have been reported by Veberic *et al*. (2004). Phenols are secondary plant products that can be found in the peel and pulp of apples and pears. Flavonoids give the fruit their colour and can contribute to its taste. It is well known that phenolic compounds have an antioxidant effect on cells and also have several pharmacological properties, such as decreasing the risk of thrombosis, increasing high-density lipoprotein (HDL)-cholesterol, lowering low-density lipoprotein (LDL)-cholesterol, and distending the vascular system (Lee *et al*., 2003, Schirrmacher and Schempp, 2003). As a result of the importance of phenolic compounds for human health, we recommend the consumption of regional organically grown varieties rather than of cultivars from integrated cultivation.

Apple varieties from integrated cultivation were bred with many reasons including their ability to be stored for a long time or to display little or no brown colour when cut. Therefore, most of apple varieties grown under integrated cultivation have lost through breeding their high content of phenolic compounds, which are responsible for the browning of the pulp (Friedrich *et al*., 1986).

Regular consumption of apples leads to a decrease in cardiovascular disease and arteriosclerosis. Mayer (2001) reported on a 20% decrease in serum cholesterol levels from eating apples regularly. It is very important, therefore, to recommend regional varieties for all the results just mentioned.

Our study points to the important role of various apples in the human metabolism. Which apple variety will be bought

depends first on its appearance, followed by its taste and aroma – some people prefer sweet varieties, others like sour ones. But, we have to be alert consumers, because sour does not always mean less sugar. The regional variety Steirische Schafnase, for example, was categorised as sour after a taste-test, a result due to its high concentration of acid. But, this apple variety also contained an extremely high sugar concentration – nearly twice as much as the cultivar Golden Delicious or Braeburn – which is masked by the high acid content.

Thus, especially in diabetic patients, it will be crucial to take into account that the sugar content of apples might vary enormously. Stressing such facts should be part of patient dietary education. Further studies on everyday foods will be necessary to improve our and our dieticians' knowledge and, finally, to further increase the quality of dietary patient education.

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