

ARE ORGANICALLY GROWN APPLES TASTIER AND HEALTHIER? A COMPARATIVE FIELD STUDY USING CONVENTIONAL AND ALTERNATIVE METHODS TO MEASURE FRUIT QUALITY

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Abstract

Since 1994 important supermarket chains in Switzerland successfully sell apples from verified organic production. However, in supermarkets customers often ask whether there are, apart from a more environmentally friendly production, objective arguments of inner fruit quality that justify the higher prices of organic apples.

In a field study with the 'Golden Delicious' cultivar, we harvested fruits of 5 pairs of organic/integrated fruit farms. The orchards within the pairs were less than 1 km from each other and were similar in micro climate, soil conditions and planting system. Maximum distance between the pairs was 180 km. To measure inner fruit quality we investigated at the beginning and at the end of cold storage (i) standard parameters (firmness, sugar, malic acid, mineral elements etc.); (ii) taste parameters by repeated panel tests; (iii) components that are good for human health (phenols, selenium, fibres, vitamin C and E) and (iv) fruit «vitality quality» by holistic approaches using image forming technique (crystallisation in copper chloride, and chromatography after Pfeiffer), degradation tests and feeding preference tests with laboratory rats.

All fruit samples of organic orchards had significantly firmer fruit flesh (14%) and had 15% higher taste marks than conventional ones. P-content was 31% higher ($p < 0.01$) in organic apples and was closely correlated with technical quality ($r_2 = 0.93$) and sensory score ($r_2 = 0.69$). Content of phenols (mainly flavanols) was 19% and image forming quality 60% higher in organic apples. The picture producing method distinguished 100% correctly the organic and integrated samples and was closely in line with technical quality ($r_2 = 0.68$).

The results show that organically grown apples can have an outstanding inner quality. However, for generalizable conclusions more extensive studies are necessary.

1. Introduction

Since 1994 important supermarket chains of Switzerland successfully sell apples from verified organic production. The prices for customers are 25-50% higher than for conventional or integrated fruit. In general the customers agree that the production of the organic apples is more environmentally friendly, but they also give more attention to the prices than customers in organic food shops. Different studies have revealed that the main

reason for supermarket clients to buy organic food are health reasons (Plöger, *et al.*, 1993; Pummer, 1994). Thus the supermarket consumers ask regularly if organic apples indeed have quality advantages in taste or health components.

This question was the subject of many recent comparison studies between conventional and organic food, as reviewed e.g. by Woese, *et al.* (1997); Worthington (1998) or Alföldi and Weibel (1998). However, all these authors underline that a correct or generalizable extrapolation of the results is often questionable because of methodological insufficiencies. Thus the question is not satisfactorily answered yet. Additionally there are still too little data about the suitability of different methods, especially the so-called «holistic» or «alternative» methods, to quantify the consumer relevant eating or health quality of apples. Recently also health promoting compounds that can exert antioxidant activity by quenching free radicals such as phenolic compounds, vitamin E or selenium are of special interest in connection with the inner quality of apple fruits (Min and Lee, 1996; Haldimann, *et al.*, 1996; Schmitz and Noga, 1997).

This paper describes the first year of a field investigation with 'Golden Delicious' apples from five organic/integrated farm pairs in Switzerland.

2. Materials and methods

2.1. Sampling methods

The fruit samples originated from 10 fruit farms in the north-west and north-east of Switzerland. At each site there was a pair with a biological (organic) and an integrated fruit farm in the neighbourhood. All farms had a grown up orchard with the cultivar 'Golden Delicious' and the orchards of each farm pair were situated reasonably close together (< 1 km). Local rainfall between 15 April and 25 September varied between 395 and 567 mm).

The harvest of the fruit samples was carried out by ourselves one day before the farmer's harvest date (23, 25 and 26 Sept. 1997). Before picking, we estimated the average crop load of the orchard (0-100%); we only harvested fruit samples from trees within $\pm 10\%$ of the average crop load. Per orchard 50 kg of fruit were randomly picked out of the central zone of the trees. Fruits were transported the same day to the same cold store with 2°C and 90-95% rH (natural atmosphere).

On 4 Nov. 1997 (40-43 d of cold storage) we took from each sample 5 random sub-samples of 3-10 kg fruit to carry out the different analyses. For the second set sub-samples were taken 18 Feb. (156-159 d of cold storage). The sub-samples were immediately brought to the individual laboratories (Coop Schweiz, Pratteln; RCC, Itingen; BAG, Bern; Ludwig Boltzmann Institut, Vienna; Labor Dr. Ursula Balzer, Wetzikon; Lehrstuhl für Obstbau, TUM-Weihenstephan; FiBL, Frick).

2.2. Standard quality parameters

To quantify standard quality we measured fruit weight, flesh firmness with penetrometer (\varnothing 11 mm, penetration 8 mm); in fruit flesh: Brix (sugar content) with refractometer, mineral contents (only in the first series) of N (Kjehldal), P (spectrophotometer), K (IES), Ca (AAS), Mg (AAS); in fruit juice: malic acid by titration.

To facilitate correlation analysis we created an empirical index for technical quality = Brix (%) + 2·firmness (kg) + 3·malic acid (g/l)

2.3. Health components

In fruit flesh the Coop Laboratory determined: vitamin C (polarography), vitamin E (HPLC-FLD, only in the first series), selenium (only in the first series, AFS after lyophilisation to 60-80% H₂O), nutritional fibres (enzymatic gravimetry). In fruit flesh and skin without core the TMU-Institute of Fruit Research determined: phenolic compounds (HPLC-analysis with diode-array-detection and post-column-derivatisation

after extraction in methanol; only in the second series). 4 groups of phenolic compounds were analysed: flavanols (13 components), cinnamonic acids (3 components), phloretin-glycosides (2 components) and quercetin-glycosides (5 components).

2.4. Panel tests

The first panel blind-test took place Nov. 10, 1997, after 6 days of shelf storage at room temperature. The test panel consisted of 14 sensorically trained persons. Each panellist was also asked for his age, sex, quantitative and sensorial preferences for apples. About 10 fruits per sub-sample were washed and cut into 20 pieces each; pieces were mixed in a bowl; 7-12 pieces per sample and panellist were served. Scoring was done by putting a mark on a 10 cm long axis representing a range of «very low» to «very high». The length of the axis the left of the mark in mm was used for data analysis. Panellists had to judge: ripeness, firmness of flesh and skin, juiciness, sugar content, acidity content, aroma content, aroma quality, overall quality. The second panel test with the same persons took place 18 Feb. after one day of shelf storage at room temperature.

2.5. Feeding Test

A food preference test was carried out at the Ludwig Boltzmann Institute in Vienna with 20 male rats. The rats were fed with the coded sub-samples and a standard feed. Food preference was quantified daily by weight of eaten apple pieces during 4 days (Plochberger and Velimirov, 1992).

2.6. Holistic methods

2.6.1. Image forming technique

In the laboratory of Dr. Ursula Balzer-Graf at Wetzikon, Switzerland, the so called «vitality quality» was determined with picture producing methods (Balzer-Graf and Balzer, 1991): (i) crystallisation of fresh and sterilised apple juice in copper chloride after Pfeiffer; (ii) chromatography in silver nitrate after Wala and (iii) chromatography in silver nitrate and iron sulphate after Pfeiffer. Juice was obtained by pressing the rasped halves of the apples; the remaining half apples were cold stored and used for a second analysis series («stress test»). Always in 4 repetitions different pictures series were made resulting in 30 pictures per sample. Picture interpretation for vitality quality was made on the basis of already existing picture series of apple by Dr. U. Balzer-Graf herself. Eight subparameters (apple typicality (1), differentiation (2), vitality (3), stability (4), vegetativity (5), lability (6), mineralising (7), conserving (8)) were estimated with values between 0-100 and combined to an index of vitality quality = $(((1) + (2) + (3) + (4))/4) - [((5) + (6) + (7) + (8))/4]$.

2.6.2. Degradation tests

At Ludwig Boltzmann Institute the degradation test after Samaras (1978) was applied on the same sub-samples as for the feeding test with rats. In 12 repetitions 20-30 g of rasped apples were incubated for 4 weeks at 25°C and 50% rH. The samples were analysed for water loss and described by their type of fungal colonisation.

2.6.3. Statistical analysis

Influence of farming system, site and interactions were analysed by ANOVA-procedures after checking the dependent variables on eventual influences of co-variables such as crop load, soil or management factors. In the panel-tests model also the panellist factor was included. Post hoc comparisons of means were made with Tukey test at alpha level of 0.05. The software used was «JMP» (v. 3.2.2, SAS-Institute, Cary-NC).

3. Results

3.1. Influences of farming system and site

Before running the ANOVA procedures to check the influences of farming system, site and interaction, we tested fruit and orchard parameters such as fruit weight, crop load, planting density, soil parameters etc. as to whether they influence the main factors. However, no such significant co-variable was found.

With many parameters organic ("biological", abbreviated bio) fruit had values of a magnitude similar to fruit from integrated orchards. In some parameters, however, organic fruit had significantly different and on the whole more favourable values (Tables 2-5). The most interesting significant differences were:

- 31.9% higher P-content in the fruit flesh (Table 2)
- 14.1% higher firmness (12% higher at the end of storage) (Table 2)
- 14.7% higher technical quality index (10.5% higher in the second series) (Table 2)
- 8.5% more nutritional fibres (Table 3)
- 18.6% more phenolic compounds, especially flavanols (Table 3)
- 15.4% higher score in the panel test (Table 4)
- 65.7% higher index of vitality quality (132% at the end of storage) (Table 5)

The means of not significantly different parameters are indicated below the corresponding tables. A significant influence of the site or the interaction between site and farming system was rarely to be found. In general, the differences between farming systems were more pronounced in the first analysis series (40-43 d of cold storage) than in the second series (156-159 d of cold storage). However, with most parameters the rankings of the samples were the same in both series. In the second analysis series the average values of quality parameters decreased remarkably, indicating the natural decay of the fruit. The decay was most pronounced with the organic samples of the sites A.o. and S., thus «pulling down» considerably the average values of the organic samples at the end of the storage period. Neither the self decomposing test nor the feeding test with laboratory rats revealed significant differences.

3.2. Interesting correlations

Apart from factor influences of farming system and site we were also interested in the correlations between the different parameters of inner fruit quality aspects. This knowledge can permit finding the parameters or methods that are most suited and reliable for quality comparisons.

It seems that P content played a dominant role for quality. P content was highly correlated with the index of technical quality in both series ($r^2 = 0.93$ and $r^2 = 0.85$) (Fig. 1a), overall sensorial score ($r^2 = 0.69$ and 0.51) and nutritional fibre content ($r^2 = 0.34$ and 0.69). P-content also showed high correlations to vital quality, with an r^2 value of 0.73 in the first series and even 0.85 in the second series. The correlations of P-content to fruit weight ($r^2 = 0.001$) or water content ($r^2 = 0.51$) were low.

Contents of K, N, Ca or Mg in the fruit flesh showed only low correlations to the quality parameters mentioned above.

The overall sensorial score was highly correlated ($r^2 = 0.85$) with the index of technical quality (Fig. 1b) in the first series and to a somewhat lesser extent in the second series ($r^2 = 0.55$).

In both series we found a high and significant correlation between the indices of vitality quality and the technical quality ($r^2 = 0.68$ and $r^2 = 0.66$) (Fig. 1c).

Among all measured parameters the phenolic compounds, especially the flavanols, correlated most with the P-content in the fruit flesh ($r^2 = 0.47$).

4. Discussion

This investigation did not want to and cannot deliver the «final proof» that organically grown fruits are better and healthier than fruits from integrated orchards. For that purpose the investigation over only one year and with only five orchards per farming system is too small. Nevertheless we found interesting differences in quality parameters and also gained valuable experience with a quite wide range of methods to quantify and qualify the complex concept of «inner fruit quality».

In all aspects of internal fruit quality (standard technical quality, health components, panel tests, vitality quality) organic fruit were on the same, and in some important parameters even on a higher level than integratedly produced fruit (taste, firmness, nutritional fibres, phenolic compounds, vitality index). The feeding test with rats and the vitamin C content did not reveal any significant differences, which is in contrast to the results of Velimirov, Plochberger *et al.* (1995), but they compared only one sample per farming system.

The P-content in the fruit seems to play a dominant role. However, on the basis of the available data, the causality chain behind this fact is not sufficiently evident and we want to intensify these investigations. A better P-uptake of the apple trees under organic orchard management has been reported previously by Deell and Pranger (1993) and Werner (1996).

Among the health-related components, mainly the nutritional fibres and the phenolic compounds showed significant differences between farming systems. According to Treutter (1998) the differences found in the phenolic compounds are in a remarkable magnitude. A possible explanation for this result could be that the improved uptake of P in the organic fruits could deliver the additional energy which is necessary to synthesise more phenolic compounds (Mayr, 1995). We are presently investigating these questions more intensively. The content of selenium was very low, near the lowest detectable concentration. Neither the contents of vitamin E and C showed significant differences. For vitamin E the highest correlation to other parameters occurred with ripeness (as estimated by the panellists) ($r^2 = 0.69$) and for vitamin C with firmness ($r^2 = -0.28$). Thus, probably neither selenium nor vitamin C or E are consumer relevant parameters to compare the health quality of differently produced apples.

It has been proven frequently that the image forming method can distinguish organic from conventional food quite well with a score rate between usually 70 and 100% (e.g. Alföldi, Mäder *et al.*, 1995). In this study, too, and in both series, the distinction between organic and integrated fruit was 100% correct (Fig. 1c). However, we consider the fact even more important that the ranking in vitality quality was well in line with the technical and sensorial quality (Fig. 1c).

Another indication for a good reliability of the image forming method is that its results of the first and the second series corresponded to a high extent ($r^2 = 0.83$). However, apart from its sharp distinction between the farming systems, our study could not yet reveal striking advantages of the expensive and time demanding image forming method. A scientific proof that the increased values for vitality quality are indeed more favourable for the consumer's well-being can not be extrapolated with this study, so that this issue certainly needs more scientific attention.

Acknowledgements

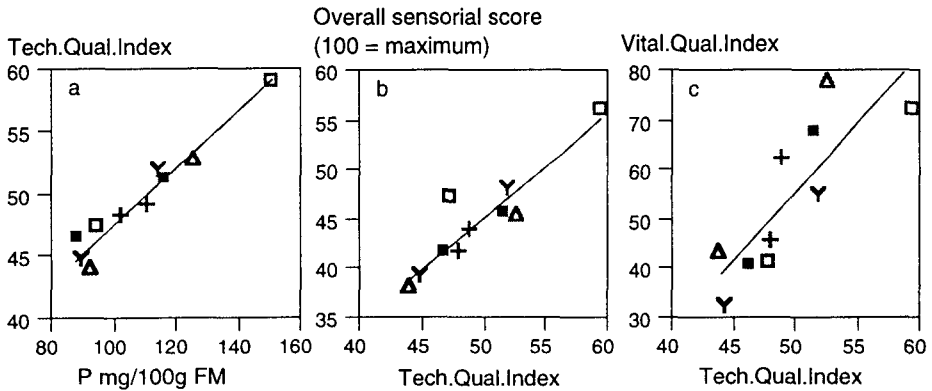
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Figures



1a-1c. Correlations between different methods of quality assessment with the results of 5 comparison pairs of organic/integrated apple orchards ('Golden Delicious'). Same symbol = same site (Tab. 1), grey symbols = organic orchards, black symbols = integrated orchard. Correlation coefficients and linear models:

- a) $r^2 = 0.93$; $y = 24.41 + 0.23 x$
- b) $r^2 = 0.85$; $y = -7.12 + 1.045 x$
- c) $r^2 = 0.68$; $y = -85.50 + 2.82 x$

Tables

1. Description of the fruit farms where the 'Golden Delicious' apples have been sampled: year of planting, rootstock, clone, planting distance, soil management in tree strip, remarks on soil and nutrition

Location of the farm pairs and symbols used in Figure 1	Organic farm	Integrated farm
Amriswil oben (A.o) +	1988; M26; clone B; 2.3 x 4.3 m, living sod mulched; heavy clay; 4% OM; medium to low in K, P, Mg-reserves (Heller, Husistein <i>et al.</i> , 1993); fertilised with 30 m ³ /ha pig slurry in March '97	1977; M26; clone B; 2.0 x 4.5 m; clean soil by herbicides; heavy clay; 2.7% OS; medium to low in K, P, Mg-reserves; fertilised with 13-6-18-2.4 kg/ha N-P-K-Mg in March '97
Amriswil unten (A.u) Y	1986; M9; clone B; 1.8 x 4.2 m; living sod mulched; heavy clay; 4% OM; medium to low in K, P, Mg-reserves	1990; M9; Smoothee; 1.2 x 3.7 m; clean soil by herbicides; heavy clay; 2% OM; medium in P, K, Mg reserves; rich in Ca reserves; 1 x 3.8 kg/ha CaCl ₂
Scherzingen (S.) ■	1986; M9; clone B; 4 x 4 m; living sod mulched; 3.5% OS; medium in K, Ca, Mg reserves, high in P reserves; 15 m ³ mature compost in March '97	1989; M9; clone B; 1.6 x 3.5 m; heavy clay; clean soil by herbicides; 4% OM; medium in Ca and Mg reserves, rich in P and K reserves; 90-90-50 kg/ha N-Ca-Mg in April '97
Remigen (R.) ▲	1984; M26; clone B; 2 x 3.5 m; clean soil by tillage; sandy loam on heavy clay; 2.9% OM; medium in P, Mg, Ca reserves, high in K reserves; 12-92-22 kg/ha P-Ca-Mg in March '97; 2 x 2 kg/ha CaCl ₂	1988; M9; Smoothee; double rows (1.5 x 1.0) x 3.8 m; clean soil by herbicides; sandy loam on heavy clay; 3% OS; medium in Ca, Mg; rich in P, K; 40 kg/ha N in March '97
Biel-Benken (B) □	1987; M9; clone B; 1.7 x 4 m; living sod mulched; loamy loess; 3% OM; medium to low in K, P, Ca, Mg reserves	1992; M9, Smoothee; 1.8 x 4 m; clean soil by herbicides; loamy loess; 2% OM; medium to low in K, Ca, Mg, P reserves; 34-30-80-16 kg/ha N-P-K-Mg in April '97; 1 x 10 kg/ha MgSO ₄ , 1 x 3.8 kg/ha CaCl ₂

2. Standard fruit quality parameters measured after 43 d (series 1) and 159 d (series 2) of cold storage

Parameter	Series	Influence of farming system bio/IP (ns. p > 5%; * p = 1-5%; ** P < 1%)	Influence of site	Interaction system x site (— = could not be determined)
Firmness (kg/cm ²)	1	** bio (6.56) > IP (5.75)	ns	ns
	2	** bio (4.56) > IP (4.07)	ns	* at A.o IP > bio
P (mg/100 g FM)	1	* bio (12.4 > IP (9.4)	ns	—
Mg (mg/100 g FM)	1	ns (5.61 ± 0.09)	* at A.u. > rest	—
Technical quality index	1	* bio (53.0) > IP (46.2)	ns	—
	2	* bio (30.8) > IP (27.8)	ns	—

Not significant in first/second series: Fruit weight (g): 175/179; H₂O-content (%): 85.0/83.8; malic acid (g/l): 4.22/2.43; Brix (%): 13.7/13.8; minerals (mg/100g FM) N: 44; K 109; Ca 5.05

3. Health-related components measured after 43 d (series 1) and 159 d (series 2) of cold storage for apple quality assessment

Parameter	Series	Influence of farming system bio/IP (ns. p > 5%; * p = 1-5%; ** P < 1%)	Influence of site	Interaction system x site (— = could not be determined)
Nutritional fibres (g/100 g; enzymatic)	1	** bio (2.54) > IP (2.34)	S. (2.3) < rest (2.4-2.55)	—
	2	ns (2.36 ± 0.118)	ns	—
Total of phenolic compounds (mg/g DM)	2	** bio (4.66) > IP (3.93)	ns	* at B. and S. bio >> IP
Total flavanols	2	* bio (3.20) > IP (2.60)	at R. > rest	** at B. and S. bio >> IP
Total cinnamon acids	2	* bio (0.94) > IP (0.84)	ns	ns
Total phloretin glycosides	2	* bio (0.24) > IP (0.20)	ns	** at S. bio >> IP

Not significant in first/second series: Selenium (ng/g DM): 1.14; vitamin C (mg/kg FM): 25.1/15.75; vitamin E (mg/kg FM): 1.15; quercetine glycosides (mg/g DM): 0.29

4. Panel test and feeding test with rats for apple quality assessment. Influence of panellist and rat was always significant (not shown). Significant influences of site or site x farming system were very rare (not shown)

Parameter	Influence of farming system bio/IP (ns. p > 5%; * p = 1-5%; ** P < 1%)	
	43 d of cold storage + 4 days at room temp.	159 d of cold storage + 1 d at room temp.
Overall sensorial score (0-100)	** bio (47.9) > IP (41.5)	ns (44.3 ± 9.51)
Aroma intensity (0-100, 50 = optimum)	* bio (39.8) > IP (34.3)	ns (36.4 ± 21.2)
Aroma quality (0-100)	* bio (4.66) > IP (3.93)	ns (46.9 ± 21.3)

Not significant in first/second series: firmness; juiciness; sugar content; acidity content; ripeness; also feeding test with laboratory rats did not reveal significant differences

5. Results of picture producing methods and self decomposing tests for apple quality assessment. Influences of site or site x farming system were very rare (not shown)

Parameter	Series	Influence of farming system bio/IP (ns. p > 5%; * p = 1-5%; ** P < 1%)	Influence of site
Overall vitality quality index	1	* bio (67.5) > IP (40.7)	ns
	2	* bio (57.9) > IP (25.0)	ns
Apple characteristic	1	* bio (80) > IP (58)	ns
	2	** bio (65) > IP (39)	ns
Vitality	1	* bio (70) > IP (60)	ns
	2	** bio (68) > IP (45)	ns

Also in both series significant were: differentiation, stability, vegetativity, lability, mineralising decay, conserving decay. Not significant: degradation test