SENSORY AND HEALTH-RELATED FRUIT QUALITY OF ORGANIC APPLES. A COMPARATIVE FIELD STUDY OVER THREE YEARS USING CONVENTIONAL AND HOLISTIC METHODS TO ASSESS FRUIT QUALITY

GESCHMACKS- UND GESUNDHEITSRELEVANTE QUALITÄT VON ÖKOLOGISCH ANGEBAUTEN ÄPFELN: EINE 3JÄHRIGE FELD-VERGLEICHSSTUDIE MIT STANDARD- UND GANZHEITLICHEN UNTERSUCHUNGSMETHODEN

Franco P. Weibel[1], Dieter Treutter[2], Ursula Graf[3] and Andi Häseli[1]

Abstract

In a 3 years lasting field study with the 'Golden Delicious' cultivar, we compared fruits of 5 pairs of organic/integrated fruit farms. The orchards were similar in microclimate, soil conditions and planting system. To assess inner fruit quality we investigated at the beginning and at the end of cold storage: (i) standard parameters (firmness, sugar, malic acid., mineral content); (ii) sensorial quality by panel tests; (iii) health related components (23 phenolic compounds, nutritional fibres; vitamins); and (v) fruit «vitality quality» by holistic approaches (crystallisation in copper chloride, self degradation tests, feeding preference tests with laboratory rats).

The most significant differences were found in year one of the study, and were by tendency confirmed in the following two years. In year one all fruit samples of organic orchards had significantly firmer fruit flesh (14%), a 10 % higher index of inner quality (on basis of sugar and malic acid content and fruit flesh firmness), and 15% higher taste scores than conventional ones. Phosphorus content of the fruit flesh was 31% higher in organic apples and closely correlated (r^2 = 0.93) with the index of inner quality and sensory score (r^2 = 0.69). No extraction method of Phosphorus in the soil (water, NH_4-EDTA, citric acid, CAL) correlated with the P-content in the fruits. However, P in the fruit flesh correlated by r^2 = 0.72 with the microbial activity of the soil expressed as the ratio of microbial-bound Nitrogen and Carbon in the soil. With a value of 3.85 the C_{mic}:N_{mic} ratio was 44.5 % lower (thus more favourable) in organic tree strips. Flavanols, with 65.7 % of the total polyphenol content were the dominant group of polyphenols. The content of flavonols was 22.7 % higher in organic apples in the first year and 15.6 % in the average of the three years. The self-degradation test didn't provide significant differences. Laboratory rats, showed a tendency to prefer IP apples probably due to their advanced ripeness. Thus rat behaviour did not correspond with the sensory panel judgement. The picture forming method provided a correct reproducibility with repeated blind samples before and after storage (r^2 = 0.83), and distinguished 100 % correctly organic an IP fruit in the first year. In the second year there was one miss qualification. The average value over three dates of the index for «vitality quality», which was especially created for this study, was 44.6 % higher with organic apples The picture forming methods correlated well with sensory scores and standard quality (r^2 = 0.63) in the first year. The study revealed interesting and consumer-relevant differences between organic and integrated apples with standard and holistic methods.

Keywords: ***apple, Golden Delicious, organic, conventional, integrated, production, comparative stuty, quality, sensorial, standard, holistic, soil microbial activity, polyphenols, health***

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

[1] Research Institute of Organic Agriculture (FiBL) CH-5070 Frick (franco.weibel@fibl.ch);
[2] Institut für Obstbauforschung, TU-München, D-85359 Freising-Weihenstephan
[3] Forschungsinstitut für Vitalqualität (fiv), CH-8620 Wetzikon

shops. Different studies have revealed that the main motive for supermarket clients to buy organic food is health reasons (Plöger, Fricke 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, Lange 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, Venner et al., 1996; Schmitz and Noga, 1997). This paper describes the methodological and analysis results of our 3 years lasting study, a field investigation with 'Golden Delicious' apples from five organic/integrated neighbouring farm pairs in Switzerland.

Material and Methods:

1. Sites and 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 a 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). Details of the sites are given in Weibel et al. (2000). 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 ± 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 at mosphere). At the beginning (December) and towards the end of the storage period (February) we took from each sample 5 random sub-samples of 3-10 kg fruit to carry out the different analyses. The sub-samples were immediately brought to the different laboratories (Coop Schweiz, Pratteln; RCC, Itingen; BAG, Bern; Ludwig Boltzmann Institut, Vienna; Labor Dr. Ursula Graf (formerly Balzer-Graf), Wetzikon; Lehrstuhl für Obstbau, TUM-Weihenstephan; FiBL, Frick).

2. Standard quality parameters

To quantify standard quality we measured fruit weight, flesh firmness with penetrometer (ø 11 mm, penetration 7 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 (Formula 1).

(1) Quality Index (dimensionless) = Brix (%) + 2 $\times$ firmness (kg/cm2) + 3 $\times$ malic acid (g/l)

3. Health-related components

In fruit flesh the Coop Laboratory determined: vitamin C (polarography), vitamin E (in first year fruit, by HPLC-FLD), selenium (in first year fruit, AFS after lyophilisation to 60-80% H_2O), nutritional fibres (in first year fruit, enzymatic gravimetry). In fruit flesh and skin without core the TUM-Institute of Fruit Research determined phenolic compounds by HPLC-analysis with diode-array-detection and post-column-derivatisation after extraction in methanol. 4 groups of phenolic compounds were analysed: flavanols (13 components), cinnamon acids (3 components), phloretin-glycosides (2 components) and quercetin-glycosides (5 components).

4. Sensory panel tests

The 6 sensory panel tests took place each year twice in Nov./Dec. and in February. The test panel consisted of 14- 25 sensorial pre-trained persons. Each panellist was also asked for his age, sex, quantitative apple consumption and flavour preference. 15 fruits per sub-sample were washed and cut in radial direction and cut into 20 slices each; slices were mixed in a bowl; 7-12 "cubes" 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 until the mark was used for data analysis. Panellists had to judge: ripeness, firmness of flesh, juiciness, sugar content, acidity content, aroma content, aroma quality, thickness of skin, overall quality. One day before testing fruits were interstored at 15-17 °C.

5. Food preference 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 IP and organic sub-samples of the same site, during 4 days for each site, and a standard feed. Food preference was quantified daily for each animal by assessing the weight of eaten apple slices during 4 days of being exposed to the same (Plochberger and Velimirov, 1992).

6. Holistic methods

6.1. Image forming methods

In the laboratory of Dr. Ursula Graf (formerly 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 U. Graf herself. Eight sub-parameters (apple typicality (1), differentiation (2), vitality (3), stability (4), vegetativity (5), liability (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].

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.

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 per tree and soil or management factors. In the panel tests model also the factor panellist was included. Post hoc comparisons of means were made with Tukey test at alpha level of 0.05. The software used was «JMP» (v. 4.2, SAS-Institute, Cary-NC).

Results:

1. Standard quality parameters

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. As shown in Weibel et al. (2000), the influence of site and interaction site were seldom significant or relevant. Thus these specific data are not presented in this paper. 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 by tendency more favourable values (Tables 1.). Mineral content of the fruit flesh showed only in the first year a significant different. In that year with generally low but quality decisive Phosphorus contents (Fig. 3) organic fruit had a 31.9 % higher P content (11.7 mg/100g FM) than in integrated fruit. Also fruit firmness, fibres and the Quality Index after formula (1) differed significantly only in the first year: this difference was in the magnitude of 13.5 % for firmness, 9.6 % for fibres and 10 % for the Quality Index. Brix content was significantly different only in the third year where organic apples had 13.7 and integrated 13.0 Brix (9.5 % difference). The food preference tests revealed a tendency ($p = 0.08$), that the rats preferred IP to organic apples (173.0 g/animal vs. 123.5 g/animal). However the with rats, feeding preference correlated positively with ripeness ($r^2 = 0.28$) whereas sensorial score of humans correlated clearly in the opposite way with ripeness ($r^2 = -48$). Neither the self-decomposing test nor the feeding test with laboratory rats revealed significant differences.

Table 1. Standard fruit quality parameters measured at the beginning (December) and towards the end (February) of storage period over three years. Indicated are the means of all 5 organic orchards, statistically compared with the means of all 5 integrated orchards (at p ≤ 0.05).

Year and Month of analysis	Sugar (Brix) % bio vs. IP	Malic acid (g/l) bio vs. IP	Fruit flesh firm-ness bio vs. IP	Quality Index *) bio vs. IP	Other Parameters bio vs. IP
1997 - Dec.	ns 14.03 > 13.58	ns 4.3 > 3.9	*** 6.35 > 5.57**	*** 40.5 > 36.4**	Vitamin C: ns Fiblres: + 9.6 % P-content: + 31.9 % Selenium: ns
1998 - Feb	ns 13.5 > 13.3	ns 2.7 > 2.1	ns 4.16 < 4.07	ns 29.9 >27.8	Vit. C: ns
1998 - Dec	ns 14.6 < 15.2	ns 4.4 > 4.2	ns 5.30 > 5.15	ns 38.2 > 37.9	Fibres: ns
1999 - Feb.	ns 13.9 < 14.7	ns 2.7 > 2.1	ns 4.55 < 4.92	ns 31.2 > 30.9	
1999 - Dec.	*** 14.5 > 13.5**	ns 4.3 > 4.2	ns 5.72 > 5.38	ns 38.5 > 36.7	Fibres: ns
2000 - Feb.	ns 13.7 > 13.0	ns 2.7 > 2.8	ns 4.50 = 4.50	ns 30.7 > 30.5	

*) Quality Index (dimensionless) = 1 × Brix + 2 × firmness + 3 × Malic acid content

2. Sensory panel tests

The results of the sensory tests were most significant in the first year (Table 2). There, the panellists gave significantly and 15 % higher score to organic apples in the over-all judgement and also in different specific taste parameters (firmness, juiciness, tartness, flavour content, flavour intensity). In the second year of the study, however there became no taste differences evident. In December of the third year organic apples were judged to be less juicy (- 8.0 %), however to be more juicy in February (+ 6,4 %). At that date, again organic apples were scored by 16.3 % better than IP fruits.

Table 2. Results of the 6 sensory panel tests carried out at the beginning (December) and towards the end (February) of storage period over three years. Where the differences between organic and integrated apples were significant the difference (Δ) of the mean scores per production method are indicated in %.

Year and Month of analysis	Ripeness org. vs. IP (sig. Δ %)	Firmness org. vs. IP (sig. Δ %)	Juiciness org. vs. IP (sig. Δ %)	Sweetness org. vs. IP (sig. Δ %)	Tartness org. vs. IP (sig. Δ %)	Flavour content org. vs. IP (sig. Δ %)	Flavour type org. vs. IP (sig. Δ %)	Overall scoring org. vs. IP (sig. Δ %)
1997 - Dec.	**- 5.3**	**+ 13.7**	**+ 9.7**	ns	ns	**+ 16.1**	**+ 12.7**	**+ 15.2**
1998 - Feb	ns	**+ 13.5**	ns	ns	**+ 20.5**	ns	ns	**+ 15.6**
1998 - Dec	ns	ns	ns	ns	ns	ns	ns	ns
1999 - Feb.	ns	ns	ns	ns	ns	ns	ns	ns
1999 - Dec.	ns	ns	**- 8.0**	ns	ns	ns	ns	ns
2000 - Feb.	ns	ns	**+ 6.4**	**+ 7.1**	ns	**+ 8.8**	**+ 16.0**	**+ 16.3**

3. Content of polyphenols

Flavanols, with in average 65.7 % of the total polyphenol content were the dominant group of polyphenols (Table 3). The content of flavonols was 22.7 % higher in organic apples in the first year and 15.6 % higher in the average over the three years. With quercetin glycosides there was in two years a significantly higher content in IP fruits (+ 11.6 and + 18.1 %). The total content of polyphenols differed significantly in the first year, with a plus of 18.7 % (4.66 mg/g DM) for organic apples. There was no significant difference in the total polyphenol content in year two and three.

Table 3. Results of the polyphenol analysis at the beginning of the storage period (December) over three years. Indicated are the mean contents in (mg/g DM) and, if significant (p ≥ 0.05) or by tendency (0.05 < p < 0.13) the difference in %.

Year and Month of analysis	Flavanols bio vs. IP	Cinnamon acids bio vs. IP	Phloretin gly-cosides bio vs. IP	Quercetin gly-cosides bio vs. IP	Total Polyphenols bio vs. IP
1997 - Dec.	**** 3.19 (+ 22.9 %)**	*** 0.94 (+ 12.4 %)**	*** 0.24 (+ 21.6 %)**	ns 0.29	*** 4.66 (+18.7 %)**
1998 - Dec	**** 2.34 + 15.8 %)**	ns 0.64	ns 0.25	*** 0.22 (- 11.6%)**	ns 3.45
1999 - Dec.	(P = 0.07) 2.70 (+ 8.0 %)	(p = 0.09) 1.23 (+6.4 %)	(p=0.06) 0.22 (+9.9 %)	*** 0.24 (- 18.1 %)**	(p = 0.13) 4.41 (+ 6.3 %)

4. **Picture Forming Methods**

The reproducibility of the results of the picture forming methods was assessed by a second analysis of the same but differently coded samples at the end of the storage period. There, the quantitative (index values) and qualitative (same ranking) correlation reaching $r^2 = 0.82$ was rather high (Fig. 1). Results of the picture forming methods revealed in most cases significant differences between organic and IP fruit (Table 4). Often theses differences were in a quantitative magnitude around > 40 % showing more favourable values for organic fruit. The classification in organic and IP fruits was 100 % correct in the first and 80 % correct in the second year. However, the created Vitality Index (with the goal to combine the values of the 8 sub-parameters in one value) correlated highly with the ranking of the technical quality and the sensory results (Fig. 5) in year one; but less in year two. There, the correlation looks like showing two parallel regression lines with a clear vital quality difference (Fig. 5).

Table 4. Results of picture forming methods for apple quality assessment. Also in both series significant but not shown were: differentiation, stability, vegetativity, lability, mineralising decay, conserving decay.

Parameters	Series	Influence of farming system bio/IP (ns. p > 5%; * p = 1-5%; ** P < 1%)	Influence of site
1997 Overall Vtality Quality Index	Dec.	*** org. (67.5) > IP (40.7)**	ns
	Feb.	**** org. (57.9) > IP (25.0)**	ns
1997 Apple typicity	Dec.	*** org. (80) > IP (58)**	ns
	Feb.	**** org. (65) > IP (39)**	ns
1997 Vitality	Dec.	*** org. (70) > IP (60)**	ns
	Feb.	**** org. (68) > IP (45)**	ns
1998 Overall Vitality quality Index	Dec.	**** org. (43) > IP (27)**	ns
1998 Apple typicity	Dec.	**** org. (49) > IP (44)**	ns
1998 Vitality	Dec.	ns org. (49), IP (44)	ns

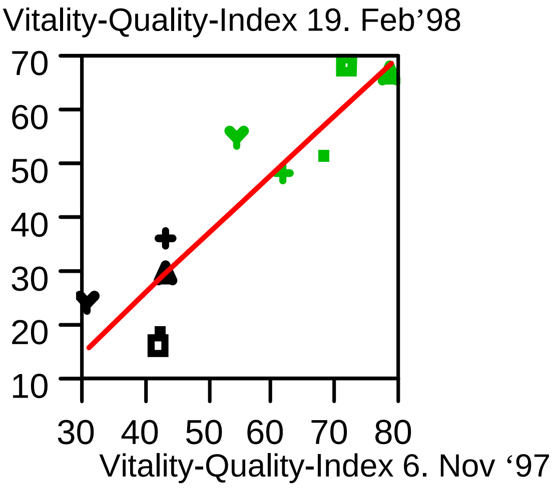

Fig. 1: Reproducebility of the picture forming methods expressed as correlation between the Vitality Quality Index of the same but twice analysed (differently coded) fruit samples.

5. Interesting correlations

The Technical Quality Index that we created to compare in our study standard fruit quality with other parameters assessed with holistic methods, sensory tests, soil etc. correlated each year well with the sensory score (r^2 = 0,85; 0.92; 0,50; Fig. 2), thus, was a relevant and useful parameter for correlation studies.

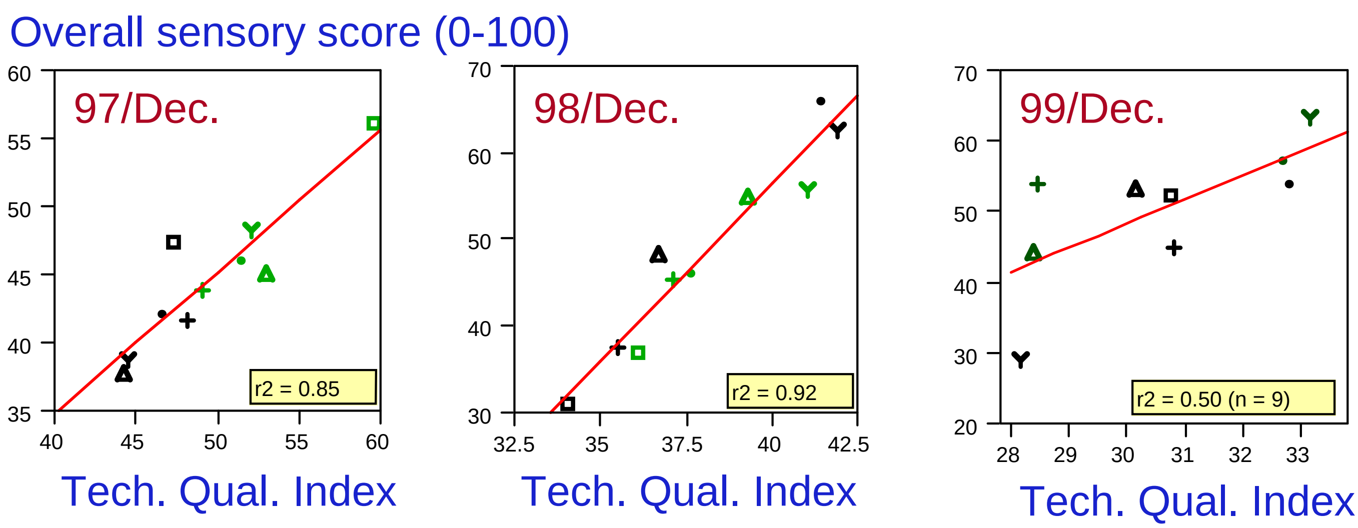

Figure 2.: Correlations between Technical Quality Index and score from sensory panel tests over all three years of the study

In the first year of the study sensorial and technical quality correlated most with the P content which was generally low that year. In the second year, however, P contents were not limiting and Potassium content was more quality decisive (Fig 3). The P content of the fruits in the first year did not correlate significantly to any of the 4 P soil extractions made. However, and excluding one outlier, it correlated fairly well (r^2 = 0.72) with the ratio of microbial bound Nitrogen and Carbon (Fig. 4). The C_{mic}:N_{mic} ratio was significantly lower (indicating higher bacterial activity) by 44 % in the organic tree strips.

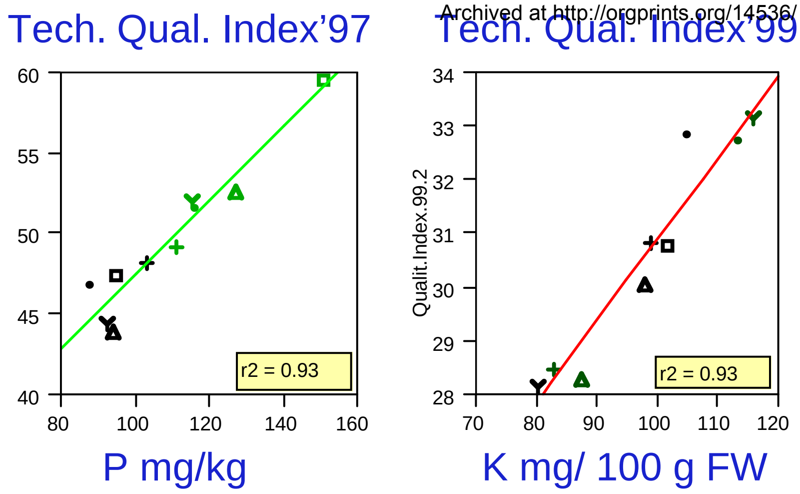

Fig. 3:: Correlations of Technical Quality Index and Phosphorus content (left) of the fruit flesh in the first and with Potassium content (right) in the second year of the study.

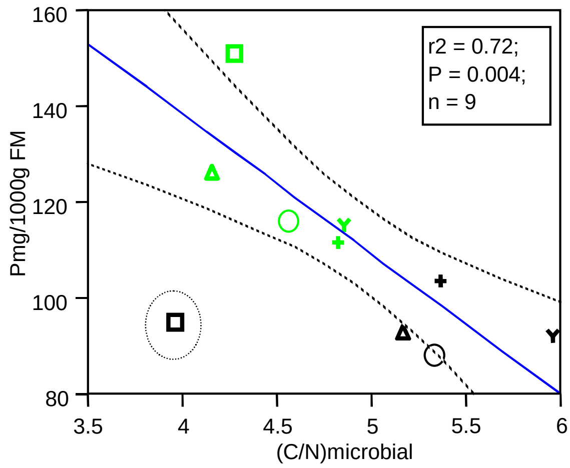

Fig. 4:: Correlations of Phosphorus content in the fruit flesh and the ratio of microbial bound Carbon:Nitrogen in 0-25 cm soil depth in the tree strip (low values are an indication of more intensive bacterial activity).

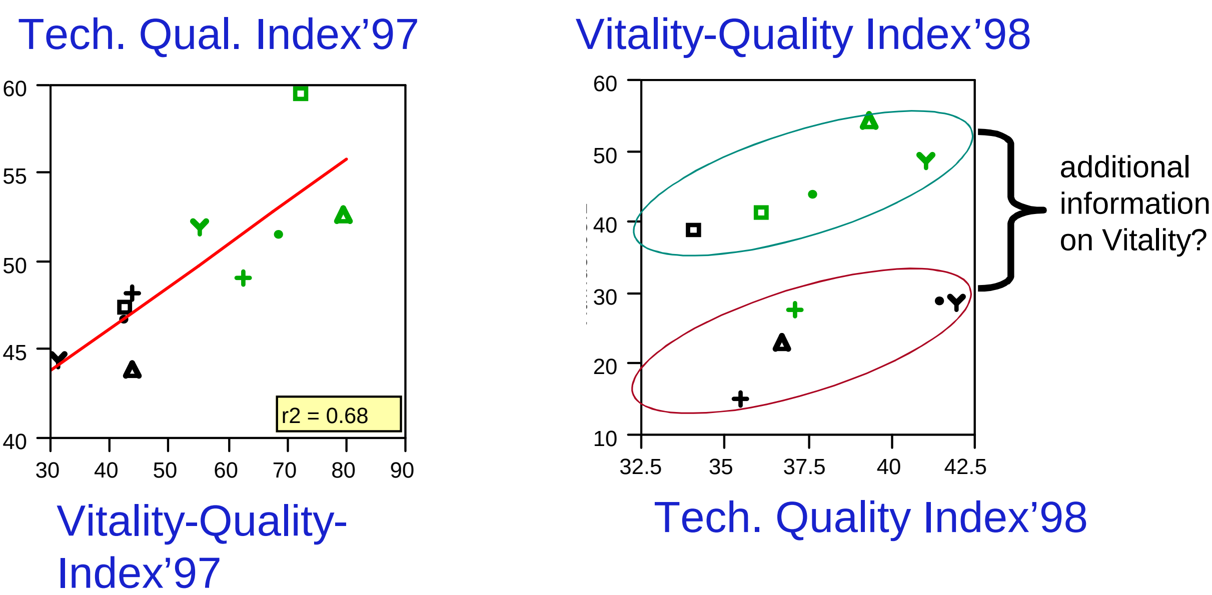

Fig. 5: Correlations between the vitality quality index and the index of technical quality in the first (left) and the second year (right) of the study.

Discussion:

In general the field study done, revealed in a consumer-relevant way that organic apples have a good and in some parameters even high potential for inner quality. This concerns the sensory, the technical and, thinking on fibres and polyphenols, also human-health related aspects. According to Treutter (1998) the differences found with the phenolic compounds are in a remarkable magnitude.

In the first year of the study, Phosphorus content of the fruit flesh was decisive for the inner quality; and we could show an interesting correlation with the microbial activity of the soil. Direct correlations between parameters of soil fertility and food quality are rarely to be found, and are subject of our follow-up studies.

The holistic methods were, in our case, not satisfying with self-degradation and the food preference test with rats. Opposite to humans, the rats reacted more on ripeness, eventually on the ethylene production of the fruits. The picture forming methods, however, revealed a high degree of quality differentiation and a high score (100 and 80 %) to classify correctly the production method. Additionally, the results were well in line with technical and sensorial quality. For a more widely, practical application the method still has some disadvantages (costs, time consuming, interpretation is not (yet) scientifically acknowledged).

Literature

See in: Weibel, F.P., R. Bickel, S. Leuthold, and T. Alföldi. 2000. Are organically grown apple tastier and healthier? A comparative field study using conventional and alternative methods to measure fruit quality, p. 417-427, *In* M. Herregods, ed. Acta Horticulturae, Vol. 517. ISHS, Bruxelles, Belgium.

Acknowledgement

Our special thanks go to the NATURAplan team of Coop Switzerland (F. Wehrle, R. Isella, K. Rapp) who partly financed the project; to the laboratory crew of Coop (S. Raggini) and the Swiss Federal Ministry of Health (BAG, M. Haldimann); to the fruit growers for their competent collaboration (W. Andres, W. Engeli, G. German, T. Kleiber, M. Kleiber, V. Rölli, P. Rutishauser, Th. Schwarz, E. Vogt and P. vd Wahl).