INFLUENCE OF MANAGEMENT PRACTICES ON QUALITY AND BIODIVERSITY OF TOMATOES IN GERMANY

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Abstract

Four old and endangered tomato cultivars were cultivated under greenhouse conditions with different levels of organic N-fertilisation and harvest at different maturity stages in order to develop a conclusive concept to preserve the diversity of old, endangered and multicolour cultivars. First results of several physio-chemical and sensory parameters were analysed to describe product quality. In order to assess consumer acceptance, 550 consumers were interviewed. The individual attributes of the cultivars, which differ in size, shape, colour, taste and health-related, beneficial physio-chemicals, are promoted by optimal harvest time. A combination of these cultivars distributed in regional markets is considered as a suitable concept for saving these endangered cultivars.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most commonly grown vegetables in the world. About 14.4 kg are consumed in German households per year (Statistisches Bundesamt, 1998). Red, round and firm cultivars dominate in mainstream production, and farmer-designed diversity is low. There has been a continuous genetic erosion of agricultural crops in the last few decades. Due to inappropriate management practices and exploitation of old and valuable genetic resources, development of hybrid cultivars to obtain early and remunerative returns is necessary. Undoubtedly, modern hybrid cultivars are uniform in colour and shape and have a longer shelf-life, yet they often have a poor taste. Preserving the diversity of old, endangered, multicolour cultivars rich in flavour and taste for the consumers will definitely help conserving the biodiversity of the tomato crop (KÖPKE, 2003). Since the shelf-life of these cultivars is often limited when the optimal ripening stage is used for harvest, short distribution distances might help to give these endangered cultivars a chance in regional markets.

Methodology

Four tomato cultivars were selected from a large collection of endangered old genotypes. The cultivars *Ananas, Auriga, Green Zebra* and *Lukullus* were cultivated under organic conditions in a greenhouse experiment at the organic research farm 'Wiesengut' in North-Rhine Westphalia, Germany (50°48'N, 7°17'O) in 2004. The experiment was arranged in a three-factorial split plot design with four replications. Plot size was 8 x 5.6 m (44.8 m^2) with 2.5 plants m^{-2}. Treatment factors were cultivar, organic fertiliser level (zero and 100 kg N/ha horn splinter) and harvest time [two different ripening stages, early (comparable with colour no. 8; The Greenery, 2004) and optimum harvest time (comparable with colour no. 12; The Greenery, 2004)]. All cultivars differed in colour, shape, size and maturity. Seven tomatoes (three from *Ananas*) of each variety were analysed to describe general physio-chemical parameters, *viz*. fruit size, shape, colour, average fruit weight, firmness, acidity (by titration), sugar content (enzymatic with test kit) and phyto-chemicals [ascorbic acid (enzymatic with test kit); lutein, chlorophyll b, β-carotene and lycopene (HPLC)]. In order to describe the taste of the cultivars, customer preference was assessed by interviewing more than 550 consumers using a

questionnaire (by semantic differential). Results from chemical analyse were evaluated by analysis of variance (ANOVA, $p<0.05$) using SAS 9.1 for Windows. The significant differences in the analytical data were calculated with the Tukey HSD test ($\alpha = 5$ %).

Results and brief discussion

Ascorbic acid and carotenoids

The red- and orange-coloured cultivars *Lukullus* and *Auriga* had a high concentration of ascorbic acid (23 and 21.9 mg 100 g^{-1}, respectively) compared with the yellow and green cvs. *Ananas* and *Green Zebra* (15.1 and 11.3 mg 100 g^{-1}, respectively) (Table 1). Optimal harvest time gave a higher vitamin C content compared with early harvest. Increased organic nitrogen fertilisation had no influence on vitamin C content, confirming other results where increased levels of N-fertilisation were shown to have no effect or to decrease the vitamin C content of many fruits and vegetables (Köpke, 2005).

The highest concentrations of chlorophyll b and lycopene were found in *Lukullus,* while *Auriga* had the highest concentration of β-carotene. No β-carotene or lycopene was detected in *Green Zebra.* Nitrogen fertilisation had no significant influence on chlorophyll b and β-carotene, whereas lycopene content was significantly increased by organic N-fertilisation. No significant interactions between the experimental factors and ascorbic acid or carotenoid content were noted.

Table 1: Effect of cultivars, harvest time and organic N-fertilisation on ascorbic acid and carotenoids (lutein, chlorophyll b, ß-carotene and lycopene) content of tomatoes (mg $100g^{-1}$FM). (Tukey-test)

	Phytochemicals				
Treatments	**Ascorbic Acid**	**Lutein**	**Chlorophyll b**	**ß-carotene**	**Lycopene**
Ananas	15.1 b	0.0 a	0.0 b	0.4 c	2.0 b
Auriga	21.9 a	0.0 a	0.2 c	4.8 a	1.2 c
Green Zebra	11.3 c	0.1 a	0.4 b	0.0 d	0.0 d
Lukullus	23.0 a	0.1 a	0.5 a	0.8 b	8.9 a
with fertilizer	18.0 a	0.1 a	0.3 a	1.5 a	3.3 a
without fertilizer	17.4 a	0.1 a	0.2 a	1.5 a	2.9 b
early harvest	16.9 b				
optimum harvest	18.6 a	Only optimal harvested tomatoes were analysed			

Citric acid and sugar content

The citric acid concentration of the four cultivars showed a large variation and was significantly different (Table 2). *Auriga* had the highest concentration (0.48 g $100g^{-1}$) followed by *Green Zebra* (0.43 g $100g^{-1}$), while *Lukullus* and *Ananas* exhibited a lower citric acid content (0.25 and 0.20 g $100g^{-1}$). The average content of citric acid given in the literature is 0.44 g $100g^{-1}$ (Souci *et al*., 1994). Neither organic N-fertilisation nor harvest time resulted in significant influence on citric acid. No significant interactions between the experimental factors were observed for citric acid content.

Table 2: Effect of cultivars and different harvest times on the citric acid and sugar (glucose, fructose, total) content of tomatoes (g $100g^{-1}$FM). (Tukey-test)

	Ingredients			
Treatments	**Citric Acid**	**Glucose**	**Fructose**	**Total Sugar**
Ananas	0.20 d	3.25 a	3.91 a	7.15 a
Auriga	0.48 a	1.25 c	1.90 b	3.15 c
Green Zebra	0.43 b	1.54 bc	1.71 b	3.25 c
Lukullus	0.25 c	1.88 b	1.97 b	3.85 b
with fertilizer	0.34 a	1.97 a	2.37 a	4.34 a
without fertilizer	0.34 a	1.99 a	2.39 a	4.35 a
optimal harvest	0.33 a	2.01 a	2.56 a	4.65 a
early harvest	0.34 a	1.84 a	2.18 b	4.05 a

The cultivar *Ananas* had the highest glucose content (3.25 g $100g^{-1}$). The other three cultivars had a lower concentration, whilst *Lukullus* (1.88 g $100g^{-1}$) showed a significant difference to *Auriga* (1.25 g

$100g^{-1}$) but not to *Green Zebra* (1.54 g $100g^{-1}$). The harvest time had no influence on glucose content. A similar result was gained for the fructose content. The cultivar *Ananas* had the highest fructose concentration (3.91 g $100g^{-1}$) while *Lukullus*, *Auriga* and *Green Zebra* had lower contents and were not significantly different (1.97 g $100g^{-1}$, 1.90 g $100g^{-1}$ and 1.71 g $100g^{-1}$, respectively). The sugar content of these three cultivars is comparable with results from Auerwald *et al*. (1999). Whether the high sugar content of *Ananas* can be confirmed will be shown in the following trials. One possible reason could be the high share of pericarp in this cultivar, because the sugar content of the pericarp is higher compared with that of the lucolar (Winsor *et al*., 1962; Stevens *et al*., 1977). In contrast to the results determinated for glucose, the optimal harvest gave a higher fructose content compared with early harvest. This difference is attributed to the high fructose content in *Ananas*, where the optimal harvest (4.66 g $100g^{-1}$) is significant to the early harvest (3.16 g $100g^{-1}$). The other three cultivars did not differ significantly.

Consumer survey

The cultivar *Ananas* was characterised as a sweet and smooth tomato with an appealing appearance. The high glucose and fructose content and the low citric acid content (Table 2) support the test results from the consumers (Figure 1). A high sugar content and low acid content generally result in a bland taste (Atherton and Rudich 1994). The sensoric attributes of *Auriga* were described as aromatic and flavoursome. The peel was felt as harder and a little bit firmer in comparison to the other cultivars. The high citric acid content and the low sugar content were not described by the consumers. A possible reason for this were other secondary metabolites, which were responsible for a sweeter taste sensation.

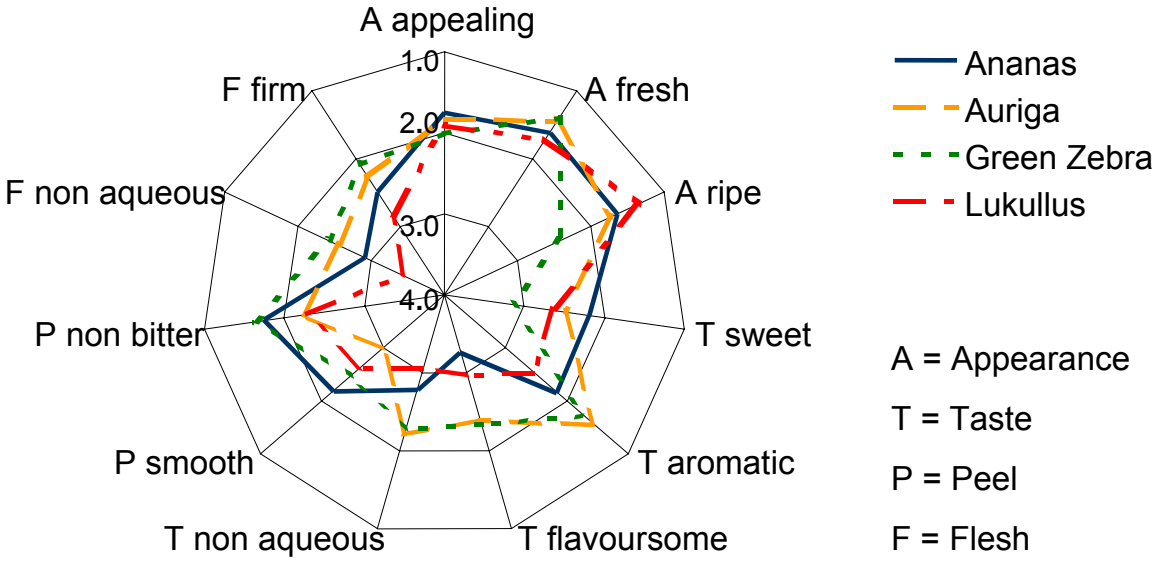

Figure 1: Radar diagram of the consumer survey given by 550 interviewed persons in a range between 1 (very good/ preferred) to 6 (very bad/rejected) on the four cultivars *Ananas*, *Auriga*, *Green Zebra* and *Lukullus*.

Green Zebra was identified and ranked as acidic and aromatic, additionally as a rather immature fruit due to its green colour. Nevertheless, the consumers described the appearance as appealing and the high citric acid and the low sugar content were confirmed. *Lukullus* was described as soft and a little bit aqueous, thus this cultivar had no true tomato taste. The relative high sugar contents were not identified in the tasting. The consumers generally scored *Auriga* as the best tomato with respect to flavour and taste.

Conclusions

With an average yield of 12 kg m^{-2} these old cultivars were competitive with those tomato cultivars currently dominating the organic market (Lindner, 2004; Koller, 2005). The cultivars *Lukullus* and *Auriga* contained the highest concentration of various health-promoting phytochemicals (ascorbic

acid, β-carotene and lycopene). *Auriga* and *Green Zebra* had the highest citric acid content, while *Ananas* showed the highest sugar concentration. The management practices (fertiliser and harvest time) had no evident influence on the analysed ingredients. The consumers characterised the cultivar *Ananas* as sweet and smooth while *Green Zebra* was characterised as more aromatic.

Each of the multicoloured cultivars has its typical properties. Therefore, we recommend a set of the different tomato cultivars to be sold and prepared in order to combine flavour, taste and shape with higher concentrations of beneficial phytochemicals. Furthermore, this strategy applied in regional markets could guarantee biodiversity in tomatoes through organic farming under economic conditions.

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References

Atherton, J.G. and Rudich J. (1994) *The Tomato Crop*, Chapman & Hall, London.

Auerwald, H., Schwarz, D., Kornelson C., Krumbein, A., Brückner, B., (1999) Sensory analysis, sugar and acid content of tomato at different EC values of the nutrient solution. *Scientia Horticulurae*. 82, 227-242

Koller, M., Vieweger, A., und Lichtenhahn, M. (2005) Sortenversuche im Biogemüsebau 2004 - Zwischenresultate [Variety trials in organic vegetable production 2004 - First results]. FiBL-Merkblatt, Forschungsinstitut für biologischen Landbau (FiBL), Frick, Schweiz.

Köpke, U. (2003) Influence of organic and conventional farming systems on the nutritional quality of food. In *Impact of Agriculture on Human Health and Nutrition*. In Cakmak, I. and Welch, R.M., (eds.) in *Encyclopaedia of Life Support Systems* (EOLSS). Developed under the auspices of the UNESCO, EOLSS Publisher, Oxford, UK. [http://www.eolss.net]

Köpke, U. (2005) Organic foods: do they have a role? In Elmadfa I. (ed.), in *Diet Diversification and Health Promotion*, in *Forum of Nutrition*. 57, 62-72 Karger, Basel.

Lindner, U. (2004) ‚Egmont' im Ertrag bei Öko-Tomaten am besten. In *Leitbetriebe Ökologischer Landbau in Nordrhein-Westfalen, Versuchsbericht 2004* (in print)

Statistisches Bundesamt (1998) Fachserie 15. (EVS) *Einkommens- und Verbrauchsstichproben*, Heft 3.

Stevens, M.A, Kader, A.A., Albright-Holton, M. (1977) Intercultivar Variation in Composition of Lucolar and Pericarp Portions of Fresh Market Tomatoes. *Journal of the American Society for Horticultural Science*. 105, 689-692

Souci, S.W., Fachmann, W., Kraut, H. (1994) *Food Composition and Nutrition Tables*, 5th edition, p. 895. CRC Press, Boca Raton, Ann Arbor, London, Tokyo.

The Greenery (2004) Kleur Stadia Tomaten, Breda

Winsor, G.W., Davies, J.N. and Massey, D. M. (1996) Composition of tomato fruit. III. Juices from whole fruit and locules at different stages of riping. *Journal of the Science of Food and Agriculture*. 13, 108