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The quality of organic food

CONTENTS

Preface

The Special Issues of the Genetic Engineering Newsletter published several times per year normally deal with specific aspects of genetic engineering in agriculture. This issue is concerned with an alternative to agricultural genetic engineering, namely organic farming.

Organic farming fulfils numerous attributes that consumers desire in food fabrication. The process of food production in organic farming preserves the environment, landscape and resources. Animals are kept in their natural environment. Hence many consumers regard organic food as tastier, healthier and safer than conventionally grown products. This Special Issue is concerned with the question whether the higher *process quality* in organic farming results in a higher *product quality*. So far there are only few reliable results on the field of quality research in food from different production systems. This issue is therefore limited to fruits and vegetables.

Terminology

Characteristics of **conventional agriculture** are an intensive use of soil, separated stock farming and crop husbandry, high commitment of capital and energy and monocropping. Application of mineral nitrogen fertiliser is permitted, growth regulators are commonly used. In plant protection all actions that are permitted by law are taken to prevent damage. The product quantity, the suitability for processing and the market quality of the food are the dominant criteria. Genetic engineering is allowed.

Organic farming stands for closed economic circuits. Sparing non-renewable resources is a top priority. Further characteristics are crop rotation and preserving soil treatment, green manuring etc. which improves the natural fertility of the soil. Application of mineral nitrogen fertiliser is strictly regularised. Synthetic pesticides are prohibited. The production aims for system quality and high food quality. Genetic engineering is interdicted.

Process quality records and evaluates the cumulative environmental effects from production to processing of the produce. This includes a variety of aspects, e.g. soil, water, air, energy and biodiversity. Altogether organic farming displays a higher process quality in these fields than conventional agriculture. The intensive application of fertilisers and plant protecting agents in conventional farming for instance has a negative impact on water quality, since nitrate and pesticides pollute ground and surface water. The nitrate load abets eutrophication (accumulation of nutrients in water), that leads to a decline of the numbers of species in waterbodies. Organically managed soils have greater humus contents, higher physical stability and better water retention capacity. Nutrients are recycled faster. Crop rotation and inhibition of synthetic pesticides in organic farming contribute to the biodiversity of agricultural as well as field flora and fauna.

Examinations of food quality

The quality of food can be measured with different criteria. In the following, the legal standards of food quality, the nutritional and sensory quality of organically grown food in comparison with conventionally grown products will be discussed.

In past years intensive research has shown that the overall quality of vegetable products depends much more on the cultivar, the local conditions and the climate than on specific cultivation parameters (Ehrenbergerova et al., 1997; Varga et al., 2000). A quality oriented production in conventional as well as in organic farming should therefore avail itself of adequate cultivars. Furthermore there are factors that contaminate all kinds of plants independent of the cultivation such as Dioxin, heavy metals and obsolete but persistent pesticides (Lindan, DDT, PCB etc.). Again the toxic loading of the agricultural products decisively depends on the location and the former land use.

Legal regulations

A range of different laws and regulations is in place to ensure food quality. Among others the Foodstuffs and Commodities Act (Lebensmittel- und Bedarfsgegenständegesetz, LMBG) as well as national and European regulations are to guarantee the safeness of food and to protect consumers against fraud. Additionally, organic products are subject to the restrictions of the European eco regulation (Öko-Verordnung, EWG 2092/91).

The Maximum Residue Level Regulation (Rückstands-Höchstmengenverordnung, RHmV) clearly defines, which amount of a given pesticide is permitted in vegetable products. Organic cultivation however works without synthetic plant protectants. Although pesticide driftage from conventional acreage can pollute organic fields as well, organic vegetables are significantly less loaded than conventional ones. The eco monitoring 2002 of the Land Baden-Württemberg (Ökomonitoring, Amt für Lebensmittelüberwachung und Tiergesundheit, 2002) proved that 93 % of the analysed organic food contained no detectable pesticide residues. Residues of different pesticides almost never occur in organic vegetables. The few samples with detectable residues are normally imported from foreign countries over several trade levels. In contrast conventionally grown vegetables often contain residues (75 % of the tested vegetables in the year 2002) – even from different pesticides. The allowed maximum levels however are rarely exceeded and depend strongly on the kind of vegetable. The journal Öko-Test for instance found out that 50 % of the analysed paprika contained more than the allowed amount of pesticide residues. Paprika from controlled organic cultivation were nearly free of residues (Öko-Test, 2002). A pesticide analysis of spring strawberries in February 2004 showed that 10 % of the conventionally grown berries exceeded the allowed maximum level of pesticide residues. Only 19 % were free of residues. In the analysed organic strawberries no residues were detected (Krautter, 2004).

The nitrate content plays an important role especially for vegetables and leaf salads. Vegetables are polluted by nitrate mainly through nitrogen fertilising in conventional agriculture. Normally, conventionally grown products therefore contain more nitrate than ecological food. In the human body nitrate is converted into nitrite that can form carcinogenic nitrosamines. The World Health Organisation WHO thus recommends that a daily intake of 3.65 mg nitrate per kg body weight should not be exceeded. A 50 kg person can already exceed this dose by eating a large portion of winter lettuce. Baby food is subject to the stronger legal constraints of the Diet Regulation (Diätverordnung, DiätV) and has therefore already been produced by organic production for a long time.

Heavy metals enter agriculturally used areas through exhausts of road traffic and industry as well as through sludge that is used for manuring. Maximum allowable amounts are defined by the European regulation EG 466/2001. Heavy metals in the atmosphere affect all agricultural products in equal measure. The application of sludge however is prohibited in organic farming so that in principle the load of heavy metals is lower. Detailed examinations are lacking though. Additionally, the concentration of heavy metals strongly depends on the particular location and the previous land use.

Pathogenic germs (e. g. salmonellae, *E. coli*) can basically appear both in conventional and organic production processes. It is commonly assumed that the risk of infection with pathogenic germs is higher in organic farming. This is based on the assumption that the ban on chemically synthesised fungicides advantages the fungal contamination. In recent investigations however only 1.5 % of the organically grown vegetable samples contained pathogenic germs (Sagoo, 2001). This confirms the hypothesis of the British consumer organisation Food Standards Agency that with good practice in agriculture products are free from pathogenic microorganisms.

Nutritional quality

The nutritional value of food is defined by the contents of energy and nutrients, for instance proteins, fats, carbohydrates, vitamins and mineral nutrients. Dietary fibres (indigestible parts of vegetable food, e. g. paring, cell walls, structural substances) and the so-called secondary plant compounds (see below) also play a role for a plant's nutritional value. However, the dietary impact of many compounds is still unknown. In general, there is a great need for research, as to what extent organically grown products differ from conventional food concerning these substances. The existing research results are contradictory and do not allow clear conclusions.

Organic produce definitely show larger amounts of dry mass due to fewer fertilising resulting in lower nitrogen availability (Sorensen et al., 1996). Consequently all substances are present in higher concentrations. Thus an organic apple comprises more valuable substances than one of the same weight that is conventionally grown.

In the following, some of the results of an overview survey about the quality of organic food (Heaton, 2001) are briefly described:

- Regarding the contents of the vitamins A, B_1, B_2 and B_6 there are no significant differences between the two cultivation methods, although higher nitrogen supply can increase the concentration of provitamin A and thiamine (precursors for the vitamins A and B_1).
- In some organically grown fruits and vegetables (especially spinach and leaf salads) the amount of vitamin C is increased. This could also be due to the higher nitrogen supply in conventional cultivation.
- In half of the surveys organic products contained more mineral nutrients. In particular the amount of iron tends to be higher. There is no explanation for these findings so far. Conventionally grown vegetables, due to mineral fertilising, show higher contents of potassium and phosphorus.

Secondary plant compounds are substances that occur only in certain plant cells. They are essential for the cell itself, but they can be helpful for the organism as a whole. Examples are blossom pigments, scents and structural substances. Naturally occurring concentrations of secondary plant compounds are generally assumed to be health conducive or even curing. They stimulate the immune system, have antioxidative, antibacterial and antiviral effects and reduce high blood pressure (Lampe, 1999). Thus, a high content of secondary plant compounds in vegetables is desirable.

Bioactive substances such as secondary plant compounds are synthesised in plants during maturation and particularly as a reaction to external stress, for example fungal infections, strong sun exposure, drought and atmospheric ozone. Nitrogen supply is also relevant. Organic produce usually have a shorter maturation period (because there is no oversupply of nitrogen) but are more matured. As synthetic chemical pesticides are not used, plants are more often exposed to pests and insects. Therefore higher contents of secondary plant compounds in organic food are assumed (Brandt et al., 2001). Several surveys endorse this assumption: tomatoes show higher concentrations of carotenoids (Pither et al., 1990), in broccoli two to six times higher contents of presumably cancer protective sulforaphan were observed (Adam, 2002), potatoes contained 10 % more polyphenols (Hamouz et al., 1999).

However, the biosynthesis of secondary plant compounds not only depends on the cultivation method but also on the varieties and local conditions. Furthermore, the analysis and quantification of single substances is not sufficient for the evaluation of the nutritional value. Metabolism paths in plants are complex. Synergistic and additive effects cannot be detected in simple content quantification. More research work, especially on the bioavailability of secondary plant compounds, is therefore needed.

Sensory quality

For the sensory quality appearance (colour, shape), smell, taste and consistency of products are determining. There are several possibilities to check the food's sensory attributes. Discrimination tests confront test persons (mostly untrained consumers) with three samples of which two are identical. The test persons are asked to define the differing sample. The results show if there is at all a noticeable difference between the samples. Additionally, the test persons can be asked which of the samples they preferred. Sensory analyses can be accomplished by trained test persons that describe and quantify the samples and their taste characteristics according to certain criteria.

The findings of sensory tests comparing conventionally and organically grown vegetables are inconsistent. In a sensory study, Basker (1992) found that on the one hand test persons favoured organic bananas, the same persons however preferred conventionally cultivated mangos. For tomatoes the preference even seems to be depending on the variety (Johansson, 1999). The amount of dry mass in organic produce accounts for higher concentration of all plant ingredients (see above), consequently also of those that are responsible for taste. In sensory tests organic products are therefore frequently described as "sweet" and "characteristic of vegetables" (Bourn, 2002). Due to the lower water content of organic vegetables the texture is often more compact than in conventionally grown food.

There is no consistent pattern in the published examinations concerning the sensory value of organic produce. Moreover it is not clear if there is a connection between the tastiness and the valuable ingredients of fruit and vegetables. It is, however, beyond controversy that development of appetite and readiness for food intake highly depend on the question if a product hits the liking of a consumer. As the consumption of fruit and vegetables can reduce the risk of degenerative diseases (e. g. cardiovascular diseases and cancer) tasty food is desirable particularly in this sector.

Complementary approaches in food quality determination

Aside from analytical chemical approaches for the evaluation of food quality there are numerous alternative methods that do not centre the analysis of single substances but regard foodstuffs as a whole. This approach is based on the proposition that life itself is more than the summation of its single constituent parts. Organisation and structure of food are important factors. Conservation of organisation and structure are signs of high food quality, structure decomposition is a synonym for the plant death. A high organising, architectural level is associated with a high "vital activity" of which living organisms greatly benefit. The aim of the complementary analysing methods is to help characterise the vital activity.

In the following some of the complementary methods and their findings are described. This includes copper chloride crystallisation, ultraweak photon emission, assessment of the post harvest behaviour as well as feeding studies.

Copper chloride crystallisation

Copper chloride crystallisation records the visualising ability of organic compounds. The organic liquid in question (plant juices, milk etc.) is added to an aqueous solution of copper chloride of a certain concentration. The solution is let to crystallise on a plane glass plate. Specific biocrystallograms are formed that are characteristic for each sample material. In the past the crystal patterns were analysed only visually (which required trained persons and high experience), whereas in recent years efforts have been made to develop a computer based texture analysis of the patterns.

Copper chloride crystallisation and other visualising methods (different chromatographic techniques) were adopted in several studies comparing different cultivation systems. Trained persons were able to discriminate between encoded product samples of organic and conventional growing. The Swiss Research Institute of Organic Agriculture (Forschungsinstitut für Biologischen Landbau, FiBL) compared the crystal patterns of apples of the Golden Delicious variety from organic-dynamic and conventional cultivation. The organic apples showed thin, widely branched crystal needles that densely covered the glass plate whereas the conventionally grown apples built a coarser crystal pattern and thicker needles.[1]

In spite of such achievements there is a lack of fundamental research work on selectivity, reproducibility and precision of these techniques. In a recent research project of the university of Kassel, however, scientists validated the copper chloride crystallisation according to the international standard ISO 17025. They were able to show significant differences in cultivation systems by assessing organic and conventional carrots and wheat (Informationsdienst Wissenschaft, 2004). The methods are still to be revised and refined but in future copper chloride crystallisation could provide valuable evidence of the products' origin.

Ultraweak photon emission

Ultraweak photon emission (also biophoton emission) refers to the phenomenon that after illuminating (optical excitation) with a light source all vegetable matter emits radiation of low intensity. For quality assessments in food the intensity of the radiation is measured over a certain period of time (mostly 10 seconds) after illumination. As time proceeds the light emission is slowly dying out (delayed

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[1] Pictures of the crystal patterns can be viewed on the internet: http://www.fibl.net/forschung/anbautechnik-mehrjaehrig/obstqualitaet.php#kristall

luminescence, DL), whereby intensity and dying out kinetic of the emitted radiation vary depending on the analysed material.

The first research on the discrimination of different cultivation methods by ultraweak photon emission have already been carried out 20 years ago. Initially white light was used for the optical excitation. But the findings were inconsistent. Not until the excitation was performed using different colours, stable results were obtained. Seeds for example irradiate more intensely when excited by blue light. Red and yellow light only trigger weak emission. Additional spectral evaluation therefore facilitates by far more detailed interpretation.

At present, the method allows the discrimination of samples of the same variety. Among others calendula seeds (Strube et al., 2001), apples (Strube et al., 2002), and white beans (Strube et al., 2000) were analysed. In a blind trial conventionally grown calendula seeds were successfully distinguished from those organically cultivated. The latter irradiated significantly weaker after excitation with yellow or red light, which can be interpreted as a better seed characteristic. Likewise apples were arrayed in a blind trial according to different stages of maturation. The riper the apples are, the stronger is the “vegetal” characteristic, i. e. the more intensive is the light emission after illumination with red and yellow light. Furthermore beans were significantly discriminated comparing hydroponics and soil cultivation.

In the holistic approach of food research the light emission is an indicator for the energy accumulated in living cells. The ability to accumulate energy, shown as a dying out trajectory or high photon counting rate, is a sign for high survival quality (Velimirov, 2003). According to Strube, a strong blue signal of the exciting spectrum points towards lifelessness. On the contrary, a widebanded excitation spectrum points towards vegetable origin. Seeds representing the “reposing form” of plants, lie in between the two concerning their exciting properties. A narrow excitation and a strong blue signal are thus signs of a distinct dormancy that is considered to be quality rising. An increasingly wide excitation spectra for example in the maturation process of apples is traced back to a stronger “internal differentiation” and is interpreted as a rising performance of organisation of the plant.

Meanwhile the method is increasingly being used. So far it is proven to be relatively reliable concerning the discrimination of food grown in different cultivation manners. Nonetheless, there is a significant lack in fundamental work on the precision, stability and reproducibility of the method as well as on basic physical and chemical principles of the measured differences. For instance, there is little known about the origin of fluorescence in plants. A connection with chlorophyll and other compounds of the photosynthesis system is though assumed (Lichtenthaler et al., 2000).

Both techniques, biophoton emission and copper chloride crystallisation, can thus prove differences between the different cultivation methods. It is, however, widely unknown which factors influence the “visualising ability” and what causes these differences. Estimating the *quality* of food based on these methods still seems to be difficult. But the possibility to distinguish agricultural commodities according to their cultivation could in future contribute to the consumer’s safety.

Post harvest management

To control the post harvest behaviour, the water and substance losses, the accumulation of noxious substances (nitrate, amines, mykotoxins, …) and the sensitivity to microbial infections are analysed. Furthermore, it is possible to characterise the stocking behaviour by means of degradation and conversion of contained compounds as well as the consistency (e.g. solidity). Post harvest treatments like artificial waxing or application of fungicides to reduce the losses during stocking are common in conventional farming. The stocking capability of organically grown products is seen as a quality aspect determined by the product itself. The post harvest behaviour is therefore directly related to the environmental and growth conditions of the plant.

According to Ahrens (1988) a high tissue and paring solidity, a high amount of dry mass and high vitamin and sugar levels enhance stocking abilities. Negative effects on the stocking ability are caused by high nitrogen and nitrate levels. Hence, a better post harvest behaviour for organic products can be assumed. In accordance with this assumption different studies (Ahrens, 1988) have shown that organically grown products perform better concerning vitiation and shrinkage. Furthermore, organic products metabolise Vitamin C more slowly and have lesser microorganisms on the surface.

Post harvest behaviour as a criteria for quality assessments of vegetable products is used (too) sparsely at present. Findings can be, however, directly linked to health and sensory values. Detailed studies on this topic are thus reasonable and useful.

Feeding studies

Feeding experiments study the impact of food on the instinctive feeding attitude of animals (rats, rabbits, chicken). The laboratory animals can choose between two congenerous products from organic and conventional cultivation. The preference is determined by the amount of food consumed per day. Omnivorous rats are especially qualified for these experiments because of their choosey feeding habits. Studies reveal that, if presented carrots, beets, wheat and apples, rats prefer organic products (e.g. Edelmüller, 1984, Plochberger, 1989, Velimirov, 2001). The studies did not examine what this preference relies on, though acid and sugar levels of the products seem to play a major role (Velimirov, 2001). Both variants (conventional and organic) in the studies came from the same producing region, but only the experiments with apples and beets compared the same varieties, so that the findings are not clearly interpretable. Feeding studies are not sufficient for a quality comparison between organic and conventional grown plants.

In other feeding experiments a group of laboratory animals is fed with organic vegetables, while the comparison group is fed with produce of conventional farming. The impact of the feed on the constitution of the test animals is studied. This is documented by changes in weight and fertility. Major benefits for the animals fed with organic products were ascertained in most of the comparative surveys. They showed *inter alia* a higher weight increase, higher fertility and lesser miscarriage. The fact that differences in performance occurred primarily in the second and third generation was particularly striking in one long-term study (Staiger, 1986). So far, there is no explanation for this. The finding however reveals, that short-term studies are not sufficient to broadly evaluate the quality of foods by the means of feeding studies.

Genetic Engineering

As a basic principle genetic engineering is not applied in organic farming. But it is possible that there are traces of genetically modified Organisms (GMO), even though this is mostly prevented by the closed cycles in organic farming. Organic farm fields can be contaminated through pollen drift (by wind or insects) from fields planted with genetically modified (GM-) plants as well as through dispersal of transgenic seed or plants. Furthermore, there is risk of seeds being contaminated with GMOs. Fertilizers, plant protecting agents or other adjuvants permitted in organic farming can contain genetically modified components. Transport and processing of organic products provide for further risks of contamination (Nowack Heimgartner et al., 2002). The deliberate use of genetic engineering is thus in principle a special case in the conventional farming. At the moment, there is a controversial discussion going on about the health effects of GMOs.

In the European Union the directive 2001/18/EG regulates the protection of the environment and human and animal health in connection to products containing GMOs or consisting of them. It specifies the approval procedure for the release of GM products, which shall ensure the toxicological and allergological innocuousness of the product. A study of the Austrian Federal Environmental Agency (Umweltbundesamt) (Spök et al., 2002) concludes that legal regulations do not ensure adequate protection from the potential dangers of genetically modified products. Toxicological experiments were only sporadically conducted in the applications analysed in this study. Mostly, the alleged harmlessness was based upon theoretical assumptions. There are no adequate experimental studies concerning the potential allergenic features of GM-products. The main argument for the sanitary harmlessness is the so-called substantial equivalence, thus the assumed fundamental parity of a GMO with an established comparison product. The authors of the study criticise especially the insufficient documentation and traceability of the tests leading to the assumption of substantial equivalence. Altogether, results on the subchronic, mutagenic, reproductiontoxic and ecotoxic impact of GM-products are missing. Furthermore, specific cultivation parameters (variety, fertilisation, soil cultivation, climate, etc) would need to be taken into consideration and must be adjusted to the realistic scenario in the research. Considering the status quo of current research a final judgment about the potential health risks of GM-products is not possible.

Conclusion

So far, it is not possible to compare and finally evaluate the product quality of foods from different production methods. There is a lack of studies, which are able to prove the differences between organic and conventional products in their nutritional values for humans.

However, significant differences between the products of both types of cultivation have in some cases been shown. Organic vegetables and fruits contain only to a small amount residues of pesticides. Though the pesticide residues in conventionally grown products are seldom above the legal maximum level – rendering them harmless by law – organically grown products are much better protected from violations of the Maximum Residue Regulation.

Moreover, organically-grown fruits and vegetables contain much lesser nitrate. The increased level of secondary plant compounds in organic products cannot be finally assessed, as there is, amongst other things, a lack of research in the field of the bioavailability. However, the constitutional effects of the secondary plant compounds are undisputed, so that comparative research would be useful.

So far, chemical-analytical methods are only insufficiently able to discriminate between agricultural products, which were cultivated differently. Complementary analytical methods seem to be able to make such a distinction, but they are currently not scientifically accredited. In future, complementary methods could contribute to the distinction of agricultural products from different cultivation methods, although quality assessment on the basis of "good inner structure and organisation" appears questionable. However, a broad validation of the methods concerning precision, robustness, etc is therefore necessary.

In conclusion, it is important to stress that each product from organic farming contributes to saving resources and protecting the environment due to the way of cultivating and therefore benefits society as a whole. This effect contributes to an individual well-being during food consumption and accordingly can have indirect effects on human health.

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Note:

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