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A Comparison of Organically and Conventionally Grown Foods—Results of a Review of the Relevant Literature

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Abstract: This review is concerned with the summary and evaluation of the results from more than 150 investigations comparing the quality of conventionally and organically produced food or of foods produced with the aid of different fertilisation systems. Cereals, potatoes, vegetables, fruits, wine, beer, bread, cakes and pastries, milk, meat, eggs and honey, as well as products made from them, have been included in the review. Most of the studies evaluated are physicochemical investigations of concentrations of desirable and undesirable ingredients, pesticide residues, contaminants, sensory analyses and feed experiments with animals. Nutritional studies in humans and experiments which used holistic methods of analysis are also included. Since different methods of sampling were used in the investigations, a summary evaluation of individual results is extremely difficult. Even when the sampling methods are of the same type, a great many factors have to be taken into consideration which are not directly related to the production system but which do influence food quality to a large degree. Despite the heterogeneity of the sample material, some differences in quality between products from conventional and organic farming or foods produced with the aid of different fertilisation systems have been identified.

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INTRODUCTION

Given people's growing awareness of health and the environment, public interest is increasingly focusing on the problem of the quality of foods. Considerable attention is being paid to organic farming. Its share and importance in the production of foods in Germany is steadily increasing. Roughly 1% of the total consumption of foods is accounted for at present by organic produce (Meier-Ploeger 1990). The European Union is forecasting an increase to approximately 2·5% by the year 2000 (Bailieux and Scharpe 1994).

Organic products are understood to be all those products which are produced under controlled cultivation conditions in line with the provisions of the EC Regulation on organic farming (for products of plant origin (Verordnung (EWG) 2092/91)) and its supplementary statutory provisions or the guidelines of the various recognised farming associations (holding organisation: International Federation of Organic Movements). Organic products of plant origin are grown without the aid of chemical-synthetic pesticides and largely without the use of readily soluble mineral fertilisers within a diverse range of crop rotation and extensive soil tillage. Sewage sludge and waste compost may not be used as fertilisers. Livestock farming is undertaken in line with

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the needs of the animals and the farm's own feed is used.

Numerous studies confirm that many people believe that organic foods are healthier than conventionally produced foods and that they are produced in a more environmentally compatible manner (Folkers 1983; Baade 1985; Bundesministerium für Jugend, Familie und Gesundheit 1985). This expectation amongst consumers presents science with the task of examining this assumption.

There are three ways of undertaking studies to compare conventionally and organically produced foods (Vetter *et al* 1987):

- market-orientated supply studies,
- surveys, and
- cultivation tests.

Market-orientated supply studies tend to monitor the situation of the consumer. Samples are taken from conventional and alternative shops. This method is relatively easy; a large number of samples can be compared. The disadvantage of this method is that the origin of the samples cannot be identified. The producer is not known and hence there is no information about the conditions under which the food was produced. Differences in ripeness and variety are not normally taken into account. Often, pseudo-organic products are included. Market-orientated supply studies can identify differences between products from varying sources but not which factors are the decisive ones.

Surveys are conducted on products from selected farms with different forms of cultivation for which the production conditions are recorded. A mean number of samples can be examined. Environmental factors such as climate and soil conditions can be made suitable for comparison by selecting neighbouring farms. The disadvantage of this method is that the accuracy of the information given cannot be verified. According to Vetter *et al* (1987), another problem is that it is very difficult to select the farms and fields in such a manner that they truly represent the cultivation forms which are to be compared.

Cultivation tests are often viewed by scientists as the most accurate form of comparative studies. They can ascertain whether foods from different forms of production show differences in quality and also to which kind of cultivation this is attributable. The remaining problem is, however, that the results of these tests only apply to the specific location and farming situations. Only a relatively small number of samples can be examined. In order to make general statements and to examine various orientations of organic and conventional farming, a very large, probably unmanageable, number of tests would be required.

On the whole, it can be said that all the above-mentioned methods for comparative investigations have both advantages and disadvantages and complement each other in terms of the statements they can make.

COMPARATIVE STUDIES

In an extensive literature review (Woese *et al* 1995) more than 150 comparative studies, which were published between 1926 and 1994, on the quality of foods from conventional and organic production or foods produced with the aid of different fertiliser systems were summarised and evaluated. A brief summary of the results of these studies is given below for each of the product groups. The volume of findings should not conceal the fact that many of the comparative studies have general shortcomings irrespective of the food or group of foods under consideration; for example, the number of samples is often very small. This reduces the reliability of the results and does not permit the generalisation and unlimited use of the respective findings.

In market-orientated supply studies in particular, pseudo-organic products were often recorded as well which meant that no clear conclusions can be drawn concerning objective quality differences which exist or do not exist between the products from the various cultivation forms. In this case the results merely offer an orientation. They illustrate the market situation facing the consumer in which genuine organic products are on offer side-by-side with pseudo-organic products.

The above-mentioned study (Woese *et al* 1995) compiles findings from comparative studies spanning several decades. During this period, organic farming methods did not change very much in respect of the use of fertilisers and pesticides. 'Conventional' farming is not characterised by clear provisions. The cultivation measures were, however, increasingly oriented towards the sparing and optimum use of chemical agents. Hence, there were probably major differences between the conventional cultivation methods in the various tests. However, this is not always clearly recognisable since many studies do not contain enough details about the cultivation methods used.

Often, in cultivation tests no real comparisons of systems are made. Fertilisation tests are merely conducted with organic, mineral and (in some cases) combined organic-mineral fertilisers. This means a further loss of information on factors which influence the ingredients of the products, such as the use of pesticides, different crop rotation, use of biodynamic preparations, etc. The complex nature of the comparison is not maintained. On the other hand, specific developments in the ingredient contents can possibly be attributed to the influence of fertilisation. Difficulties arise when putting together the results of the system comparisons (eg in the case of market-orientated supply studies and surveys) and the pure fertilisation tests.

In many studies there are no details on the variety, age and degree of ripeness of the plant samples. These do, however, influence to a major degree the concentra-

tions of the ingredients and can conceal the effects of the various cultivation forms.

RESULTS OF THE LITERATURE REVIEW

Cereals and cereal products

In the comparative literature review of the Federal Institute for Health Protection of Consumers and Veterinary Medicine (Woese *et al* 1995), 30 physicochemical studies are described in which the nutritional quality and processing properties of cereals and cereal products were compared from conventional and organic production or using different fertilisation systems.

Comparative studies on the pesticide content of cereals and cereal products do not permit any general statements because of many shortcomings in the test design and evaluation.

In comparative studies on heavy metal content, no clear differences were observed between the products from the various cultivation systems. Only one survey observed that the cadmium content in malting barley was significantly higher in conventional cultivation than in the samples from organic farming (Kjer 1993).

Based on the data available on the content of mineral substances (eight studies) and the content of vitamin B (two studies), no differences could be determined between the samples from conventional and organic cultivation.

In respect of the protein content of cereals, mainly wheat and rye, there was a trend to lower values in the organically produced or organically fertilised harvested products (19 studies, for references see Woese *et al* (1995)). Particularly in the case of wheat this leads to undesirable consequences for baking properties (see below). In the case of malting barley the aim is to achieve a lower protein content in order to promote the storage of carbohydrates.

Only three comparative studies examined the amino acid composition in corn (2 × wheat (Belderok 1978; Steineck and Liebhard 1984), 1 × maize (Wolfson and Shearer 1981). In some cases, major differences were observed between the samples from different cultivation forms. However, general statements on the effects of the cultivation form on the protein-efficiency ratio, which would be important above all for feed grain, are not possible because of the limited scale of the studies.

Only in the product group of cereals and cereal products, was there any larger scale analysis in comparative quality studies of the processing properties in products from conventional and organic production in addition to parameters of nutritional quality. The focus was on comparative studies on the influence of various cultivation systems on the milling and baking quality of wheat and rye.

Baking tests are often used to describe the baking suitability. Indirect parameters which are often selected are protein content, gluten content, sedimentation value (statements on protein level and quality) and the falling number (starch grade and enzyme activity). Other parameters which are of importance when assessing the processing properties of wheat are physical (rheological) dough parameters (farinogram, extensogram) and milling criteria (corn quality, flour yield).

The data evaluated shows that wheat from organic cultivation systems has a reduced protein content. This often has clear effects on its baking quality (which is obvious above all when considering the loaf volume in the test baking). When a suitable variety is selected, however, the baking suitability of wheat from organic production, too, was guaranteed. No effect of the production form on the milling properties could be observed.

The protein content does not play as important a role in baking terms in the case of rye as it does in the case of wheat. Hence, in the comparative studies which were evaluated no major differences could be observed in respect of baking potential despite observed lower protein contents of rye from organic production compared with conventionally produced rye (Seibel 1984; Bolling *et al* 1986; Gerstenkorn 1987).

Potatoes

Twenty two of the reviewed publications evaluated the nutritional value and/or the sensory properties of potatoes from conventional and organic cultivation or from different fertilisation systems.

Up to now, comparative analyses of the contamination of conventional and organic potatoes with pesticide residues have not been conducted on a sufficient scale. The few findings available do not permit any conclusions about the cultivation system.

In respect of contamination with environmental pollutants (eg heavy metals, PCB), too, no clear differences were observed between potatoes from the two production systems (Oberösterreichische Landeskorrespondenz 1982; Niedersächsicher Sozialminister 1983; Vetter *et al* 1983).

No clear differences in the nitrate content of potatoes were found in samples from different origins or there was a slight trend towards a lower nitrate content in organically produced potatoes. The differences in nitrate content are probably due above all to differences in the intensity of fertilisation. But in one cultivation test in which the various fertilisation alternatives were designed to promote the supply of equally large amounts of nitrogen, it was observed that mineral fertilisation had a greater influence on the nitrate content than the alternative with farmyard manure fertilisation (Abele 1987).

Clear differences in the content of minerals or trace elements in connection with the cultivation system could not be derived from the eight studies which were evaluated. Only for phosphorus and potassium Abele (1987) and Matthies (1991) observed higher values in

organically produced or organically fertilised samples than in conventional samples or samples fertilised with mineral manure.

Given the status of the potato as an important source of vitamin C, a relatively large number of the comparative studies evaluated focused on the effects of the cultivation system on vitamin C content. Only in two older studies were slightly lower vitamin C levels observed in organic compared with mineral fertilisation (Wacholder and Nehring 1938, 1940). In all other cases there was either no difference at all or a higher vitamin C content could be determined in organically fertilised or organically produced potatoes.

The results of studies on the contents of starch and dry matter did not reveal any major differences between the different cultivation systems.

As the test findings document, there is a clear trend towards higher crude and pure protein contents in minerally fertilised or conventionally produced potatoes. In most cases the use of readily soluble mineral fertilisers slightly reduced the relative protein content (share of pure protein among crude protein) whereas the concentration of free amino acids increased slightly in some cases.

The six reviewed comparative studies to examine the sensory quality of potatoes from different cultivation systems, if mentioned, were conducted with trained investigators. In these tests sensory differences were noticed between the different kinds of potatoes but no clear statements could be made on the whole in favour of one cultivation from (Svec *et al* 1976; Pettersson 1977, 1982; Koepf *et al* 1980; Dlouhy 1977, 1981, 1990; Zenz 1982; Vetter *et al* 1983; Matthies 1991).

Vegetables and vegetable products

Seventy of the studies which were evaluated involved a quality comparison of vegetables and vegetable products from conventional and organic production.

More than half of the comparative studies evaluated, which addressed the contamination of harvested crops with residues, had shortcomings which meant that unlimited use of the findings was not advisable. The number of samples is normally so small that general statements cannot be made. In the five market-orientated supply studies or the combined studies/surveys, pseudo-organic products were also included which means that the results do not truly reflect the actual situation concerning the quality of vegetables and vegetable products from conventional and organic production. Often, the test descriptions did not contain any details about the pesticides or metabolites for which the products had been analysed.

Given the above-mentioned shortcomings, it can be said on the basis of the material available that there is a slight trend towards lower levels of pesticide residues in vegetables and vegetable products from organic production. Where residues of authorised pesticides were found in conventional products, these were mostly below the statutory maximum amounts. Residue levels in the range between detection limit and maximum limit were determined on a larger scale in conventionally produced vegetables than in organic ones. This is to be expected because of the ban on the utilisation of chemical-synthetic pesticides in organic farming. As a rule, these products did not reveal any exceeding of the maximum amounts and were, if at all, contaminated with traces of persistent active ingredients which seemed to point to existing contamination.

It should be stressed that the statements are backed by a very small number of comparative studies which means that the lower contamination of organic vegetables with residues can only be viewed as a minor trend.

Only three out of the seven studies which sought to determine the degree of contamination of vegetables and vegetable products with heavy metals are available in a form which makes it possible to use the results in a relatively unrestricted manner (Vetter *et al* 1983: Cd and Hg; Niedersächsischer Sozialminister 1983: Pb, Cd and Hg; Pommer and Lepschy 1985: Cd, Cu and Zn). From these limited data it can be deduced that there are no major differences in respect of the levels of the above-mentioned heavy metals between vegetables and vegetable products from conventional and organic production. Nor is this to be expected given the opportunities for uptake into agricultural produce. One exception is cadmium which could reach conventionally produced vegetables via sewage sludge. However, no differences were visible for cadmium in the comparative studies evaluated for the two forms of cultivation.

As was to be expected, there was no difference in the contamination of vegetables and vegetable products from organic and conventional cultivation by polychlorinated biphenyls since these environmental contaminants are present more or less everywhere and uptake into food cannot be influenced by the cultivation form.

Forty-one comparative studies addressed the problem of nitrate content in vegetables and vegetable products from different cultivation forms (for references see Woese *et al* (1995)). Most of the cultivation tests were not designed as real system comparisons of conventional and organic cultivation forms but as fertilisation tests with evaluation of the effects of various organic and mineral types of fertiliser. In some cases, the studies also included combinations of organic and mineral fertilisation which are used in both organic and conventional farming.

On the whole it can be said that despite specific shortcomings in some studies both in the comparison of systems and in the fertilisation tests, there were clear findings confirming a lower nitrate content in vegetables from organic cultivation or vegetables grown with

organic fertilisers. In some cases, this was a minor, in most cases, however, it was a clear and significant difference. Higher nitrate levels in conventionally cultivated crops or those treated with mineral fertilisers were found mainly in leaf, root and tuber vegetables. These types of vegetables, which are known as nitrophillic, were the most frequent subject of study in the data material available.

In the case of other vegetables with a lower nitrate-accumulating potential such as fruit, seed and bulb vegetables, there is a roughly equal number of studies in which no differences in nitrate content were found and the studies in which organic products or organically fertilised products had lower nitrate levels. In only one of the studies which dealt with nitrate in vegetables was a higher content determined in one organic product (Stan 1982). It dealt only with a comparison of one sample of carrots from the two production forms.

No differences were observed in the contents of minerals and trace elements in vegetables between organic and conventional products or between organic and mineral fertilisation. No clear statement is possible for iron content, as in half of the studies, no differences in the corresponding comparative studies were found (Lairon *et al* 1984; Matthies 1991; Lagace *et al* unpublished; Lairon unpublished) and in the other half, organically produced or fertilised vegetables had higher contents (Reuff 1970); Schuphan 1974, 1975; Vetter *et al* 1987; Naredo 1993).

In 27 reviewed comparative studies the contents of vitamins A (or β-carotin), B_1, B_2 and C were determined (for references see Woese *et al* (1995)). No differences were determined on the whole in respect of the first three substances mentioned in organic and conventional cultivation or following mineral and organic fertilisation. Nor were any differences observed when considering individual types or groups of vegetables. As far as the content of vitamin C is concerned, in roughly half of the corresponding studies no major difference was observed but the other half did reveal a trend towards a slightly higher content in organically cultivated vegetables or organically fertilised vegetables. Hence, no clear statement can be made about this constituent. It is noticeable that differences were observed in the vitamin C content above all in leaf vegetables such as lettuce, savoy cabbage, spinach and chard (leaf beet).

No differences between the cultivation forms or fertilisation methods were observed in the examined 17 publications for fructose, glucose and saccharose or for the proportion of monosaccharides in total sugar (for references see Woese *et al* (1995)). There was no clear trend concerning the total sugar contents.

On the whole, no unequivocal trend could be identified in the 13 evaluated studies for the contents of total protein (crude protein), pure protein and relative protein content (share of pure protein among total protein) (for references see Woese *et al* (1995)). Consideration of each individual group of vegetable variety did not produce any clear picture either. There was a trend towards a slightly lower content of free amino acids in organically cultivated or organically fertilised products.

The contents of organic acids were only determined in six cultivation tests (Wilberg 1972; Wedler 1977, 1982; Abele 1987; Kopp *et al* 1989; Reinken *et al* 1990). The parameters were total acid, malic acid, citric acid and oxalic acid. The types of vegetables investigated were spinach, beetroot, carrots, celery and leeks. There was no clear trend in favour of one type of cultivation or fertilisation for any of the above-mentioned parameters.

When determining the dry matter contents, differences did arise between above-ground (leaf vegetables) and below-ground (root and tuber vegetables) plants. Whereas no clear picture emerged for the latter between vegetables from conventional or organic cultivation or mineral and organic fertilisation, a higher content of dry matter could be determined in the case of leaf vegetables (spinach; chard (leaf beet), lettuce, savoy cabbage and white cabbage) in organically produced or organically fertilised plants (Schuphan 1974; Schudel *et al* 1979; El-Saidy 1982; Vetter *et al* 1983; Matthies 1991).

Other ingredients which were determined were the concentrations of betaine in beetroot (Wedler 1982; Abele 1987; Reinken *et al* 1990), mustard oils in white cabbage and leeks (Reinken *et al* 1990), raw fibres in carrots and tomatoes (Kerpen 1988; Evers 1989; Lagace *et al* unpublished), and lycopene in tomatoes (Kopp *et al* 1989). No reliable differences could be established for the above-mentioned substances between the vegetables produced in different ways.

Comparative sensory examinations of vegetables from different cultivation and fertilisation systems were undertaken in 18 studies (for references see Woese *et al* (1995)). Mostly, the investigators were trained test panels. The results from them varied considerably as did the results from tests with untrained persons which means that on the whole no clear trend was recognisable concerning differences in sensory properties between organically and conventionally grown vegetables.

Fruit and fruit products, nuts and nut products and oil seeds

On the whole, very few comparative studies addressed the issue of qualitative differences between fruit, nuts and oil seeds from organic and conventional cultivation. Hence, the spectrum of species examined is also very limited: apples (Naumann and de Haas 1972; Stan 1982; Niedersächsischer Sozialminister 1983; Vetter *et al* 1983; Reinken *et al* 1990), strawberries (Niedersächsischer Sozialminister 1983), oranges and

lemons (Stan 1982), pineapple (Alvarez *et al* 1993), fruit in general (miscellaneous fruits or no further specification) (Reinhard and Wolff 1986; Schüpbach 1986; Chemische Landesuntersuchungsanstalt Stuttgart 1993) and peanut butter (Gilbert and Shepherd 1985). General statements are thus scarcely possible on the basis of the data available. It should be noted that all of the studies examined were system comparisons; pure fertilisation tests were not conducted.

In respect of the contamination of fruit with residues, it can be observed that there is a trend towards lower contents of pesticides in organic products. This corresponds to the findings for vegetables. In most cases, the studies focused on screening for pesticides, the use of which was permitted at the time the studies were conducted. Given the small number of studies, the results should not be overestimated.

The contamination of fruit with heavy metals (Vetter *et al* 1983: Cd, Hg; Niedersächsischer Sozialminister 1983: Pb, Cd, Hg) and PCB (Vetter *et al* 1983; Schüpbach 1986) was examined in only two studies each. No differences were observed concerning the contamination of products from various production forms.

The nitrate concentrations determined in apples and strawberries were very low on the whole and in some cases they were below the detection limit. No differences were found between conventional and organic fruit (Niedersächsischer Sozialminister 1983; Vetter *et al* 1983; Reinken *et al* 1990: only apples).

In respect of important desirable ingredients such as minerals, vitamins (B_1, B_2 and C), carbohydrates, proteins and free amino acids as well as organic acids no major differences could be observed between fruit (apples, pineapples and strawberries) from organic and conventional production (Naumann and de Haas 1972; Vetter *et al* 1983; Reinken *et al* 1990; Alvarez *et al* 1993). The concentration of dry matter and the sensory properties of apples did not differ either (Vetter *et al* 1983; Reinken *et al* 1990).

What is noticeable is that in the case of apples the differences between varieties had a far greater influence on the ingredients than the different cultivation forms (Naumann and de Haas 1972; Reinken *et al* 1990). Similar data comparing the influence of varieties for the other mentioned fruits are not available.

Gilbert and Shepherd (1985) examined aflatoxin contents in peanut butter from alternative and conventional shops. Here, it was shown that products from alternative production had higher contents of total aflatoxin and aflatoxin B_1.

Wine

Five comparative studies examined the quality of wine and grape must from organic and conventional production. They mainly focused on the contamination of plants by pesticides.

There were no significant differences between grape must and wine from organic and conventional production in respect of the concentration of desirable ingredients and parameters such as ethanol, sugar, total acid and extract (Danner 1986; Lutz 1990). It is not generally possible to differentiate between the cultivation methods on the basis of residue levels of common fungicides and insecticides (Danner 1986; Chemisches Untersuchungsamt Koblenz 1990; Lutz 1990; Reinhard 1991; Chemisches Untersuchungsamt Koblenz, about 1989).

Beer

Two comparative studies (Kjer 1993; Taschan *et al* 1993) were evaluated which deal with the quality of beer from alternative and conventional production. The classification of products in the respective production forms differed. Whereas in one study beer from pub breweries was viewed as 'alternative', this description was reserved in the second study for beers with raw materials from orgnic cultivation. On the whole, the results do not lend themselves to compilation and the few results available have been included for reasons of completeness.

Apart from protein content, the beers did not show any differences in desirable ingredients such as original wort, ethanol, bitter agents and fermentation by-products. Furthermore, the contents of nitrate and nitrite and highly volatile halogenated hydrocarbons are the same in alternatively and conventionally produced beer. Beer brewed with organically grown raw material had a lower protein content than beer made from conventionally grown sources. This was due to the lower protein content of the barley used.

On the whole, the small number of comparative studies and the above-mentioned problems on classification meant that no definitive statements can be made on the quality of beers from different production forms.

Bread

Six of the studies which were evaluated had to do with the quality of bread from conventional and alternative production. However, the scale of the studies was mostly limited. On the basis of the data available, no major differences could be determined in connection with the pollutant content and the content of desirable ingredients between conventionally and alternatively produced bread (Stan 1982; Vetter *et al* 1983; Loges and Nöh 1984; Loges and Voss 1984; Meuser *et al* 1984; Ocker 1990).

Sensory tests showed that greater fluctuations were observed in quality characteristics in the case of bread produced with grain from organic origin in the past

than in bread from conventional production (Meuser *et al* 1984; Seibel *et al* 1984).

Generally speaking, it must be borne in mind when evaluating the test results on the nutritional and sensory quality of bread that differences between the samples may be due not only to the different source of the bread grain but above all to the differences in recipe and baking methods.

Milk and dairy products

Nine comparative studies focused on the quality of milk from conventional and organic production (Gedek *et al* 1981; Arnold 1984; Knöppler and Averdunk 1986; Kypke-Hutter 1987; Gravert *et al* 1989; Frank Hansen 1990; Guinot-Thomas *et al* 1991; Chemische Landesuntersuchungsanstalt Stuttgart 1993; Lund 1991). In three studies, there was an additional or sole focus on the quality of dairy products, butter and cheese (Kypke-Hutter 1987; Chemische Landesuntersuchungsanstalt Stuttgart 1993; Staatliche Milchwirtwchaftliche Lehr- und Forschungsanstalt Wangen 1993).

The production forms differed mostly in respect of the feed given to the animals. A major problem was, however, the inclusion of animals of different breeds within the individual studies. Only in one comparative study was care taken to ensure that genetically identical cows were used as milk producers (Gravert *et al* 1989). Gedek *et al* (1981) observed that differences in the contents of various ingredients in the milk from different production forms (eg fat and protein) were probably due to genetic differences between the animals.

On the whole, no major differences have been established between milk from conventional and alternative/organic production in respect of its content of desirable ingredients. Only residues of no longer authorised persistent chlorinated hydrocarbons at the time of the respective studies were determined as residues of pesticides. The contamination of milk from different production forms did not differ. Nor were any greatly differing concentrations of PCB found (Gedek *et al* 1981; Arnold 1984; Knöppler and Averdunk 1986; Kypke-Hutter 1987; Gravert *et al* 1989; Frank Hansen 1990; Guinot-Thomas *et al* 1991; Lund 1991; Chemische Landesuntersuchungsanstalt Stuttgart 1993). Generally speaking, there were not any differences either in respect of microbiological condition, suitability for cheesemaking or sensory properties (Gedek *et al* 1981; Arnold 1984; Knöppler and Averdunk 1986; Gravert *et al* 1989; Frank Hansen 1990; Lund 1991; Guinot-Thomas *et al* 1991; Staatliche Milchwirtschaftliche Lehr-und Forschungsanstalt Wangen 1993).

Milk from alternative/organic production was found to have higher nitrate contents than conventionally produced milk. This parameter, however, was only observed in two studies which means that no general statement is possible (Arnold 1984; Guinot-Thomas *et al* 1991). The concentrations of aflatoxin M_1 were determined in two studies and were lower in organic than in conventional milk (Gravert *et al* 1981; Frank Hansen 1990).

Similar levels of residue concentrations were determined for conventionally and organically produced cheese in a comparative study but differing levels of contamination were determined with biogenic amines (lower concentrations in cheese from organic production).

Meat and meat products

General statements on the quality of meat from animals from different livestock farming and feed forms cannot be made on the basis of the data available from four comparative studies all concerning only pork since they are not uniform at all (Agde and Eidam 1990; Dufey 1992; Chemische Landesuntersuchungsanstalt Stuttgart 1993; Kreuzer *et al* 1994).

The preconditions under which the comparative studies were carried out varied considerably. Whereas in some studies only various livestock farming systems were compared, the differences in the other studies also or only concerned feed. The concept 'alternative meat production' is not clearly defined in this connection.

In alternative meat production methods many factors are different 'compared with conventional production . . . (animal material, composition and nutrient density in feed, livestock farming system, fattening period, final weight, etc). Should a sweeping comparison confirm a real quality difference there would be no way of interpreting the underlying mechanisms of action . . . . Useable findings could only be expected by separating off and varying individual aspects of production coupled with the continuation of all other factors.' (Fischer 1994).

Eggs

The quality of eggs from hens kept in different ways was only considered in one comparative study (Lambing 1992) which means that these results, too, have only been included for reasons of completeness and are not generally applicable.

It has been shown that in the case of genetically identical but differently kept hens there are differences in the contents of protein, lecithin and total carotenoid content in the eggs. The protein content was lower in eggs from hens from free-range husbandry compared with eggs from hens in cages whereas the lecithin values were higher. The higher total carotenoid content in eggs from free-range hens with access to vegetation compared with products from cage, ground or free-range

husbandry without vegetation is due to the additional uptake of carotenoid from grass and green plants.

Honey

Only one comparative study (Taschan unpublished/ Taschan *et al* 1993a) is available on the quality of honey from different production forms. Hence, no general statements can be made.

Differences between products from conventional and alternative production were not observed in the concentrations of desirable ingredients, pesticide residues, veterinary medicinal products or sensory properties.

Nutritional tests

Products from organic and conventional production have not been compared so far in nutritional tests in man. Tests of that kind are very difficult to carry out and evaluate since all the factors which influence human health must be kept constant for the test persons in order to be able to identify the effects of different food sources. In this connection, no attention is paid to genetic differences between the test persons. Altogether, there are major ethical reservations about studies of this kind.

A few experiments from the 1930s and 1940s compared the nutritional quality of vegetables and potatoes exposed to different fertilisers (within the framework of a balanced diet). These studies focused on the effects of the test diet on the general health condition, body weight, proneness to infection, haemogram and the vitamin balance (vitamins A and C).

No differences were observed in experiments with about 260 adolescents (Wendt 1943) and about 300 adults (Reiter *et al* 1938) in respect of the above-mentioned parameters.

In infant food tests (Reiter *et al* 1938; Dost and Schotola 1940; Dost and Schuphan 1944; Dost 1941, 44) with a total of 74 children (given the more sensitive infant organism and the more easily controllable environmental conditions, these tests led to more identifiable reactions to the test diet involving different fertilisers), improvement of nutrition success was observed by use of combined fertilisation with farmyard manure and mineral NPK-fertiliser compared with fertilisation involving farmyard manure alone. Given the relatively limited test scope and the heterogeneity of the test participants, no extensive conclusions can be drawn from these results.

Furthermore, a chemical analysis of the products tested in the infant food test indicated clear differences in the content of desirable ingredients. Vegetables produced with farmyard manure together with mineral NPK-fertiliser had a higher content in caroten (carrots), iron (carrots, parsnips, spinach) and copper (carrots, parsnips, spinach, kohlrabi) compared with vegetables produced with farmyard manure alone (Dost and Schuphan 1944).

Feeding experiments with animals

Twenty two authors described feeding experiments with animals in respect of the comparison of the quality of products of plant origin from organic and conventional agriculture or different fertilisation systems. The oldest study of these was published in 1926. Five different species of animal were used, mainly mammals: rabbits, mice, rats, hens and pigeons.

The fertility of animals often is taken as indicator for unfavourable environmental conditions since it is less strongly genetically determined than other parameters (Scott *et al* 1960; Hahn and Aehnelt 1972; Staiger 1986). In the feeding experiments evaluated, reproduction characteristics were therefore amongst the preferred test criteria. Several studies examined the effects of the test feed on body weight, general health condition and organ weights as well as the feeding behaviour of the animals in the feed selection experiments.

In all three feeding experiments with hens there were differences between the test groups. Two older studies (Pfeiffer and Sabarth 1932, 1934) reported on a higher laying performance of animals who had been given organically fertilised wheat instead of minerally fertilised wheat. In a current, very informative comparison of products from organic and conventional production (Plochberger' 1989) no clear differences could be identified in respect of the weight development of chicks. However, there were significant differences in respect of egg weight and the distribution of the egg components (higher egg weight and higher yolk weight but lower albumen weight when chicks were fed with organic products).

In the 1970s and 1980s rabbits were amongst the preferred test animals for feeding experiments with organically grown products.

In a series of animal tests the same investigation method was used. Whereas the study of various fertility parameters (number of egg cells recovered, development ability of egg cells *in vitro*, histological findings in female genital organs) did produce results in some cases, which indicate major impairment of fertility through the feeding of products exposed to intensive mineral fertilisation (Hahn *et al* 1971; Aehnelt and Hahn 1973), in other studies no clear differences could be recognised concerning these parameters (Bram 1974; Alter 1978; Meinecke 1982). In respect of organ changes in ovaries, uteri and suprarenal glands, which were examined as potential indicators of impairment of the reproduction function through the effects of fertilisation, on the whole any influence by the type of fertilisation could not be clearly proved.

Furthermore, there were major uncertainties in the interpretation of findings of these rabbit feed experiments because (with one exception (Meinecke 1982) no exactly comparable test conditions in respect of feed type and origin could be established in these studies and only a relatively small test scale could be achieved with in some cases not genetically defined animal material.

In three other, extensive studies in rabbits (Gottschewski 1975; Edelmüller 1984; Staiger 1986), the main focus was on mating and rearing results. Contradictory findings were obtained on gestation rate and the size of the litter. Correlating or better results for the animals fed on organic products were obtained in respect of the share of young animals born alive per litter and the rearing losses in both feed groups. An effect of the different cultivation methods on the average weight at birth of the animals was not observed.

In the feed tests with mice (Pfeiffer 1931; von Grone-Gültzow 1931; Scott *et al* 1960; McSheehy 1977; Neudecker 1987) and rats (McCarrison 1926; Scheunert *et al* 1934; Scheunert 1935; Miller and Dema 1958; Neudecker 1987; Plochberger and Velimirov 1992; Velimirov *et al* 1992; Mäder *et al* 1993), fertility and rearing performance of the animals were also to the fore.

Three older studies did observe in some cases positive (McCarrison 1926: greater gain in weight; Pfeiffer 1931: smaller rate of death at the age of up to 9 weeks) and in some cases negative effects (Scheunert *et al* 1934; shorter life span, worse health at the end of the test) of organic fertilisation compared with mineral fertilisation.

Some of the feed tests evaluated with mice and rats focused on a comparison of three different fertilisation alternatives. Here it was observed that feed grown with a combination of mineral and organic fertilisers had different effects on fertility and weaning weight in mice from feed exposed solely to organic or mineral fertilisers (Scott *et al* 1960: smaller number of young born alive, smaller number of young surviving at 21 days; McSheehy 1977: heavier animals at weaning).

The results which have been obtained in more recent feed experiments with mice and rats (Neudecker 1987; Velimirov *et al* 1992) are of special interest in connection with a current evaluation of the situation in the quality of organically and conventionally grown food. No clear differences could be detected in respect of gestation rate and litter weight at the time of birth and weaning and/or the litter size and the birth and weaning weights per young animal. In some cases in litters of animals fed on conventionally produced feed, the share of stillborn young animals and of animals which died shortly after birth was, however, significantly higher.

The feed consumption behaviour of animals (hens, rabbits, mice, rats) was observed in feed selection tests. In five (von Grone-Gültzow 1931: mice; Neudecker 1987: rats; Plochberger 1989: hens; Plochberger and Velimirov 1992: rats; Mäder *et al* 1993: rats) out of six studies (the sixth, Edelmüller 1984: rabbits) it was clearly recognisable that the test animals preferred organically produced products to conventionally produced products. In a further test (Mäder *et al* 1993) with products from three different cultivation systems (organic-biological, biological-dynamic, conventional) in which two varieties of feed were compared, rats showed a significantly higher preference for organic-biologically produced feed. The animals did not, however, differentiate between feed from biological-dynamic and conventional agriculture.

Only the more or less correlative results of the feed selection tests permit a general conclusion: animals distinguish between the foods on offer from the various agricultural systems and almost exclusively prefer organic produce.

The reason for this preference is not known. A possible factor may be a different taste or Neudecker's interpretation as 'additional compensatory consumption' to balance the lower crude protein content in organically fertilised carrots since no effect could be observed on the weight development of the test animals (Neudecker 1987). On the other hand a feed preference of organically grown food in comparison with conventionally grown food was also demonstrated when, according to chemical analysis both met the physiological needs of the test animals (Plochberger and Velimirov 1992).

Further studies

The evaluation of comparative studies, which are based on 'alternative, holistic methods' such as the ascending-imaging method, round filter chromatography and copper chloride crystallisation (Balzer-Graf and Balzer 1988) or the measurement of ultraweak photon emissions (Köhler *et al* 1991; Lambing 1992), is very difficult since the conduct and assessment of these studies require a high degree of practice and experience. The above-mentioned investigation methods are not generally recognised by established scientists. Since, they are, however, used to examine foods from organic cultivation, they were presented here from a neutral angle.

Eleven comparative studies were described. The products involved were vegetables (spinach, radish, beetroot, white cabbage, carrots and tomatoes), potatoes, cereals (wheat), medicinal plants (*Digitalis lanata* and garden sage), beer, milk and eggs.

Altogether it was mostly concluded from the ascending and copper chloride crystallisation images of juices and/or extracts from organically produced or fertilised products that they have a higher form-shaping ability and thus have more vital activity than the corresponding conventionally produced or minerally fertilised foods (Engquist 1961; Balzer-Graf 1987; Balzer-Graf and Balzer 1991; Lieblein 1993). For beer a stronger trend towards the degradation processes

typical of beer was observed in organic products (Kjer 1993).

When using ultraweak photon emission measurements, no clear trend could be observed in the differences between organically and minerally fertilised plants. Differences in the photon emission and in parameters of decay kinetics following light stimulation of samples were observed but not systematically. In one study differences could be observed between the various husbandry systems in respect of the photon emission of eggs from hens which could be attributed to sun exposure or lack of sun exposure (free-range, cage or ground). However, no general conclusions can be drawn from just one study.

In various comparative studies, further analytical methods were used to determine differences and common features in the quality of foods from organic and conventional production. They include, for example, electrochemical, plant physiological and multivariable physico-chemical methods (determination and statistical processing of several analytical parameters), investigation of infection proneness of plants and post-harvest behaviour. Approaches of this kind to the problem of comparing the quality of different production forms have been gaining ground in the last few years and offer new and interesting material for the discussion of quality differences and their detection.

Unfortunately, it was not possible to examine these studies within the framework of the present literature review.

SUMMARY

The results presented concern a literature review of the quality of conventionally or organically produced foods or foods produced with the aid of different fertilisation systems. The review covered more than 150 comparative studies (see Woese *et al* (1995)) on the product groups cereals, potatoes, vegetables, fruit, wine, beer, bread, cakes and pastries, milk, eggs and honey as well as products made from them. Most of the studies evaluated are physico-chemical investigations of concentrations of desirable and undesirable ingredients, pesticide residues and environmental contaminants as well as sensory tests and feed experiments with animals. Furthermore, nutritional studies and investigations using holistic methods of analysis have been included.

Despite difficulties in the compilation and generalisation of results, the overview does reveal some differences in quality between conventionally and organically produced foods or foods produced with the aid of different fertilisation systems.

Conventionally cultivated or minerally fertilised vegetables normally have a far higher nitrate content than organically produced or fertilised vegetables. Higher nitrate contents are to be found above all in what are known as nitrophillic leaf, root and tuber vegetables. A trend towards this difference can also be identified in the case of potatoes.

In respect of the pesticides which are permitted in conventional agriculture, lower residue levels can be expected in both vegetables and fruit from organic production. In the case of conventionally cultivated produce, too, the contents of pesticide residues are almost all below the statutory maximum limits.

Contamination with persistent, chlorinated hydrocarbons, which have been subject to a ban for some time now, do not constitute today for any of the product groups examined a suitable differentiation criterion for products from both production forms.

In the case of vegetables, in particular leaf vegetables, a higher dry matter concentration can be observed in organically grown or organically fertilised products than in conventionally grown or minerally fertilised products.

With regard to all other desirable nutritional values, it was either the case that no major differences were observed in physico-chemical analyses between the products from different production forms or contradictory findings did not permit any clear statements. The same applies to sensory tests.

In the product group cereals, there are differences in terms of processing properties. Given its higher protein content and superior protein quality, conventionally grown or minerally fertilised wheat corresponds better to the common baking requirements.

In feed selection experiments it has been shown that animals differentiate between foods from the various agricultural systems and prefer organic produce. Feed experiments with animals, in which fertility parameters and rearing performance were determined, produced a contradictory picture.

REFERENCES

Abele U 1987 Produktqualität und Düngung—mineralisch, organisch, biologisch-dynamisch. *Schriftenreihe of the German Ministry for Nutrition, Agriculture and Forestry, Reihe A: Angewandte Wissenschaft* (Heft 345). Landwirtschaftsverlag, Münster-Hiltrup, Germany.

Aehnelt E, Hahn J 1973 Fruchtbarkeit der Tiere—eine Möglichkeit zur biologischen Qualitätsprüfung von Futter- und Nahrungsmitteln? *Tieraerztl Umsch* **28** 155–160.

Agde K, Eidam K H 1990 Erste Untersuchungen über den Einfluß extensiver Haltung und Fütterung auf die Mastleistung und Schlachtkörperqualität von Schweinen. *Schweine-Zucht und Schweine-Mast* **38** 42–44.

Alter G 1978 Uber den Einfluß von Fütterungsfaktoren auf das Fruchtbarkeitsgeschehen, den Ascorbinsäuregehalt und den histologischen Aufbau der Ovarien von weiblichen Kaninchen. Dissertation, Tierärztliche Hochschule Hannover, Germany.

Alvarez C E, Carracedo A E, Iglesias E, Martinez M C 1993 Pineapples cultivated by conventional and organic methods in a soil from a banana plantation—A comparative study of soil fertility, plant nutrition and yields. *Biol Agric Hort* **9** 161–171.

Arnold R 1984 Vergleichende Qualitätsuntersuchungen von konventionell und alternativ erzeugter Konsummilch. *Arch Lebensmittelhyg* **35** 66–69.

Baade E 1985 Einstellungen und Verhaltensweisen bei Verbrauchern von 'Bio'-Produkten. *AID-Verbraucherdienst* **30** 245–253.

Bailieux P, Scharpe A 1994 Grünes Europa. Der ökologische Landbau. *Amt für amtliche Veröffentlichungen der Europäischen Gemeinschaften*. Luxemburg.

Balzer-Graf U 1987 Vitalaktivität von Nahrungsmitteln im Spiegel bildschaffender Methoden. *Elemente der Naturwissenschaft* **46** 69–92.

Balzer-Graf U R, Balzer F M 1988 Steigbild und Kupferchloridkristallisation. Spiegel der Vitalaktivität von Lebensmitteln. In: *Lebensmittelqualität—ganzheitliche Methoden und Konzepte* eds Meier-Ploeger A & Vogtmann H CF Müller, Karlsruhe, Germany, pp 162–210.

Balzer-Graf U R, Balzer F M 1991 Milchqualität im Spiegel bildschaffender Methoden. *Lebendige Erde* 236–254.

Belderok B 1978 Infloed van alternatieve landbouwmethoden bij de teelt van tarwe op de voedingswaarde en de verwekingseigenschappen. *Voeding* **39** 352–356.

Bolling H, Gerstenkorn P, Weipert D 1986 Vergleichende Untersuchungen zur Verarbeitungsqualität von alternativ und konventionell angebautem Brotgetreide. *Getreide Mehl Brot* **40** 46–51.

Bram L 1974 Über den Einfluß von Fütterungsfaktoren auf den Ascorbinsäuregehalt und den histologischen Aufbau der Nebennieren von weiblichen Kaninchen unter besonderer Berücksichtigung der Beziehungen zwischen Nebennierenfunktion und Fruchtbarkeit. Dissertation. Tierärztliche Hochschule Hannover, Germany.

Bundesministerium für Jugend, Familie und Gesundheit (ed) 1985 Was erwartet der Verbraucher von Biolebensmitteln? Ergebnisse einer Repräsentativbefragung. *Verbraucherschutz-Report* 1–7.

Chemische Landesuntersuchungsanstalt Stuttgart (ed) 1993 *Jahresbericht 1992*. Stuttgart, Germany, pp 88–118.

Chemisches Untersuchungsamt Koblenz (ed) (about 1989) Untersuchungen auf Rückstände von Pflanzenschutz- und Schädlingsbekämpfungsmitteln. In: *Jahresbericht*. Koblenz, Germany.

Chemisches Untersuchungsamt Koblenz (ed) 1990 Pflanzenschutzmittel-Rückstände. In: *Jahresbericht 1989*. Koblenz, Germany, pp 38–43.

Danner R 1986 Vergleichende Untersuchungen zum konventionellen, organisch-biologischen und biologisch-dynamischen Weinbau. *Mitt Klosterneuburg* **36** 96–100.

Dlouhy J 1977 Qualität pflanzlicher Produkte bei konventionellem und biologisch-dynamischem Anbau. *Lebendige Erde* 181–184.

Dlouhy J 1981 *Alternativa Odlingsformer—Växtprodukters Kvalitet Vid Konventionell Och Biodynamisk Odling* [Summary: Alternative forms of agriculture—quality of plant products from conventional and biodynamic growing] (Rapport 91). Sveriges Lantbruksuniversitet, Uppsala, Sweden.

Dlouhy J 1990 Product quality in alternative agriculture. In: *Food Quality—Concepts and Methodology*. Elm Farm Research Centre, Newbury, UK, pp 30–35.

Dost F H 1941 Ernährungsversuch und Vitaminbestimmungen zum Nachweis von Qualitätsmerkmalen verschieden gedüngter Gärtnereiprodukte. *Monatsschr Kinderheilkd* **86** 322–340.

Dost F H 1944 Ein weiterer Ernährungsversuch zur Prüfung des Einflusses der Düngung auf die Qualität landwirtschaftlicher Produkte. *Monatsschr Kinderheilkd* **93** 310–321.

Dost F H, Schotola H 1940 Eine kritische Stellungnahme von Agrikulturchemie und Medizin zur Frage der alleinigen Stallmistdüngung bei Gemüse.
Teil B: Säuglingsernährungsversuche mit verschieden gedüngten Gartenmöhren und Tomaten (2. Versuch). *Ernaehrung* (*Leipzig*) **5** 37–42.

Dost F H, Schuphan W 1944 Über Ernährungsversuche mit verschieden gedüngten Gemüsen. III. Teil. *Ernaehrung* (*Leipzig*) **9** 1–27.

Dufey P-A 1992 Vergleich unterschiedlicher Mastformen bei Schweinen—Teil 2: Fleischqualität. *Landwirtschaft Schweiz* **5** 581–586.

Edelmüller I 1984 Untersuchungen zur Qualitätserfassung von Produkten aus unterschiedlichen Anbausystemen (biologisch-dynamisch bzw. konventionell) mittels Fütterungsversuchen an Kaninchen. Dissertation, University of Vienna, Austria.

El-Saidy S M 1982 Das Nachernteverhalten von Gemüse, insbesondere Spinat (*Spinacia oleracea* L.) unter besonderer Berücksichtigung der Nitritanreicherung in Abhängigkeit von den Lagerbedingungen und von der Düngung. Dissertation, University Gießen, Germany.

Engqvist M 1961 Struktur-Veränderungen im Kupferchlorid-Kristallisationsbild von Pflanzensubstanzen durch Alterung und Düngung. *Lebendige Erde* 112–113.

Evers A-M 1989 Effects of different fertilization practices on the NO_3-N, N, P, K, Ca, Mg, ash and dietary fibre contents of carrot. *J Agric Sci Finland* **61** 99–111.

Fischer K 1994 Alternativen der Fleischerzeugung. Produktionsformen und Qualitätsaspekte. Teil I. *Fleischwirtschaft* **74** 35–40.

Folkers D 1983 Biologischer Anbau von Obst und Gemüse—Die Einstellung der Bundesbürger. *Ernaehr Umsch* **30** B36.

Frank Hansen L 1990 Characterization of organically produced milk. In: *Alternativ odling No 5—Proc Ecological Agriculture NJF-Seminar 166, Miljövard*. ed Granstedt A. Sveriges Lantbruksuniversitet, Uppsala, Sweden, pp 219–222.

Gedek W, Knöppler H-O, Averdunk G 1981 Vergleichende Qualitätsuntersuchungen von Milch aus landwirtschaftlichen Betrieben mit konventioneller und alternativer Wirtschaftsweise. *Arch Lebensmittelhyg* **32** 149–151.

Gerstenkorn P 1987 Äußere Beschaffenheit sowie Mahl- und Backqualität des auf dem Boschheide Hof erzeugten Brotgetreides. In: *Biologisch-dynamischer Land- und Gartenbau* (Number 44). Forschung und Beratung, Reihe C, pp 230–234.

Gilbert J, Shepherd M J 1985 A survey of aflatoxins in peanut butters, nuts and nut confectionary products by HPLC with fluorescence detection. *Food Add Contam* **2** 171–183.

Gottschewski G H M 1975 Neue Möglichkeiten zur größeren Effizienz der toxikologischen Prüfung von Pestiziden, Rückständen und Herbiziden. *Qual Plant Plant Foods Hum Nutr* **25** 21–42.

Gravert H O, Pabst K, Ordolff D, Treitel U 1989 Milcherzeugung im alternativen Landbau. *Kiel Milchwirtsch Forschungsber* **41** 211–223.

Guinot-Thomas P, Jondreville C, Laurent F 1991 Comparison of milk from farms with biological, conventional and transitional feeding. *Milchwissenschaft* **46** 779–782.

Hahn J, Aehnelt E 1972 Nachweis von schädlichen Nahrungsfaktoren im Kaninchenversuch. *Deutsch Tieraerztl Wochenschr* **79** 155–157.

Hahn J, Aehnelt E, Grunert E, Schiller H, Lengauer E, Schulz L-Cl, Pohlenz J 1971 Uterus- und Ovarbefunde bei Kaninchen nach Fütterung mit Heu von ungedüngtem und intensiv gedüngtem Grünland. *Deutsch Tieraerztl Wochenschr* **78** 114–118.

Kerpen J 1988 Untersuchungen zum Vergleich von Möhren (*Daucus carota* L.) aus ökologischem und konventionellem Landbau. Dissertation, Technische Universität, Berlin, Germany.

Kjer I 1993 Die Qualität von Hopfen und Gerste aus ökologischem Anbau und deren Einfluß auf die Zwischen- und Endprodukte der Bierherstellung. Dissertation, Gesamthochschule Kassel-Witzenhausen, Germany.

Knöppler H-O, Averdunk G 1986 Vergleichende Qualitätsuntersuchungen von konventionell und alternativ erzeugter Kuhmilch. *Arch Lebensmittelhyg* **37** 94–96.

Koepf H, Pettersson D, Schaumann W 1980 Biologisch-dynamische Landwirtschaft. Verlag Eugen Ulmer, Stuttgart, Germany.

Köhler B, Lambing K, Neurohr R, Nagl W, Popp F A, Wahler J 1991 Photonenemission—Eine neue Methode zur Erfassung der 'Qualität' von Lebensmitteln. *Deutsch Lebensm Rundsch* **87** 78–83.

Kopp H-J, Paduch K-D, Gierschner K 1989 Qualitätsuntersuchungen an Gemüse aus konventionellem und alternativem Anbau. In: *Berichtsband XXIV*. Deutsche Gesellschaft für Qualitätsforschung, Vortragstagung, Germany, pp 102–125.

Kreuzer M, Lange M, Köhler P, Jaturasitha S 1994 Schlachtkörper- und Fleischqualität in Markenfleischprogrammen beim Schwein unter Produktionsauflagen mit dem Ziel besonders tiergemäßer Haltung bzw. einer günstigeren Körperfettkonsistenz. *Zuechtungskunde* **66** 136–151.

Kypke-Hutter K 1987 Diskussionsbeitrag. In: *Landbaumethoden und Nahrungsqualität* (*Materialien und Berichte Nr 60*). Akademie für politische Bildung, Tutzing, Germany, pp 6–47.

Lairon D, Termine E, Gautier S, Trouilloud M, Lafont H, Hauton J-Ch 1984 Effects of organical and mineral fertilizations on the contents of vegetables in minerals, vitamin C and nitrates. In: *Proc 5th IFOAM International Scientific Conference at the University of Kassel*. Verlagsgruppe Witzenhausen, Germany, pp 249–260.

Lambing K 1992 Nutzung der 'low-level-luminescence'-Meßtechnik zur Untersuchung von Lebensmitteln. Dissertation. University of Kaiserslautern, Germany.

Lieblein G 1993 Quality and yield of carrots as influenced by composted manure and mineral fertilizer. I. A univariate approach. In: *Quality and Yield of Carrots: Effects of Composted Manure and Mineral Fertilizer*. Doctor theses. Agricultural University of Norway, Department of Horticulture, Norway.

Loges G, Nöh J 1984 Pesticidbelastung von Brot und Brotgetreide bei Erzeugnissen aus herkömmlichem Landbau und alternativem Landbau. *Lebensmittelchem Gerichtl Chem* **38** 46.

Loges G, Voss W 1984 Cadmiumbelastung von Brot und Brotgetreide bei Erzeugnissen aus herkömmlichem Landbau und alternativem Landbau. *Lebensmittelchem Gerichtl Chem* **38** 46–47.

Lund P 1991 Characterization of alternatively produced milk. *Milchwissenschaft* **46** 166–169.

Lutz A 1990 Qualitätswein mit Oko-Prädikat. *Öko-Test-Magazin* **1** 32–41.

Mäder P, Pfiffner L, Niggli U, Balzer U, Balzer F, Plochberger K, Velimirov A, Besson J-M 1993 Effect of three farming systems (bio-dynamic, bio-organic, conventional) on yield and quality of beetroot (*Beta vulgaris* L. var. *esculenta* L.) in a seven year crop rotation. *Acta Hor* **339** 10–31.

Matthies K 1991 Qualitätserfassung pflanzlicher Produkte aus unterschiedlichen Düngungs- und Anbauverfahren. Dissertation, Gesamthochschule Kassel-Witzenhausen, Germany.

McCarrison R 1926 The effect of manurial conditions on the nutritive and vitamin values of millet and wheat. *Ind J Med Res* **14** 351–378.

McSheehy T W 1977 Nutritive value of wheat grown under organic and chemical systems of farming. *Qual Plant Plant Foods Human Nutr* **27** 113–123.

Meier-Ploeger A 1990 Consumer expectations and research on food quality. In: *Food Quality—Concepts and Methodology*, Elm Farm Research Centre, Newbury, UK, pp 21–26.

Meinecke B 1982 Untersuchungen zur Wirkung intensiv mineralisch gedüngten Futters auf die Fruchtbarkeit des Kaninchens. *Zentralbl Veterinaermed* **29** 5–15.

Meuser F, Suckow P, Kossmehl U 1984 Qualität 'alternativer Brote' aus den handwerklichen Bäckereien Berlins. *Nutrition/Ernährung* **8** 264–269.

Miller D S, Dema I S 1958 Nutritive value of wheat from the Rothamsted Broadbalk field. *Proc Nutr Soc* **17** xliv–xlv.

Naredo J M 1993 La agricultura ecológica—III. Sobre la relación calidad-precio de los productos 'ecológicos'. *Cuadernos del Banco de Crédito Agrícola* **3** 38–59.

Naumann W D, de Haas P G 1972 Die Wirkung 'naturgemäßer' Humuspflege- und Pflanzenschutzmaßnahmen auf Wuchs, Ertrag und Fruchtqualität beim Apfel. *Gartenbauwissenschaft* **37** 431–454.

Neudecker C 1987 Düngung und Qualität von Lebensmitteln—Tierfütterungsversuche mit mineralisch und organisch gedüngten Kartoffeln und Möhren. In: *Landbaumethoden und Nahrungsqualität* (Materialien und Berichte Nr 60). Akademie für Politische Bildung, Tutzing, Germany, pp 110–125.

Niedersächsischer Sozialminister und Niedersächsischer Minister für Ernährung, Landwirtschaft und Forsten (ed) 1983 Rückstandsuntersuchungen Alternativ und Konventionell Erzeugter Pflanzlicher Nahrungsmittel.

Oberösterreichische Landeskorrespondenz 1982 Biologische oder konventionelle Produkte—der Unterschied liegt in der Anschauung. *Ernährung/Nutrition* **6** 616.

Ocker H-D 1990 Vergleich zwischen alternativen und konventionellen Erzeugnissen-Schadstoffbelastungen-. In: *Bericht über die 4. Detmolder Studientage für Lehrer an berufsbildenden Schulen vom 19–21 February 1990*. Detmold: Granum Verlag, pp 42–49.

Pettersson B D 1977 Vergleichende Untersuchungen von konventionellem und biologisch-dynamischem Anbau mit besonderer Berücksichtigung von Erträgen und Qualitäten. *Lebendige Erde* **5** 175–184.

Pettersson B D 1982 Konventionell und biologisch-dynamisch erzeugte pflanzliche Nahrungsstoffe im Vergleich. In: *Alternativen im Landbau*. Schriftenreihe des Bundesministers für Ernährung, Landwirtschaft und Forsten, Reihe A: Angewandte Wissenschaft, Heft 263. Landwirtschaftsverlag, Münster-Hiltrup, Germany, pp 218–228.

Pfeiffer E 1931 Vergleichender Fütterungsversuch mit mineralisch gedüngtem und biologisch-dynamisch gedüngtem Getreide. *Demeter* **6** 87—89.

Pfeiffer E, Sabarth E 1932 Vergleichender Fütterungsversuch mit Hühnern. *Demeter* **7** 198–200.

Pfeiffer E, Sabarth E 1934 Vergleichender Fütterungsversuch mit Hühnern, Teil II. *Demeter* **9** 9–11.

Plochberger K 1989 Feeding experiments. A criterion for quality estimation of biologically and conventionally produced foods. *Agric Ecosyst Environ* **27** 419–428.

Plochberger K, Velimirov A 1992 Are food preferences tests with laboratory rats a proper method for evaluating nutritional quality? *Biol Agric Hortic* **8** 221–233.

Pommer G, Lepschy J 1985 Untersuchungen über Inhaltsstoffe von Winterweizen und Karotten aus verschiedener Produktionsweise und Vermarktung. *Bayerisches Landwirtschaftliches Jahrbuch* **62** 549–563.

Reinhard C 1991 Alternativ erzeugte Weine. *Weinwirtschaft—Anbau* **7** 1720.

Reinhard C, Wolff I 1986 Rückstände an Pflanzenschutzmitteln bei alternativ und konventionell angebautem Obst und Gemüse. *Ind Obst Gemueseverwert* **71** 51–54.

Reinken G, Keipert K, Lindner U, Overbeck G, Rüger H, Tauscher B, Wedler A 1990 Alternativer Anbau von Äpfeln und Gemüse. *Schriftenreihe der Landwirtschaftskammer Rheinland* **66** 1–195.

Reiter H, Ertel H, Wendt H, Pies Prüfer J, Barth L, Schröder H, Catel W, Dost F H, Scheunert A 1938 Über Ernährungsversuche mit verschieden gedüngten Gemüsen. *Ernaehrung* (*Leipzig*) **3** 53–69.

Reuff B 1970 Vitamin-und Spurenelementgehalt von Spinat unter dem Einfluß verschiedener Stickstofformen und Stickstoffmengen. *Landwirtschaftliche Forschung.* **25** 106–114.

Scheunert A 1935 Vergleichende Untersuchung der physiologischen Wirkungen fortgesetzten Genusses von Nahrungsmitteln, die mit und ohne Handelsdünger gezogen sind. *Angew Chem* **48** 42–46.

Scheunert A, Sachße M, Specht R 1934 Über die Wirkung fortgesetzter Verfütterung von Nahrungsmitteln, die mit und ohne künstlichen Dünger gezogen sind. *Biochem Z* **274** 372–396.

Schudel P, Eichenberger M, Augstburger F, Kläy R, Vogtmann H 1979 Über den Einfluß von Kompost- und NPK-Düngung auf Ertrag, Vitamin-C- und Nitratgehalt von Spinat und Schnittmangold. *Schweiz Landwirtsch Forsch* **4** 337–350.

Schüpbach M R 1986 Spritzmittelrückstände in Obst und Gemüse. *Deutsch Lebensm Rundsch* **82** 76–80.

Schuphan W 1974 Nutritional value of crops as influenced by organic and inorganic fertilizer treatments—Results of 12 years' experiments with vegetables (1960–1972). *Qual Plant Plant Foods Hum Nutr* **23** 333–358.

Schuphan W 1975 'Biologischer' oder 'chemischer' Anbau? Glaube und Wirklichkeit. *Hippokrates* **46** 158–179.

Scott P P, Greaves J P, Scott M G 1960 Reproduction in laboratory animals as a measure of the value of some natural and processed foods. *J Reprod Fertil* **1** 130–138.

Seibel W 1984 Qualität von pflanzlichen Lebensmitteln aus alternativem Anbau. In: *Alternativen im Landbau* (Beiträge zur Sache Nr 26/84). Landwirtschaftskammer, Westfalen/Lippe, Germany, pp 42–50.

Seibel W, Stephan H, Zwingelberg H 1984 Herstellung alternativer Vollkornschrotbrote. *Getreide Mehl Brot* **38** 339–345.

Staatliche Milchwirtschaftliche Lehr- und Forschungsanstalt Wangen (ed) 1993 Einflußfaktoren auf die sensorische Qualität von Emmentaler unter Einbeziehung des Aspektes 'Biogene Amine'. In: *Tätigkeitsbericht 1991–1992*, pp 18–22.

Staiger D 1986 Einfluß konventionell und biologisch-dynamisch angebauten Futters auf Fruchtbarkeit, allgemeinen Gesundheitszustand und Fleischqualität beim Hauskaninchen. Dissertation, Rheinische Friedrich-Wilhelms-Universität, Bonn, Germany.

Stan H-J 1982 Ständige Kontrolle ist notwendig—Biokost und Normalkost im Vergleich. *Der Spiegel* **30** 75–76.

Steineck O, Liebhard P 1984 Qualität und Ertrag von Brotgetreide aus naturwissenschaftlich-biologischer und alternativ-biologischer Pflanzenproduktion. *Allgemeiner Mühlen-Markt* **85** 35–40.

Svec L V, Thoroughgood C A, Mok H C S 1976 Chemical evaluation of vegetables grown with conventional or organic soil amendments. *Commun Soil Sci Plant Anal* **7** 213–228.

Taschan H, Walger K, Puchtinger T, Muskat E 1993a Vergleich von Honigen aus verschiedenen Handelsformen hinsichtlich ihrer Qualität. *In: 24. GDCh-Hauptversammlung Hamburg 5–11 September 1993—Kurzreferate und Teilnehmerverzeichnis.* Ed Gesellschaft Deutscher Chemiker, Frankfurt, Germany p 349.

Taschan H, Lenz B, Muskat E 1993b 'Alternativ-Biere' im Vergleich zu 'herkömmlichen' Bieren—Untersuchungsergebnisse unter Berücksichtigung der Öko-Verordnung. *Brauwelt* **133** 2208–2220.

Velimirov A, Plochberger K, Huspeka U, Schott W 1992 The influence of biologically and conventionally cultivated food on the fertility of rats. *Biol Agric Hort* **8** 325–337.

Verordnung (EWG) Nr. 2092/91 des Rates vom 24. Juni 1991 über den ökologischen Landbau und die entsprechende Kennzeichnung der landwirt-schaftlichen Erzeugnisse und Lebensmittel. *Amtsblatt der Europäischen Gemeinschaften* **L 1981/1** vom 22.7.1991.

Vetter H, Kampe W, Ranfft K 1983 Qualität pflanzlicher Nahrungsmittel. Ergebnisse dreijähriger Vergleichsuntersuchungen an Gemüse, Obst und Brot des modernen und alternativen Warenangebotes. *Schriftenreihe des Verbandes Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten* **7** 1–147.

Vetter H, von Abercron M, Bischoff R, Kampe W, Klasink A, Ranfft K 1987 Qualität pflanzlicher Nahrungsmittel—'alternativ' und 'modern' im Vergleich, Teil III. *AID-Schriftenreihe Verbraucherdienst* **3100** 1–3.

von Grone-Gültzow I 1931 Einfluß der Düngung auf die Futterqualität. *Demeter* **6** 162–165.

Wacholder K, Nehring K 1938 Über den Vitamin C-Gehalt verschiedener Kartoffelsorten und seine Abhängigkeit von der Düngung. *Bodenk Pflanzenemaehr* **9/10** 708–724.

Wacholder K, Nehring K 1940 Über den Einfluß von Düngung und Boden auf den Vitamin C-Gehalt verschiedener Kartoffelsorten. 2. Mitt. *Bodenk Pflanzenernaehr* **16** 245–260.

Wedler A 1977 Ergebnisse eines langjährigen Anbauversuches in Geisenheim. In: *Konventioneller und alternativer Landbau-Vergleichende Untersuchungen über die Qualität der Ernteprodukte.* Eds Diehl J F & Wedler A. BFE-Bericht 1977/1, pp 101–143.

Wedler A 1982 Pflanzenernährung und Nahrungsqualität von Hackfrüchten und Gemüse. In: *Alternativen im Landbau.* Schriftenreihe des Bundesministeriums für Ernährung, Landwirtschaft und Forsten, Reihe A: Angewandte Wissenschaft, Heft 263. Landwirtschaftsverlag, Münster-Hiltrup, Germany, pp 193–206.

Wendt H 1943 Über einen langjährigen Ernährungsversuch am Menschen mit verschieden gedüngten Gemüsen und Kartoffeln. *Ernaehrung* (*Leipzig*) **8** 281–295.

Wilberg E 1972 Über die Qualität von Spinat aus 'Biologischem Anbau'. *Landwirtschaftliche Forschung* **25** 167–169.

Woese K, Lange D, Boess C, Bögl K W 1995 Okologisch und konventionell erzeugte Lebensmittel im Vergleich. Eine Literaturstudie. Bundesinstitut für gesundheitlichen Verbraucherschutz und Veterinärmedizin (ed). Hefte 04/95 und 05/95.

Wolfson J L, Shearer G 1981 Amino acid composition of grain protein grown with and without pesticides and standard commercial fertilizers. *Agron J* **73** 611–613.

Zenz 1982 Zur Geschmacksqualität 'biologisch' bzw. konventionell erzeugter Kartoffeln. *Der Kartoffelbau* **33** 351–352.